CCAMP Working Group   E. Bellagamba, Ed.
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Expires: April 10, 2013   P. Skoldstrom, Ed.
                                                              Acreo AB
                                                               D. Ward
                                                               Juniper
                                                             A. Takacs
                                                              Ericsson
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Configuration of Pro-Active Operations, Administration, and Maintenance
    (OAM) Functions for MPLS-based Transport Networks using RSVP-TE
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Abstract

   This specification describes the configuration of pro-active MPLS-TP
   Operations, Administration, and Maintenance (OAM) Functions for a
   given LSP using a set of TLVs that are carried by the RSVP-TE
   protocol.

   This document is a product of a joint Internet Engineering Task Force
   (IETF) / International Telecommunication Union Telecommunication
   Standardization Sector (ITU-T) effort to include an MPLS Transport
   Profile within the IETF MPLS and PWE3 architectures to support the
   capabilities and functionalities of a packet transport network.

Status of this Memo

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1. Introduction

   This document describes the configuration of pro-active MPLS-TP
   Operations, Administration, and Maintenance (OAM) Functions for a
   given LSP using TLVs carried by RSVP-TE [RFC3209]. In particular it
   specifies the mechanisms necessary to establish MPLS-TP OAM entities
   at the maintenance points for monitoring and performing measurements
   on an LSP, as well as defining information elements and procedures to
   configure pro-active MPLS OAM functions running between LERs.
   Initialization and control of on-demand MPLS OAM functions are
   expected to be carried out by directly accessing network nodes via a
   management interface; hence configuration and control of on-demand
   OAM functions are out-of-scope for this document.

   The Transport Profile of MPLS must, by definition [RFC5654], be
   capable of operating without a control plane. Therefore there are
   several options for configuring MPLS-TP OAM, without a control plane
   by either using an NMS or LSP Ping, or with a control plane using
   signaling protocols RSVP-TE and/or T-LDP. Use of T-LDP for
   configuration of MPLS-TP OAM is outside of scope of this document.

   Pro-active MPLS OAM is performed by three different protocols,
   Bidirectional Forwarding Detection (BFD) [RFC6428] for Continuity
   Check/Connectivity Verification, the delay measurement protocol (DM)
   [RFC6374] for delay and delay variation (jitter) measurements, and
   the loss measurement protocol (LM) [RFC6374] for packet loss and
   throughput measurements. Additionally there is a number of Fault
   Management Signals that can be configured.

   BFD is a protocol that provides low-overhead, fast detection of
   failures in the path between two forwarding engines, including the
   interfaces, data link(s), and to the extent possible the forwarding
   engines themselves. BFD can be used to track the liveliness and
   detect data plane failures of MPLS-TP point-to-point and might also
   be extended to support point-to-multipoint connections.

   The delay and loss measurements protocols [RFC6374] use a simple
   query/response model for performing bidirectional measurements that
   allows the originating node to measure packet loss and delay in both
   directions. By timestamping and/or writing current packet counters
   to the measurement packets at four times (Tx and Rx in both
   directions) current delays and packet losses can be calculated. By
   performing successive delay measurements the delay variation (jitter)
   can be calculated. Current throughput can be calculated from the
   packet loss measurements by dividing the number of packets sent/
   received with the time it took to perform the measurement, given by
   the timestamp in LM header. Combined with a packet generator the
   throughput measurement can be used to measure the maximum capacity of

a particular LSP.

MPLS Transport Profile (MPLS-TP) describes a profile of MPLS that enables operational models typical in transport networks, while providing additional OAM, survivability and other maintenance functions not currently supported by MPLS. [RFC5860] defines the requirements for the OAM functionality of MPLS-TP.

This document is a product of a joint Internet Engineering Task Force (IETF) / International Telecommunication Union Telecommunication Standardization Sector (ITU-T) effort to include an MPLS Transport Profile within the IETF MPLS and PWE3 architectures to support the capabilities and functionalities of a packet transport network.

