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Abstract

This document provides the draft revised G.8112/Y.1371 (Version 3) for consent.

It consists of:

- [G.8112\(2012\)](#) (In-force version)
- [Amendment 1 \(2014\)](#) - New Appendix II
- [Corrigendum 1 \(2015\)](#) – Replace IETF Ethernet-addressing draft by RFC 7213
- Updates in clause 2. The published year of some Recommendations is updated.

Contact:	Yuji Tochio Fujitsu Japan	Tel: +81-44-754-8829 Fax: +81-44-754-2741 Email: tochio@jp.fujitsu.com
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Contact:	Jia He Huawei Technologies Co., Ltd. P.R.China	Tel: +86-755-28972293 Fax: +86-755-28972935 Email: hejia@huawei.com
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ITU-T

G.8112/Y.1371

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STANDARDIZATION SECTOR
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(10/2012)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
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INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS
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Internet protocol aspects – Transport

**Interfaces for the MPLS Transport Profile layer
network**

Recommendation ITU-T G.8112/Y.1371



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Draft revised Recommendation ITU-T G.8112/Y.1371

Interfaces for the MPLS Transport Profile layer network

Summary

Recommendation ITU-T G.8112/Y.1371 specifies the interfaces for the Multi-Protocol Label Switching (MPLS) Transport Profile (MPLS-TP) layer network. The interfaces for the MPLS-TP layer network use various server layer networks, like the plesiochronous digital hierarchy (PDH), synchronous digital hierarchy (SDH), optical transport hierarchy (OTH) and the Ethernet MAC layer network (ETH).

History

Edition	Recommendation	Approval	Study Group
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1.1	ITU-T G.8112/Y.1371 (2006) Cor. 1	2007-01-09	15
2.0	ITU-T G.8112/Y.1371	2012-10-29	15

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Interfaces for the MPLS Transport Profile layer network

1 Scope

This Recommendation specifies the interfaces for the Multi-Protocol Label Switching (MPLS) Transport Profile (MPLS-TP) layer network, in particular the:

- encapsulation of MPLS-TP client signals into the MPLS-TP characteristic information that will be present on MPLS-TP network network interface (NNI) links in the transport network;
- encapsulation of MPLS-TP characteristic information into the MPLS-TP link frames that will be present on MPLS-TP NNI links in the transport network;
- MPLS-TP layer network within the transport network and associated MPLS-TP multiplexing;
- MPLS-TP nested connection monitoring per layer network level within the transport network;
- MPLS-TP operation, administration and maintenance (OAM) associated with nested connection monitoring in the transport network;
- encapsulation of MPLS-TP control plane information.

The MPLS-TP network uses various server layer networks like optical transport hierarchy (OTH), synchronous digital hierarchy (SDH), plesiochronous digital hierarchy (PDH) and Ethernet MAC layer network (ETH). The detailed requirements are specified in a number of ITU-T Recommendations, ANSI Standards, IEEE Standards and IETF RFCs, which are referred to.

This Recommendation specifies point-to-point label switched paths (LSPs); point-to-multipoint LSPs are for further study.

This Recommendation does not cover inter-operator control plane aspects of the MPLS-TP network network interface (NNI).

This Recommendation provides a representation of the MPLS-TP technology using the methodologies that have been used for other transport technologies (e.g., SDH, optical transport network (OTN) and Ethernet).¹

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.704] Recommendation ITU-T G.704 (1998), *Synchronous frame structures used at 1544, 6312, 2048, 8448 and 44 736 kbit/s hierarchical levels.*

¹ This ITU-T Recommendation is intended to be aligned with the IETF MPLS RFCs normatively referenced by this Recommendation.

- [ITU-T G.707] Recommendation ITU-T G.707/Y.1322 (2007), *Network node interface for the synchronous digital hierarchy (SDH)*.
- [ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2012), *Interfaces for the optical transport network*.
- [ITU-T G.832] Recommendation ITU-T G.832 (1998), *Transport of SDH elements on PDH networks – Frame and multiplexing structures*.
- [ITU-T G.7041] Recommendation ITU-T G.7041/Y.1303 (2011), *Generic framing procedure*.
- [ITU-T G.7043] Recommendation ITU-T G.7043/Y.1343 (2004), *Virtual concatenation of plesiochronous digital hierarchy (PDH) signals*.
- [ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2010), *Architecture and specification of data communication network*.
- [ITU-T G.8001] Recommendation G.8001/Y.1354 (201~~3~~²), *Terms and definitions for Ethernet frames over Transport*.
- [ITU-T G.8012] Recommendation G.8012/Y.1354 (2012), *Ethernet UNI and Ethernet NNI*.
- [ITU-T G.8040] Recommendation ITU-T G.8040/Y.1340 (2005), *GFP frame mapping into plesiochronous digital hierarchy (PDH)*.
- [ITU-T G.8101] Recommendation G.8101/Y.1355 (201~~5~~⁺), *Terms and definitions for MPLS Transport Profile*.
- [ITU-T G.8110.1] Recommendation ITU-T G.8110.1/Y.1370.1 (2011), *Architecture of the Multi-Protocol Label Switching transport profile layer network*.
- [ITU-T G.8151] Recommendation ITU-T G.8151/Y.1374 (201~~5~~²), *Management aspects of the MPLS-TP network element*.
- [ITU-T Y.1415] Recommendation ITU-T Y.1415 (2005), *Ethernet-MPLS network interworking – User plane interworking*.
- [ITU-Y Y.1711] Recommendation ITU-T Y.1711 (2004), *Operation & Maintenance mechanism for MPLS networks*.
- [ANSI T1.107] ANSI T1.107²-2002, *Digital hierarchy – Formats Specifications*.
- [IEEE 802.3] IEEE 802.3-2012, *IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.
- [IETF RFC 3031] IETF RFC 3031 (2001), *Multiprotocol Label Switching Architecture*.
- [IETF RFC 3032] IETF RFC 3032 (2001), *MPLS Label Stack Encoding*.
- [IETF RFC 5586] IETF RFC 5586 (2009), *MPLS Generic Associated Channel*.
- [IETF RFC 5921] IETF RFC 5921(2010), *A Framework for MPLS in Transport Networks*.
- [IETF RFC 5960] IETF RFC 5960 (2010), *MPLS Transport Profile Data Plane Architecture, plus Errata 2533 (2010) and Errata 2534 (2010)*.

² T1 standards are maintained since November 2003 by ATIS.

[IETF RFC 6215] IETF RFC 6215 (2011), *MPLS Transport Profile User-to-Network and Network-to-Network Interfaces*.

[IETF RFC 7213] IETF RFC 7213 (2014), *MPLS Transport Profile (MPLS-TP) Next-Hop Ethernet Addressing*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 CE: See [IETF RFC 5921].

3.1.2 MPLS-TP_CI traffic unit: See [ITU-T G.8101].

3.1.3 MPLS-TP PE: See [IETF RFC 5921].

3.1.4 NNI: See [ITU-T G.8001].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 MPLS-TP-NNI: An NNI for the transfer of MPLS-TP_CI traffic unit over a transport layer network referred to in this Recommendation.

