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Detecting Data Plane Failures in Point-to-Multipoint Multiprotocol Label Switching (MPLS) - Extensions to LSP Ping

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Status of this Memo

Abstract

Recent proposals have extended the scope of Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) to encompass point-to-multipoint (P2MP) LSPs.

The requirement for a simple and efficient mechanism that can be used to detect data plane failures in point-to-point (P2P) MPLS LSPs has been recognised and has led to the development of techniques for fault detection and isolation commonly referred to as "LSP Ping".

The scope of this document is fault detection and isolation for P2MP MPLS LSPs. This documents does not replace any of the mechanism of LSP Ping, but clarifies their applicability to MPLS P2MP LSPs, and extends the techniques and mechanisms of LSP Ping to the MPLS P2MP environment.

Conventions used in this document

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].

Contents

0. Change Log

This section to be removed before publication as an RFC.

0.1 Changes from 00 to 01

- Update references.

- Fix boilerplate.

0.2 Changes from 01 to 02

- Update entire document so that it is not specific to MPLS-TE, but also includes multicast LDP LSPs.

- Move the egress identifier sub-TLVs from the FEC Stack TLV to a new egress identifier TLV.

- Include Multicast LDP FEC Stack Sub-TLV definition from [MCAST-CV].

- Add brief section on use of LSP Ping for bootstrapping.

- Add new references to References section.

- Add details of two new authors.

0.3 Changes from 02 to 03

- Update references.

- Update boilerplate.

- Fix typos.

- Clarify in 3.2.2 that a recipient of an echo request must reply only once it has applied incoming rate limiting.

- Tidy references to bootstrapping for [MCAST-CV] in 1.1.

- Allow multiple sub-TLVs in the P2MP Egress Identifier TLV in sections 3.2.1, 3.2.2, 3.2.4, 3.3.1, and 3.3.4.

- Clarify how to handle a P2MP Egress Identifier TLV with no sub-TLVs in sections 3.2.1 and 3.2.2.

0.4 Changes from 03 to 04

- Revert to previous text in sections 3.2.1, 3.2.2, 3.2.4, 3.3.1, and 3.3.4 with respect to multiple sub-TLVs in the P2MP Egress Identifier TLV.

1. Introduction

Simple and efficient mechanisms that can be used to detect data plane failures in point-to-point (P2P) MPLS LSP are described in [RFC4379]. The techniques involve information carried in an MPLS

"echo request" and "echo reply", and mechanisms for transporting the echo reply. The echo request and reply messages provide sufficient information to check correct operation of the data plane, as well as a mechanism to verify the data plane against the control plane, and thereby localize faults. The use of reliable reply channels for echo request messages as described in [RFC4379] enables more robust fault isolation. This collection of mechanisms is commonly referred to as "LSP Ping".

The requirements for point-to-multipoint (P2MP) MPLS traffic engineered (TE) LSPs are stated in [RFC4461]. [P2MP-RSVP] specifies a signaling solution for establishing P2MP MPLS TE LSPs.

The requirements for point-to-multipoint extensions to the Label Distribution Protocol (LDP) are stated in [P2MP-LDP-REQ]. [P2MP-LDP] specifies extensions to LDP for P2MP MPLS.

P2MP MPLS LSPs are at least as vulnerable to data plane faults or to discrepancies between the control and data planes as their P2P counterparts. Mechanisms are, therefore, desirable to detect such data plane faults in P2MP MPLS LSPs as described in [RFC4687].

This document extends the techniques described in [RFC4379] such that they may be applied to P2MP MPLS LSPs and so that they can be used to bootstrap other OAM procedures such as [MCAST-CV]. This document stresses the reuse of existing LSP Ping mechanisms used for P2P LSPs, and applies them to P2MP MPLS LSPs in order to simplify implementation and network operation.

1.1 Design Considerations

An important consideration for designing LSP Ping for P2MP MPLS LSPs is that every attempt is made to use or extend existing mechanisms rather than invent new mechanisms.