1.1. Contributing Authors

This document is the result of a large team of authors and contributors. The following is a list of the co-authors:

Gregory Mirsky

John Drake

Benoit Tremblay

1.2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. Overview of MPLS OAM for Transport Applications

[MPLS-TP-OAM-FWK] describes how MPLS OAM mechanisms are operated to meet transport requirements outlined in [RFC5860].

[BFD-CCCV] specifies two BFD operation modes: 1) "CC mode", which uses periodic BFD message exchanges with symmetric timer settings, supporting Continuity Check, 2) "CV/CC mode" which sends unique maintenance entity identifiers in the periodic BFD messages supporting Connectivity Verification as well as Continuity Check.

[RFC6374] specifies mechanisms for performance monitoring of LSPs, in particular it specifies loss and delay measurement OAM functions.

[MPLS-FMS] specifies fault management signals with which a server LSP can notify client LSPs about various fault conditions to suppress

alarms or to be used as triggers for actions in the client LSPs. The
following signals are defined: Alarm Indication Signal (AIS), Link
Down Indication (LDI) and Locked Report (LKR). To indicate client
faults associated with the attachment circuits Client Signal Failure
Indication (CSF) can be used. CSF is described in [MPLS-TP-OAM-FWK]
and in the context of this document is for further study.

[MPLS-TP-OAM-FWK] describes the mapping of fault conditions to
consequent actions. Some of these mappings may be configured by the
operator, depending on the application of the LSP. The following
defects are identified: Loss Of Continuity (LOC), Misconnectivity,
MEP Misconfiguration and Period Misconfiguration. Out of these
defect conditions, the following consequent actions may be
configurable: 1) whether or not the LOC defect should result in
blocking the outgoing data traffic; 2) whether or not the "Period
Misconfiguration defect" should result in a signal fail condition.

3. Theory of Operations

3.1. MPLS OAM Configuration Operation Overview

RSVP-TE, or alternatively LSP Ping [LSP-PING CONF], can be used to
simply enable the different OAM functions, by setting the
corresponding flags in the "OAM Functions TLV". For a more detailed
configuration one may include sub-TLVs for the different OAM
functions in order to specify various parameters in detail.

Typically intermediate nodes should not process or modify any of the
OAM configuration TLVs but simply forward them to the end-node.
There is one exception to this and that is if the "MPLS OAM FMS sub-
TLV" is present. This sub-TLV has to be examined even by
intermediate nodes. The sub-TLV MAY be present if a flag is set in
the "Function Flags sub-TLV", see section [3.2. OAM Configuration
TLV].

3.1.1. Configuration of BFD sessions

For this specification, BFD MUST be run in either one of the two
modes:

   - Asynchronous mode, where both sides should be in active mode

   - Unidirectional mode

In the simplest scenario LSP Ping, or alternatively RSVP-TE [RSVP-TE
CONF], is used only to bootstrap a BFD session for an LSP, without
any timer negotiation.

Timer negotiation can be performed either in subsequent BFD control
messages (in this case the operation is similar to LSP Ping based
bootstrapping described in [RFC5884]) or directly in the LSP ping
configuration messages.

When BFD Control packets are transported in the G-ACh they are not
protected by any end-to-end checksum, only lower-layers are providing
error detection/correction. A single bit error, e.g. a flipped bit
in the BFD State field could cause the receiving end to wrongly
conclude that the link is down and in turn trigger protection
switching. To prevent this from happening the "BFD Configuration
sub-TLV" has an Integrity flag that when set enables BFD
Authentication using Keyed SHA1 with an empty key (all 0s) [RFC5880].
This would make every BFD Control packet carry an SHA1 hash of itself
that can be used to detect errors.

If BFD Authentication using a pre-shared key / password is desired
(i.e. authentication and not only error detection) the "BFD
Authentication sub-TLV" MUST be included in the "BFD Configuration
sub-TLV". The "BFD Authentication sub-TLV" is used to specify which
authentication method that should be used and which pre-shared key /
password that should be used for this particular session. How the
key exchange is performed is out of scope of this document.