3.2.2 UNI: An interface that is used for the interconnection of customer equipment with a network element of the MPLS-TP network.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CE	Customer Edge
CI	Characteristic Information
CW	Control Word
DA	Destination Address
DCN	Data Communication Network
ETH	Ethernet MAC layer network
ETH_CI	Ethernet MAC Characteristic Information
FCS	Frame Check Sequence
G-ACh	Generic Associated Channel
GAL	G-ACh Label
GFP	Generic Framing Procedure
GFP-F	Generic Framing Procedure – Frame Mapped
IaDI	Intra-Domain Interface
IrDI	Inter-Domain Interface
IP	Internet Protocol

LCAS	Link Capacity Adjustment Scheme
LSP	Label Switched Path
M_SDU	MAC Service Data Unit
MAC	Media Access Control
MoE	MPLS-TP over ETH
MoO	MPLS-TP over OTH
MoP	MPLS-TP over PDH
MoS	MPLS-TP over SDH
MPLS	Multi-Protocol Label Switching
MT	MPLS Transport Profile
MTP	MPLS-TP path layer
MPLS-TP	MPLS Transport Profile
MPLS-TPP	MPLS-TP Path
MPLS-TPT	MPLS-TP Tandem connection monitoring
MUG	MPLS-TP Unit Group
NNI	Network Node Interface or Network Network Interface
OAM	Operation, Administration and Maintenance
ODU	Optical Channel Data Unit
ODU _j	Optical Channel Data Unit – order j
ODU _j -X _v	Virtual concatenated Optical Channel Data Unit – order j
ODU _k	Optical Channel Data Unit – order k
ODU _k -X _v	Virtual concatenated Optical Channel Data Unit – order k
OTH	Optical Transport Hierarchy
OTN	Optical Transport Network
P11s	1 544 kbit/s PDH path layer with synchronous 125 μs frame structure according to [ITU-T G.704]
P12s	2 048 kbit/s PDH path layer with synchronous 125 μs frame structure according to [ITU-T G.704]
P31s	34 368 kbit/s PDH path layer with synchronous 125 μs frame structure according to [ITU-T G.832]
P4s	139 264 kbit/s PDH path layer with synchronous 125 μs frame structure according to [ITU-T G.832]
PA	(Ethernet) Preamble
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge
PHY	Physical

RFC	Request for Comments
SA	Source Address
SCN	Signalling Communication Network
SDH	Synchronous Digital Hierarchy
SFD	Start of Frame Delimiter
SNAP	Sub-Network Access Protocol
SPME	Sub-Path Maintenance Element
STM-N	Synchronous Transport Module – level N
TC	Traffic Class
TNE	Transport Network Element
UNI	User-to-Network Interface
UNI-C	User-to-Network Interface, Client side
UNI-N	User-to-Network Interface, Network side
VC	Virtual Container (SDH)
VC-m	Lower Order VC – order m
VC-n	Higher Order VC – order n
VC-n-Xc	Contiguous concatenated VC – order n
VC-n-Xv	Virtual concatenated VC – order n

5 Conventions

None.

6 MPLS Transport Profile layer network interface structure

The MPLS Transport Profile (MPLS-TP) layer network as specified in [ITU-T G.8110.1] implies two interface classes:

- MPLS Transport Profile layer network interface as specified in [IETF RFC 5921] and [IETF RFC 6215];
- client layer network interface as specified in [IETF RFC 5921] and [IETF RFC 6215].

The MPLS-TP layer interface can be deployed as a network network interface (NNI) and within the transport network.

As described in [IETF RFC 5921], the MPLS Transport Profile layer network consists of the Transport Service layer and the Transport Path layer.

The MPLS-TP NNI provides the interface between two MPLS-TP PEs and could be used for the support of client layer connection services, i.e., the Transport Service layer and the connection within transport, i.e., Transport Path layer.

The User to Network Interface (UNI) provides the interface for client services that are carried by MPLS-TP layers. UNIs are used for such a service. The location of the UNI and NNI is illustrated in Figure 6-1.

UNI functions are located at the customer edge (CE) and provider edge (PE). The UNI-C is located and terminated at the CE and the UNI-N is located and terminated at the PE. The functions for UNI-C and UNI-N are described in [IETF RFC 5921] and [IETF RFC 6215].

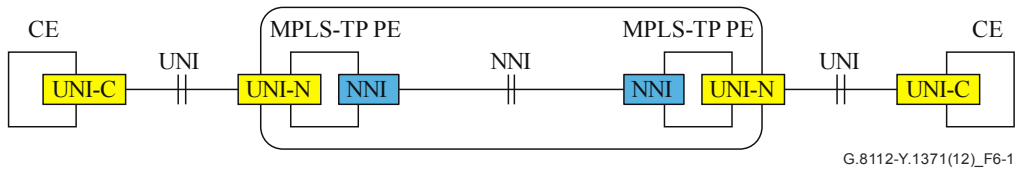


Figure 6-1 – Locations of UNI and MPLS-TP NNI

The MPLS-TP-NNI may be deployed as an intra-domain interface (IaDI) within a single administrative domain and as an inter-domain interface (IrDI) between two administrative domains as illustrated in Figure 6-2.

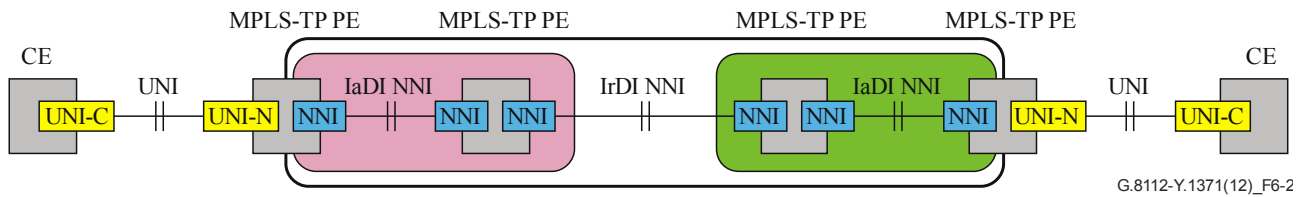


Figure 6-2 – Locations of client-UNI and MPLS-TP NNI

UNI and MPLS-TP NNI can encompass multiple layer networks. Appendix I describes an example that Ethernet is the client service.

The MPLS-TP NNI could be used to carry informational elements of three planes (Figure 6-3):

- data (or user) plane, optionally including a data communication network (DCN) supporting management plane and control plane communications;
- control plane (e.g., signalling and routing);
- management plane.

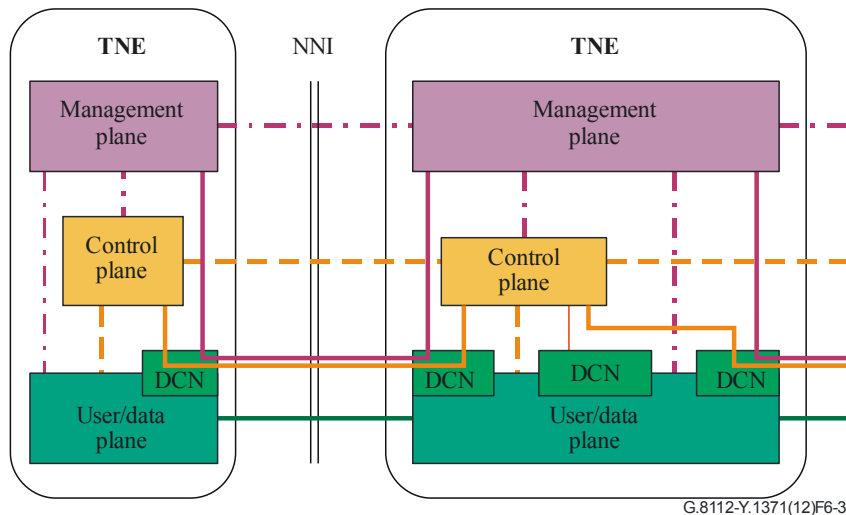


Figure 6-3 – Three planes of MPLS-TP NNI

Each NNI is divided into three plane-specific NNIs:

- NNI_D for the data plane informational elements, including OAM which is terminated in the layer's termination, adaptation and connection/flow forwarding functions;
- NNI_C for the control plane informational elements;
- NNI_M for the management plane informational elements.

This Recommendation specifies NNI_D and NNI_C as defined in [IETF RFC 6215]. In [IETF RFC 6215], NNI_D and NNI_C are represented as NNI (network-to-network interface) function. An NNI function is defined at the interface of an MPLS-TE PE node as described in Figure 2 of [IETF RFC 6215].

