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GMPLS RSVP-TE extensions for OAM Configuration
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Abstract

Operations, Administration and Maintenance is an integral part of transport connections, hence it is required that Operations, Administration and Maintenance functions are activated/deactivated in sync with connection commissioning/decommissioning; avoiding spurious alarms and ensuring consistent operation. In certain technologies, Operations, Administration and Maintenance entities are inherently established once the connection is set up, while other technologies require extra configuration to establish and configure Operations, Administration and Maintenance entities. This document specifies extensions to RSVP-TE to support the establishment and configuration of Operations, Administration and Maintenance entities along with Label Switched Path signaling.

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 [RFC2119].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

GMPLS is designed as an out-of-band control plane supporting dynamic connection provisioning for any suitable data plane technology; including spatial switching (e.g., incoming port or fiber to outgoing port or fiber), wavelength-division multiplexing (e.g., DWDM), time-division multiplexing (e.g., SONET/SDH, G.709), and Ethernet Provider Backbone Bridging - Traffic Engineering (PBB-TE) and MPLS. In most of these technologies, there are Operations, Administration and Maintenance (OAM) functions employed to monitor the health and performance of the connections and to trigger data plane (DP) recovery mechanisms. Similar to connection provisioning, OAM functions follow general principles, but also have some technology specific characteristics.

OAM is an integral part of transport connections. Therefore it is required that OAM functions are activated/deactivated in sync with connection commissioning/decommissioning; avoiding spurious alarms and ensuring consistent operation. In certain technologies, OAM entities are inherently established once the connection is set up, while other technologies require extra configuration to establish and configure OAM entities. In some situations the use of OAM functions, such as Fault Management (FM) and Performance Management (PM), may be optional (based on network management policies). Hence, the network operator must be able to choose which set of OAM functions to apply to specific connections and which parameters should be configured and activated. To achieve this objective, OAM entities and specific functions must be selectively configurable.

In general, it is required that the management plane and control plane connection establishment mechanisms are synchronized with OAM establishment and activation. In particular, if the GMPLS control plane is employed, it is desirable to bind OAM setup and configuration to connection establishment signaling to avoid two separate management/configuration steps (connection setup followed by OAM configuration) which increases delay, processing, and more importantly may be prone to misconfiguration errors. Once OAM entities are setup and configured, pro-active as well as on-demand OAM functions can be activated via the management plane. On the other hand, it should be possible to activate/deactivate pro-active OAM functions via the GMPLS control plane as well. In some situations it may be possible to use the GMPLS control plane to control on-demand OAM functions too.

This document describes requirements for OAM configuration and control via RSVP-TE. Extensions to the RSVP-TE protocol are specified providing a framework to configure and control OAM entities along with the capability to carry technology specific information.

Extensions can be grouped into: generic elements that are applicable to any OAM solution; and technology specific elements that provide additional configuration parameters, which may only be needed for a specific OAM technology. This document specifies the technology agnostic elements and specifies the way additional technology specific OAM parameters are provided.

This document addresses end-to-end OAM configuration, that is, the setup of OAM entities bound to an end-to-end LSP, and configuration and control of OAM functions running end-to-end in the LSP. Configuration of OAM entities for LSP segments and tandem connections are out of the scope of this document.

The mechanisms described in this document provide an additional option for bootstrapping OAM that is not intended to replace or deprecate the use of other technology specific OAM bootstrapping techniques; e.g., LSP Ping [RFC4379] for MPLS networks. The procedures specified in this document are intended only for use in environments where RSVP-TE signaling is used to set up the LSPs that are to be monitored using OAM.

2. Requirements

This section summarizes various technology-specific OAM requirements which can be used as a basis for an OAM configuration framework.

MPLS OAM requirements are described in [RFC4377], which provides requirements to create consistent OAM functionality for MPLS networks. The following list is an excerpt of MPLS OAM requirements documented in [RFC4377] that bear a direct relevance to the discussion set forth in this document.

- It is desired to support the automation of LSP defect detection. It is especially important in cases where large numbers of LSPs might be tested.

- In particular some LSPs may require automated ingress-LSR to egress-LSR testing functionality, while others may not.

- Mechanisms are required to coordinate network responses to defects. Such mechanisms may include alarm suppression, translating defect signals at technology boundaries, and synchronizing defect detection times by setting appropriately bounded detection time frames.

MPLS-TP defines a profile of MPLS targeted at transport applications [RFC5921]. This profile specifies the specific MPLS characteristics and extensions required to meet transport requirements, including

providing additional OAM, survivability, and other maintenance functions not currently supported by MPLS. Specific OAM requirements for MPLS-TP are specified in [RFC5654] and [RFC5860]. MPLS-TP poses the following requirements on the control plane to configure and control OAM entities:

- From [RFC5860]: OAM functions MUST operate and be configurable even in the absence of a control plane. Conversely, it SHOULD be possible to configure as well as enable/disable the capability to operate OAM functions as part of connectivity management, and it SHOULD also be possible to configure as well as enable/disable the capability to operate OAM functions after connectivity has been established.