3.1.2. Configuration of Performance Monitoring

It is possible to configure Performance Monitoring functionalities
such as Loss, Delay and Throughput as described in [RFC6374].

When configuring Performance monitoring functionalities it is
possible to choose either the default configuration, by only setting
the respective flags in the "OAM functions TLV", or a customized
configuration. To customize the configuration one would set the
respective flags in the including the respective Loss and/or Delay
sub-TLVs).

By setting the PM Loss flag in the "OAM Functions TLV" and including
the "MPLS OAM PM Loss sub-TLV" one can configure the measurement
interval and loss threshold values for triggering protection.

Delay measurements are configured by setting PM Delay flag in the
"OAM Functions TLV" and including the "MPLS OAM PM Loss sub-TLV" one
can configure the measurement interval and the delay threshold values
for triggering protection.

3.1.3. Configuration of Fault Management Signals

   To configure Fault Monitoring Signals and their refresh time the FMS
   flag in the "OAM Functions TLV" MUST be set and the "MPLS OAM FMS
   sub-TLV" included. When configuring Fault Monitoring Signals it can
   be chosen either the default configuration (by only setting the
   respective flags in the "OAM functions TLV") or a customized
   configuration (by including the "MPLS OAM FMS sub-TLV").

   If an intermediate point is meant to originate fault management
   signal messages this means that such an intermediate point is
   associated to a server MEP through a co-located MPLS-TP client/server
   adaptation function. Such a server MEP needs to be configured by its
   own RSVP-TE session (or, alternatively, via an NMS or LSP-ping).
   However, by setting the "Fault Management subscription" flag in the
   "MPLS OAM FMS sub-TLV" a client LSP can indicate that it would like
   an association to be created to the server MEP(s) on any intermediate
   nodes.

3.2. OAM Configuration TLV

   The "OAM Configuration TLV" is depicted in the following figure. It
   specifies the OAM functions that are to be used for the LSP and it is
   defined in [OAM-CONF-FWK]. The "OAM Configuration TLV" is carried in
   the LSP_ATTRIBUTES object in Path and Resv messages.

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |          Type (2) (IANA)      |            Length             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   OAM Type    |                Reserved                       |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                                                               |
 ~                          sub-TLVs                             ~
 |                                                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Type: indicates the "OAM Configuration TLV" (2) (IANA to assign).

   OAM Type: one octet that specifies the technology specific OAM Type.
   If the requested OAM Type is not supported, an error must be
   generated: "OAM Problem/Unsupported OAM Type".

   This document defines a new OAM Type: "MPLS OAM" (suggested value 2,

IANA to assign) from the "RSVP-TE OAM Configuration Registry". The
"MPLS OAM" type is set to request the establishment of OAM functions
for MPLS-TP LSPs. The specific OAM functions are specified in the
"Function Flags" sub-TLV as depicted in [OAM-CONF-FWK].

The receiving edge LSR when the MPLS-TP OAM Type is requested should
check which OAM Function Flags are set in the "Function Flags TLV"
(also defined in [OAM-CONF-FWK]) and look for the corresponding
technology specific configuration TLVs.

Additional corresponding sub-TLVs are as follows:

   - "BFD Configuration sub-TLV", which MUST be included if the CC
   and/or the CV OAM Function flag is set. This sub-TLV MUST carry a
   "BFD Local Discriminator sub-TLV" and a "Timer Negotiation
   Parameters sub-TLV" if the N flag is cleared. If the I flag is
   set, the "BFD Authentication sub-TLV" may be included.

   - "MPLS OAM PM Loss sub-TLV" within the "Performance Monitoring
   sub-TLV", which MAY be included if the PM/Loss OAM Function flag
   is set. If the "MPLS OAM PM Loss sub-TLV" is not included,
   default configuration values are used. Such sub-TLV MAY also be
   included in case the Throughput function flag is set and there is
   the need to specify measurement interval different from the
   default ones. In fact the throughput measurement make use of the
   same tool as the loss measurement, hence the same TLV is used.