NNI_C and NNI_M realized via the DCN interface are described in [ITU-T G.7712] and [ITU-T G.8151] respectively.

6.1 NNI basic signal structure

The basic structure is shown in Figure 6-4. The relationship between clients and MPLS-TP is described in [IETF RFC 5921] and the example of the clients for pseudowire (PW) is described in [IETF RFC 5960]. Note that this Recommendation only describes Ethernet as a client; other clients for LSP or PW are for further study.

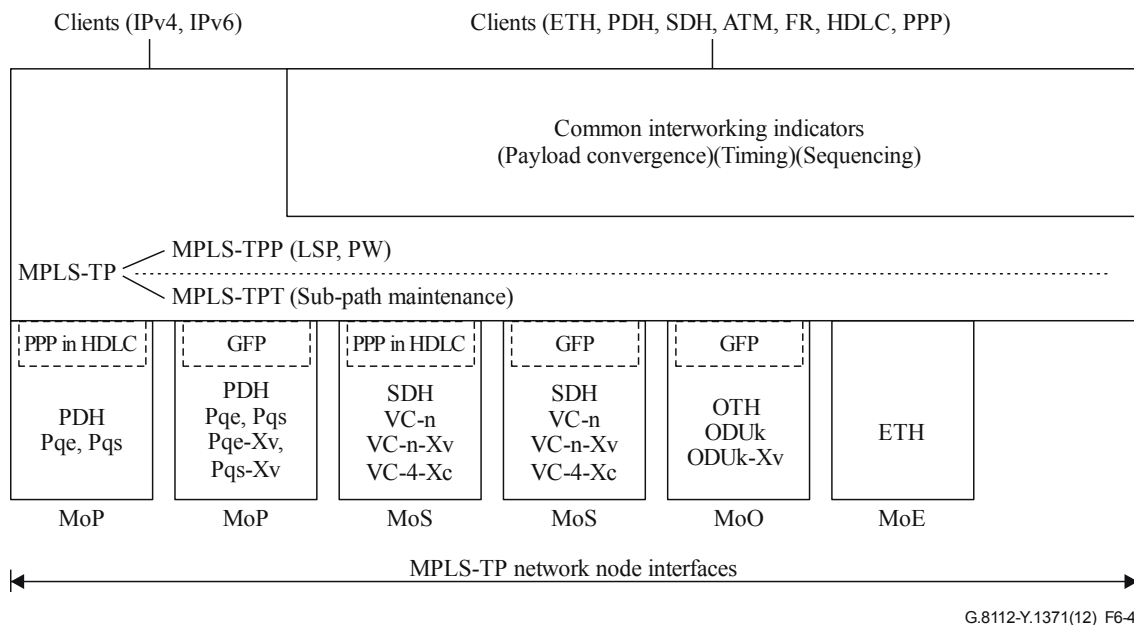


Figure 6-4 – Structure of the MPLS-TP network node interfaces

6.1.1 MPLS-TP substructure

The MPLS-TP layer as defined in [ITU-T G.8110.1] is further structured in sublayers in order to support the tunnelling (aggregation of lower level MPLS_CI), network management and supervision functionalities defined in [ITU-T G.8110.1]:

- tunnelling;
- end-to-end path supervision (MPLS-TPP);
- tandem connection monitoring (MPLS-TPT);
- optional adaptation of client signals via control word, as known common interworking indicator, headers.

As described in [ITU-T G.8110.1], a tunnel is associated with one or more LSPs. The tunnel is one of the primary constructs that is identified and it is used to identify the LSPs that are associated with it.

6.1.2 MPLS-TP transport network structure

As described in [IETF RFC 5960], the MPLS-TP network has no awareness of the internals of the server layer of which it is a client; it requires only that the server layer be capable of delivering the type of service required by the MPLS-TP transport entities that make use of it.

As described in [ITU-T G.8110.1], MPLS-TP may also be used to add a connection-oriented packet transport capability to an existing transport network, regardless of whether it is a circuit switched or packet switched transport network.

The MPLS-TP transport network interface consists of the multiple layers, of which only the first one is illustrated in Figure 6-4. The next layers are outside the scope of this Recommendation; the reader is referred to the appropriate technology Recommendations (e.g., [ITU-T G.707] for SDH).

There are a number of such MPLS-TP interfaces defined under this Recommendation as depicted in Figure 6-4:

- MPLS-TP-over-ETH (MoE);
- MPLS-TP-over-SDH (MoS);
- MPLS-TP-over-OTH (MoO);
- MPLS-TP-over-PDH (MoP).

In the case of circuit-switched transport, the payload bandwidths available are shown in Tables 6-1, 6-2 and 6-3, respectively, for PDH, SDH and OTH.

Table 6-1 – Bandwidth of the payload of PDH path signals

PDH type	PDH payload (kbit/s)	In steps of (kbit/s)
P11s	$1\,536 - (64/24) \approx 1\,533$	
P12s	1 980	
P31s	33 856	
P32e	$4\,696/4\,760 * 44\,736 \approx 44\,134$	
P11s-Xv, X = 1 to 16	$\approx 1\,533$ to $\approx 24\,528$	$\approx 1\,533$
P12s-Xv, X = 1 to 16	1 980 to 31 680	1 980
P31s-Xv, X = 1 to 8	33 856 to 270 848	33 856
P32e-Xv, X = 1 to 8	$\approx 44\,134$ to $\approx 353\,072$	$\approx 44\,134$

Table 6-2 – Bandwidth of the payload of SDH virtual containers (VCs)

VC type	VC payload (kbit/s)	In steps of (kbit/s)
VC-11	1 600	
VC-12	2 176	
VC-2	6 784	
VC-3	48 384	

VC type	VC payload (kbit/s)	In steps of (kbit/s)
VC-4	149 760	
VC-4-4c	599 040	
VC-4-16c	2 396 160	
VC-4-64c	9 584 640	
VC-4-256c	38 338 560	
VC-11-Xv, X = 1 to 64	1 600 to 102 400	1 600
VC-12-Xv, X = 1 to 64	2 176 to 139 264	2 176
VC-2-Xv, X = 1 to 64	6 784 to 434 176	6 784
VC-3-Xv, X = 1 to 256	48 384 to 12 386 304	48 384
VC-4-Xv, X = 1 to 256	149 760 to 38 338 560	149 760

Table 6-3 – Bandwidth of the OTH ODUs

ODU type	OPU payload (kbit/s)	In steps of (kbit/s)
ODU flex	$238/239 \times \text{ODUflex signal rate (for GFP-F mapped client signals)}$	
ODU0	1238954.310	
ODU1	2 488 320	
ODU2	$238/237 \times 9\,953\,280 \approx 9\,995\,277$	
ODU3	$238/236 \times 39\,813\,120 \approx 40\,150\,519$	
ODU4	104355975.330	
ODU1-Xv, X = 1 to 256	2 488 320 to 637 009 920	2 488 320
ODU2-Xv, X = 1 to 256	$\approx 9\,995\,277$ to $\approx 2\,558\,709\,902$	$\approx 9\,995\,277$
ODU3-Xv, X = 1 to 256	$\approx 40\,150\,519$ to $\approx 10\,278\,532\,946$	$\approx 40\,150\,519$

6.2 Information structure for the MPLS-TP network node interfaces

The information structure for the MPLS-TP network node interfaces is represented by information containment relationships and flows. The principal information containment relationships are described in Figure 6-5.