- From [RFC5654]: The MPLS-TP control plane MUST support the configuration and modification of OAM maintenance points as well as the activation/ deactivation of OAM when the transport path or transport service is established or modified.

Ethernet Connectivity Fault Management (CFM) defines an adjunct connectivity monitoring OAM flow to check the liveliness of Ethernet networks [IEEE.802.1Q-2011]. With PBB-TE [IEEE.802.1Q-2011] Ethernet networks support explicitly-routed Ethernet connections. CFM can be used to track the liveliness of PBB-TE connections and detect data plane failures. In the IETF, the GMPLS controlled Ethernet Label Switching (GELS) (see [RFC5828] and [RFC6060]) work extended the GMPLS control plane to support the establishment of PBB-TE data plane connections. Without control plane support separate management commands would be needed to configure and start CFM.

GMPLS based OAM configuration and control needs to provide a general framework to be applicable to a wide range of data plane technologies and OAM solutions. There are three typical data plane technologies used for transport applications: wavelength based such as WSON, TDM based such as SDH/SONET, and packet based such as MPLS-TP [RFC5921] and Ethernet PBB-TE [IEEE.802.1Q-2011]. For all these data planes, the operator MUST be able to configure and control the following OAM functions:

- It MUST be possible to explicitly request the setup of OAM entities for the signaled LSP and provide specific information for the setup if this is required by the technology.

- Control of alarms is important to avoid false alarm indications and reporting to the management system. It MUST be possible to enable/disable alarms generated by OAM functions. In some cases, selective alarm control may be desirable when, for instance, the

operator is only concerned about critical alarms. Therefore the non-service affecting alarms should be inhibited.

- When periodic messages are used for liveliness check (continuity check) of LSPs, it MUST be possible to set the frequency of messages. This allows proper configuration for fulfilling the requirements of the service and/or meeting the detection time boundaries posed by possible congruent connectivity check operations of higher layer applications. For a network operator to be able to balance the trade-off between fast failure detection and data overhead, it is beneficial to configure the frequency of continuity check messages on a per LSP basis.

- Pro-active Performance Monitoring (PM) functions are used to continuously collect information about specific characteristics of the connection. For consistent measurement of Service Level Agreements (SLAs), it MUST be possible to set common configuration parameters for the LSP.

- The extensions MUST allow the operator to use only a minimal set of OAM configuration and control features if supported by the OAM solution or network management policy. Generic OAM parameters and data plane or OAM technology specific parameters MUST be supported.

3. RSVP-TE based OAM Configuration

In general, two types of maintenance points can be distinguished: Maintenance Entity Group End Points (MEPs) and Maintenance Entity Group Intermediate Points (MIPs). MEPs reside at the ends of an LSP and are capable of initiating and terminating OAM messages for Fault Management (FM) and Performance Monitoring (PM). MIPs on the other hand, are located at transit nodes of an LSP and are capable of reacting to some OAM messages but otherwise do not initiate messages. Maintenance Entity (ME) refers to an association of MEPs and MIPs that are provisioned to monitor an LSP.

When an LSP is signaled, a forwarding association is established between endpoints and transit nodes via label bindings. This association creates a context for the OAM entities monitoring the LSP. On top of this association, OAM entities may be configured to unambiguously identify MEs.

In addition to ME identification parameters, pro-active OAM functions (e.g., Continuity Check (CC) and Performance Monitoring (PM)) may have additional parameters that require configuration as well. In particular, the frequency of periodic CC packets and the measurement interval for loss and delay measurements may need to be configured.

The above parameters may be either derived from LSP provisioning information, or alternatively, pre-configured default values can be used. In the simplest case, the control plane MAY provide information on whether or not OAM entities need to be setup for the signaled LSP. If OAM entities are created, control plane signaling MUST also provide a means to activate/deactivate OAM message flows and associated alarms.

OAM identifiers, as well as the configuration of OAM functions, are technology specific (i.e., vary depending on the data plane technology and the chosen OAM solution). In addition, for any given data plane technology, a set of OAM solutions may be applicable. Therefore, the OAM configuration framework allows selecting a specific OAM solution to be used for the signaled LSP and provides means to carry detailed OAM configuration information in technology specific TLVs.