   - "MPLS OAM PM Delay sub-TLV" within the "Performance Monitoring
   sub-TLV", which MAY be included if the PM/Delay OAM Function flag
   is set. If the "MPLS OAM PM Delay sub-TLV" is not included,
   default configuration values are used.

   - "MPLS OAM FMS sub-TLV", which MAY be included if the FMS OAM
   Function flag is set. If the "MPLS OAM FMS sub-TLV" is not
   included, default configuration values are used.

Moreover, if the CV or CC flag is set, the CC flag MUST be set as
well. The format of an MPLS-TP CV/CC message is shown in [BFD-CCCV]
and it requires, together with the BFD control packet information,
the "Unique MEP-ID of source of BFD packet". [MPLS-TP-IDENTIF]
defines the composition of such identifier as:

<"Unique MEP-ID of source of BFD packet"> ::=
<src_node_id><src_tunnel_num><lsp_num>

Note that support of ITU IDs is out-of-scope.

GMPLS signaling [RFC3473] uses a 5-tuple to uniquely identify an LSP

within an operator's network. This tuple is composed of a Tunnel
Endpoint Address, Tunnel_ID, Extended Tunnel ID, and Tunnel Sender
Address and (GMPLS) LSP_ID.

Hence, the following mapping is used without the need of redefining a
new TLV for MPLS-TP proactive CV purpose.

      - Tunnel ID = src_tunnel_num

      - Tunnel Sender Address = src_node_id

      - LSP ID = LSP_Num

"Tunnel ID" and "Tunnel Sender Address" are included in the "SESSION"
object [RFC3209], which is mandatory in both Path and Resv messages.

"LSP ID" will be the same on both directions and it is included in
the "SENDER_TEMPLATE" object [RFC3209] which is mandatory in Path
messages.

[Author's note: the same "Unique MEP-ID of source" will be likely
required for Performance monitoring purposes. This need to be agreed
with [RFC6374] authors.]

3.3. BFD Configuration sub-TLV

The "BFD Configuration sub-TLV" (depicted below) is defined for BFD
OAM specific configuration parameters. The "BFD Configuration sub-
TLV" is carried as a sub-TLV of the "OAM Configuration TLV".

This TLV accommodates generic BFD OAM information and carries sub-
TLVs.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  BFD Conf. Type (3) (IANA)    |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Vers.| PHB |N|S|I|G|U|B|    Reserved (set to all 0s)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
~                           sub-TLVs                            ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "BFD Configuration sub-TLV" (IANA to
define).

Length: indicates the total length including sub-TLVs.

Version: identifies the BFD protocol version. If a node does not support a specific BFD version an error must be generated: "OAM Problem/Unsupported OAM Version".

PHB: Identifies the Per-Hop Behavior (PHB) to be used for periodic continuity monitoring messages.

BFD Negotiation (N): If set timer negotiation/re-negotiation via BFD Control Messages is enabled, when cleared it is disabled.

Symmetric session (S): If set the BFD session MUST use symmetric timing values.

Integrity (I): If set BFD Authentication MUST be enabled. If the "BFD Configuration sub-TLV" does not include a "BFD Authentication sub-TLV" the authentication MUST use Keyed SHA1 with an empty pre-shared key (all 0s).

Encapsulation Capability (G): if set, it shows the capability of encapsulating BFD messages into G-Ach channel. If both the G bit and U bit are set, configuration gives precedence to the G bit.

Encapsulation Capability (U): if set, it shows the capability of encapsulating BFD messages into UDP packets. If both the G bit and U bit are set, configuration gives precedence to the G bit.

Bidirectional (B): if set, it configures BFD in the Bidirectional mode. If it is not set it configures BFD in unidirectional mode. In the second case, the source node does not expect any Discriminator values back from the destination node.