6.2.1 MPLS-TP principle information containment relationship

The MPLS-TP_CI consists of a stream of MPLS-TP_CI traffic units and OAM units. MPLS-TP_CI traffic units consist of a MPLS-TP_AI traffic unit extended with an MPLS-TP_CI header containing the TTL field of the MPLS-TP shim header (refer to clause 6.4). The MPLS-TP_AI traffic unit consists of a MPLS-TP_AI header containing the S field of the MPLS-TP shim header and a MPLS-TP payload field. The MPLS-TP payload field carries adapted client information or a label stack entry. A client signal of the MPLS-TP layer network is mapped into the MPLS-TP payload field via one of two different encapsulations (see Figure 6-5):

- direct encapsulation (IPv4, IPv6);
- control word based encapsulation (ETH).

MPLS-TP OAM signal and encapsulation is described in clause 6.2.1.1.

Table 6-4 – Overview of encapsulated units

Encapsulation type	Reference
IP client encapsulation	(IPv4) [IETF RFC 3032], clauses 2 and 3 (IPv6) [IETF RFC 3032], clauses 2 and 3
ETH client encapsulation	[ITU-T G.8110.1]
OAM encapsulation	[IETF RFC 5586] and [ITU-T G.8110.1]
Other	For further study

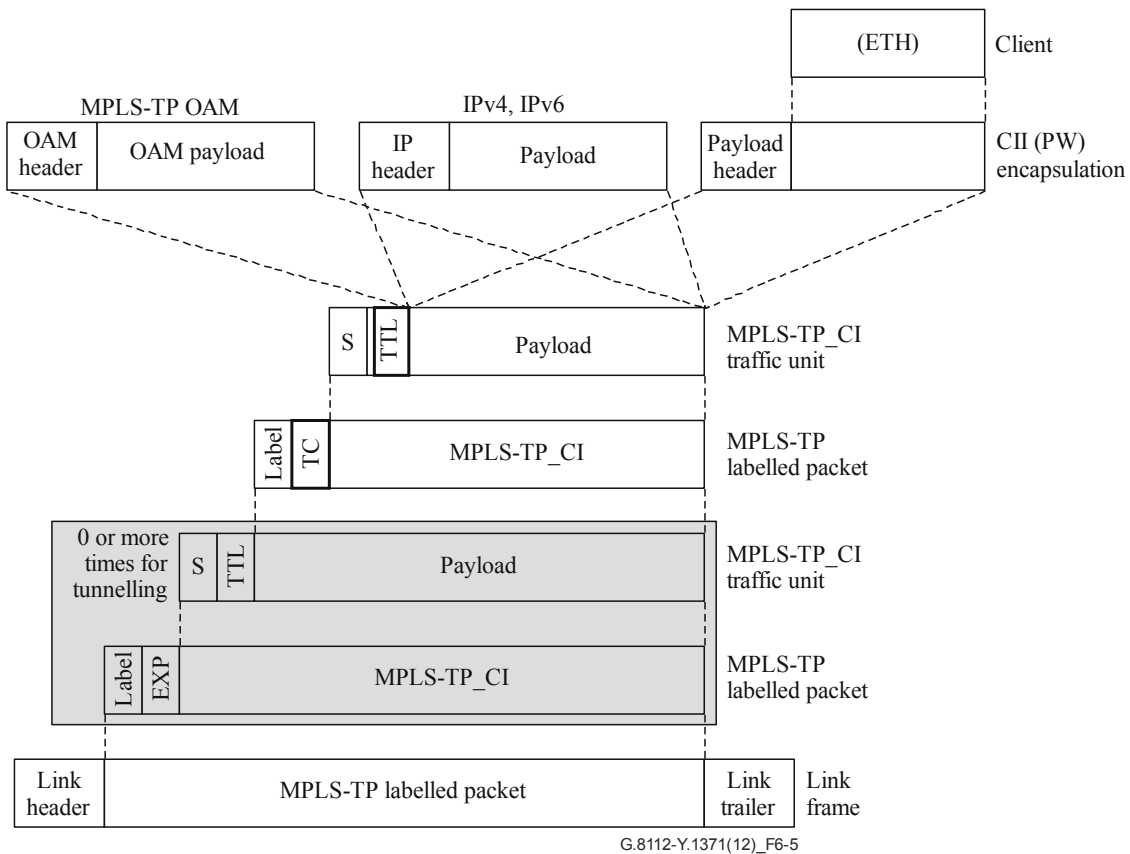


Figure 6-5 – MPLS-TP principle information containment

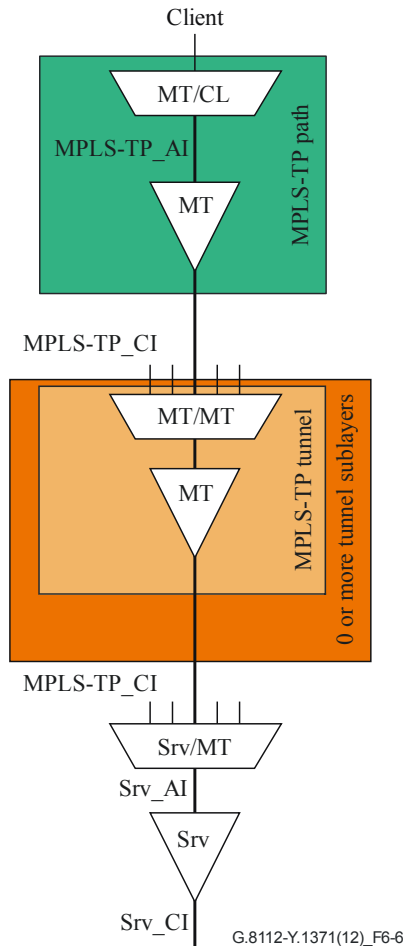


Figure 6-6 – Example of information flow relationship

6.2.1.1 MPLS-TP OAM

Figure 6-7 illustrates the generic format for MPLS-TP OAM.

The MPLS-TP OAM header consists of an MPLS-TP GAL as defined in [IETF RFC 5586]. The MPLS-TP OAM payload consists of G-ACh header, ACH TLV (optional), and G-ACh message. MPLS-TP OAM packets are distinguished from user data packets using the OAM header. Specific formats for MPLS-TP OAM are out of the scope of this Recommendation.

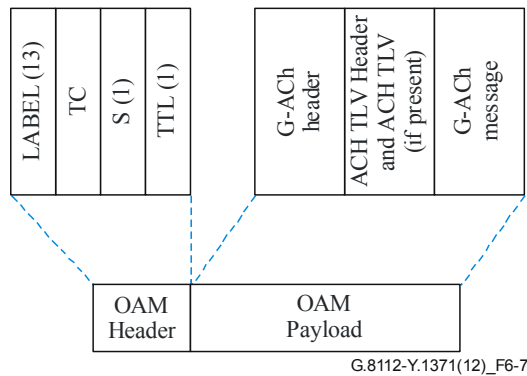


Figure 6-7 – Generic format for MPLS-TP OAM

6.2.1.2 Payload headers

6.2.1.2.1 ETH payload header

Mapping ETH payload header is described in clause 7.1 of [ITU-T G.8110.1].

6.2.2 MPLS-TP link frames

6.2.2.1 ETH link frame

The MPLS-TP_CI traffic unit (see [ITU-T G.8110.1]) is extended with a 3-bit TC field, a 20-bit label to complete the shim header. The resulting MPLS-TP labelled packet is then mapped as specified in [IETF RFC 3032], clauses 5 and 6.1 of [ITU-T G.8012] into the ETH payload information field using type encapsulation.

With the type encapsulation, the MAC DA, MAC SA and Type fields are prepended. The MAC DA can be the MAC address of the MPLS-TP next hop's interface or the broadcast MAC address (see ~~the IETF Ethernet addressing~~ IETF RFC 7213]). The MAC SA is the MAC address of the sending interface. The Type has value 0x8847. The 802.3 FCS field with a 32-bit CRC is appended. See Figure 6-8.