As for P2P LSPs, a critical requirement is that the echo request messages follow the same data path that normal MPLS packets would traverse. However, it can be seen this notion needs to be extended for P2MP MPLS LSPs, as in this case an MPLS packet is replicated so that it arrives at each egress (or leaf) of the P2MP tree.

MPLS echo requests are meant primarily to validate the data plane, and they can then be used to validate data plane state against the control plane. They may also be used to bootsrap other OAM procedures

such as [MPLS-BFD] and [MCAST-CV]. As pointed out in [RFC4379], mechanisms to check the liveness, function, and consistency of the control plane are valuable, but such mechanisms are not a feature of LSP Ping and are not covered in this document.

As is described in [RFC4379], to avoid potential Denial of Service attacks, it is RECOMMENDED to regulate the LSP Ping traffic passed to the control plane. A rate limiter should be applied to the well-known UDP port defined for use by LSP Ping traffic.

2. Notes on Motivation

2.1. Basic Motivations for LSP Ping

The motivations listed in [RFC4379] are reproduced here for completeness.

When an LSP fails to deliver user traffic, the failure cannot always be detected by the MPLS control plane. There is a need to provide a tool that would enable users to detect such traffic "black holes" or misrouting within a reasonable period of time; and a mechanism to isolate faults.

[RFC4379] describes a mechanism that accomplishes these goals. This mechanism is modeled after the ping/traceroute paradigm: ping (ICMP echo request [RFC792]) is used for connectivity checks, and traceroute is used for hop-by-hop fault localization as well as path tracing. [RFC4379] specifies a "ping mode" and a "traceroute" mode for testing MPLS LSPs.

The basic idea as expressed in [RFC4379] is to test that the packets that belong to a particular Forwarding Equivalence Class (FEC) actually end their MPLS path on an LSR that is an egress for that FEC. [RFC4379] achieves this test by sending a packet (called an "MPLS echo request") along the same data path as other packets belonging to this FEC. An MPLS echo request also carries information about the FEC whose MPLS path is being verified. This echo request is forwarded just like any other packet belonging to that FEC. In "ping" mode (basic connectivity check), the packet should reach the end of the path, at which point it is sent to the control plane of the egress LSR, which then verifies that it is indeed an egress for the FEC. In "traceroute" mode (fault isolation), the packet is sent to the control plane of each transit LSR, which performs various checks that it is indeed a transit LSR for this path; this LSR also returns further information that helps to check the control plane against the data plane, i.e., that forwarding matches what the routing protocols determined as the path.

One way these tools can be used is to periodically ping a FEC to

ensure connectivity. If the ping fails, one can then initiate a

traceroute to determine where the fault lies. One can also periodically traceroute FECs to verify that forwarding matches the control plane; however, this places a greater burden on transit LSRs and thus should be used with caution.

2.2. Motivations for LSP Ping for P2MP LSPs

As stated in [RFC4687], MPLS has been extended to encompass P2MP LSPs. As with P2P MPLS LSPs, the requirement to detect, handle and diagnose control and data plane defects is critical. For operators deploying services based on P2MP MPLS LSPs the detection and specification of how to handle those defects is important because such defects may affect the fundamentals of an MPLS network, but also because they may impact service level specification commitments for customers of their network.

P2MP LDP [P2MP-LDP] uses the Label Distribution Protocol to establish multicast LSPs. These LSPs distribute data from a single source to one or more destinations across the network according to the next hops indicated by the routing protocols. Each LSP is identified by an MPLS multicast FEC.

P2MP MPLS TE LSPs [P2MP-RSVP] may be viewed as MPLS tunnels with a single ingress and multiple egresses. The tunnels, built on P2MP LSPs, are explicitly routed through the network. There is no concept or applicability of a FEC in the context of a P2MP MPLS TE LSP.