Administrative Status Information is carried in the ADMIN_STATUS Object. The Administrative Status Information is described in [RFC3471], the ADMIN_STATUS Object is specified for RSVP-TE in [RFC3473]. Two bits are allocated for the administrative control of OAM monitoring: the "OAM Flows Enabled" (M) and "OAM Alarms Enabled" (O) bits. When the "OAM Flows Enabled" bit is set, OAM mechanisms MUST be enabled; if it is cleared, OAM mechanisms MUST be disabled. When the "OAM Alarms Enabled" bit is set OAM triggered alarms are enabled and associated consequent actions MUST be executed including the notification to the management system. When this bit is cleared, alarms are suppressed and no action SHOULD be executed and the management system SHOULD NOT be notified.

The LSP_ATTRIBUTES and the LSP_REQUIRED_ATTRIBUTES objects are defined in [RFC5420] to provide means to signal LSP attributes and options in the form of TLVs. Options and attributes signaled in the LSP_ATTRIBUTES object can be passed transparently through LSRs not supporting a particular option or attribute, while the contents of the LSP_REQUIRED_ATTRIBUTES object MUST be examined and processed by each LSR. One bit "OAM MEP entities desired" is allocated in the LSP Attributes Flags TLV to be used in the LSP_ATTRIBUTES object. If the "OAM MEP entities desired" bit is set it is indicating that the establishment of OAM MEP entities are required at the endpoints of the signaled LSP. One bit "OAM MIP entities desired" is allocated in the LSP Attributes Flags TLV to be used in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUES objects. If the "OAM MIP entities desired" bit is set in the LSP_ATTRIBUTES Flags TLV in the LSP_REQUIRED_ATTRIBUTES Object, it is indicating that the establishment of OAM MIP entities is required at every transit node of the signaled LSP.

3.1. Establishment of OAM Entities and Functions

In order to avoid spurious alarms, OAM functions should be setup and enabled in the appropriate order. When using the GMPLS control plane for both LSP establishment and to enable OAM functions on the LSPs, the control of both processes is bound to RSVP-TE message exchanges.

An LSP may be signaled and established without OAM configuration first, and OAM entities may be added later with a subsequent re-signaling of the LSP. Alternatively, the LSP may be setup with OAM entities with the first signaling of the LSP. The below procedures apply to both cases.

Before initiating a Path message with OAM Configuration information, an initiating node MUST establish and configure the corresponding OAM entities locally. But until the LSP is established, OAM source functions MUST NOT start sending any OAM messages. In the case of bidirectional connections, in addition to the OAM source function, the initiator node MUST set up the OAM sink function and prepare it to receive OAM messages. During this time the OAM alarms MUST be suppressed (e.g., due to missing or unidentified OAM messages). To achieve OAM alarm suppression, Path message MUST be sent with the "OAM Alarms Enabled" ADMIN_STATUS flag cleared.

When the Path message arrives at the receiver, the remote end MUST establish and configure OAM entities according to the OAM information provided in the Path message. If this is not possible, a PathErr SHOULD be sent and neither the OAM entities nor the LSP SHOULD be established. If OAM entities are established successfully, the OAM sink function MUST be prepared to receive OAM messages, but MUST NOT generate any OAM alarms (e.g., due to missing or unidentified OAM messages). In the case of bidirectional connections, in addition to the OAM sink function, an OAM source function MUST be set up and, according to the requested configuration, the OAM source function MUST start sending OAM messages. Then a Resv message MUST be sent back, including the LSP_Attributes Flags TLV, with the appropriate setting of the "OAM MEP entities desired" and "OAM MIP entities desired" flags, and the OAM Configuration TLV that corresponds to the established and configured OAM entities and functions. Depending on the OAM technology, some elements of the OAM Configuration TLV MAY be updated/changed; i.e., if the remote end is not supporting a certain OAM configuration it may suggest an alternative setting, which may or may not be accepted by the initiator of the Path message. If it is accepted, the initiator will reconfigure its OAM functions according to the information received in the Resv message. If the alternate setting is not acceptable a ResvErr may be sent tearing down the LSP. Details of this operation are technology specific and should be described in accompanying technology specific documents.

When the initiating side receives the Resv message, it completes any pending OAM configuration and enables the OAM source function to send OAM messages.

After this exchange, OAM entities are established and configured for the LSP and OAM messages are exchanged. OAM alarms can now be enabled. The initiator, during the period when OAM alarms are disabled, sends a Path message with "OAM Alarms Enabled" ADMIN_STATUS flag set. The receiving node enables the OAM alarms after processing the Path message. The initiator enables OAM alarms after it receives the Resv message. Data plane OAM is now fully functional.