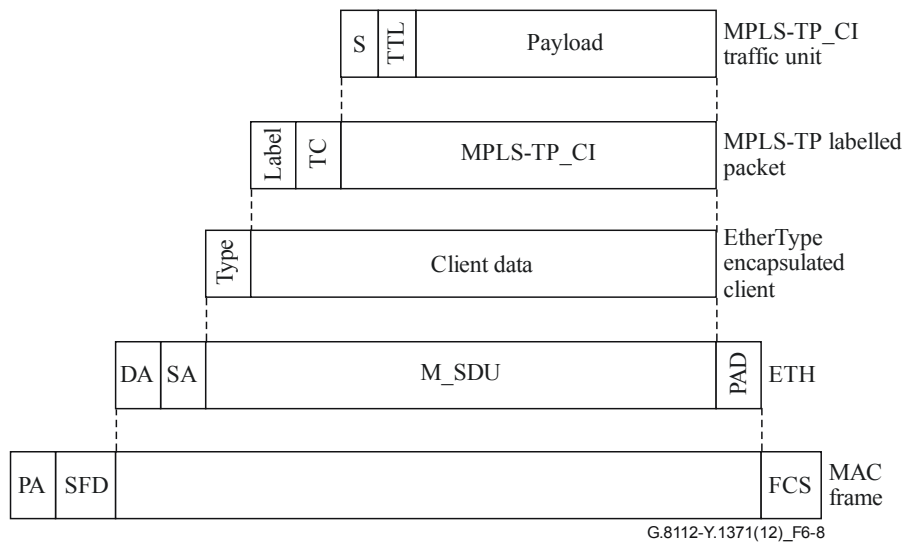


Figure 6-8 – Type encapsulation ETH link frame

6.2.2.2 GFP-F link frame

The MPLS-TP_CI traffic unit (see [ITU-T G.8110.1]) is extended with a 3-bit TC field, a 20-bit label to complete the shim header. The resulting MPLS-TP labelled packet is then mapped as specified in clause 7.6 of [ITU-T G.7041] in the GFP payload information field. A core header with PLI and cHEC fields and a payload header field with PTI, PFI, EXI, UPI and tHEC subfields are prepended. The PTI subfield has value 000, the PFI subfield has value 1, the EXI subfield has value 0000 and the UPI subfield has value 0x0D. A payload FCS field with a 32-bit CRC is appended. See Figure 6-9. The maximum size of the GFP payload information field is specified in clause 6.1.2 of [ITU-T G.7041].

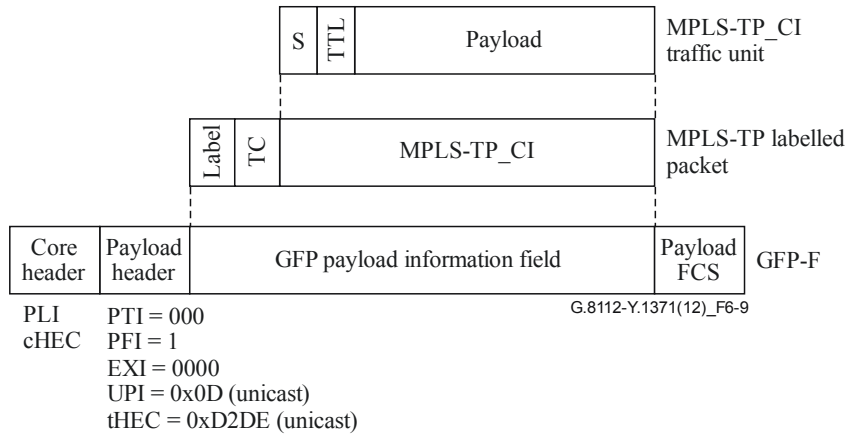


Figure 6-9 – GFP-F link frame

Figure 6-10 illustrates the mapping of the bits in the MPLS-TP labelled packet into the GFP payload information field within the GFP-F frame.

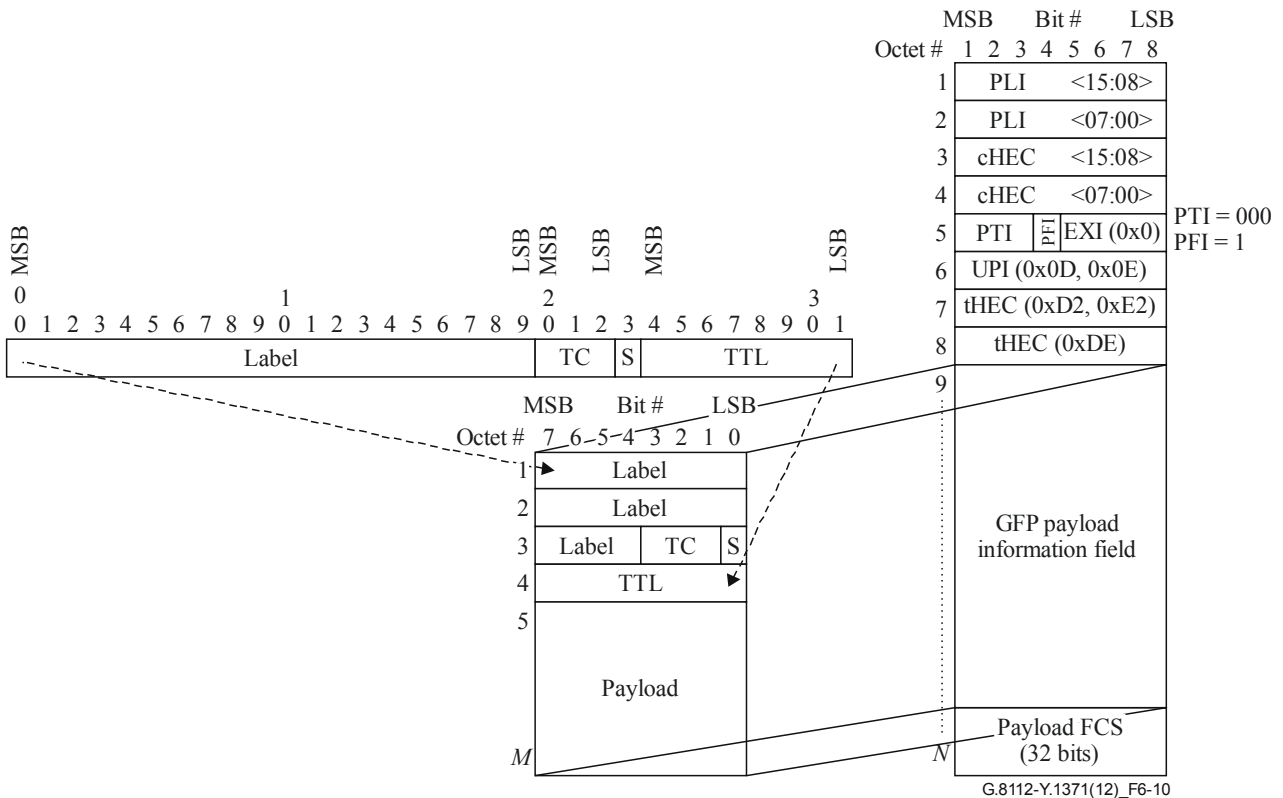


Figure 6-10 – Mapping MPLS-TP labelled packet into GFP-F link frame

6.2.3 MPLS-TP control frames

MPLS-TP control plane communication (NNI_C) for signalling and routing purposes are used for SCN links.

Four alternatives for SCN links are defined in [ITU-T G.7712].

- SCN link sharing a server layer trail with MPLS-TP user traffic.
- SCN link utilizing the MPLS-TP SCC.
- SCN link utilizing a dedicated MPLS-TP LSP.

- Separate and independent SCN link.

When SCN link uses sharing a server layer trail, MPLS-TP control frames are encapsulated either in IPv4 or in IPv6 or in OSI network layer packets and sent natively on the MPLS-TP NNI interface.