Reserved: Reserved for future specification and set to 0 on transmission and ignored when received.

The "BFD Configuration sub-TLV" MUST include the following sub-TLVs in the Path message:

   - "Local Discriminator sub-TLV";

   - "Negotiation Timer Parameters sub-TLV" if the N flag is cleared.

The "BFD Configuration sub-TLV" MUST include the following sub-TLVs in the Resv message:

   - "Local Discriminator sub-TLV;"

   - "Negotiation Timer Parameters sub-TLV" if:

      - the N and S flags are cleared, or if:

      - the N flag is cleared and the S flag is set, and the
      Negotiation Timer Parameters sub-TLV received by the egress
      contains unsupported values. In this case an updated
      Negotiation Timer Parameters sub-TLV, containing values
      supported by the egress node, is returned to the ingress.

3.3.1. Local Discriminator sub-TLV

   The "Local Discriminator sub-TLV" is carried as a sub-TLV of the "BFD
   Configuration sub-TLV" and is depicted below.


```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Lcl. Discr. Type (1) (IANA)   |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Local Discriminator                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Type: indicates a new type, the Local Discriminator sub-TLV (1) (IANA
   to define).

   Length: indicates the TLV total length in octets. (8)

   Local Discriminator: A unique, nonzero discriminator value generated
   by the transmitting system and referring to itself, used to
   demultiplex multiple BFD sessions between the same pair of systems.

3.3.2. Negotiation Timer Parameters sub-TLV

   The "Negotiation Timer Parameters sub-TLV" is carried as a sub-TLV of
   the "BFD Configuration sub-TLV" and is depicted below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Timer Neg. Type (2) (IANA)   |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Acceptable Min. Asynchronous TX interval              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Acceptable Min. Asynchronous RX interval              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Required Echo TX Interval                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "Negotiation Timer Parameters sub-
TLV" (IANA to define).

Length: indicates the TLV total length in octets. (16)

Acceptable Min. Asynchronous TX interval: in case of S (symmetric)
flag set in the "BFD Configuration sub-TLV", it expresses the desired
time interval (in microseconds) at which the ingress LER intends to
both transmit and receive BFD periodic control packets. If the
receiving edge LSR can not support such value, it can reply with an
interval greater than the one proposed.

In case of S (symmetric) flag cleared in the "BFD Configuration sub-
TLV", this field expresses the desired time interval (in
microseconds) at which a edge LSR intends to transmit BFD periodic
control packets in its transmitting direction.

Acceptable Min. Asynchronous RX interval: in case of S (symmetric)
flag set in the "BFD Configuration sub-TLV", this field MUST be equal
to "Acceptable Min. Asynchronous TX interval" and has no additional
meaning respect to the one described for "Acceptable Min.
Asynchronous TX interval".

In case of S (symmetric) flag cleared in the "BFD Configuration sub-
TLV", it expresses the minimum time interval (in microseconds) at
which edge LSRs can receive BFD periodic control packets. In case
this value is greater than the "Acceptable Min. Asynchronous TX
interval" received from the other edge LSR, such edge LSR MUST adopt
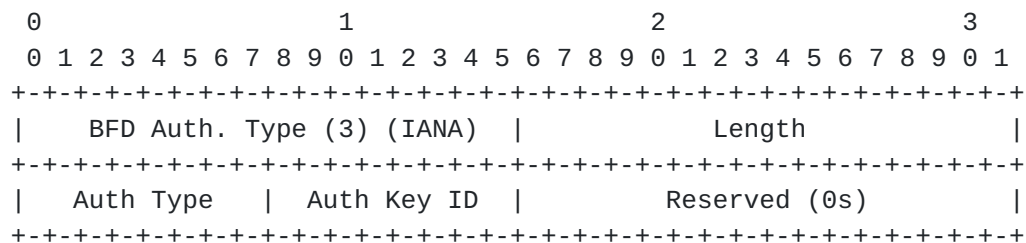the interval expressed in this "Acceptable Min. Asynchronous RX
interval".