In case an egress LSR does not support the extensions defined in this document, according to [RFC5420], it will silently ignore the new LSP Attributes Flags as well as the TLVs carrying additional OAM configuration information, and therefore no error will be raised that would notify the ingress LSR about the missing OAM configuration actions on the egress side. However, as described above, an egress LSR conformant to the specification of this document will set the LSP Attributes Flags and include the OAM Configuration TLV in the Resv message indicating the configuration of the OAM mechanisms, therefore an ingress LSR by detecting the missing information in the Resv message will be able to recognize that the remote end does not support the OAM configuration functionality and therefore it SHOULD tear down the LSP, and if appropriate, signal the LSP without any OAM configuration information.

3.2. Adjustment of OAM Parameters

There may be a need to change the parameters of an already established and configured OAM function during the lifetime of the LSP. To do so the LSP needs to be re-signaled with the updated parameters. OAM parameters influence the content and timing of OAM messages and identify the way OAM defects and alarms are derived and generated. Hence, to avoid spurious alarms, it is important that both sides, OAM sink and source, are updated in a synchronized way. First, the alarms of the OAM sink function should be suppressed and only then should expected OAM parameters be adjusted. Subsequently, the parameters of the OAM source function can be updated. Finally, the alarms of the OAM sink side can be enabled again.

In accordance with the above operation, the LSP MUST first be re-signaled with "OAM Alarms Enabled" ADMIN_STATUS flag cleared, including the updated OAM Configuration TLV corresponding to the new parameter settings. The initiator MUST keep its OAM sink and source functions running unmodified, but it MUST suppress OAM alarms after the updated Path message is sent. The receiver MUST first disable all OAM alarms, then update the OAM parameters according to the

information in the Path message and reply with a Resv message acknowledging the changes by including the OAM Configuration TLV. Note that the receiving side has the possibility to adjust the requested OAM configuration parameters and reply with an updated OAM Configuration TLV in the Resv message, reflecting the actually configured values. However, in order to avoid an extensive negotiation phase, in the case of adjusting already configured OAM functions, the receiving side SHOULD NOT update the parameters requested in the Path message to an extent that would provide lower performance (e.g., lower frequency of monitoring packets) than what has been in operation previously.

The initiator MUST only update its OAM sink and source functions after it received the Resv message. After this Path/Resv message exchange (in both unidirectional and bidirectional LSP cases) the OAM parameters are updated and OAM is running according the new parameter settings. However, OAM alarms are still disabled. A subsequent Path /Resv message exchange with "OAM Alarms Enabled" ADMIN_STATUS flag set is needed to enable OAM alarms again.

3.3. Deleting OAM Entities

In some cases it may be useful to remove some or all OAM entities and functions from an LSP without actually tearing down the connection.

To avoid any spurious alarms, first the LSP MUST be re-signaled with "OAM Alarms Enabled" ADMIN_STATUS flag cleared but unchanged OAM configuration. Subsequently, the LSP is re-signaled with "OAM MEP Entities desired" and "OAM MIP Entities desired" LSP ATTRIBUTES flags cleared, and without the OAM Configuration TLV, this MUST result in the deletion of all OAM entities associated with the LSP. All control and data plane resources in use by the OAM entities and functions SHOULD be freed up. Alternatively, if only some OAM functions need to be removed, the LSP is re-signaled with the updated OAM Configuration TLV. Changes between the contents of the previously signaled OAM Configuration TLV and the currently received TLV represent which functions MUST be removed/added.

OAM source functions MUST be deleted first and only after the "OAM Alarms Disabled" can the associated OAM sink functions be removed, this will ensure that OAM messages do not leak outside the LSP. To this end the initiator, before sending the Path message, MUST remove the OAM source, hence terminating the OAM message flow associated to the downstream direction. In the case of a bidirectional connection, it MUST leave in place the OAM sink functions associated to the upstream direction. The remote end, after receiving the Path message, MUST remove all associated OAM entities and functions and reply with a Resv message without an OAM Configuration TLV. The

initiator completely removes OAM entities and functions after the Resv message arrived.

4. RSVP-TE Extensions

RFC Editor Note: remove/update "IANA" and "IANA to assign" notes in the document once the assignments have been made.

4.1. LSP Attributes Flags

In RSVP-TE the Flags field of the SESSION_ATTRIBUTE object is used to indicate options and attributes of the LSP. The Flags field has 8 bits and hence is limited to differentiate only 8 options. [RFC5420] defines new objects for RSVP-TE messages to allow the signaling of arbitrary attribute parameters making RSVP-TE easily extensible to support new applications. Furthermore, [RFC5420] allows options and attributes that do not need to be acted on by all Label Switched Routers (LSRs) along the path of the LSP. In particular, these options and attributes may apply only to key LSRs on the path such as the ingress LSR and egress LSR. Options and attributes can be signaled transparently, and only examined at those points that need to act on them. The LSP_ATTRIBUTES and the LSP_REQUIRED_ATTRIBUTES objects are defined in [RFC5420] to provide means to signal LSP attributes and options in the form of TLVs. Options and attributes signaled in the LSP_ATTRIBUTES object can be passed transparently through LSRs not supporting a particular option or attribute, while the contents of the LSP_REQUIRED_ATTRIBUTES object MUST be examined and processed by each LSR. One TLV is defined in [RFC5420]: the Attributes Flags TLV.

