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This working document contains the consolidation of all WDs with contributions for G.tpoam: WD05, WD06, WD08, WD09, WD12, WD13, WD14 and WD15.

<u>Outline</u>	<u>WD05</u>
<u>Clause 1-5</u>	<u>WD06</u>
<u>Clause 6</u>	<u>WD08/09</u>
<u>Clause 7</u>	<u>WD15</u>
<u>Clause 8</u>	<u>WD12</u>
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Operations, Administration and Maintenance mechanism for MPLS-TP networks

1. Scope

This Recommendation specifies mechanisms for user-plane OAM (Operations, Administration and Maintenance) in MPLS-TP networks to meet the MPLS-TP OAM requirements defined in [IETF RFC 5860]. It also specifies the MPLS-TP OAM packet formats, syntax and semantics of MPLS-TP OAM packet fields.

The OAM mechanisms defined in this Recommendation assume common forwarding of the MPLS-TP user packets and MPLS-TP OAM packets. In transport networks, the OAM return path is always in-band.

The MPLS-TP OAM mechanisms as described in this Recommendation apply to ~~both~~ co-routed bidirectional point-to-point MPLS-TP connections ~~and unidirectional point to point and point to multipoint MPLS TP connections.~~ Unidirectional point-to-point and point-to-multipoint MPLS-TP connections will be addressed in a future version of this Recommendation.

This Recommendation is compliant with the transport profile of MPLS as defined by the IETF. In the event of a misalignment in MPLS-TP related architecture, framework, and protocols between this ITU-T Recommendation and the normatively referenced IETF RFCs, the RFCs will take precedence.

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.805] ITU-T Recommendation G.805 (2000), *Generic functional architecture of transport networks*.
- [ITU-T G.806] ITU-T Recommendation G.806 (2004), *Characteristics of transport equipment – Description methodology and generic functionality*.
- [ITU-T G.826] ITU-T Recommendation G.826 (2002), *End-to-end error performance parameters and objectives for international, constant bit-rate digital paths and connections*.
- [ITU-T G.7710] ITU-T Recommendation G.7710 (2007), *Common equipment management function requirements*.
- [ITU-T G.7712] ITU-T Recommendation G.7712 (2010), *Architecture and specification of data communication network*.

- [ITU-T Y.1731] ITU-T Recommendation Y.1731 (2008), *OAM functions and mechanisms for Ethernet based networks*, plus Amendment 1 (2010).
- [ITU-T M.1400] ITU-T Recommendation M.1400 (2006), *Designations for interconnections among operators' networks*
- [ITU-T G.8021] ITU-T Recommendation G.8021 (2010), *Characteristics of Ethernet transport network equipment functional blocks*.
- [ITU-T M.20] ITU-T Recommendation M.20 (1992), *Maintenance philosophy for telecommunication networks*.
- [ITU-T G.8010] ITU-T Recommendation G.8010/Y.1306 (2004), *Architecture of Ethernet layer networks*, plus Amendment 1 (2006).
- [ITU-T G.8110.1] ITU-T Recommendation G.8110.1/Y.1370.1 (2011), *Architecture of MPLS Transport Profile (MPLS-TP) layer network*.
- [IETF RFC 3031] IETF RFC 3031 (2001), *Multiprotocol Label Switching Architecture*.
- [IETF RFC 3032] IETF RFC 3032 (2001), *MPLS Label Stack Encoding*.
- [IETF RFC 4385] IETF RFC 4385 (2006), *Pseudowire Emulation Edge-to-Edge (PWE3) Control Word for Use over an MPLS PSN*.
- [IETF RFC 5462] IETF RFC 5462 (2009), *Multiprotocol Label Switching (MPLS) Label Stack Entry: "EXP" Field Renamed to "Traffic Class" Field*.
- [IETF RFC 3443] IETF RFC 3443 (2003), *Time To Live (TTL) Processing in Multi-Protocol Label Switching (MPLS) Networks*.
- [IETF RFC 5586] IETF RFC 5586 (2009), *MPLS Generic Associated Channel*.
- [IETF RFC 5654] IETF RFC 5654 (2009), *Requirements of an MPLS Transport Profile*.
- [IETF RFC 5718] IETF RFC 5718 (2010), *An In-Band Data Communication Network For the MPLS Transport Profile*.
- [IETF RFC 5860] IETF RFC 5860 (2010), *Requirements for OAM in MPLS Transport Networks*.
- [IETF RFC xxxx] IETF RFC ietf-mpls-tp-oam-framework (2010), *Operations, Administration and Maintenance Framework for MPLS-based Transport Networks*.

3. Definitions

This Recommendation introduces some terminology, which is required to discuss the functional network components associated with OAM. These definitions are consistent with G.805 terminology.

3.1 defect: see [ITU-T G.806].

3.2 failure: see [ITU-T G.806].

3.3 MPLS Transport Profile

Set of MPLS functions used to support packet transport services and network operations.

4. Abbreviations

This Recommendation uses the following abbreviations:

<u>IDM</u>	<u>One-way Delay Measurement</u>
<u>A</u>	<u>Adaptation function</u>
<u>AIS</u>	<u>Alarm Indication Signal</u>
<u>AP</u>	<u>Access Point</u>
<u>APS</u>	<u>Automatic Protection Switching</u>
<u>C</u>	<u>Customer</u>
<u>CC</u>	<u>Continuity Check</u>
<u>CCM</u>	<u>Continuity Check Message</u>
<u>C-DCI</u>	<u>Client - Defect Clear Indication</u>
<u>CFI</u>	<u>Client Failure Indication</u>
<u>CSF</u>	<u>Client Signal Fail</u>
<u>CV</u>	<u>Connectivity Verification</u>
<u>DCC</u>	<u>Data Communication Channel</u>
<u>DM</u>	<u>Delay Measurement</u>
<u>DMM</u>	<u>Delay Measurement Message</u>
<u>DMR</u>	<u>Delay Measurement Reply</u>
<u>DT</u>	<u>Diagnostic Test</u>
<u>ES</u>	<u>Experimental Specific</u>
<u>EXM</u>	<u>Experimental oam Message</u>
<u>EXP</u>	<u>Experimental</u>
<u>EXR</u>	<u>Experimental oam Reply</u>
<u>FC</u>	<u>Frame Count</u>
ACH	Associated Channel Header
G-ACh	Generic Associated Channel
GAL	G-ACh Label
<u>IANA</u>	<u>Internet Assigned Numbers Authority</u>
<u>ICC</u>	<u>ITU-T Carrier Code</u>
<u>ID</u>	<u>Identifier</u>
<u>IETF</u>	<u>Internet Engineering Task Force</u>
<u>IF</u>	<u>Interface</u>
<u>IO</u>	<u>Intermediate Operator</u>
<u>IP</u>	<u>Intermediate Provider</u>
<u>LBM</u>	<u>Loopback Message</u>

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<u>LBR</u>	<u>Loopback Reply</u>
<u>LCK</u>	<u>locked Signal</u>
<u>LER</u>	<u>Label Edge Router</u>
<u>LM</u>	<u>Loss Measurement</u>
<u>LMM</u>	<u>Loss Measurement Message</u>
<u>LMR</u>	<u>Loss Measurement Reply</u>
<u>LOC</u>	<u>Loss Of Continuity</u>
<u>LSE</u>	<u>Label Stack Entry</u>
<u>LSP</u>	<u>Label Switched Path</u>
<u>LSR</u>	<u>Label Switch Router</u>
<u>MCC</u>	<u>Maintenance Communication Channel</u>
MPLS-TP	<u>MPLS Transport Profile</u>
ME	<u>Maintenance Entity</u>
<u>MEL</u>	<u>MEG Level</u>
MEG	<u>Maintenance Entity Group</u>
MEP	<u>MEG End Point</u>
<u>MIP</u>	<u>MEG Intermediate Point</u>
<u>MMG</u>	<u>Mis-merge</u>
<u>MPLS</u>	<u>Multi Protocol Label Switching</u>
MPLS-TP	<u>MPLS Transport Profile</u>
<u>N</u>	<u>Network</u>
<u>NE</u>	<u>Network Element</u>
<u>Num</u>	<u>Number</u>
<u>O</u>	<u>Operator</u>
<u>OAM</u>	<u>Operation, Administration & Maintenance</u>
<u>OpCode</u>	<u>Operations Code</u>
<u>P</u>	<u>Provider</u>
<u>PD</u>	<u>Packet Delay</u>
<u>PDU</u>	<u>Protocol Data Unit</u>
<u>PDV</u>	<u>Packet Delay Variation</u>
<u>PHB</u>	<u>Per-Hop Forwarding Behaviour</u>
<u>PRBS</u>	<u>Pseudo-Random Bit Sequence</u>
<u>PSN</u>	<u>Packet Switched Network</u>
<u>PW</u>	<u>PseudoWire</u>
<u>PWE3</u>	<u>PseudoWire Emulation Edge-to-Edge</u>

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<u>RDI</u>	<u>Remote Defect Indication</u>
<u>RFC</u>	<u>Requests for Comments</u>
<u>Rx</u>	<u>Receive</u>
<u>S</u>	<u>Stack</u>
<u>SCC</u>	<u>Signalling Communication Channel</u>
<u>Sk</u>	<u>Sink</u>
<u>SLA</u>	<u>Service Level Agreement</u>
<u>So</u>	<u>Source</u>
<u>SPME</u>	<u>Sub-Path Maintenance Entity</u>
<u>SRV</u>	<u>Server</u>
<u>TC</u>	<u>Traffic Class</u>
<u>TCM</u>	<u>Tandem Connection Monitoring</u>
<u>TLV</u>	<u>Type, Length, and Value</u>
<u>TrCP</u>	<u>Traffic Conditioning Point</u>
<u>TSB</u>	<u>Telecommunication Standardization Bureau</u>
<u>TST</u>	<u>Test</u>
<u>TTL</u>	<u>Time To Live</u>
<u>Tx</u>	<u>Transmit</u>
<u>UNI</u>	<u>User Network Interface</u>
<u>UNL</u>	<u>UNexpected meg Level</u>
<u>UNM</u>	<u>UNexpected Mep</u>
<u>UNP</u>	<u>UNexpected Period</u>
<u>UNPr</u>	<u>UNexpected Priority</u>
<u>VCCV</u>	<u>Virtual Circuit Connectivity Verification</u>
<u>VS</u>	<u>Vendor Specific</u>
<u>VSM</u>	<u>Vendor Specific oam Message</u>
<u>VSR</u>	<u>Vendor Specific oam Reply</u>
<u>MIP</u>	<u>MEG Intermediate Point</u>

~~[Editor's note]: To be added in a future version.~~

5. Conventions

The diagrammatic conventions for Maintenance Entity (ME) Group (MEG) End Point (MEP) and MEG Intermediate Point (MIP) compound functions are those of [ITU-T G.8010].

The values of the OAM PDU fields are expressed in decimal format.

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6. Functional Components

6.1.Maintenance Entity (ME)

A Maintenance Entity (ME) can be viewed as the association between two MEG End Points (MEPs) that applies maintenance and monitoring operations to a network connection or a tandem connection.

In case of a co-routed bi-directional point-to-point connection, a single bidirectional ME is defined to monitor both directions congruently.