Required Echo TX Interval: the minimum interval (in microseconds)
between received BFD Echo packets that this system is capable of
supporting, less any jitter applied by the sender as described in
[RFC5880] sect. 6.8.9. This value is also an indication for the
receiving system of the minimum interval between transmitted BFD Echo

packets. If this value is zero, the transmitting system does not
support the receipt of BFD Echo packets. If the receiving system can
not support this value an error MUST be generated "Unsupported BFD TX
rate interval".

3.3.3. BFD Authentication sub-TLV

The "BFD Authentication sub-TLV" is carried as a sub-TLV of the "BFD
Configuration sub-TLV" and is depicted below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    BFD Auth. Type (3) (IANA)   |             Length            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Auth Type   |  Auth Key ID   |          Reserved (0s)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "BFD Authentication sub-TLV" (IANA to
define).

Length: indicates the TLV total length in octets. (8)

Auth Type: indicates which type of authentication to use. The same
values as are defined in section 4.1 of [RFC5880] are used.

Auth Key ID: indicates which authentication key or password
(depending on Auth Type) should be used. How the key exchange is
performed is out of scope of this document.

Reserved: Reserved for future specification and set to 0 on
transmission and ignored when received.

3.4. Performance Monitoring sub-TLV

If the "OAM functions TLV" has either the L (Loss), D (Delay) or T
(Throughput) flag set, the "Performance Monitoring sub-TLV" MUST be
present.

In case the values need to be different than the default ones the
"Performance Monitoring sub-TLV", "MPLS OAM PM Loss sub-TLV" MAY
include the following sub-TLVs:

   - "MPLS OAM PM Loss sub-TLV" if the L flag is set in the "OAM
     functions TLV";

- "MPLS OAM PM Delay sub-TLV" if the D flag is set in the "OAM
  functions TLV";

The "Performance Monitoring sub-TLV" depicted below is carried as a
sub-TLV of the "OAM Functions TLV".

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Perf Monitoring Type(4) (IANA)|           Length              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|D|L|J|Y|K|C|           Reserved (set to all 0s)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
~                         sub-TLVs                              ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Length: indicates the TLV total length in octets.

Configuration Flags, for the specific function description please
refer to [RFC6374]:

- D: Delay inferred/direct (0=INFERRED, 1=DIRECT)

- L: Loss inferred/direct (0=INFERRED, 1=DIRECT)

- J: Delay variation/jitter (1=ACTIVE, 0=NOT ACTIVE)

- Y: Dyadic (1=ACTIVE, 0=NOT ACTIVE)

- K: Loopback (1=ACTIVE, 0=NOT ACTIVE)

- C: Combined (1=ACTIVE, 0=NOT ACTIVE)

Reserved: Reserved for future specification and set to 0 on
transmission and ignored when received.

3.4.1. MPLS OAM PM Loss sub-TLV

The "MPLS OAM PM Loss sub-TLV" depicted below is carried as a sub-TLV
of the "Performance Monitoring sub-TLV".

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  PM Loss Type (1) (IANA)      |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| OTF |T|B|          Reserved (set to all 0s)                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Measurement Interval                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Test Interval                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Loss Threshold                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "MPLS OAM PM Loss sub-TLV" (IANA to
define, suggested value 1).