MPLS packets inserted at the ingress of a P2MP LSP are delivered equally (barring faults) to all egresses. In consequence, the basic idea of LSP Ping for P2MP MPLS TE LSPs may be expressed as an intention to test that packets that enter (at the ingress) a particular P2MP LSP actually end their MPLS path on the LSRs that are the (intended) egresses for that LSP. The idea may be extended to check selectively that such packets reach specific egresses.

The technique in this document makes this test by sending an LSP Ping echo request message along the same data path as the MPLS packets. An echo request also carries the identification of the P2MP MPLS LSP (multicast LSP or P2MP TE LSP) that it is testing. The echo request is forwarded just as any other packet using that LSP and so is replicated at branch points of the LSP and should be delivered to all egresses. In "ping" mode (basic connectivity check), the echo request should reach the end of the path, at which point it is sent to the control plane of the egress LSRs, which verify that they are indeed an egress (leaf) of the P2MP LSP. An echo response message is sent by an egress to the ingress to confirm the successful receipt (or announce the erroneous arrival) of the echo request.

In "traceroute" mode (fault isolation), the echo request is sent to

the control plane at each transit LSR, and the control plane checks

that it is indeed a transit LSR for this P2MP MPLS LSP. The transit LSR also returns information on an echo response that helps verify the control plane against the data plane. That is, the information is used by the ingress to check that the data plane forwarding matches what is signaled by the control plane.

P2MP MPLS LSPs may have many egresses, and it is not necessarily the intention of the initiator of the ping or traceroute operation to collect information about the connectivity or path to all egresses. Indeed, in the event of pinging all egresses of a large P2MP MPLS LSP, it might be expected that a large number of echo responses would arrive at the ingress independently but at approximately the same time. Under some circumstances this might cause congestion at or around the ingress LSR. Therefore, the procedures described in this document provide a mechanism that allows the responders to randomly delay (or jitter) their responses so that the chances of swamping the ingress are reduced.

Further, the procedures in this document allow the initiator to limit the scope of an LSP Ping echo request (ping or traceroute mode) to one specific intended egress or a set of egresses.

The scalability issues surrounding LSP Ping for P2MP MPLS LSPs may be addressed by other mechanisms such as [MCAST-CV] that utilise the LSP Ping procedures in this document to provide bootstrapping mechanisms as described in Section 2.3.

LSP Ping can be used to periodically ping a P2MP MPLS LSP to ensure connectivity to any or all of the egresses. If the ping fails, the operator or an automated process can then initiate a traceroute to determine where the fault is located within the network. A traceroute may also be used periodically to verify that data plane forwarding matches the control plane state; however, this places an increased burden on transit LSRs and should be used infrequently and with caution.

2.3 Bootstrapping other OAM Procedures using LSP Ping

[MPLS-BFD] describes a process where LSP Ping [RFC4379] is used to bootstrap the Bidirectional Forwarding Detection (BFD) mechanism [BFD] for use to track the liveliness of an MPLS LSP. In particular BFD can be used to detect a data plane failure in the forwarding path of an MPLS LSP.

Requirements for MPLS P2MP LSPs extend to hundreds or even thousands of endpoints. If a protocol required explicit acknowledgments to each probe for connectivity verification, the response load at the root would be overwhelming.

A more scalable approach to monitoring P2MP LSP connectivity is

desribed in [MCAST-CV]. It relies on using the MPLS Echo Request/Response messages of LSP Ping [RFC4379] to bootstrap the monitoring mechanism in a manner similar to [MPLS-BFD]. The actual monitoring is done using a separate process defined in [MCAST-CV].

Note that while the approach described in [MCAST-CV] was developed in response to the multicast scalability problem, it can be applied to P2P LSPs as well.

3. Operation of LSP Ping for a P2MP LSP

This section describes how LSP Ping is applied to P2MP MPLS LSPs. It covers the mechanisms and protocol fields applicable to both ping mode and traceroute mode. It explains the responsibilities of the initiator (ingress), transit LSRs and receivers (egresses).