6.2.Maintenance End Group (MEG)

A Maintenance Entity Group (MEG) is the set of one or more MEs that belong to the same connection and are maintained and monitored as a group.

6.2.1. Tandem Connection Monitoring

Tandem Connection Monitoring (TCM) can be supported by the instantiation of Sub-Path Maintenance Entity (SPME), as described in [IETF RFC xxxx], that has a 1:1 relationship with the monitored connection. The SPME is then monitored using normal LSP monitoring.

When an SPME is established between non-adjacent nodes, the edges of the SPME become adjacent at the client sub-layer network and any intermediate node that were previously in between becomes an intermediate node for the SPME.

TCMs can nest but not overlap.

6.3.MEG End Points (MEPs)

A MEG end point (MEP) marks the end point of a MEG which is responsible for initiating and terminating OAM packets for fault management and performance monitoring.

A MEP may initiate an OAM packet to be transferred to its corresponding peer MEP, or to an intermediate MIP that is part of the MEG.

As the MEP corresponds to the termination of the forwarding path for a MEG at the given (sub-) layer, OAM packets never leak outside of a MEG in a properly configured error free implementation.

A MEP may be a per-node MEP or a per-interface MEP.

Per-node MEP is a MEP which is located somewhere within one node. There is no other MEG Intermediate Point (MIP) or MEP in the same MEG within the same node.

Per-interface MEP is a MEP which is located on a specific interface within the node. In particular a per-interface MEP is called "Up MEP" or "Down MEP" depending on its location relative to the connection function¹, which is shown in Figure 6-1.

NOTE – It is possible that two Up MEPs of a MEG are set, one on each side of the connection function, such that the MEG is entirely internal to the node.

¹ The connection function is called forwarding engine in [IETF RFC xxxx]

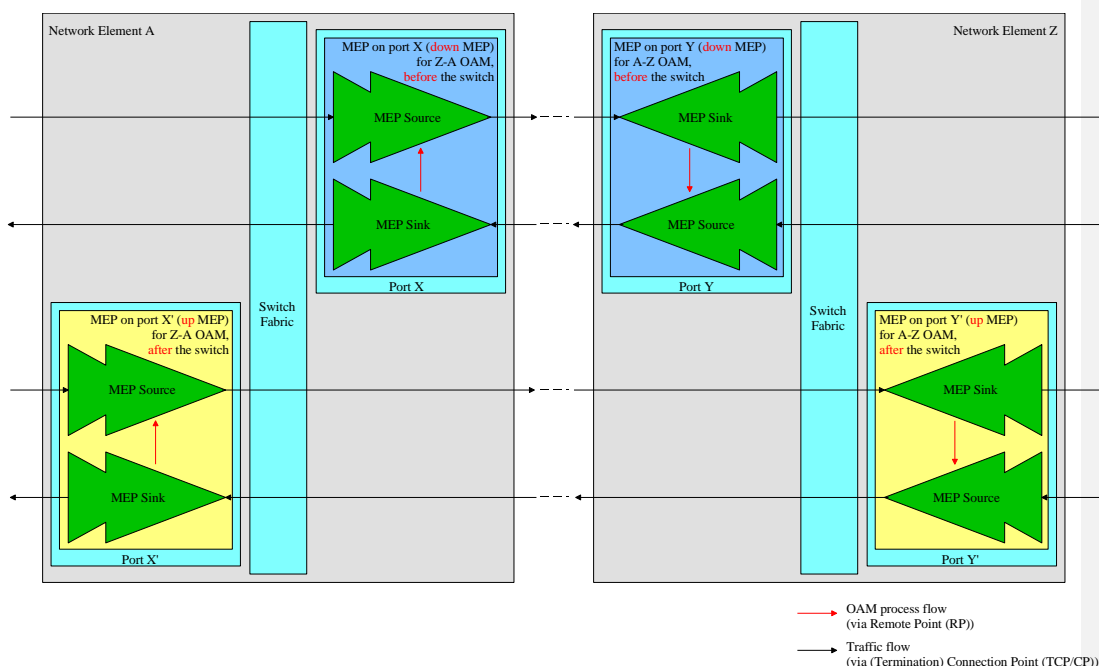


Figure 6-1/G.tpoam: Up/Down MEPs

In Figure 6-1 above, the MEP of the transport entity traversing interface port X of NE-A is a Down MEP. Similarly the MEP of interface port Y of NE-Z is also a Down MEP. Note that an interface port may support multiple transport entities. In the figure, only one transport entity is shown. For simplicity, refer to these two MEPs as MEP_{AX} and MEP_{ZY}. If these two MEPs belong to the same MEG (i.e. they peer to each other), OAM flow (e.g. loopback OAM packets) from the MEP_{AX} to MEP_{ZY} will be processed (looped back) by MEP_{ZY} and the connection function of NE-Z is not involved in this OAM flow. Similarly, OAM packets from MEP_{ZY} to MEP_{AX} will be processed by MEP_{AX} and do not transit the connection function of NE-A.

In Figure 6-1 above, the MEP of the transport entity traversing interface port X' of NE-A is an Up MEP. Similarly the MEP of interface port Y' of NE-Z is also an Up MEP. If these two MEPs (MEP_{AX'} and MEP_{ZY'}) belong to the same MEG, OAM packets (e.g. loopback packets) from MEP_{AX'} to MEP_{ZY'} will traverse through the connection function of NE-Z and then be processed by MEP_{ZY'} and therefore the connection function of NE-Z is involved in this OAM flow. Similarly, the OAM packets from MEP_{ZY'} to MEP_{AX'} will be processed by MEP_{AX'} and transit the connection function of NE-A.

More details are described in [IETF RFC xxxx].

6.4.MEG Intermediate Points (MIPs)

A MEG Intermediate Point (MIP) is an intermediate point between the two MEPs within a MEG that is capable of reacting to some OAM packets and forwarding all the other OAM packets while ensuring fate sharing with user-plane packets.

A MIP does not initiate unsolicited OAM packets, but may be addressed by OAM packets initiated by one of the MEPs of the MEG. A MIP can generate OAM packets only in response to OAM packets that are sent on the MEG it belongs to.

MIPs are unaware of any OAM flows running between MEPs or between MEPs and other MIPs. MIPs can only receive and process OAM packets addressed to them.

A MIP may be a per-node MIP or a per-interface MIP.

Per-node MIP is a MIP which is located somewhere within one node. There is no other MIP or MEP on the same MEG within the same node.

Per-interface MIP is a MIP which is located on a node interface, independently from the connection function². The MIP can be placed at the ingress interface or at the egress interface of any node along the MEG.

A node at the edge of a MEG that has a per-interface Up MEP can also support a per-interface MIP on the other side of the connection function as illustrated in Figure 6-2.

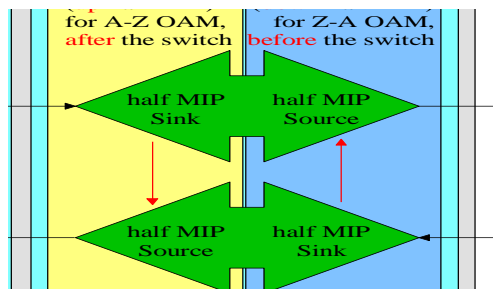


Figure 6-2/G.tpoam: Per-interface Up MEP and MIP in a node at the edge of a MEG

An intermediate node within a MEG can either:

- Support per-node MIP (i.e. a single MIP per node in an unspecified location within the node);
- Support per-interface MIPs (i.e. two MIPs per node, one on each side of the forwarding engine, for co-routed point-to-point bidirectional connections).

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According to [ITU-T G.8110.1], a MIP is functionally modeled as two back-to-back half MIPs as illustrated in Figure 6-3.

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² The connection function is called forwarding engine in [IETF RFC xxxx]

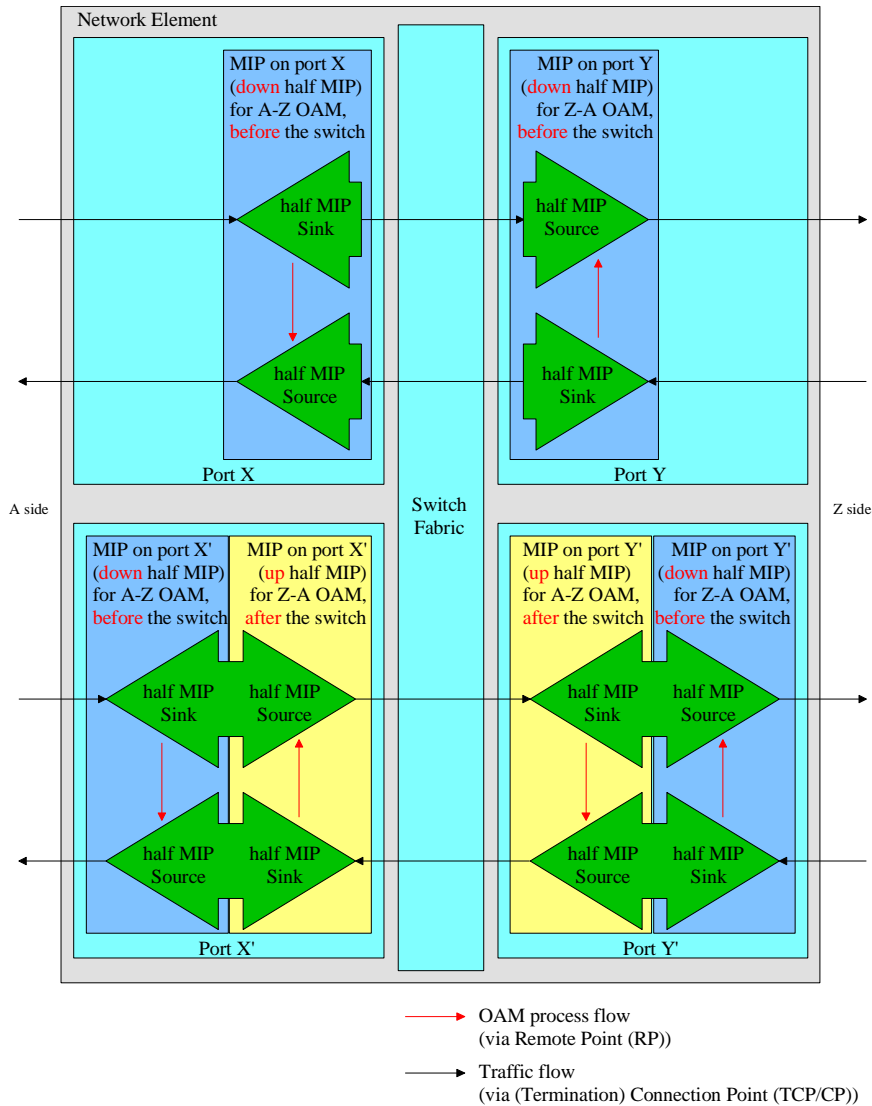


Figure 6-3/G.tpoam: Up/Down half MIPs

In Figure 6-3 above, MIP_{AX} is on the interface port X on the A-side of the NE, MIP_{ZY} is on the interface port Y on the Z-side of the NE, $MIP_{AX'}$ is on the interface port X' on the A-side of the NE, and $MIP_{ZY'}$ is on the interface port Y' on the Z-side of the NE.