One bit (IANA to assign): "OAM MEP entities desired" is allocated in the LSP Attributes Flags TLV to be used in the LSP_ATTRIBUTES object. If the "OAM MEP entities desired" bit is set it is indicating that the establishment of OAM MEP entities are required at the endpoints of the signaled LSP. If the establishment of MEPs is not supported an error MUST be generated: "OAM Problem/MEP establishment not supported".

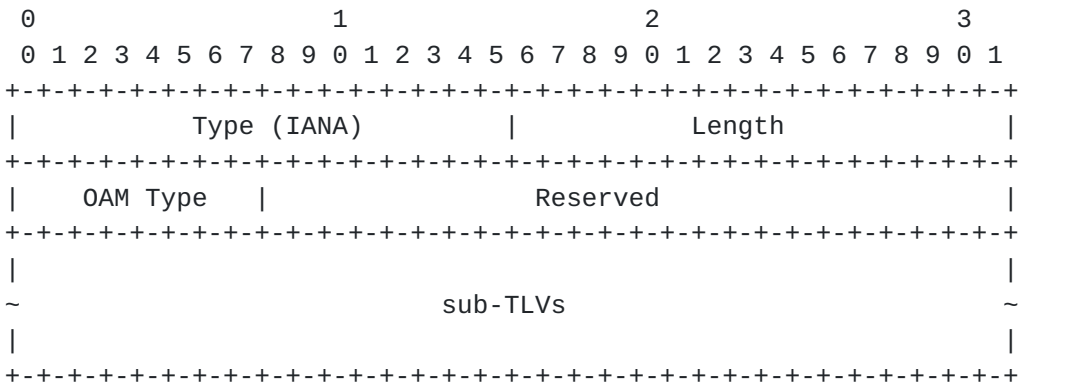
If the "OAM MEP entities desired" bit is set and additional parameters need to be configured, an OAM Configuration TLV MAY be included in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUTES object.

One bit (IANA to assign): "OAM MIP entities desired" is allocated in the LSP Attributes Flags TLV to be used in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUES objects. If the "OAM MEP entities desired" bit is not set then this bit MUST NOT be set. If the "OAM MIP entities desired" bit is set in the LSP_ATTRIBUTES Flags TLV in the LSP_REQUIRED_ATTRIBUTES Object, it is indicating that the

establishment of OAM MIP entities is required at every transit node of the signaled LSP. If the establishment of a MIP is not supported an error MUST be generated: "OAM Problem/MIP establishment not supported". If an intermediate LSR does not support the extensions defined in this document it will not recognize the "OAM MIP entities desired" flag and although the LSP_REQUIRED_ATTRIBUTES object was used it will not configure MIP entities and will not raise any errors. If LSRs that are not supporting this document are to be assumed in the network, the ingress LSR SHOULD collect per-hop information about the LSP Attributes utilizing the LSP Attributes sub-object of the Record Route Object as defined in [RFC5420]. When the Record Route object is received the ingress SHOULD check whether all intermediate LSRs set the "OAM MIP entities desired" flag indicating support of the function, if not, depending on operator policy the LSP MAY need to be torn down.

4.2. OAM Configuration TLV

This TLV provides information about which OAM technology/method should be used and carries sub-TLVs for any additional OAM configuration information. One OAM Configuration TLV MAY be carried in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUTES object in Path and Resv messages. When carried in the LSP_REQUIRED_ATTRIBUTES object, it is indicating that intermediate nodes MUST recognize and react on the OAM configuration information.



Type: indicates a new type: the OAM Configuration TLV (IANA to assign).

OAM Type: specifies the technology specific OAM method. When carried in the LSP_REQUIRED_ATTRIBUTES Object, if the requested OAM method is not supported at any given node an error MUST be generated: "OAM Problem/Unsupported OAM Type". When carried in the LSP_ATTRIBUTES Object, intermediate nodes not supporting the OAM Type pass the object forward unchanged as specified in [RFC5420]. Ingress and egress nodes that support the OAM Configuration TLV but that do not

support a specific OAM Type MUST respond with an error indicating "OAM Problem/Unsupported OAM Type".

OAM Type	Description
0-255	Reserved

This document defines no types. IANA is requested to maintain the values in a new "RSVP-TE OAM Configuration Registry".