3.1. Identifying the LSP Under Test

3.1.1. Identifying a P2MP MPLS TE LSP

[RFC4379] defines how an MPLS TE LSP under test may be identified in an echo request. A Target FEC Stack TLV is used to carry either an RSVP IPv4 Session or an RSVP IPv6 Session sub-TLV.

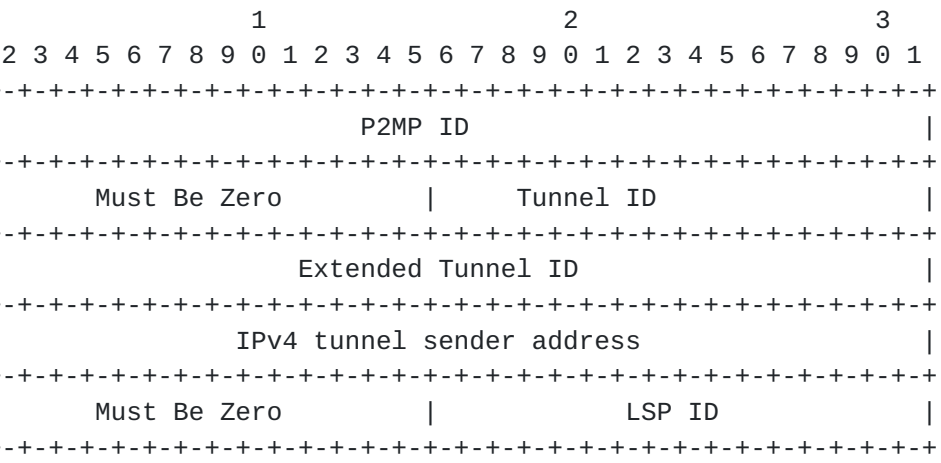
In order to identify the P2MP MPLS TE LSP under test, the echo request message MUST carry a Target FEC Stack TLV, and this MUST carry exactly one of two new sub-TLVs: either an RSVP P2MP IPv4 Session or an RSVP P2MP IPv6 Session sub-TLV. These sub-TLVs carry fields from the RSVP-TE P2MP Session and Sender-Template objects [P2MP-RSVP] and so provide sufficient information to uniquely identify the LSP.

The new sub-TLVs are assigned sub-type identifiers as follows, and are described in the following sections.

Sub-Type #	Length	Value Field
TBD	20	RSVP P2MP IPv4 Session
TBD	56	RSVP P2MP IPv6 Session