MIP_{AX} is a Down half MIP. It can respond to OAM flow coming from A-side and targeted to it. It cannot respond to OAM flow coming from Z-side even targeted to it.

MIP_{ZY} is a Down half MIP. It can respond to OAM flow coming from Z-side and targeted to it. It cannot respond to OAM flow coming from A-side even targeted to it.

$MIP_{AX'}$ is a full MIP, which consists of a Down half MIP and an Up half MIP. It can respond to OAM flow coming from A-side and targeted to it. It can also respond to OAM flow targeted to it coming from Z-side and traversing the connection function.

MIP_{ZY} is a full MIP, which consists of a Down half MIP and an Up half MIP. It can respond to OAM flow coming from Z-side and targeted to it. It can also respond to OAM flow targeted to it coming from A-side and traversing the connection function.

Editor notes: need to consider per interface MIP with per platform labeling

6.5. Server MEP

A server MEP is a MEP of a MEG that is either:

- Defined in a layer network that is "below", which is to say encapsulates and transports the MPLS-TP layer network being referenced, or
- Defined in a sub-layer of the MPLS-TP layer network that is "below" which is to say encapsulates and transports the sub-layer being referenced.

A server MEP can coincide with a MIP or a MEP in the client MPLS-TP (sub-)layer network.

A server MEP also provides server layer OAM indications to the server/MPLS-TP adaptation function. The adaptation function maintains state on the mapping of MPLS-TP connections that are setup over that server (sub-)layer's trail.

The Server MEP is expected to run OAM mechanisms specific to its (sub-)layer.

7. OAM functions

7.1. Identification of OAM packets from user traffic packets

In order to ensure proper operational control, MPLS-TP network elements exchange OAM packets that strictly follow the same path as user traffic packets; that is, OAM packets are subject to the exact same forwarding schemes (e.g. fate sharing) as the user traffic packets. These OAM packets can be distinguished from the user traffic packets by using the G-ACh and GAL constructs, as defined in [IETF RFC 5586].

The G-ACh is a generic associated control channel mechanism for Sections, LSPs and PWs, over which OAM and other control messages can be exchanged.

The GAL is a label based exception mechanism to alert LERs/LSRs of the presence of an Associated Channel Header (ACH) after the bottom of the stack.

TTL expiration is an other exception mechanism to alert intermediate LSRs of the presence of an OAM packet that requires processing.

7.1.1. G- Ach

The Generic Associated Channel (G-ACh) is similar to the Virtual Circuit Connectivity Verification (VCCV), a control channel associated with a PW that carries OAM and other control messages, except that it is generic and can carry such messages over either a section, a PW, ~~or~~ an LSP or a tandem connection.

Specifically, the VCCV uses an Associated Channel Header (ACH) to provide a PW-associated control channel between a PW's end points for exchanging OAM and other control messages. The G-ACh is an associated control channel that generalizes the applicability of the ACH to LSPs and Sections, while maintaining compatibility with the PW-associated channel. The ACH, specified in [IETF RFC 4385], may be used with additional code points to support additional OAM functions

on the G-ACh and is common to Sections, LSPs ~~and~~, PWs and tandem connections. The format of the G-ACh is specified in Sub-clause 8.1 in alignment with [IETF RFC 5586].

7.1.2. GAL

A G-ACh Alert Label (GAL) is used to flag the G-ACh. Specifically, the GAL is used to indicate that a packet contains an ACH followed by a non-service payload (i.e., the G-ACh packet payload), thus generalizing the associated control channel mechanism to LSPs ~~and~~ Sections and tandem connections.

The GAL provides an alert based exception mechanism to:

- Differentiate G-ACh packets (e.g., OAM, DCC, APS, etc.) from those of user traffic packets
- Indicate that the ACH appears immediately after the bottom of the label stack.

One of the reserved label values defined in [IETF RFC 3032] is assigned for this purpose: the reserved label value assigned is 13. The GAL must always be at the bottom of the label stack (i.e., S bit set to 1). The format of the GAL is specified in Sub-clause 8.1 in alignment with [IETF RFC 5586].

7.2.OAM functions specification

Table 7-1/G.tpoam: OAM Functions

Application	OAM Function	
Fault Management	Pro-active	Continuity Check and Connectivity Verification (CC/CV)
		Remote Defect Indication (RDI)
		Alarm Indication Signal (AIS)
		Client Signal Fail (CSF) ³
	On-demand	Connectivity Verification (CV)
		Diagnostic test (DT)
Locked Signal (LCK) ⁴		
Performance Management	Pro-active	Loss measurement (LM)
		Delay measurement (DM)
	On-demand	Loss measurement (LM)
		Delay measurement (DM)
Other Applications	Automatic Protection Switching (APS)	
	Management communication channel/ Signaling communication channel (MCC/SCC)	
	Vendor-specific (VS)	
	Experimental (EXP)	

7.2.1. OAM Functions for Fault Management

7.2.1.1 Proactive OAM Functions for Fault Management

7.2.1.1.1 Continuity Check and Connectivity Verification

The source MEP sends CC/CV OAM packets periodically at the configured rate. The sink MEP monitors for the arrival of these CC/CV OAM packets at the configured rate and detects the defect of loss of continuity (LOC).

The following connectivity verification defects are also detected by this function:

- a) Mis-merge: unintended connectivity between two MEGs;
- b) Unexpected MEP: unintended connectivity within the MEG with an unexpected MEP;

The following misconfiguration defect is also detected by this function:

³ Client Signal Fail (CSF) is called Client Failure Indication (CFI) in [IETF RFC 5860]

⁴ Locked Signal (LCK) is called Lock Reporting in [IETF RFC 5860]

- a) Unexpected Period: CC/CV OAM packets are received with a period field value that is different from the configured CC/CV OAM packet rate.

CC/CV is mainly used for the fault management, performance monitoring and protection switching. A MEP periodically transmits the proactive CC/CV OAM packet at the configured transmission period. In transport networks, the following default transmission periods are defined:

- a) **3.33ms**: default transmission period for protection switching application (transmission rate of 300 packets/second)
- b) **100ms**: default transmission period for performance monitoring application (transmission rate of 10 packets/second)
- c) **1s**: default transmission period for fault management application (transmission rate of 1 packet/second)

Other transmission periods are not precluded, however the behavior of the intended application is not guaranteed unless the default values are used.

7.2.1.1.2 Remote Defect Indication

RDI is an indicator that is transmitted by a MEP to communicate to its peer MEPs that a signal fail condition exists. When a MEP detects a signal fail condition, it sends RDI to its peer MEP.

RDI is only used for bidirectional connections and is associated with proactive CC/CV activation.

7.2.1.1.3 Alarm Indication

This function is mainly used to suppress alarms following detection of defect conditions at the server (sub-)layer. When a server MEP asserts LOC or signal fail, sets a flag that results in generation of OAM packets with AIS information that are forwarded in the downstream direction to the sink MEP in the client (sub-)layer, which allows the suppression of secondary alarms (LOC, etc) in the client (sub-)layer.

7.2.1.1.4 Locked Signal

The locked signal (LCK) function is used to communicate to the client (sub-)layer MEPs the administrative locking of a server (sub-)layer MEP and consequential interruption of data traffic forwarding in the client (sub-)layer. It allows a client (sub-)layer MEP receiving packets with LCK information to differentiate between a defect condition and an administrative locking action at the server (sub-)layer MEP. An example of an application that would require administrative locking of a MEP is the out-of-service diagnostic test, as described in clause 7.2.1.2.2.

When a server MEP is administratively locked, it sets a flag that results in generation of OAM packets with LCK information that are forwarded in both upstream and downstream directions to the client (sub-)layer MEPs until the administrative lock condition is removed (see Figure 7-1).

NOTE – When a Server MEP is administratively locked, the server (sub-)layer is blocked from carrying user traffic. The Server MEP source blocks any client (sub-)layer traffic received from upstream to be forwarded over the server (sub-)layer; however it allows locally-generated client (sub-)layer LCK packets to be sent over the server (sub-)layer. The server MEP sink blocks any client (sub-)layer traffic received from the server layer MEG to be forwarded downstream.

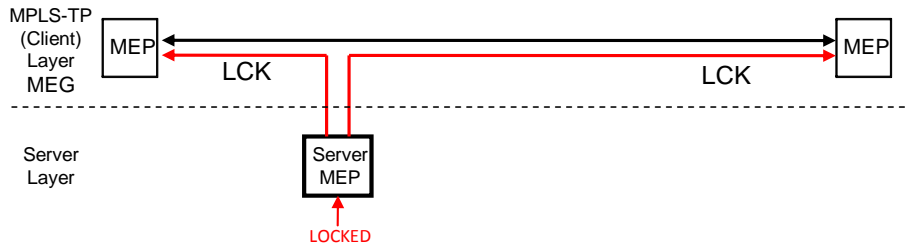


Figure 7-1/G.tpoam: Example of LCK transmission

7.2.1.1.5 Client Signal Fail

This function is used to process client defects and propagate a client signal defect to the associated remote MEP using OAM packets. This function is usually used in case the client of the MPLS-TP trail does not support a native defect/alarm indication mechanism.

7.2.1.2 On-demand OAM Functions for Fault Management

7.2.1.2.1 Connectivity Verification

On-demand connectivity verification (CV) allows detection of failures in the path for trouble shooting purposes. The on-demand CV can be used to check either the entire MEG (end-to-end) or just between a MEP and a specific MIP. When the on-demand CV function is invoked on a MEP, an OAM CV request packet is sent from the MEP to the target MIP or MEP within the MEG. The originating MEP expects to receive an OAM packet with the CV reply information from the target MIP or MEP. Upon reception of OAM CV request packet information, the receiving MIP or MEP validates it and transmits an OAM packet with CV reply information to the originating MEP.

7.2.1.2.2 Diagnostic test

The diagnostic test (DT) function is used to perform diagnostic tests such as bandwidth throughput, packet loss, and bit errors estimation, etc by sending OAM diagnostic test packets on one direction of the MEG.

a) When out-of-service test is performed, the source MEP configured for the out-of-service test transmits LCK packets to suppress the secondary alarms, the client data traffic is disrupted in the MEG and the OAM diagnostic test packets are sent to realize this function.

NOTE – When the out-of-service test is performed, the MEP also generates LCK packets at the immediate client (sub-)layer in the same direction where DT packets are transmitted (see Figure 7-1) and this needs to be taken into account when performing throughput measurement tests.

b) When in-service test function is performed, data traffic should not be disrupted and the OAM diagnostic test packets have to be transmitted in such a manner that a limited portion of the service bandwidth is utilized.

NOTE – When the in-service test is performed, the DT packets can impact the data traffic.

When the diagnostic test function is invoked on a MEP, a test signal generator associated with the MEP can transmit OAM diagnostic test packets as often as the test signal generator configuration. Each DT packet is transmitted with a specific sequence number. A different sequence number must be used for every DT packet, and no sequence number from the same MEP may be repeated within one minute.

When a MEP receives OAM diagnostic test packets, it examines them to ensure they are valid. If the receiving MEP is configured for diagnostic test function, the test signal detector associated with the MEP detects bit errors from the pseudo-random bit sequence of the received DT packets and reports such errors. Further, when the receiving MEP is configured for an out-of-service test, it also generates LCK packets at the client (sub-)layer in the direction in which the DT packets are received.