Two groups of TLVs are defined: generic sub-TLVs and technology specific sub-TLVs. Generic sub-TLVs carry information that are applicable independent of the actual OAM technology, while technology specific sub-TLVs are providing configuration parameters for specific OAM technologies. This document defines one generic sub-TLV, see Section 4.2.1, while it is foreseen that technology specific sub-TLVs will be defined by separate documents.

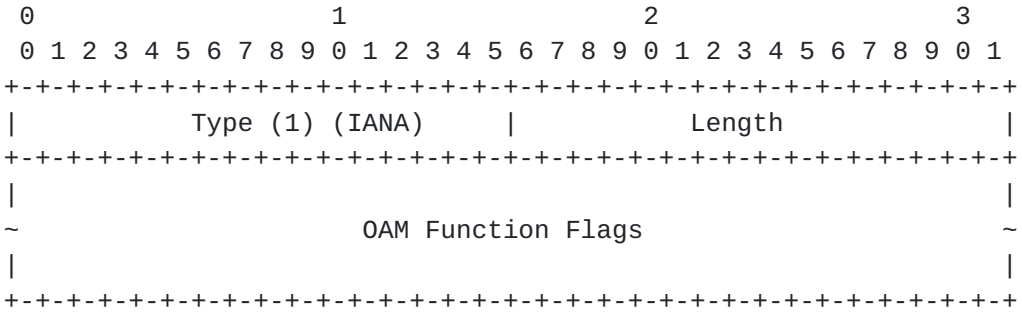
The receiving node, based on the OAM Type, will check if a corresponding technology specific OAM configuration sub-TLV is included in the OAM Configuration TLV. If the included technology specific OAM configuration sub-TLV is different from what is specified in the OAM Type an error MUST be generated: "OAM Problem/ OAM Type Mismatch". IANA is requested to maintain the sub-TLV space in the new "RSVP-TE OAM Configuration Registry".

Sub-TLV Type	Description
0	Reserved
1	OAM Function Flags Sub-TLV
2-31	Reserved for generic Sub-TLVs
32-	Reserved for technology specific Sub-TLVs

Note that there is a hierarchical dependency between the OAM configuration elements. First, the "OAM MEP entities desired" flag needs to be set. Only when that flag is set MAY an "OAM Configuration TLV" be included in the LSP_ATTRIBUTES or LSP_REQUIRED_ATTRIBUTES Object. When this TLV is present, based on the "OAM Type" field, it MAY carry a technology specific OAM configuration sub-TLV. If this hierarchy is broken (e.g., "OAM MEP entities desired" flag is not set but an OAM Configuration TLV is present) an error MUST be generated: "OAM Problem/Configuration Error".

4.2.1. OAM Function Flags Sub-TLV

The "OAM Configuration TLV" MUST always include a single instance of the "OAM Function Flags Sub-TLV" and it MUST always be the first sub-TLV. "OAM Function Flags" specifies which pro-active OAM functions (e.g., connectivity monitoring, loss and delay measurement) and which fault management signals MUST be established and configured. If the selected OAM Function(s) is(are) not supported, an error MUST be generated: "OAM Problem/Unsupported OAM Function".



OAM Function Flags is bitmap with extensible length based on the Length field of the TLV. Bits are numbered from left to right. The TLV is padded to 4-octet alignment. The Length field indicates the size of the padded TLV in octets. IANA is requested to maintain the OAM Function Flags in the new "RSVP-TE OAM Configuration Registry". This document defines the following flags.

OAM Function Flag bit#	Description
0	Continuity Check (CC)
1	Connectivity Verification (CV)
2	Fault Management Signal (FMS)
3	Performance Monitoring/Loss (PM/Loss)
4	Performance Monitoring/Delay (PM/Delay)
5	Performance Monitoring/Throughput Measurement (PM/Throughput)

4.2.2. Technology Specific Sub-TLVs

If technology-specific configuration information is needed for a specific "OAM Type", then this information is carried in a technology-specific sub-TLV. Such sub-TLVs are OPTIONAL and an OAM Configuration TLV MUST NOT contain more than one technology- specific sub-TLV. IANA is requested to maintain the OAM technology specific sub-TLV space in the new "RSVP-TE OAM Configuration Registry".

4.3. Administrative Status Information

Administrative Status Information is carried in the ADMIN_STATUS Object. The Administrative Status Information is described in [RFC3471], the ADMIN_STATUS Object is specified for RSVP-TE in [RFC3473].