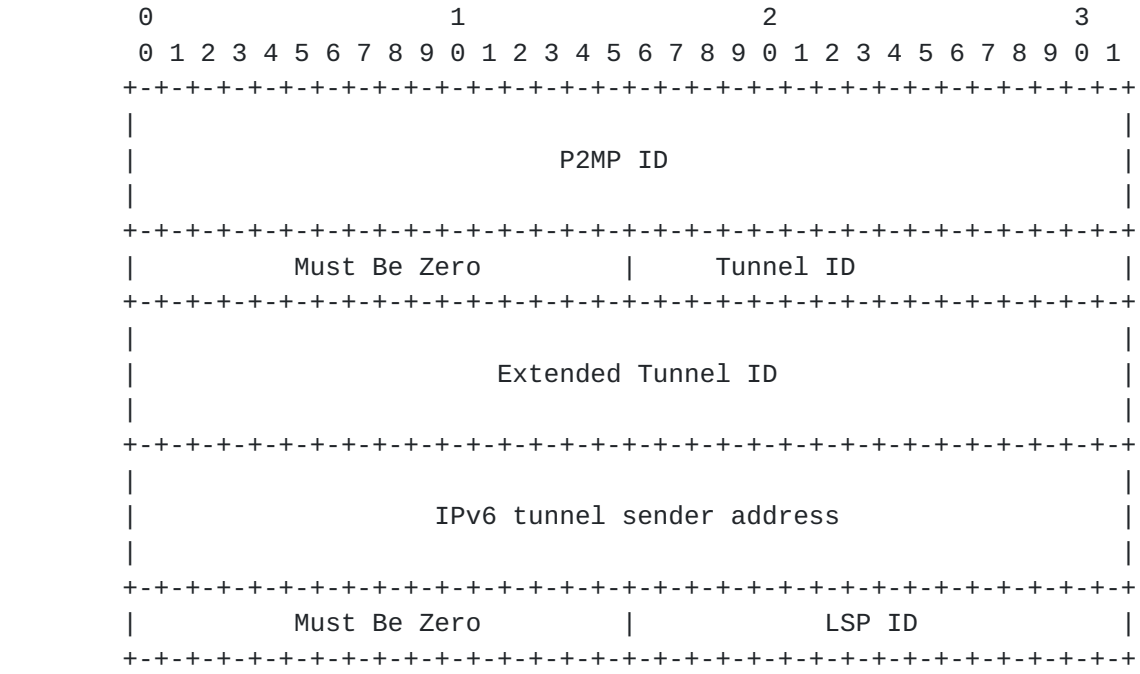
3.1.1.1. RSVP P2MP IPv4 Session Sub-TLV

The format of the RSVP P2MP IPv4 Session Sub-TLV value field is specified in the following figure. The value fields are taken from the definitions of the P2MP IPv4 LSP Session Object, and the P2MP IPv4 Sender-Template Object in [P2MP-RSVP]. Note that the Sub-Group ID of the Sender-Template is not required.



3.1.1.2. RSVP P2MP IPv6 Session Sub-TLV

The format of the RSVP P2MP IPv6 Session Sub-TLV value field is specified in the following figure. The value fields are taken from the definitions of the P2MP IPv6 LSP Session Object, and the P2MP IPv6 Sender-Template Object in [P2MP-RSVP]. Note that the Sub-Group ID of the Sender-Template is not required.



3.1.2. Identifying a Multicast LDP LSP

[RFC4379] defines how a P2P LDP LSP under test may be identified in an echo request. A Target FEC Stack TLV is used to carry one or more Sub-TLVs (for example, an IPv4 Prefix FEC Sub-TLV) that identify the LSP.

In order to identify a multicast LDP LSP under test, the echo request

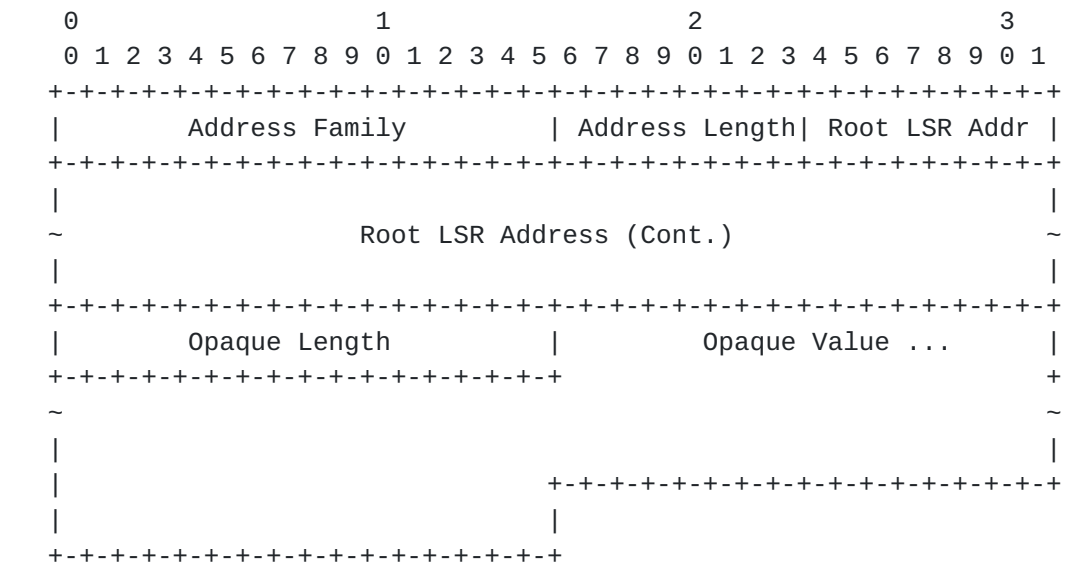
message MUST carry a Target FEC Stack TLV, and this MUST carry exactly one new sub-TLVs: the Multicast LDP FEC Stack Sub-TLV. This Sub-TLVs fields from the multicast LDP messages [P2MP-LDP] and so provides sufficient information to uniquely identify the LSP.