7.2.2. OAM Functions for Performance Monitoring

7.2.2.1 Proactive OAM Functions for Performance Monitoring

7.2.2.1.1 Proactive Loss Measurement

Proactive loss measurement function is for performance monitoring purposes. It is performed continuously and its result is used for verifying the performance of the connection against the service level agreement (SLA). This function is used to measure packets loss on a connection. To perform the loss measurement function (LM), the MEP periodically sends OAM packets with LM information to the peer MEP and similarly receives packets with LM information from the peer MEP. Each MEP performs packet loss measurements which contribute to unavailable time. Since a bidirectional service is defined as unavailable if either of the two directions is declared unavailable, LM must allow each MEP to perform near-end and far-end packet loss measurements.

Note: For a MEP, near-end packet loss refers to packet loss associated with ingress data packets while far-end packet loss refers to packet loss associated with egress data packets. Both near-end and far-end packet loss measurements contribute to near-end severely errored seconds (near-end SES) and far-end severely errored seconds (far-end SES) respectively which together contribute to unavailable time, in a manner similar to [ITU-T G.826] and defined in [ITU-T G.7710].

7.2.2.2 On-demand OAM Functions for Performance Monitoring

7.2.2.2.1 On-demand Loss Measurement

On-demand loss measurement (LM) function is for maintenance purpose. It is performed during a configured specific time interval and its result can be used for diagnosis and analysis. This function is used to measure packets loss on a connection. To perform the LM function, the MEP sends OAM packets with LM information to the peer MEP and similarly receives packets with LM information from the peer MEP. Each MEP performs packet loss measurements, but the measurements do not contribute to the SES and unavailable time of the connection.

For a MEP, near-end packet loss refers to packet loss associated with ingress data packets while far-end packet loss refers to packet loss associated with egress data packets.

7.2.2.2.2 On-demand Delay Measurement

On-demand delay measurement (DM) function is for maintenance purposes. It is performed during a configured specific time interval and its result can be used for diagnose and analysis. This function is used to measure packet delay and packet delay variation on a connection. The DM function can be performed in two fashions: one-way DM and two-way DM.

When a MEP is invoked to perform the on-demand delay measurement function (DM), it periodically sends DM packets with DM information (such as timestamps) to its peer MEP. It also expects to receive packets with DM information from its peer MEP. Packet delay (PD) and packet delay variation (PDV) measurements is derived from the DM information in the DM packets. The individual raw measurements of PD and PDV, instead of the summary statistics, will be reported to the maintenance system or craft for analysis and diagnosis.

The processing details of performing on-demand DM are similar to that of proactive DM.

7.2.3. Other Functions

7.2.3.1 Automatic protection switching (APS) communications

Automatic Protection Switching (APS) communications allows MPLS-TP nodes to exchange protection switching control via the Generalized Associated Channel (G-ACh).

The specific use of APS communications is outside the scope of this Recommendation.

7.2.3.2 Management communication Channel/ Signaling communication channel

Management Communication Channel (MCC) and Signaling Communication Channel (SCC) allow MPLS-TP nodes to exchange management plane and control plane messages via the Generalized Associated Channel (G-ACh).

The specific use of MCC and SCC is outside the scope of this Recommendation.

NOTE – MPLS-TP MCC and SCC are defined in [ITU-T G.7712] and [IETF RFC 5718].

7.2.3.3 Vendor-specific

Vendor-specific (VS) functions can be used by a vendor across its equipment. Interoperability of vendor-specific functionality is not expected across different vendor’s equipment.

The protocol design allows different vendor-specific protocols to be distinguished/separated from standard protocols, experimental protocols as well as from other vendor-specific protocols.

The specific application of vendor-specific functions is outside the scope of this Recommendation.

7.2.3.4 Experimental

Experimental (EXP) functions can be used within an administrative domain on a temporary basis. Interoperability of experimental functionality is not expected across different administrative domains.

The protocol design allows different experimental protocols to be distinguished/separated from standard protocols, vendor-specific protocols as well as from other experimental protocols.

The specific application of experimental functions is outside the scope of this Recommendation.

8. OAM Packet Formats

8.1.Common OAM packets

The format of GAL is as described in Figure 8-1 below:

1								2								3								4							
1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Label (13)																TC		S	TTL												

Figure 8-1/G.tpoam: GAL Format

The value of GAL is 13 as defined in [IETF RFC 5586].

The Traffic Class (TC) field (formerly known as the EXP field) of the Label Stack Entry (LSE) containing the GAL follows the definition and processing rules specified and referenced in [IETF RFC 5462].

S bit is set to 1. GAL is always at the bottom of the label stack.

The Time-To-Live (TTL) field of the LSE that contains the GAL MUST be set to at least 1 and follow the definition and processing rules specified in [IETF RFC 3443].

The format of Associated Channel Header is as described in Figure 8-2 below:

1				2				3				4											
1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
0001				Version(0)				Reserved (0)				Channel Type											

Figure 8-2/G.tpoam: ACH Format

The first nibble is set to 0001b to indicate a control channel associated with a PW, an LSP or a Section as defined in [IETF RFC 5586].

The Version field is set to 0 as defined in [IETF RFC 5586].

The Reserved field is set to 0 and ignored on reception as defined in [IETF RFC 5586].

Channel Type indicates the specific OAM protocol carried in the associated control channel.

The Registry of the allocated Channel Type values is maintained by IANA [b-IANA PW Reg]. The values used in this Recommendation are described in Table 8-1 below:

Table 8-1/G.tpoam – Channel Type values

Channel Type value	Description	Reference Clause
0x0001	Management Communication Channel (MCC)	8.3
0x0002	Signaling Communication Channel (SCC)	8.4
0xXXXX	Y.1731-based OAM	8.2

8.2.OAM PDU Formats based on Y.1731

This clause describes the information elements and formats for different OAM PDU types used to meet the requirements of OAM functions described in clause 7 that are inherited from [ITU-T Y.1731].

Within the MPLS-TP OAM Framework [IETF RFC xxxx], OAM packets are distinguished from user data packets using the G-ACh construct (see clause 7.1) and they are addressed to MEPs or MIPs using existing MPLS forwarding mechanisms (i.e. label stacking and TTL expiration). It is therefore possible to reuse the OAM PDUs defined in [ITU-T Y.1731] within MPLS-TP and encapsulate them within the G-ACh.

A single ACH Channel Type (0xXXXX) is required to identify the presence of the OAM PDU. Within the OAM PDU, the OpCode field, defined in [ITU-T Y.1731], identifies the specific OAM PDU, as described in Figure 8-3 below:

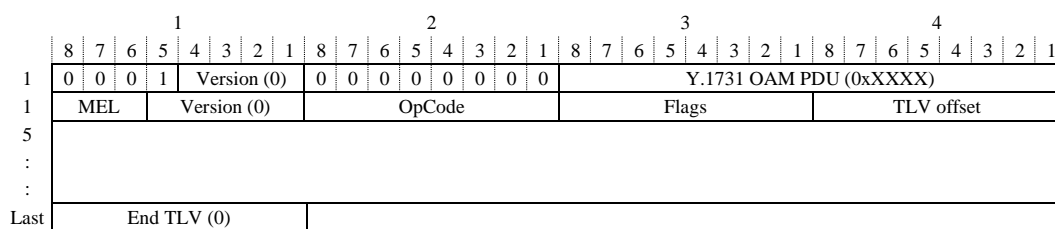


Figure 8-3/G.tpoam – Common OAM packet format based on Y.1731

The MEL field is configurable. It is set to the default value “111” on transmission and checked at reception for compliancy with [ITU-T Y.1731].

The OpCode field identifies the type of the OAM PDU. The Registry of the allocated OpCode values is maintained by ITU-T in [ITU-T Y.1731]. The values used in this Recommendation are described in Table 8-2 below:

Table 8-2/G.tpoam – OpCode values

OpCode value	OAM PDU type	OpCode relevance for MEPs/MIPs
1	CCM	MEPs
3	LBM	MEPs and MIPs (connectivity verification)
2	LBR	MEPs and MIPs (connectivity verification)
33	AIS	MEPs
35	LCK	MEPs
37	TST	MEPs
39	APS	MEPs
43	LMM	MEPs
42	LMR	MEPs
45	IDM	MEPs
47	DMM	MEPs
46	DMR	MEPs
49	EXM	Outside the scope of this Recommendation
48	EXR	Outside the scope of this Recommendation
51	VSM	Outside the scope of this Recommendation
50	VSR	Outside the scope of this Recommendation
52	CSF	MEPs

The setting of the Version, Flags and TLV Offset is OpCode specific and described in [ITU-T Y.1731].

The generic format of TLVs is defined in Figure 9.1-2 of [ITU-T Y.1731].

The Registry of the allocated Type values is maintained by ITU-T in [ITU-T Y.1731]. The values used in this Recommendation are described in Table 8-3 below:

Table 8-3/G.tpoam – Type values

Type value	TLV name
0	End TLV
3	Data TLV
32	Test TLV
33	Target MEP/MIP ID TLV
34	Replying MEP/MIP ID TLV
35	Requesting MEP ID TLV

8.2.1. Continuity Check Message (CCM)

The CCM PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the following MPLS-TP OAM functional requirements:

- Pro-active continuity check (section 2.2.2 of [IETF RFC 5860]);
- Pro-active connectivity verification (section 2.2.3 of [IETF RFC 5860]);
- Pro-active remote defect indication (section 2.2.9 of [IETF RFC 5860]);
- Pro-active packet loss measurement (section 2.2.11 of [IETF RFC 5860]).

Procedures for generating and processing CCM PDUs are defined in clause 9.1.1.

In order to perform pro-active Connectivity Verification, the CCM packet contains a globally unique identifier of the source MEP, which is the combination of a globally unique MEG ID with a MEP ID that is unique within the scope of the Maintenance Entity Group.

The generic format for MEG ID is defined in Figure A-1 of [ITU-T Y.1731]. Different formats of MEG ID are allowed: the MEG ID format type is identified by the MEG ID Format field.

The format of the ICC-based MEG ID is defined in Annex A of [ITU-T Y.1731]. This format is applicable to MPLS-TP Sections, LSPs and PWs.

MPLS-TP supports also IP-based format for MEG ID. These formats are outside the scope of this version of the Recommendation.⁵

8.2.2. OAM Loopback (LBM/LBR)

The LBM/LBR PDUs are defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, they can be used to support the following MPLS-TP OAM functional requirements:

- On-demand bidirectional connectivity verification (section 2.2.3 of [IETF RFC 5860]);
- Bidirectional in-service or out-of-service diagnostic test (section 2.2.5 of [IETF RFC 5860]).

Procedures for generating and processing LBM and LBR PDUs are defined in clause 9.1.2.

In order to allow proper identification of the target MEP/MIP the LBM is addressed to, the LBM PDU is required to include the Target MEP/MIP ID TLV: this TLV is always present in an LBM PDU and it is always located at the top of the TLVs (i.e., it starts at the offset indicated by the TLV Offset field).