NOTE – The encapsulation of the MPLS-TP control frames into IPv4, IPv6 or OSINL packets is out of scope of this Recommendation.

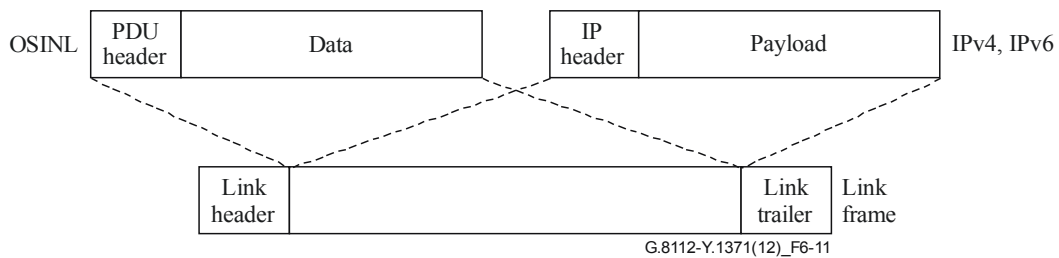


Figure 6-11 – MPLS-TP control frame over shared trail SCN links

Additional control frames can be required by the specific encapsulation method used for sending MPLS-TP link frames.

MPLS-TP control frames are distinguished from MPLS-TP data frames because they are not MPLS-TP link frames: the multiplexing of MPLS-TP and non-MPLS-TP link frames is required on all the MPLS-TP NNI interfaces.

The encapsulation method used for MPLS-TP control frames is the same as the one used for the MPLS-TP link frames.

NOTE – For cases other than SCN links sharing a server layer trail, the encapsulation of MPLS-TP control frames is for further study.

6.2.3.1 ETH link frame

For further study.

6.2.3.2 GFP-F link frame

The signalling and routing message is encapsulated into either IPv4 or IPv6 or OSI CNLS (IS-IS) packet as described in [ITU-T G.7712].

When the MPLS-TP NNI uses the GFP-F encapsulation, there are no other control protocols defined.

Control packets are encapsulated as specified in the standard references of Table 6-6 in the GFP payload information field. A core header with PLI and cHEC fields and a payload header field with PTI, PFI, EXI, UPI and tHEC subfields are prepended. The PTI subfield has value 000, the PFI subfield has value 1, the EXI subfield has value 0000 and the UPI subfield has the values defined in Table 6-6. A payload FCS field with a 32-bit CRC is appended.

Table 6-6 – Overview of GFP-F encapsulated control packets

Encapsulation type	Reference	UPI value
IP control packets	(IPv4) clause 7.7 of [ITU-T G.7041]	0x10
	(IPv6) clause 7.7 of [ITU-T G.7041]	0x11
OSI network layer control packets	(OSINL) clause 7.7 of [ITU-T G.7041]	0x0F

6.2.4 MPLS-TP UNI

For further study.

6.2.5 MPLS-TP NNI

The MPLS-TP NNI is supported by the interfaces listed below.

6.2.5.1 MoE NNI

The MPLS-TP over ETH (MoE) NNI deploys the Type encapsulation based ETH link frame as specified in clause 6.2.2.1.

6.2.5.2 MoS NNI

The MPLS-TP over SDH (MoS) NNI deploys the GFP-F link frame as specified in clause 6.2.2.2. The mapping of the GFP-F link frames into VC-11/VC-11-Xv, VC-12/VC-12-Xv, VC-3/VC-3-Xv, VC-4/VC-4-Xv and VC-4-Xc is specified in clause 10.6 of [ITU-T G.707].

Path overhead and virtual concatenation of the VCs is specified in [ITU-T G.707].

The components of the MPLS-TP over SDH NNI using the default encapsulation are illustrated in Figure 6-12.

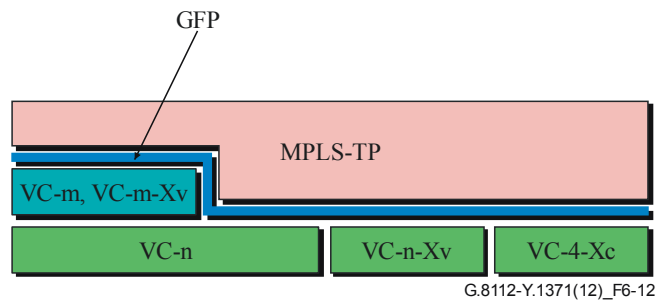


Figure 6-12 – Components of the MPLS-TP over SDH NNI using GFP-F encapsulation

6.2.5.3 MoO NNI

The MPLS-TP over OTH NNI deploys the GFP-F link frame as specified in clause 6.2.2.2 and its components are illustrated in Figure 6-13. The mapping of the GFP-F link frame into ODUj/ODUk and ODUj-Xv is specified in clauses 17.3 and 18.2.4 respectively of [ITU-T G.709].

Path overhead and virtual concatenation of the ODUs is specified in [ITU-T G.709].

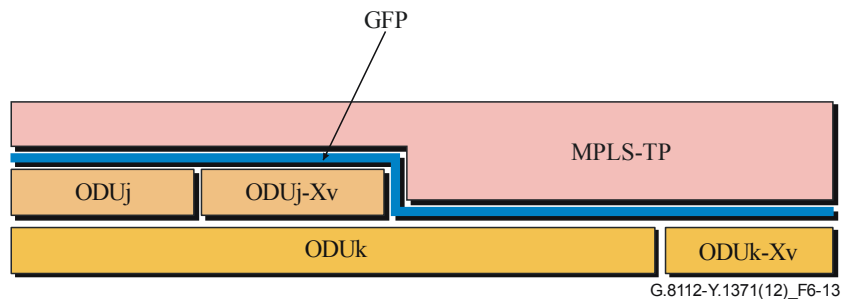


Figure 6-13 – Components of the MPLS-TP over OTH NNI

6.2.5.4 MoP NNI

The MPLS-TP over PDH NNI deploys the GFP-F link frame as specified in clause 6.2.2.2.

The mapping of the GFP-F link frames into P11s/P11s-Xv, P12s/P12s-Xv, P31s/P31s-Xv and P32e/P32e-Xv is specified in [ITU-T G.8040].

The frame structure of P11s, P12s, and P32e is specified in [ITU-T G.704], the frame structure of P31e is specified in [ITU-T G.951] and the frame structure of P31s is specified in [ITU-T G.832]. Virtual concatenation of the P11s, P12s, P32s and P32e signals is specified in [ITU-T G.7043].

For the channelized P32e the direct multiplexing of P11s into P32e is specified in clause 9.3 of [ANSI T1.107].

Figure 6-14 illustrates the relation of the components of MPLS-TP over PDH NNI using GFP-F.

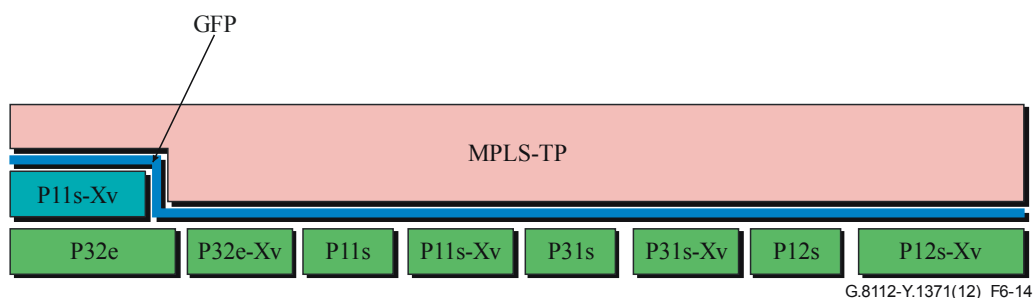


Figure 6-14 – Components of the MPLS-TP over PDH NNI using GFP-F

6.3 MPLS-TP labels

20 bits are available in the label field of the shim header for MPLS-TP connection identification. Some of these values are pre-assigned. The interpretation of these values is as described in Table 6-7.