The new sub-TLV is assigned a sub-type identifier as follows, and is described in the following sections.

Sub-Type #	Length	Value Field
TBD	Variable	Multicast LDP FEC Stack

3.1.2.1. Multicast LDP FEC Stack Sub-TLV

The format of the Multicast LDP FEC Stack Sub-TLV is shown below.



Address Family

A two octet quantity containing a value from ADDRESS FAMILY NUMBERS in [IANA-PORT] that encodes the address family for the Root LSR Address.

Address Length

The length of the Root LSR Address in octets.

Root LSR Address

An address of the LSR at the root of the P2MP LSP encoded according to the Address Family field.

Opaque Length

The length of the Opaque Value, in octets.

Opaque Value

An opaque value elements of which uniquely identifies the P2MP LSP in the context of the Root LSR.

If the Address Family is IPv4, the Address Length MUST be 4. If the Address Family is IPv6, the Address Length MUST be 16. No other Address Family values are defined at present.

3.2. Ping Mode Operation

3.2.1. Controlling Responses to LSP Pings

As described in Section 2.2, it may be desirable to restrict the operation of LSP Ping to a single egress. Since echo requests are forwarded through the data plane without interception by the control plane (compare with traceroute mode), there is no facility to limit the propagation of echo requests, and they will automatically be forwarded to all (reachable) egresses.

However, the intended egress under test can be identified by the inclusion of a P2MP Egress Identifier TLV containing an IPv4 P2MP Egress Identifier sub-TLV or an IPv6 P2MP Egress Identifier sub-TLV. The P2MP Egress Identifier TLV SHOULD contain precisely one sub-TLV. If the TLV contains no sub-TLVs it SHOULD be processed as if the whole TLV were absent (causing all egresses to respond as described below). If the TLV contains more than one sub-TLV, the first MUST be precessed as described in this document, and subsequent sub-TLVs SHOULD be ignored.

An initiator may indicate that it wishes all egresses to respond to an echo request by omitting the P2MP Egress Identifier TLV.

Note that the ingress of a multicast LDP LSP will not know the identities of the egresses of the LSP except by some external means such as running P2MP LSP Ping to all egresses.

3.2.2. Ping Mode Egress Procedures

An egress LSR is RECOMMENDED to rate limit its receipt of echo request messages as described in [RFC4379]. After rate limiting, an egress LSR that receives an echo request carrying an RSVP P2MP IPv4 Session sub-TLV, an RSVP P2MP IPv6 Session sub-TLV, or a Multicast LDP FEC Stack Sub-TLV MUST determine whether it is an intended egress of the P2MP LSP in question by checking with the control plane. If it is not supposed to be an egress, it MUST respond according to the setting of the Response Type field in the echo message following the rules defined in [RFC4379].

If the egress LSR that receives an echo request and allows it through its rate limiting is an intended egress of the P2MP LSP, the LSR MUST check to see whether it is an intended Ping recipient. If a P2MP Egress Identifier TLV is present and contains an address that indicates any address that is local to the LSR, the LSR MUST respond according to the setting of the Response Type field in the echo message following the rules defined in [RFC4379]. If the P2MP Egress Identifier TLV is present, but does not identify the egress LSR, it MUST NOT respond to the echo request. If the P2MP Egress Identifier TLV is not present (or, in the error case, is present but does not a sub-TLVs), but the egress LSR that received the echo request is an intended egress of the LSP, the LSR MUST respond according to the setting of the Response Type field in the echo message following the rules defined in [RFC4379].