⁵ The IP-based format for MEG ID is under definition in IETF: see [b-IETF tp-id]

To allow proper identification of the actual MEP/MIP that has replied to an LBM PDU, the LBR PDU is required to include the Replying MEP/MIP ID TLV: this TLV is always present in an LBR PDU and it is always located at the top of the TLVs (i.e., it starts at the offset indicated by the TLV Offset field).

NOTE – In order to simplify hardware-based implementations, these TLVs have been defined to have a fixed position (as indicated by the TLV Offset field) and a fixed length (see clause 8.2.2.1).

It is worth noting that the MEP/MIP identifiers used in the Target MEP/MIP ID and in the Replying MEP/MIP ID TLVs are required to be unique within the scope of the MEG. When LBM/LBR OAM is used for connectivity verification purposes, there are some misconnectivity cases that could not be easily located by simply relying upon these TLVs. In order to locate these misconnectivity configurations, the LBM PDU can carry a Requesting MEP ID TLV that provides a globally unique identification of the MEP that has originated the LBM PDU. When the Requesting MEP ID TLV is present in the LBM PDU, the replying MIP/MEP is required to check that the received requesting MEP identifier matches with the expected requesting MEP identifier before replying. In this case, the LBR PDU is required to carry the Requesting MEP ID TLV to confirm to the MEP the LBR PDU is sent to that the Requesting MEP ID TLV in the LBM PDU has been checked before replying.

When LBM/LBR OAM is used for bidirectional diagnostic tests, the Requesting MEP ID TLVs are never included.

The format of the LBM and LBR PDUs are shown in Figure 8-4 and in Figure 8-5.

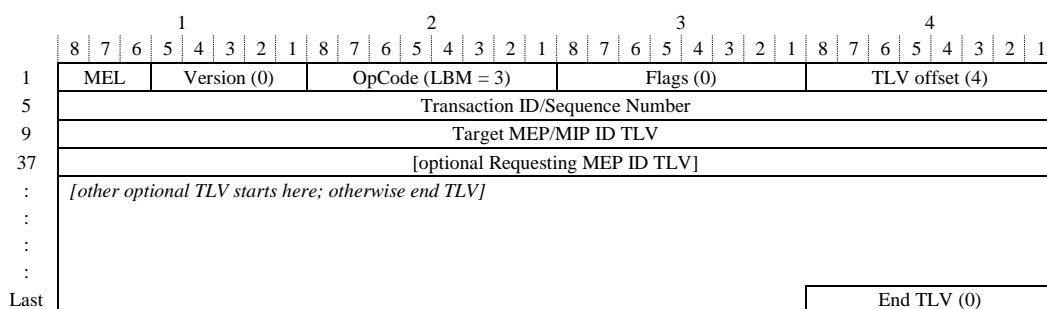


Figure 8-4/G.tpoam – LBM PDU format

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The Target MEP/MIP ID TLV is always present as the first TLV within the LBM PDU. When present, the Requesting MEP ID TLV always follows the Target MEP/MIP ID TLV within the LBM PDU.

NOTE – When the LBM packet is sent to a target MIP, the source MEP knows the hop count to the target MIP and sets the TTL field accordingly as described in [IETF RFC xxxx].

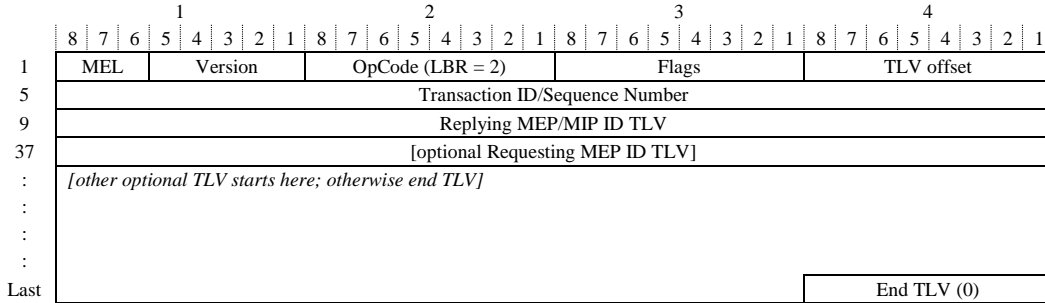


Figure 8-5/G.tpoam – LBR PDU format

Formatted: French (France)

The Replaying MEP/MIP ID TLV is always present as the first TLV within the LBR PDU. When present, the Requesting MEP ID TLV always follows the Replaying MEP/MIP ID TLV within the LBR PDU.

8.2.2.1 Target and Replaying MEP/MIP ID TLVs

The format of the Target and Replaying MIP/MEP ID TLVs are shown in Figure 8-6 and Figure 8-7.

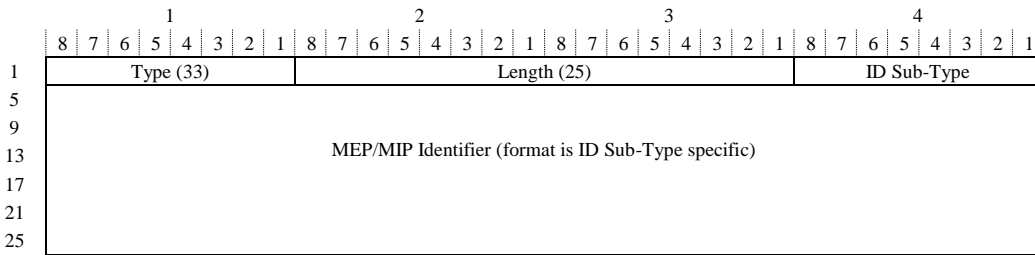


Figure 8-6/G.tpoam – Target MEP/MIP ID TLV format

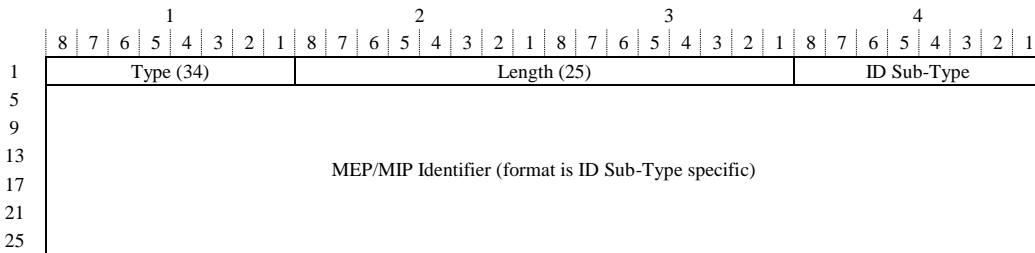


Figure 8-7/G.tpoam – Replaying MEP/MIP ID TLV format

Different formats of MEP/MIP identifiers can be defined: the format type is described by the MEP/MIP ID Sub-Type field (see Table 8-4).

Table 8-4 /G.tpoam– MEP/MIP Identifier Sub-Type values

ID Sub-Type	MEP/MIP Identifier Name	MEP/MIP Identifier Length
0x00	Discovery ingress/node MEP/MIP	0

0x01	Discovery egress MEP/MIP	0
0x02	ICC-based MEP ID	2 bytes
0x03	ICC-based MIP ID	14 bytes
0x04-0xFF	Reserved	

The “Discovery ingress/node MEP/MIP” and the “Discovery egress MEP/MIP” identifiers can only be used within the LBM PDU (and cannot appear in an LBR PDU) for discovering the identifiers of the MEPs or of the MIPs located at a given TTL distance from the MEP originating the LBM PDU.

The format of the Target MEP/MIP ID TLV carrying a “Discovery ingress/node MEP/MIP” is shown in Figure 8-8.

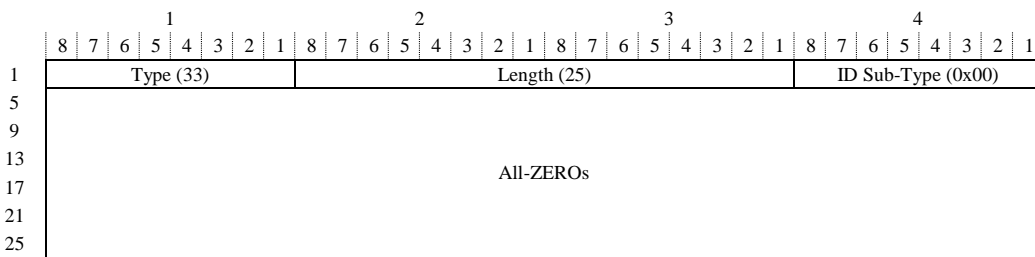


Figure 8-8/G.tpoam – Target MEP/MIP ID TLV format (discovery ingress/node MEP/MIP)

The format of the Target MEP/MIP ID TLV carrying a “Discovery egress MEP/MIP” is shown in Figure 8-9.

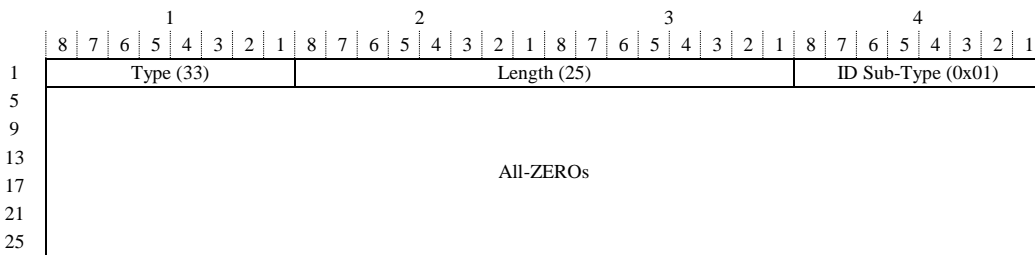


Figure 8-9 /G.tpoam– Target MEP/MIP ID TLV format (discovery egress MEP/MIP)

The format of the Target or Replying MEP/MIP ID TLV carrying an “ICC-based MEP ID” is shown in Figure 8-10.

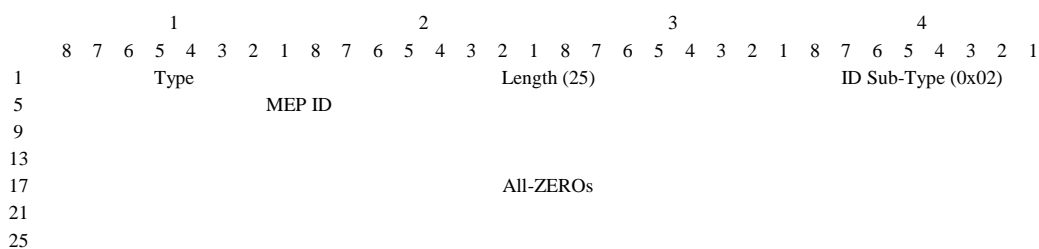


Figure 8-10/G.tpoam – Target or Replying MEP/MIP ID TLV format (ICC-based MEP ID)

The MEP ID is a 16-bit integer value identifying the transmitting MEP within the MEG.

The format of the Target or Replying MEP/MIP ID TLV carrying an “ICC-based MIP ID” is shown in Figure 8-11.