Table 6-7 – MPLS-TP label value interpretation

MPLS-TP label value	Interpretation
0-3	Defined in [IETF RFC 3032]; not used in MPLS-TP
4-12	Reserved for future standardization (Note)
13	Defined in [IETF RFC 5586]
14	Defined in [ITU-T Y.1711]; not used in MPLS-TP
15	Reserved for future standardization (Note)
16-1,048,575	MPLS-TP connection identifier range (values assigned as per [IETF RFC 3031])
NOTE – IANA allocates these values through the IETF consensus action process.	

6.4 MPLS-TP shim header

The MPLS-TP traffic unit includes one or more MPLS shim headers as defined in [IETF RFC 3031] and specified as label stack entry in section 2 of [IETF RFC 3032].

7 Multiplexing/mapping principles

Figure 7-1 shows the relationship between various information structure elements and illustrates the multiplexing structure and mappings for the MPLS-TP from client signal to link frames. It illustrates an n-level multiplexing of MPLS-TP signals into MPLS-TP LSP. The MT_CI traffic is multiplexed into an MPLS-TP Unit Group level 1 (MUG1). The MUG1 is extended with a second level MPLS shim header and then multiplexed into a higher MUG level.

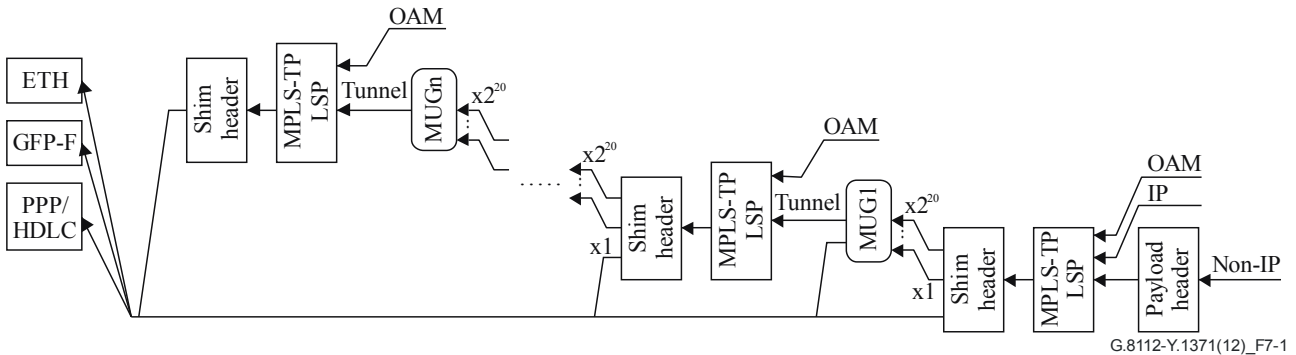


Figure 7-1 – MPLS-TP mapping, multiplexing and segment monitoring

7.1 Mapping

The client signal is mapped into the MPLS-TP LSP directly (like IP clients). For non-IP clients like Ethernet, CW (control word) is optionally used as referred to [ITU-T G.8110.1]. The CW is also known as the common interworking indicators (CII) in [ITU-T Y.1415].

MPLS-TP OAM (refer to 6.2.1.1) may be added and both data and OAM packets are extended with a shim header (refer to 6.4).

The MPLS-TP packets are then mapped into the applicable link frames as specified in 6.2.2 and those link frames are transported over a MPLS-TP topological link.

7.2 MPLS-TP multiplex

The label stacking mechanism in MPLS-TP provides an n-level MPLS-TP LSP multiplexing capability. The 20-bit label in the shim header identifies the individual MPLS-TP tributaries within the aggregate (MPLS-TP tunnel) signal. Up to 2^{20} MPLS-TP tributaries can be supported in the aggregate signal.

7.3 MPLS-TP tandem connection monitoring

Multiplexing may not be performed in all stacking steps to support one or more levels of MPLS-TP tandem connection monitoring (Sub-Path Maintenance Element (SPME)) as described in [ITU-T G.8110.1]. The mechanism is for further study.

8 Physical specification of the MPLS-TP interfaces

There are no dedicated MPLS-TP physical interfaces. MPLS-TP interfaces are supported by physical interfaces specified in the following transport technologies: PDH, SDH, OTH and Ethernet.

Appendix I

Example of layer networks in ETH UNI and MPLS-TP NNI

(This appendix does not form an integral part of this Recommendation.)

[ITU-T G.8110.1] defines Ethernet as the client of MPLS-TP. Ethernet UNI and NNI are defined in [ITU-T G.8012]. The ETH UNI, ETH NNI and MPLS-TP NNI encompass multiple layer networks, each with its dedicated UNI and NNI (Figure I.1). ETY UNI is defined in [ITU-T G.8012].

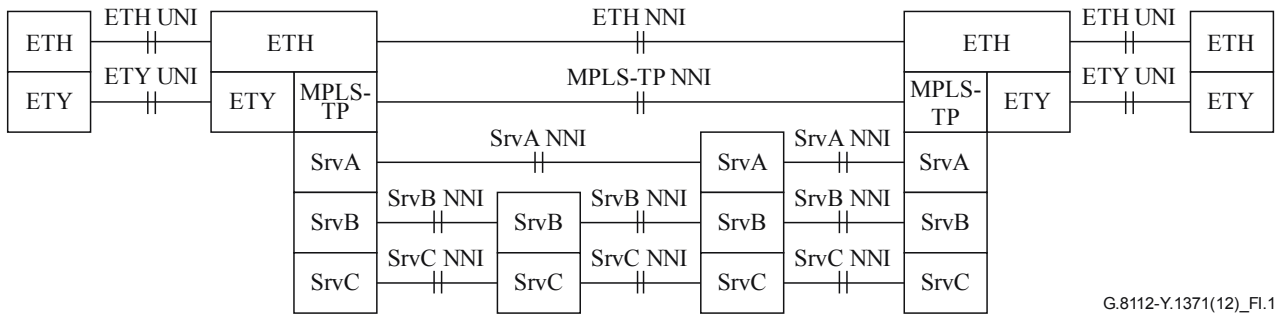


Figure I.1 – Example of layer networks in ETH UNI and MPLS-TP NNI

Appendix II

Bandwidth requirements for MPLS-TP transport

(This appendix does not form an integral part of this Recommendation.)

This appendix shows the transport bandwidth requirements for ETH client encapsulation over MPLS-TP over ETH link as a function of the Ethernet MAC rate, the client payload field length, whether or not the network has inserted a VLAN tag. This is shown in Tables II.1 and II.2.

NOTE – The MAC bit rate in Table II.1 is the actual bit rate of the Ethernet MAC frames after the removal of the 12-byte inter-packet gap plus 7-byte preamble + 1-byte start of frame delimiter. In other words, MAC bit rate = (Ethernet interface rate) (# of bits in the MAC frame)/(# of bits in the MAC frame + 12-byte inter-packet gap + 7-byte preamble + 1-byte start of frame delimiter). The calculations in Table II.2 are the same except that 10 gigabit Ethernet uses a 5-byte minimum inter-packet gap instead of 12 bytes.