Two bits are allocated for the administrative control of OAM monitoring. Two bits (IANA to assign) are allocated by this document: the "OAM Flows Enabled" (M) and "OAM Alarms Enabled" (O) bits. When the "OAM Flows Enabled" bit is set, OAM mechanisms MUST be enabled; if it is cleared, OAM mechanisms MUST be disabled. When the "OAM Alarms Enabled" bit is set OAM triggered alarms are enabled and associated consequent actions MUST be executed including the notification to the management system. When this bit is cleared, alarms are suppressed and no action SHOULD be executed and the management system SHOULD NOT be notified. For a detailed description of the use of these flags see Section 3.

4.4. Handling OAM Configuration Errors

To handle OAM configuration errors, a new Error Code (IANA to assign) "OAM Problem" is introduced. To refer to specific problems, a set of Error Values are defined under the "OAM Problem" error code.

If a node does not support the establishment of OAM MEP or MIP entities it MUST use the error value: "MEP establishment not supported" or "MIP establishment not supported" respectively in the PathErr message.

If a node does not support a specific OAM technology/solution it MUST use the error value: "Unsupported OAM Type" in the PathErr message.

If a different technology specific OAM configuration TLV is included than what was specified in the OAM Type an error MUST be generated with error value: "OAM Type Mismatch" in the PathErr message.

There is a hierarchy between the OAM configuration elements. If this hierarchy is broken, the error value: "Configuration Error" MUST be used in the PathErr message.

If a node does not support a specific OAM Function, it MUST use the error value: "Unsupported OAM Function" in the PathErr message.

4.5. Considerations on Point-to-Multipoint OAM Configuration

RSVP-TE extensions for the establishment of point-to-multipoint (P2MP) LSPs are specified in [RFC4875]. A P2MP LSP is comprised of multiple source-to-leaf (S2L) sub-LSPs. These S2L sub-LSPs are set up between the ingress and egress LSRs, and are appropriately combined by the branch LSRs using RSVP semantics to result in a P2MP TE LSP. One Path message may signal one or multiple S2L sub-LSPs for a single P2MP LSP. Hence, the S2L sub-LSPs belonging to a P2MP LSP can be signaled using one Path message or split across multiple Path messages.

P2MP OAM mechanisms are very specific to the data plane technology, therefore in this document, we only highlight the basic principles of P2MP OAM configuration. We consider only the root to leaf OAM flows, and as such, aspects of the configuration of return paths are outside the scope of our discussions. We also limit our consideration to the case where all leaves must successfully establish OAM entities with identical configuration in order the P2MP OAM is successfully established. In any case, the discussion set forth below provides only guidelines for P2MP OAM configuration. However at minimum the below procedures SHOULD be specified for P2MP OAM configuration in a technology specific document.

The root node may use a single Path message or multiple Path messages to setup the whole P2MP tree. In the case when multiple Path messages are used, the root node is responsible to keep the OAM Configuration information consistent in each of the sent Path messages, i.e., the same information MUST be included in all Path messages used to construct the multicast tree. Each branching node will propagate the Path message downstream on each of the branches, when constructing a Path message the OAM Configuration information MUST be copied unchanged from the received Path message, including the related ADMIN_STATUS bits, LSP Attribute Flags and the OAM Configuration TLV. The latter two also imply that the LSP_ATTRIBUTES and LSP_REQUIRED_ATTRIBUTES Object MUST be copied for the upstream Path message to the subsequent downstream Path messages.

Leaves MUST create and configure OAM sink functions according to the parameters received in the Path message, for P2MP OAM configuration there is no possibility for parameter negotiation on a per leaf basis. This is due to the fact that the OAM source function, residing in the root of the tree, will operate with a single configuration, which then must be obeyed by all leaves. If a leaf cannot accept the OAM parameters it MUST use the RRO Attributes sub-object [RFC5420] to notify the root about the problem. In particular, if the OAM configuration was successful, the leaf would set the "OAM MEP entities desired" flag in the RRO Attributes sub-

object in the Resv message. On the other hand, if OAM entities could not be established the Resv message should be sent with the "OAM MEP entities desired" bit cleared in the RRO Attributes sub-object. Branching nodes should collect and merge the received RROs according to the procedures described in [RFC4875]. This way, the root when receiving the Resv message (or messages if multiple Path messages were used to set up the tree) will have a clear information about which of the leaves could establish the OAM functions. If all leaves established OAM entities successfully, the root can enable the OAM message flow. On the other hand, if at some leaves the establishment was unsuccessful additional actions will be needed before the OAM message flow can be enabled. Such action could be to setup two independent P2MP LSPs. One LSP with OAM Configuration information towards leaves which could successfully setup the OAM function. This can be done by pruning the leaves which failed to setup OAM of the previously signaled P2MP LSP. The other P2MP LSP could be constructed for leaves without OAM entities. The exact procedures will be described in technology specific documents.