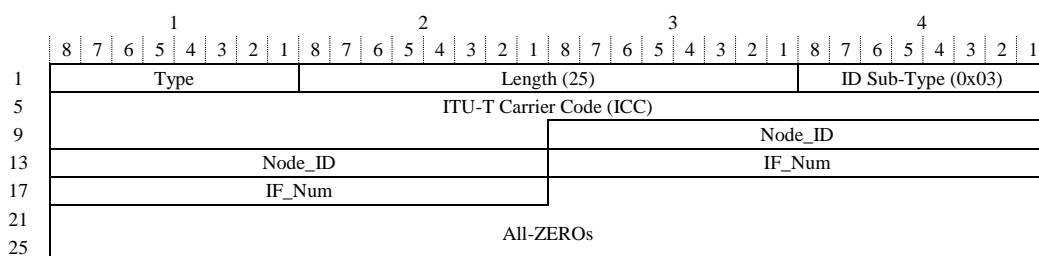


Figure 8-11/G.tpoam – Target or Replying MEP/MIP ID TLV format (ICC-based MIP ID)

The ITU-T Carrier Code (ICC) is a code assigned to a network operator/service provider and maintained by the ITU-T Telecommunication Standardization Bureau (TSB) as per [ITU-T M.1400].

The Node_ID is a numeric identifier of the node where the MIP is located. Its assignment is a matter for the organization to which the ICC has been assigned, provided that uniqueness within that organization is guaranteed.

The IF_Num is a numeric identifier of the Access Point (AP) toward the server layer trail, which can be either an MPLS-TP or a non MPLS-TP server layer, where a per-interface MIP is located. Its assignment is a matter for the node the MIP is located, provided that uniqueness within that node is guaranteed. Note that the value 0 for IF_Num is reserved to identify per-node MIPs.

MPLS-TP supports also IP-based format for MIP and MEP identifiers. These formats are outside the scope of this version of the Recommendation.⁶

8.2.2.2 Requesting MEP ID TLV

The format of the Requesting MEP ID TLVs is shown in Figure 8-12.

⁶ The IP-based format for MIP and MEP identifiers are under definition in IETF: see [b-IETF tp-id]

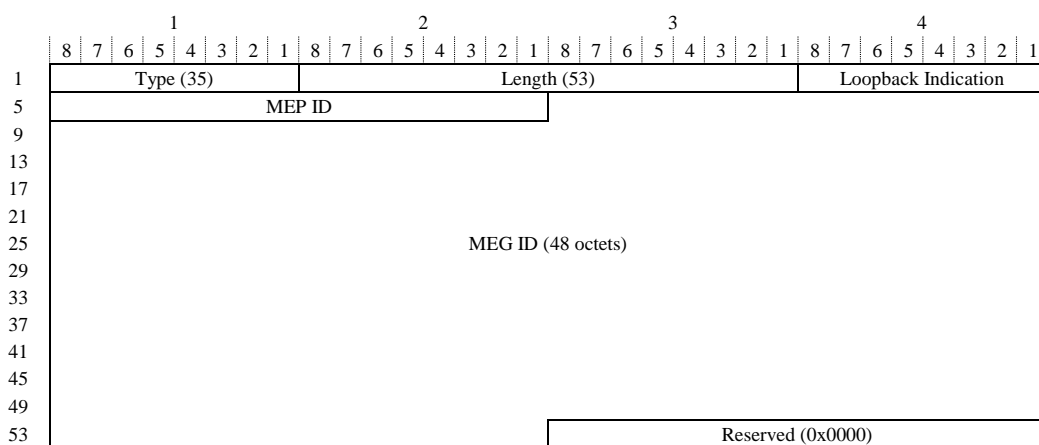


Figure 8-12/G.tpoam – Requesting MEP ID TLV format

The MEP ID and MEG ID carry the globally unique MEP ID as defined in section 8.2.1.

The Reserved bits are set to all-ZEROes in transmission and ignored in reception.

The Loopback Indication is set to 0x0000 when this TLV is inserted in an LBM PDU and set to 0x0001 in the LBR PDU. This is used to indicate that the value of this TLV has been checked by the node that generated the LBR PDU.

8.2.3. Alarm Indication Signal (AIS)

The AIS PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the alarm reporting MPLS-TP OAM functional requirement (section 2.2.8 of [IETF RFC 5860]).

Procedures for generating and processing AIS PDUs are defined in clause 9.1.3.

8.2.4. Locked Signal (LCK)

The LCK PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the lock reporting MPLS-TP OAM functional requirement (section 2.2.7 of [IETF RFC 5860]).

Procedures for generating and processing LCK PDUs are defined in clause 9.1.4.

8.2.5. Test (TST)

The TST PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the uni-directional in-service or out-of-service diagnostic tests MPLS-TP OAM functional requirement (section 2.2.8 of [IETF RFC 5860]).

Procedures for generating and processing TST PDUs are defined in clause 9.1.5.

8.2.6. Loss Measurement (LMM/LMR)

The LMM/LMR PDUs are defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, they can be used to support on-demand packet loss measurement MPLS-TP OAM functional requirement (section 2.2.11 of [IETF RFC 5860]).

Procedures for generating and processing LMM and LMR PDUs are defined in clause 9.1.6.

8.2.7. One-way Delay Measurement (1DM)

The 1DM PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the on-demand one-way packet delay measurement MPLS-TP OAM functional requirement (section 2.2.12 of [IETF RFC 5860]).

Procedures for generating and processing 1DM PDUs are defined in clause 9.1.7.

8.2.8. Two-way Delay Measurement (DMM/DMR)

The DMM/DMR PDUs are defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, they can be used to support the on-demand two-ways packet delay measurement MPLS-TP OAM functional requirement (section 2.2.12 of [IETF RFC 5860]).

Procedures for generating and processing 1DM PDUs are defined in clause 9.1.8.

8.2.9. Client Signal Fail (CSF)

The CSF PDU is defined in [ITU-T Y.1731]. When encapsulated within MPLS-TP, as described in clause 8.2, it can be used to support the client failure indication MPLS-TP OAM functional requirement (section 2.2.10 of [IETF RFC 5860]). Procedures for generating and processing CSF PDUs are defined in clause 9.1.9.

8.2.10. Automatic Protection Switching (APS)

The APS PDU supports the requirement for MPLS-TP protection switching coordination.

The common formats for APS PDUs are defined in [ITU-T Y.1731]. The complete format of the APS PDUs and the associated procedures are outside the scope of [ITU-T Y.1731] and of this Recommendation.

8.2.11. Experimental (EXM/EXR)

The EXM/EXR PDUs support the requirement for support of MPLS-TP experimental functions.

The common formats for EXM/EXR PDUs are defined in [ITU-T Y.1731]. The complete format of the EXM/EXR PDUs and the associated procedures are outside the scope of [ITU-T Y.1731] and of this Recommendation.

8.2.12. Vendor-Specific (VSM/VSR)

The VSM/VSR PDUs support the requirement for support of MPLS-TP vendor-specific functions.

The common formats for VSM/VSR PDUs are defined in [ITU-T Y.1731]. The complete format of the VSM/VSR PDUs and the associated procedures are outside the scope of [ITU-T Y.1731] and of this Recommendation.

8.3. Management Communication Channel (MCC)

The packet format for carrying management communication (i.e., MCC packets) over an ACH and associated procedures are defined in [ITU-T G.7712] and [IETF RFC 5718].

8.4. Signaling Communication Channel (SCC)

The packet format for carrying signalling communication (i.e., SCC packets) over an ACH and associated procedures are defined in [ITU-T G.7712] and [IETF RFC 5718].

9. MPLS-TP OAM Procedures

9.1. MPLS-TP OAM Procedures based on Y.1731 PDUs

The high level procedures for processing Y.1731 OAM PDUs are described in [ITU-T Y.1731]. The technology independent procedures are also applicable to MPLS-TP OAM.

More detailed and formal procedures for processing Y.1731 OAM PDUs are defined in [ITU-T G.8021]. Although the description in [ITU-T G.8021] is Ethernet specific, the technology independent procedures are also applicable to MPLS-TP OAM.

This clause describes the MPLS-TP OAM procedures based on the technology independent ones defined in [ITU-T Y.1731] and [ITU-T G.8021].

9.1.1. Continuity Check Message (CCM) procedures

The CCM PDU format is defined in section 8.2.1.

When CCM generation is enabled, the MEP generates CCM OAM packets with the periodicity and the PHB configured by the operator:

- MEL field is set to the configured value (see clause 8.2);
- Version field is set to 0 (see clause 8.2);
- OpCode field is set to 01 (see clause 8.2.1);
- RDI flag is set, if the MEP asserts signal file. Otherwise, it is cleared;
- Reserved flags are set to 0 (see clause 8.2.1);
- Period field is set according to the configured periodicity (see Table 9-3 of [ITU-T Y.1731]);
- TLV Offset field is set to 70 (see clause 8.2.1);
- Sequence Number is set to 0 (see clause 8.2.1);
- MEP ID and MEG ID fields are set to carry the configured values;
- The TxFCf field is set with the current value of the counter for in-profile data packets transmitted towards the peer MEP, when proactive loss measurement is enabled. Otherwise it is set to 0.
- The RxFCb field is set with the current value of the counter for in-profile data packets received from the peer MEP, if proactive loss measurement is enabled. Otherwise it is set to 0.
- The TxFCb field is set with the value of TxFCf of the last received CCM PDU from the peer MEP, if proactive loss measurement is enabled. Otherwise it is set to 0.
- Reserved field is set to 0 (see clause 8.2.1);
- End TLV is inserted after the Reserved field (see clause 8.2.1).

NOTE 1 – The transmission period of the CCM is always the configured period and does not change unless the operator reconfigures it. The period field in CCM PDU is transmitted with a value of transmission period configured at the transmitting MEP.

When a MEP receives a CCM OAM packet, it checks the various fields (see Figure 8-19 of [ITU-T G.8021]). The following defects are detected as described in clause 6.1 of [ITU-T G.8021]: LOC defect (dLOC), Unexpected MEG Level defect (dUNL)⁷, Mis-merge defect (dMMG), Unexpected MEP defect (dUNM), Unexpected Periodicity defect (dUNP), Unexpected Priority defect (dUNPr) and RDI defect (dRDI).

⁷ The dUNL defect will not be raised if the default value for MEL is used.

If the Version, MEL, MEG and MEP fields are valid and pro-active loss measurement is enabled, the values of the packet counters fields are processed as described in clause 8.1.7.4 of [ITU-T G.8021].

The CCM packet also allows measurement of proactive dual-ended packet loss for co-routed point-to-point bidirectional MPLS-TP connections.

When configured for proactive loss measurement, a MEP periodically transmits CCM packets with the following information elements TxFCf, RxFCb, TxFCb as described above.

When configured for pro-active loss measurement, a MEP, upon receiving a CCM packet, uses the following values to make near-end and far-end loss measurements:

- Received CCM packet's TxFCf, RxFCb and TxFCb values and local counter RxFCI value at the time this CCM packet was received. These values are represented as TxFCf[tc], RxFCb[tc], TxFCb[tc] and RxFCI[tc], where tc is the reception time of the current frame.
- Previous CCM packet's TxFCf, RxFCb and TxFCb values and local counter RxFCI value at the time the previous CCM packet was received. These values are represented as TxFCf[tp], RxFCb[tp], TxFCb[tp] and RxFCI[tp], where tp is the reception time of the previous packet.

$$\text{packet loss}_{\text{far-end}} = |\text{TxFCb[tc]} - \text{TxFCb[tp]}| - |\text{RxFCb[tc]} - \text{RxFCb[tp]}|$$

$$\text{packet loss}_{\text{near-end}} = |\text{TxFCf[tc]} - \text{TxFCf[tp]}| - |\text{RxFCI[tc]} - \text{RxFCI[tp]}|$$

NOTE 2- For dual-ended loss measurement, the counters do not count on-demand OAM packets for LBM/LBR, LMM/LMR, DMM/DMR, 1DM, TST and CCM. However, proactive OAM packets for APS are counted.