3.2.3. Jittered Responses

The initiator (ingress) of a ping request MAY request the responding egress to introduce a random delay (or jitter) before sending the response. The randomness of the delay allows the responses from multiple egresses to be spread over a time period. Thus this technique is particularly relevant when the entire LSP tree is being pinged since it helps prevent the ingress (or nearby routers) from being swamped by responses, or from discarding responses due to rate limits that have been applied.

It is desirable for the ingress to be able to control the bounds within which the egress delays the response. If the tree size is small only a small amount of jitter is required, but if the tree is large greater jitter is needed. The ingress informs the egresses of the jitter bound by supplying a value in a new TLV (the Echo Jitter TLV) carried on the Echo request message. If this TLV is present, the responding egress MUST delay sending a response for a random amount of time between zero seconds and the value indicated in the TLV. If the TLV is absent, the responding egress SHOULD NOT introduce any additional delay in responding to the echo request.

LSP ping SHOULD NOT be used to attempt to measure the round-trip

time for data delivery. This is because the LSPs are unidirectional, and the echo response is often sent back through the control plane. The timestamp fields in the echo request/response MAY be used to deduce some information about delivery times and particularly the variance in delivery times.

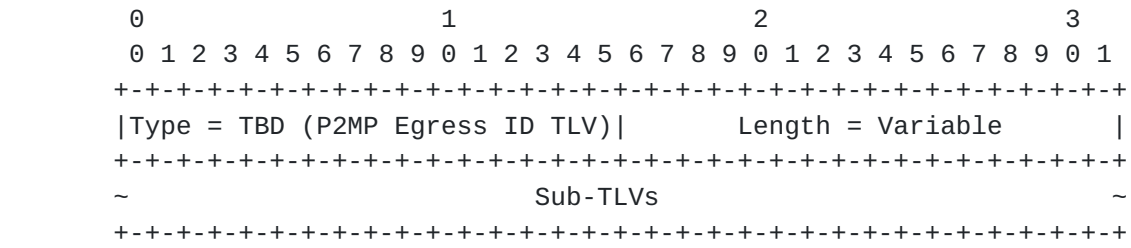
The use of echo jittering does not change the processes for gaining information, but note that the responding egress MUST set the value in the Timestamp Received fields before applying any delay.

It is RECOMMENDED that echo response jittering is not used except in the case of P2MP LSPs. If the Echo Jitter TLV is present in an echo request for any other type of TLV, the responding egress MAY apply the jitter behavior described here.

3.2.4. P2MP Egress Identifier TLV and Sub-TLVs

A new TLV is defined for inclusion in the Echo request message.

The P2MP Egress Identifier TLV is assigned the TLV type value TBD and is encoded as follows.



Sub-TLVs:

Zero, one or more sub-TLVs as defined below.

If no sub-TLVs are present, the TLV MUST be processed as if it were absent. If more than one sub-TLV is present the first MUST be processed as described in this document, and subsequent sub-TLVs SHOULD be ignored.

The P2MP Egress Identifier TLV only has meaning on an echo request message. If present on an echo response message, it SHOULD be ignored.