Table II.1 – Maximum (un)tagged MAC bit rate per "1 Gbit/s" MAC server signal

		<u>Payload bit rate (bit/s, nominal bit rate for Ethernet)</u>					
		<u>1 000 000 000</u>		<u>1 000 000 000</u>		<u>1 000 000 000</u>	
		<u>MAC bit rate (kbit/s), throughput (%) relative to maximum MAC bit rate</u>			<u>Packets per second (pps), throughput (%) relative to maximum packet per second</u>		
<u>VLAN tag</u>	<u>MAC-size (Bytes)</u>	<u>1000Base-X</u>	<u>MPLS-TP over 1000Base-X</u>	<u>Throughput</u>	<u>1000Base-X</u>	<u>MPLS-TP over 1000Base-X</u>	<u>Throughput</u>
<u>0</u>	<u>64</u>	<u>761,905</u>	<u>581,818</u>	<u>76.36%</u>	<u>1,488,095</u>	<u>1,136,364</u>	<u>76.36%</u>
<u>0</u>	<u>128</u>	<u>864,865</u>	<u>735,632</u>	<u>85.06%</u>	<u>844,595</u>	<u>718,391</u>	<u>85.06%</u>
<u>0</u>	<u>256</u>	<u>927,536</u>	<u>847,682</u>	<u>91.39%</u>	<u>452,899</u>	<u>413,907</u>	<u>91.39%</u>
<u>0</u>	<u>512</u>	<u>962,406</u>	<u>917,563</u>	<u>95.34%</u>	<u>234,962</u>	<u>224,014</u>	<u>95.34%</u>
<u>0</u>	<u>1024</u>	<u>980,843</u>	<u>957,009</u>	<u>97.57%</u>	<u>119,732</u>	<u>116,822</u>	<u>97.57%</u>
<u>0</u>	<u>1518</u>	<u>986,996</u>	<u>970,588</u>	<u>98.34%</u>	<u>81,274</u>	<u>79,923</u>	<u>98.34%</u>
<u>0</u>	<u>9618</u>	<u>997,925</u>	<u>995,240</u>	<u>99.73%</u>	<u>12,969</u>	<u>12,935</u>	<u>99.73%</u>
<u>1</u>	<u>64</u>	<u>772,727</u>	<u>596,491</u>	<u>77.19%</u>	<u>1,420,455</u>	<u>1,096,491</u>	<u>77.19%</u>
<u>1</u>	<u>128</u>	<u>868,421</u>	<u>741,573</u>	<u>85.39%</u>	<u>822,368</u>	<u>702,247</u>	<u>85.39%</u>
<u>1</u>	<u>256</u>	<u>928,571</u>	<u>849,673</u>	<u>91.50%</u>	<u>446,429</u>	<u>408,497</u>	<u>91.50%</u>
<u>1</u>	<u>512</u>	<u>962,687</u>	<u>918,149</u>	<u>95.37%</u>	<u>233,209</u>	<u>222,420</u>	<u>95.37%</u>
<u>1</u>	<u>1024</u>	<u>980,916</u>	<u>957,169</u>	<u>97.58%</u>	<u>119,275</u>	<u>116,387</u>	<u>97.58%</u>
<u>1</u>	<u>1518</u>	<u>987,030</u>	<u>970,663</u>	<u>98.34%</u>	<u>81,064</u>	<u>79,719</u>	<u>98.34%</u>
<u>1</u>	<u>9618</u>	<u>997,926</u>	<u>995,242</u>	<u>99.73%</u>	<u>12,964</u>	<u>12,929</u>	<u>99.73%</u>

NOTE 1 – VLAN tag; value gives the number of VLAN tags (no VLAN tag = 0).

NOTE 2 – Encapsulation overhead; 20 bytes for physical Ethernet interface (7-byte preamble, 1-byte SFD and 12-byte minimum IPG). 26-byte Encapsulation overhead for ETH client over MPLS-TP with Control Word.

Table II.2 – Maximum (un)tagged MAC bit rate per "10 Gbit/s" MAC server signal

		<u>Payload bit rate (nominal bit rate for Ethernet)</u>					
		<u>10 000 000 000</u>		<u>10 000 000 000</u>		<u>1 000 000 000</u>	
		<u>MAC bit rate (kbit/s), throughput (%) relative to maximum MAC bit rate</u>			<u>Packets per second (pps), throughput (%) relative to maximum packet per second</u>		
<u>VLAN tag</u>	<u>MAC-size (Bytes)</u>	<u>10GBase-R</u>	<u>MPLS-TP over 10GBase-R</u>	<u>Throughput</u>	<u>10GBase-R</u>	<u>MPLS-TP over 10GBase-R</u>	<u>Throughput</u>
<u>0</u>	<u>64</u>	<u>7,619,048</u>	<u>5,818,182</u>	<u>76.36%</u>	<u>14,880,952</u>	<u>11,363,636</u>	<u>76.36%</u>
<u>0</u>	<u>128</u>	<u>8,648,649</u>	<u>7,356,322</u>	<u>85.06%</u>	<u>8,445,946</u>	<u>7,183,908</u>	<u>85.06%</u>
<u>0</u>	<u>256</u>	<u>9,275,362</u>	<u>8,476,821</u>	<u>91.39%</u>	<u>4,528,986</u>	<u>4,139,073</u>	<u>91.39%</u>
<u>0</u>	<u>512</u>	<u>9,624,060</u>	<u>9,175,627</u>	<u>95.34%</u>	<u>2,349,624</u>	<u>2,240,143</u>	<u>95.34%</u>
<u>0</u>	<u>1024</u>	<u>9,808,429</u>	<u>9,570,093</u>	<u>97.57%</u>	<u>1,197,318</u>	<u>1,168,224</u>	<u>97.57%</u>
<u>0</u>	<u>1518</u>	<u>9,869,961</u>	<u>9,705,882</u>	<u>98.34%</u>	<u>812,744</u>	<u>799,233</u>	<u>98.34%</u>
<u>0</u>	<u>9618</u>	<u>9,979,249</u>	<u>9,952,401</u>	<u>99.73%</u>	<u>129,695</u>	<u>129,346</u>	<u>99.73%</u>
<u>1</u>	<u>64</u>	<u>7,727,273</u>	<u>5,964,912</u>	<u>77.19%</u>	<u>14,204,545</u>	<u>10,964,912</u>	<u>77.19%</u>
<u>1</u>	<u>128</u>	<u>8,684,211</u>	<u>7,415,730</u>	<u>85.39%</u>	<u>8,223,684</u>	<u>7,022,472</u>	<u>85.39%</u>
<u>1</u>	<u>256</u>	<u>9,285,714</u>	<u>8,496,732</u>	<u>91.50%</u>	<u>4,464,286</u>	<u>4,084,967</u>	<u>91.50%</u>
<u>1</u>	<u>512</u>	<u>9,626,866</u>	<u>9,181,495</u>	<u>95.37%</u>	<u>2,332,090</u>	<u>2,224,199</u>	<u>95.37%</u>
<u>1</u>	<u>1024</u>	<u>9,809,160</u>	<u>9,571,695</u>	<u>97.58%</u>	<u>1,192,748</u>	<u>1,163,873</u>	<u>97.58%</u>
<u>1</u>	<u>1518</u>	<u>9,870,298</u>	<u>9,706,633</u>	<u>98.34%</u>	<u>810,636</u>	<u>797,194</u>	<u>98.34%</u>
<u>1</u>	<u>9618</u>	<u>9,979,257</u>	<u>9,952,420</u>	<u>99.73%</u>	<u>129,641</u>	<u>129,293</u>	<u>99.73%</u>

NOTE 1 – VLAN tag; value gives the number of VLAN tags (no VLAN tag = 0).

NOTE 2 – Encapsulation overhead; 20 bytes for physical Ethernet interface (7-byte preamble, 1-byte SFD and 12-byte minimum IPG). 26-byte Encapsulation overhead for ETH client over MPLS-TP with Control Word.

Bibliography

~~[b-IETF Ethernet addressing] Approved IETF Internet Draft draft-ietf-mpls-tp-ethernet-addressing-08 (2013), *MPLS-TP Next-Hop Ethernet Addressing*.~~

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