9.1.2. OAM Loopback (LBM/LBR) procedures

The LBM/LBR PDU formats are defined in section 8.2.2.

When an out-of-service OAM loopback function is performed, client data traffic is disrupted in the diagnosed ME. The MEP configured for the out-of-service test transmits LCK packets in the immediate client (sub-) layer, as described in sub-clause 9.1.4.

When an in-service OAM loopback function is performed, client data traffic is not disrupted and the packets with LBM/LBR information are transmitted in such a manner that a limited part of the service bandwidth is utilized. The periodicity for packets with LBM/LBR information is pre-determined.

NOTE 1 – The maximum rate at which packets with LBR/LBM information can be sent without adversely impacting the client data traffic for an in-service LBR/LBM is outside the scope of this Recommendation. It may be mutually agreed between the user of the LBM/LBR function and the user of the service.

NOTE 2 – Additional configuration information elements may be needed, such as the transmission rate of LBM/LBR information, the total interval of the test, etc. These additional configuration information elements are outside the scope of this Recommendation.

The LBM/LBR PDU formats are defined in section 8.2.2 and described in details in clauses 9.3 and 9.4 of [ITU-T Y.1731].

When on-demand OAM loopback is enabled at a MEP, the (requesting) MEP generates and sends to one of the MIPs or the peer MEP LBM OAM packets with the periodicity and the PHB configured by the operator:

- MEL field is set to the configured value (see clause 8.2);
- Version field is set to 0 (see clause 8.2);

- OpCode field is set to 03 (see clause 8.2.2);
- Flags field is set to all-ZEROes (see clause 8.2.2);
- TLV Offset field is set to 4 (see clause 8.2.2);
- Transaction field is a 4-octet field that contains the transaction ID/sequence number for the loop back measurement;
- Target MEP/MIP ID is set to carry the configured value;

NOTE 3 – When performing a discovery function, the Target MEP/MIP-ID is configured to be the “Discovery ingress/node MEP/MIP” or the “Discovery egress MEP/MIP”.

- The Originator MEP-ID TLV is inserted if configured and it is set to carry the configured value;

NOTE 4 – When performing a bidirectional diagnostic test function, the Originator MEP ID is configured not to be sent.

- Optional TLV field whose length and contents are configurable at the requesting MEP. The contents can be a test pattern and an optional checksum. Examples of test patterns include pseudo-random bit sequence (PRBS) ($2^{31}-1$) as specified in sub-clause 5.8/O.150, all ‘0’ pattern, etc. For bidirectional diagnostic test application, configuration is required for a test signal generator and a test signal detector associated with the MEP;
- End TLV field is set to all-ZEROes (see clause 8.2.2).

Whenever a valid LBM packet is received by a (receiving) MIP or a (receiving) MEP, an LBR packet is generated and transmitted by the receiving MIP/MEP to the requesting MEP:

- MEL field is set to the value which is copied from the last received LBM PDU;
- Version field is set to the value which is copied from the last received LBM PDU;
- OpCode field is set to 2 (see clause 8.2.2);
- Flags field is set to the value which is copied from the last received LBM PDU;
- TLV Offset field is set to the value which is copied from the last received LBM PDU;
- Transaction field is set to the value which is copied from the last received LBM PDU;
- The Target MEP/MIP ID and Originator MEP ID fields are set to the value which is copied from the last received LBM PDU;
- The Optional TLV field is set to the value which is copied from the last received LBM PDU;
- End TLV field is inserted after the last TLV field; it is set to the value which is copied from the last received LBM PDU.

NOTE 5 – The transmission period of the LBR is always the same as the period of the LBM.

9.1.3. Alarm Indication Signal (AIS) procedures

The AIS PDU format is described in clause 8.2.3.

When the server layer trail termination sink asserts signal fail, it notifies the server/MT_A_Sk function that raises the aAIS consequent action. The aAIS is cleared when the server layer trail termination clears the signal fail condition and notifies the server/MT_A_Sk.

When the aAIS consequent action is raised, the server/MT_A_Sk continuously generates MPLS-TP OAM packets carrying the AIS PDU until the aAIS consequent action is cleared:

- MEL field is set to the configured value (see clause 8.2);
- Version field is set to 0 (see clause 8.2);
- OpCode is set to 33 (see clause 8.2.3);

- Reserved flags are set to 0 (see clause 8.2.3);
- Period field is set according to the configure periodicity (see Table 9-4 of [ITU-T Y.1731]);
- TLV Offset is set to 0 (see clause 8.2.3);
- End TLV is inserted after the TLV Offset field (see clause 8.2.3).

It is recommended that AIS is generated once per second.

The generated AIS packets are inserted in the incoming stream, i.e., the output stream contains the incoming packets and the generated AIS packets.

When a MEP receives an AIS packet with the correct MEL value, it detects the dAIS defect as described in clause 6.1 [ITU-T G.8021].

9.1.4. Locked Signal (LCK) procedures

The LCK PDU format is described in clause 8.2.4.

When the access to the server layer trail is administratively locked by the operator, the server/MT_A_So and server/MT_A_Sk functions raise the aLCK consequent action. The aLCK is cleared when the access to the server layer trail is administratively unlocked.

When the aLCK consequent action is raised, the server/MT_A_So and server/MT_A_Sk continuously generate, on both directions, MPLS-TP OAM packets carrying the LCK PDU until the aLCK consequent action is cleared:

- MEL field is set to the configured value (see clause 8.2):
- Version field is set to 0 (see clause 8.2):
- OpCode is set to 35 (see clause 8.2.4):
- Reserved flags are set to 0 (see clause 8.2.4):
- Period field is set according to the configure periodicity (see Table 9-4 of [ITU-T Y.1731]);
- TLV Offset is set to 0 (see clause 8.2.4):
- End TLV is inserted after the TLV Offset field (see clause 8.2.4).

It is recommended that LCK is generated once per second.

When a MEP receives an LCK packet with the correct MEL value, it detects the dLCK defect as described in clause 6.1 [ITU-T G.8021].

9.1.5. Test (TST) procedures

The TST function allows performing on-demand in-service or out-of-service one-way diagnostic tests between a pair of peer MEPs in point-to-point MPLS-TP connections. This includes verifying bandwidth throughput, detecting bit errors, etc.

The TST PDU format is described in section 8.2.5 of this Recommendation and defined in detail in clause 9.9 of [ITU-T Y.1731].

When an out-of-service TST function is performed, client data traffic is disrupted in the diagnosed ME. The MEP configured for the out-of-service test transmits LCK packets, as described in sub-clause 9.1.4, in the immediate client (sub-) layer.

When an in-service TST function is performed, client data traffic is not disrupted and the packets with TST information are transmitted in such a manner that a limited part of the service bandwidth is utilized. The periodicity for packets with TST information is pre-determined.

NOTE 1 – The maximum rate at which packets with TST information can be sent without adversely impacting the client data traffic for an in-service TST is outside the scope of this Recommendation. It may be mutually agreed between the user of the MS-TST function and the user of the service.

NOTE 2 – Additional configuration information elements may be needed, such as the transmission rate of TST information, the total interval of the test, etc. These additional configuration information elements are outside the scope of this Recommendation.

A MIP is transparent to the TST packets and therefore does not require any configuration information to support the TST functionality.

When on-demand diagnostics test is enabled at a MEP, it periodically generates and transmits TST OAM packets to its peer MEP in the same ME. The receiving MEP detects these TST OAM packets and makes the intended measurements.

The TST PDU format is defined in section 8.2.5.

The requesting MEP generates and sends the TST OAM packets with the periodicity and the PHB configured by the operator.

- MEL field is set to the configured value (see clause 8.2);
- Version field is set to 0 (see clause 8.2);
- OpCode field is set to 37 (see clause 8.2);
- Flags field is set to all-ZEROes;
- TLV Offset field is set to 4 (see clause 8.2.5);
- Sequence Number field: A 4-octet value containing the sequence number which is incremented in successive TST PDUs.
- Test TLV field: Test TLV as specified in clause 8.2.5 and described in Figure 9.3-4 of [ITU-T Y.1731]. Test TLV whose length and contents are configurable at the requesting MEP. The contents can be a test pattern and an optional checksum. Examples of test patterns include pseudo-random bit sequence (PRBS) ($2^{31}-1$) as specified in sub-clause 5.8/O.150, all '0' pattern, etc.
- End TLV field is set to all-ZEROes,

9.1.6. Loss Measurement (LMM/LMR) procedures

The LMM/LMR function allows measurement of on-demand single-ended packet loss for point-to-point bidirectional MPLS-TP connections.

The LMM/LMR PDU formats are described in section 8.2.6 of this Recommendation and defined in details in clauses 9.12 and 9.13 of [ITU-T Y.1731].

When on-demand loss measurement is enabled at a MEP, the MEP (i.e. the requesting MEP) generates and sends to its peer MEP the LMM OAM packets with the periodicity and the PHB configured by the operator:

- The MEL field is set to the configured value (see clause 8.2);
- The Version field is set to 0 (see clause 8.2);
- The OpCode field is set to 43 (see clause 8.2);
- The Flag field is set to all-ZEROes;
- The TLV Offset field is set to 12 (see clause 8.2.6);
- The TxFCf field is set to the current value of the counter for in-profile data packets transmitted by the MEP towards its peer MEP, at the time of LMM packet transmission;

- The Reserved fields for RxFCf and TxFCb are set to 0 (see clause 8.2.6);
- The End TLV is set to all-ZEROes (see clause 8.2). No TLVs other than the End TLV are present in the LMM PDU.

NOTE1- For LMM/LMR, the counters do not count on-demand OAM packets for LBM/LBR, LMM/LMR, DMM/DMR, 1DM and TST. Instead, CCM and APS packets are counted.

An LMM packet with a valid MEG level is considered to be a valid LMM packet. A LMM packet is discarded if not valid. Whenever a valid LMM packet is received by a MEP (i.e. the receiving MEP), an LMR packet is generated and transmitted by the receiving MEP to the requesting MEP as follows:

- The MEL field is set to the value which is copied from the last received LMM PDU;
- The Version field is set to the value which is copied from the last received LMM PDU;
- The OpCode field is set to 42 (see clause 8.2);
- The Flag field is set to the value which is copied from the last received LMM PDU;
- The TLV Offset field is set to the value which is copied from the last received LMM PDU;
- The TxFCf field is set to the value which is copied from the last received LMM PDU;
- The RxFCf field is set to the value of the counter of in-profile data packets received by the MEP (receiving MEP) from its peer MEP (requesting MEP), at the time of receiving last LMM packet from that peer MEP;
- The TxFCb field is set to the value of the counter of in-profile data packets transmitted by the MEP (receiving MEP) towards its peer MEP (requesting) at the time of LMR packet transmission;
- The End TLV is set to all-ZEROes. No TLVs other than the End TLV are present in the LMR PDU.