Length: indicates the length of the parameters in octets (20).

OTF: Origin Timestamp Format of the Origin Timestamp field described
in [RFC6374]. By default it is set to IEEE 1588 version 1.

Configuration Flags, please refer to [RFC6374] for further details:

   - T: Traffic-class-specific measurement indicator. Set to 1 when
   the measurement operation is scoped to packets of a particular
   traffic class (DSCP value), and 0 otherwise. When set to 1, the
   DS field of the message indicates the measured traffic class. By
   default it is set to 1.

   - B: Octet (byte) count. When set to 1, indicates that the
   Counter 1-4 fields represent octet counts. When set to 0,
   indicates that the Counter 1-4 fields represent packet counts. By
   default it is set to 0.

Reserved: Reserved for future specification and set to 0 on
transmission and ignored when received.

Measurement Interval: the time interval (in microseconds) at which
Loss Measurement query messages MUST be sent on both directions. If
the edge LSR receiving the Path message can not support such value,
it can reply back with a higher interval. By default it is set to
(TBD).

Test Interval: test messages interval as described in [RFC6374]. By
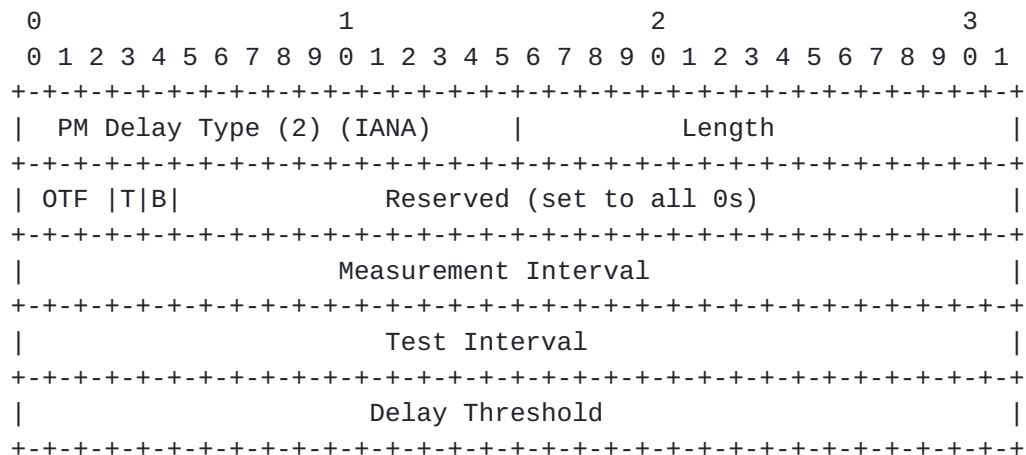default it is set to (TBD).

Loss Threshold: the threshold value of lost packets over which

protections MUST be triggered. By default it is set to (TBD).

[3.4.2](). **MPLS OAM PM Delay sub-TLV**

The "MPLS OAM PM Delay sub-TLV" depicted below is carried as a sub-
TLV of the "OAM Functions TLV".

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  PM Delay Type (2) (IANA)     |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| OTF |T|B|             Reserved (set to all 0s)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Measurement Interval                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Test Interval                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Delay Threshold                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "MPLS OAM PM Loss sub-TLV" (IANA to
define, suggested value 1).

Length: indicates the length of the parameters in octets (20).

OTF: Origin Timestamp Format of the Origin Timestamp field described
in [RFC6374]. By default it is set to IEEE 1588 version 1.

Configuration Flags, please refer to [RFC6374] for further details:

   - T: Traffic-class-specific measurement indicator. Set to 1 when
   the measurement operation is scoped to packets of a particular
   traffic class (DSCP value), and 0 otherwise. When set to 1, the
   DS field of the message indicates the measured traffic class. By
   default it is set to 1.

   - B: Octet (byte) count. When set to 1, indicates that the
   Counter 1-4 fields represent octet counts. When set to 0,
   indicates that the Counter 1-4 fields represent packet counts. By
   default it is set to 0.

Reserved: Reserved for future specification and set to 0 on
transmission and ignored when received.

Measurement Interval: the time interval (in microseconds) at which
Delay Measurement query messages MUST be sent on both directions. If

the edge LSR receiving the Path message can not support such value,
it can reply back with a higher interval. By default it is set to
(TBD).

Test Interval: test messages interval as described in [RFC6374]. By
default it is set to (TBD).

Delay Threshold: the threshold value of measured delay (in
microseconds) over which protections MUST be triggered. By default
it is set to (TBD).

3.5. MPLS OAM FMS sub-TLV

The "MPLS OAM FMS sub-TLV" depicted below is carried as a sub-TLV of
the "OAM Configuration sub-TLV". When both working and protection