5. IANA Considerations

5.1. ADMIN_STATUS Object Bit Flags

IANA maintains a registry called "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Parameters" with a sub-registry called "Administrative Status Information Flags".

IANA is requested to allocate two new flags as follows:

Bit Number	Hex Value	Name	Reference
TBA	TBA	OAM Alarms Enabled (O)	[This.ID]
TBA	TBA	OAM Flows Enabled (M)	[This.ID]

5.2. LSP Attributes Flags

IANA maintains a registry called "Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Parameters" with a subregistry called "Attribute Flags".

IANA is requested to allocate two new flags as follows:

Bit No	Name	Attribute Flags Path	Attribute Flags Resv	RRO	Reference
TBA	OAM MEP entities desired	Yes	Yes	Yes	[This.ID]
TBA	OAM MIP entities desired	Yes	Yes	Yes	[This.ID]

5.3. New LSP Attributes

IANA maintains a registry called "Resource Reservation Protocol-Traffic Engineering (RSVP-TE) Parameters" with a subregistry called "Attributes TLV Space"

IANA is requested to allocate one new TLV type as follows:

Type	Name	Allowed on LSP_ATTRIBUTES	Allowed on LSP_REQUIRED_ATTRIBUTES	Reference
TBA	OAM Configuration TLV	Yes	Yes	[This.ID]

5.4. RSVP Error Code

IANA maintains a registry called "Resource Reservation Protocol (RSVP) Parameters" with a subregistry called "Error Codes and Globally-Defined Error Value Sub-Codes".

IANA is requested to allocate one new Error Code as follows:

Error Code	Meaning	Reference
TBA	OAM Problem	[This.ID]

The value is to be selected from the range 0-239.

The following Error Value sub-codes are defined for this new Error Code as follows:

Value	Description	Reference
1	MEP establishment not supported	[This.ID]
2	MIP establishment not supported	[This.ID]
3	Unsupported OAM Type	[This.ID]
4	Configuration Error	[This.ID]
5	OAM Type Mismatch	[This.ID]
6	Unsupported OAM Function	[This.ID]

5.5. RSVP-TE OAM Configuration Registry

IANA is requested to create a new registry called "RSVP-TE OAM Configuration Registry".

IANA is requested to create sub-registries as defined in the following subsections:

5.5.1. OAM Types Sub-Registry

IANA is requested to create the "OAM Types" sub-registry of the "RSVP-TE OAM Configuration Registry" as follows:

Range	Registration Procedures
0-255	IETF Review

There are no initial values in this registry. IANA should show the registry as follows:

OAM Type Number	OAM Type Description	Reference
0-255	Not allocated	

5.5.2. OAM Sub-TLVs Sub-Registry

IANA is requested to create the "OAM Sub-TLVs" sub-registry of the "RSVP-TE OAM Configuration Registry" as follows:

Range	Purpose	Registration Procedures
0-31	Generic Sub-TLVs	IETF Review
32-65534	Technology-specific Sub-TLVs	IETF Review
65535-65536	Experimental Sub-TLVs	Experimental

IANA is requested to populate the registry as follows:

Sub-TLV Type	Description	Reference
0	Reserved	[This.ID]
1	OAM Function Flags Sub-TLV	[This.ID]
2-31	Not allocated	
32-65534	Not allocated	

5.5.3. OAM Function Flags Sub-Registry

IANA is requested to create the "OAM Function Flags Sub-Registry" sub-registry of the "RSVP-TE OAM Configuration Registry".

New values in the registry are allocated by "IETF Review". There is no top value to the range. Bits are counted from bit 0 as the first bit transmitted.

IANA is requested to populate the registry as follows.

OAM Function Flag bit number	Description
0	Continuity Check (CC)
1	Connectivity Verification (CV)
2	Fault Management Signal (FMS)
3	Performance Monitoring/Loss (PM/Loss)
4	Performance Monitoring/Delay (PM/Delay)
5	Performance Monitoring/Throughput Measurement (PM/Throughput)
6-...	Not allocated

6. Security Considerations

The signaling of OAM related parameters and the automatic establishment of OAM entities based on RSVP-TE messages adds a new aspect to the security considerations discussed in [RFC3473]. In particular, a network element could be overloaded, if a remote attacker could request liveliness monitoring, with frequent periodic messages, for a high number of LSPs, targeting a single network element. Such an attack can efficiently be prevented when mechanisms for message integrity and node authentication are deployed. Since the OAM configuration extensions rely on the hop-by-hop exchange of exiting RSVP-TE messages, procedures specified for RSVP message security in [RFC2747] can be used to mitigate possible attacks.

For a more comprehensive discussion of GMPLS security, and attack mitigation techniques, please see the Security Framework for MPLS and GMPLS Networks [RFC5920].

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