Upon receiving an LMR packet, a MEP (the requesting MEP) uses the following values to make near-end loss measurement (i.e. loss associated with ingress data packets) and far-end loss measurements (i.e. loss associated with egress data packets):

- Received LMR packet's TxFCf, RxFCf and TxFCb values and local counter RxFCI value at the time this LMR packet was received. These values are represented as TxFCf[tc], RxFCf[tc], TxFCb[tc] and RxFCI[tc], where tc is the reception time of the current reply packet.
- Previous LMR packet's TxFCf, RxFCf and TxFCb values and local counter RxFCI value at the time the previous LMR packet was received. These values are represented as TxFCf[tp], RxFCf[tp], TxFCb[tp] and RxFCI[tp], where tp is the reception time of the previous reply packet.

$$\text{packet loss}_{\text{far-end}} = |\text{TxFCf}[t_c] - \text{TxFCf}[t_p]| - |\text{RxFCf}[t_c] - \text{RxFCf}[t_p]|$$

$$\text{packet loss}_{\text{near-end}} = |\text{TxFCb}[t_c] - \text{TxFCb}[t_p]| - |\text{RxFCI}[t_c] - \text{RxFCI}[t_p]|$$

9.1.7. One-way Delay Measurement (1DM) procedures

The 1DM function allows measurement of on-demand one-way packet delay and packet delay variation for point-to-point unidirectional or bidirectional MPLS-TP connections.

The 1DM PDU format is described in section 8.2.7 of this Recommendation and defined in details in clause 9.14 of [ITU-T Y.1731].

When on-demand packet delay measurement is enabled at a MEP, it periodically generates and transmits 1DM OAM packets to its peer MEP in the same ME. It also expects to receive 1DM OAM packets from its peer MEP in the same ME.

The transmitting MEP generates and sends the 1DM OAM packets with the periodicity and the PHB configured by the operator:

- The MEL field is set to the configured value (see clause 8.2);
- The Version field is set to 0 (see clause 8.2);
- The OpCode field is set to 45 (see clause 8.2);
- The Flag field is set to all-ZEROes;
- The TLV Offset field is set to 16 (see clause 8.2.7);
- The TxTimeStampf field is set to the timestamp at the transmission of the 1DM packet. The format of TxTimeStampf is equal to the TimeRepresentation format in [IEC 61588];
- The Reserved field is set to all-ZEROes ;
- The End TLV is set to all-ZEROes (see clause 8.2). No TLVs other than the End TLV are present in the 1DM PDU.

Upon receiving a valid 1DM packet, the receiving MEP can compare the TxTimeStampf value in the received 1DM packet with the RxTimef, the time at the reception of the 1DM packet and calculate the one-way packet delay. A 1DM packet with a valid MEG level is considered to be a valid 1DM packet. The one-way packet delay is calculated as:

$$\text{Packet Delay} = \text{RxTimef} - \text{TxTimeStampf}$$

Packet delay variation measurement is calculated based on the difference between subsequent packet delay measurements.

Consideration regarding impact of clock synchronization on one-way packet delay measurement is described in clause 8.2 of [ITU-T Y.1731].

9.1.8. Two-way Delay Measurement (DMM/DMR) procedures

The DMM/DMR function allows measurement of on-demand two-way packet delay and packet delay variation for point-to-point bidirectional MPLS-TP connections.

The DMM/DMR PDU formats are described in section 8.2.8 of this Recommendation and defined in details in clauses 9.15 and 9.16 of [ITU-T Y.1731].

When on-demand two-way packet delay measurement is enabled at a MEP (the requesting MEP), it periodically generates and transmits DMM OAM packets to its peer MEP in the same ME with the periodicity and the PHB configured by the operator:

- The MEL field is set to the configured value (see clause 8.2);
- The Version field is set to 0 (see clause 8.2);
- The OpCode field is set to 47 (see clause 8.2);
- The Flag field is set to all-ZEROes;
- The TLV Offset field is set to 32 (see clause 8.2.8);
- The TxTimeStampf field is set to the timestamp at the transmission of the DMM packet. The format of TxTimeStampf is equal to the TimeRepresentation format in [IEC 61588];
- The Reserved field is set to all-ZEROes
- The End TLV is set to all-ZEROes (see clause 8.2). No TLVs other than the End TLV are present in the DMM PDU.

A DMM packet with a valid MEG level is considered to be a valid DMM packet. A DMM packet is discarded if not valid. Whenever a valid DMM packet is received by a MEP (i.e. the receiving

MEP), a DMR packet is generated and transmitted by the receiving MEP to the requesting MEP as follows:

- The MEL field is set to the value which is copied from the last received DMM PDU;
- The Version field is set to the value which is copied from the last received DMM PDU;
- The OpCode field is set to 46 (see clause 8.2);
- The Flag field is set to the value which is copied from the last received DMM PDU;
- The TLV Offset field is set to the value which is copied from the last received DMM PDU;
- The TxTimeStampf field is set to the value which is copied from the last received DMM PDU;
- The RxTimeStampf field is optional. If used, it is set to the timestamp of DMM reception. If not used, it is set to all-ZEROes;
- The TxTimeStampb field is optional. If used, it is set to the timestamp of DMR transmission. If not used, it is set to all-ZEROes;
- The Reserved field is set to all-ZEROes;
- The End TLV is set to all-ZEROes. No TLVs other than the End TLV are present in the DMR PDU.

Upon receiving a DMR packet, the requesting MEP can compare the TxTimeStampf value in the received DMR packet with the RxTimeb, the time at the reception time of the DMR packet and calculate the two-way packet delay as:

$$\text{Packet Delay} = \text{RxTimeb} - \text{TxTimeStampf}$$

If the optional timestamps are carried in the DMR packet, which is determined by non-zero values of the RxTimeStampf and TxTimeStampb fields, the more precise two-way packet delay (i.e., excluding the local processing time at the receiving MEP) is calculated to be:

$$\text{Packet Delay} = (\text{RxTimeb} - \text{TxTimeStampf}) - (\text{TxTimeStampb} - \text{RxTimeStampf})$$

Packet delay variation measurement is calculated based on the difference between subsequent packet delay measurements.

9.1.9. Client Signal Fail (CSF) procedures

The CSF function is used to propagate an indication from the ingress of an ME to the egress of the same ME that a failure of the ingress client signal has been detected. This is used in case the client layer itself does not support an alarm suppression mechanism, e.g. AIS. This supports the application described in Appendix VIII of [ITU-T G.806].

CSF packets with CSF information can be issued by a MEP, upon receiving signal fail information from its client layer. Detection rules for client signal fail events are by definition client-specific and outside the scope of this Recommendation. Upon receiving signal fail indication from its client layer the MEP can immediately start transmitting periodic CSF packets. A MEP continues to transmit periodic packets with CSF information until the client layer signal fail indication is removed.

Transmission of CSF packets can be enabled or disabled on a MEP.

The period of CSF generation is client layer specific and outside the scope of this recommendation.

Upon receiving an CSF packet a MEP detects the client layer signal fail condition and forwards this as a signal fail indication to its client layer.

The clearing conditions of CSF are client layer specific and outside the scope of this recommendation.

Upon receiving the clearing of the signal fail indication from its client layer the MEP communicates this condition to its peer MEP by:

- Ceasing the transmission of CSF packets and starting to forward client PDUs, or
- Transmitting CSF packets with Client Defect Clear Indication (C-DCI) information.

A MIP is transparent to packets with CSF information and therefore does not require any information to support CSF functionality.

The CSF PDU format is defined in section 8.2.9.

The requesting MEP generates and sends the CSF OAM packets with the periodicity and the PHB configured by the operator.

- MEL field is set to the configured value (see clause 8.2);
- Version field is set to 0 (see clause 8.2);
- OpCode field is set to 52 (see clause 8.2);
- Flags field consist of:
 - Reserved bits are set to all-ZEROes;
 - Type field set according to CSF condition (see Table 9-5 of [ITU-T Y.1731]);
 - Period field configured by operator;
- TLV Offset field is set to 0 (see clause 8.2.9);
- End TLV field is set to all-ZEROes,

Appendix I

MPLS-TP network scenarios

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

I.1 MEG nesting example

Figure I.1 provides an example scenario, using the default MEG level, of nested MEGs for customer, provider and operator roles. In the figure, triangles represent MEPs, circles represent MIPs, and diamonds represent Traffic Conditioning Points (TrCPs).

Figure I.1 shows an example of network implementation; MEPs and MIPs should be configured per interface, not per node. Upside-down triangles (▼) indicate Down MEPs and normal triangles (▲) indicate Up MEPs.

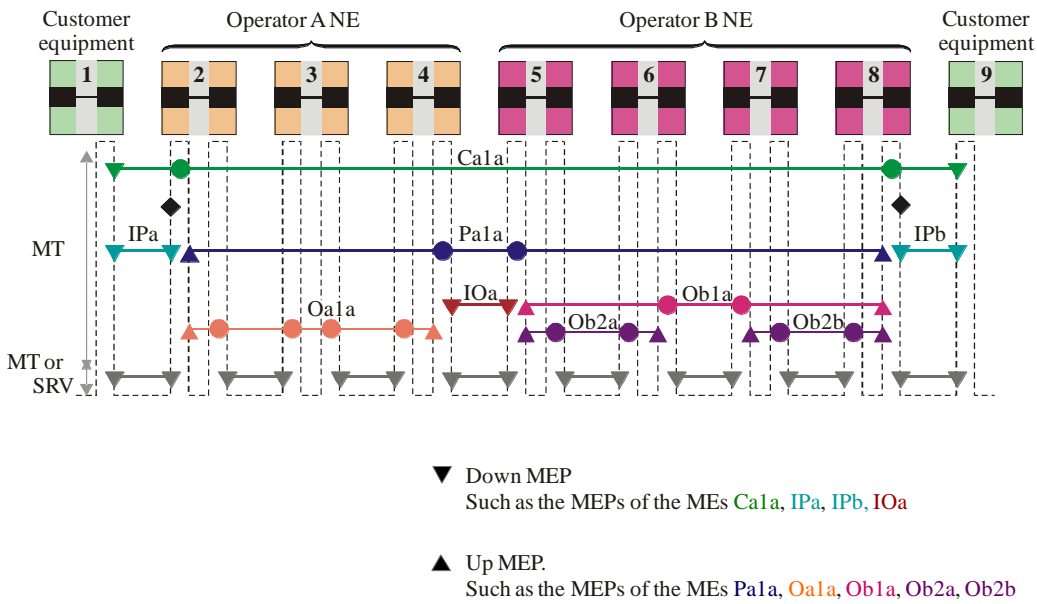


Figure I.1/G.tpoam – Example MEG nesting

- UNI_C to UNI_C customer ME (Ca1a).
- UNI_N to UNI_N provider ME (Pa1a).
- End-to-end operator MEs (Oa1a and Ob1a).
- Segment operator MEs in operator B's network (Ob2a and Ob2b).
- UNI_C to UNI_N MEs (IPa and IPb) between the customer and provider.
- Inter-operator ME (IOa).