paths are signaled, both LSPs SHOULD be signaled with identical
settings of the E flag, T flag, and the refresh timer.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  MPLS OAM FMS Type (5) (IANA) |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|E|S|T| Reserved (set to all 0s)|     Refresh Timer     | PHB |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Type: indicates a new type, the "MPLS OAM FMS sub-TLV" (IANA to
define).

Length: indicates the TLV total length in octets. (8)

FMS Signal Flags are used to enable the FMS signals at end point MEPs
and the Server MEPs of the links over which the LSP is forwarded. In
this document only the S flag pertains to Server MEPs.

The following flags are defined:

   - E: Enable Alarm Indication Signal (AIS) and Locked Report (LKR)
   signalling as described in [MPLS-FMS]. Default value is 1
   (enabled).

   - S: Indicate to a server MEP that its should transmit AIS and LKR
   signals on the client LSP. Default value is 0 (disabled).

   - T: Set timer value, enabled the configuration of a specific
   timer value. Default value is 0 (disabled).

   - Remaining bits: Reserved for future specification and set to 0.

   Refresh Timer: indicates the refresh timer of fault indication
   messages. If the edge LSR receiving the Path message can not support
   such value, it can reply back with a higher interval.

   - PHB: identifies the per-hop behavior of packets with fault
   management information.

4. IANA Considerations

   This document specifies the following new TLV types:

   - "BFD Configuration" type: 3;

   - "Performance Monitoring" type: 4;

   - "MPLS OAM FMS" type: 5.

   sub-TLV types to be carried in the "BFD Configuration sub-TLV":

   - "Local Discriminator" sub-TLV type: 1;

   - "Negotiation Timer Parameters" sub-TLV type: 2.

   - "BFD Authentication" sub-TLV type: 3.

   sub-TLV types to be carried in the "BFD Configuration sub-TLV":

   - "MPLS OAM PM Loss" type: 1;

   - "MPLS OAM PM Delay" type: 2;

5. BFD OAM configuration errors

   In addition to error values specified in [OAM-CONF-FWK] and [ETH-OAM]
   this document defines the following values for the "OAM Problem"
   Error Code:

   - "MPLS OAM Unsupported Functionality";

   - "OAM Problem/Unsupported TX rate interval";

   - "OAM Problem/Unsupported RX rate interval";

   - "OAM Problem/Unsupported unsupported Authentication Type";

   - "OAM Problem, mismatch of Authentication Key ID ".

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7. Security Considerations

   The signaling of OAM related parameters and the automatic
   establishment of OAM entities introduces additional security
   considerations to those discussed in [RFC3473]. In particular, a
   network element could be overloaded if an attacker were to request
   high frequency liveliness monitoring of a large number of LSPs,
   targeting a single network element.

   Security aspects will be covered in more detailed in subsequent
   versions of this document.

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Authors' Addresses

   Elisa Bellagamba (editor)
   Ericsson
   Torshamnsgatan 48
   Kista,   164 40
   Sweden

   Email: elisa.bellagamba@ericsson.com

   Loa Andersson (editor)
   Ericsson
   Torshamnsgatan 48
   Kista,   164 40
   Sweden

   Phone:
   Email: loa.andersson@ericsson.com

   Pontus Skoldstrom (editor)
   Acreo AB
   Electrum 236
   Kista,   164 40
   Sweden

   Phone: +46 8 6327731
   Email: pontus.skoldstrom@acreo.se

   Dave Ward
   Juniper

   Phone:
   Email: dward@juniper.net

   Attila Takacs
   Ericsson
   1. Laborc u.
   Budapest,
   HUNGARY

   Phone:
   Email: attila.takacs@ericsson.com