Two Sub-TLVs are defined for inclusion in the P2MP Egress Identifier TLV carried on the echo request message. These are:

Sub-Type #	Length	Value Field
1	4	IPv4 P2MP Egress Identifier
2	16	IPv6 P2MP Egress Identifier

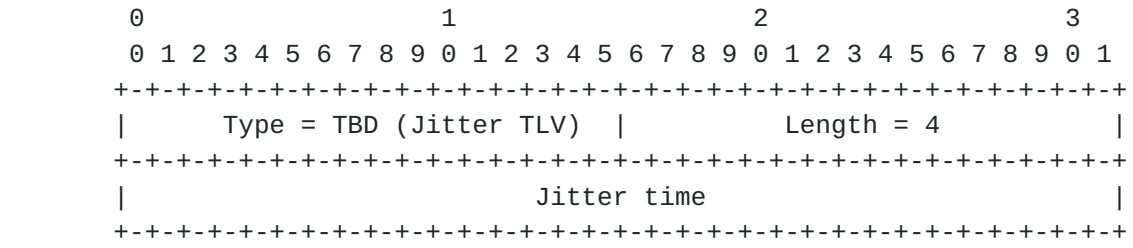
The value of an IPv4 P2MP Egress Identifier consists of four octets of an IPv4 address. The IPv4 address is in network byte order.

The value of an IPv6 P2MP Egress Identifier consists of sixteen octets of an IPv6 address. The IPv6 address is in network byte order.

3.2.5. Echo Jitter TLV

A new TLV is defined for inclusion in the Echo request message.

The Echo Jitter TLV is assigned the TLV type value TBD and is encoded as follows.



Jitter time:

This field specifies the upper bound of the jitter period that should be applied by a responding egress to determine how long to wait before sending an echo response. An egress SHOULD wait a random amount of time between zero seconds and the value specified in this field.

Jitter time is specified in milliseconds.

The Echo Jitter TLV only has meaning on an echo request message. If present on an echo response message, it SHOULD be ignored.

3.3. Traceroute Mode Operation

The traceroute mode of operation is described in [RFC4379]. Like other traceroute operations, it relies on the expiration of the TTL of the packet that carries the echo request. Echo requests may include a Downstream Mapping TLV, and when the TTL expires the echo request is passed to the control plane on the transit LSR which responds according to the Response Type in the message. A responding LSR fills in the fields of the Downstream Mapping TLV to indicate the downstream interfaces and labels used by the reported LSP from the responding LSR. In this way, by successively sending out echo requests with increasing TTLs, the ingress may gain a picture of the path and resources used by an LSP up to the point of failure when no response is received, or an error response is generated by an LSR where the control plane does not expect to be handling the LSP.

This mode of operation is equally applicable to P2MP MPLS TE LSPs as described in the following sections.

The traceroute mode can be applied to all destinations of the P2MP tree just as in the ping mode. In the case of P2MP MPLS TE LSPs, the traceroute mode can also be applied to individual destinations identified by the presence of a P2MP Egress Identifier TLV. However, since a transit LSR of a multicast LDP LSP is unable to determine whether it lies on the path to any one destination, the traceroute mode limited to specific egresses of such an LSP MUST NOT be used.

In the absence of a P2MP Egress Identifier TLV, the echo request is asking for traceroute information applicable to all egresses.

The echo response jitter technique described for the ping mode is equally applicable to the traceroute mode and is not additionally described in the procedures below.

3.3.1. Traceroute Responses at Non-Branch Nodes

When the TTL for the MPLS packet carrying an echo request expires the packet MUST be passed to the control plane as specified in [RFC4379].

If the LSP under test is a multicast LDP LSP and if the echo request carries a P2MP Egress Identifier TLV the LSR MUST treat the echo request as malformed and MUST process it according to the rules specified in [RFC4379].

Otherwise, the LSR MUST NOT return an echo response unless the responding LSR lies on the path of the P2MP LSP to the egress identified by the P2MP Egress Identifier TLV carried on the request, or if no such Sub-TLV is present.

If sent, the echo response MUST identifiy the next hop of the path of the LSP in the data plane by including a Downstream Mapping TLV as described in [RFC4379].

3.3.1.1. Correlating Traceroute Responses

When traceroute is being simultaneously applied to multiple egresses, it is important that the ingress should be able to correlate the echo responses with the branches in the P2MP tree. Without this information the ingress will be unable to determine the correct ordering of transit nodes. One possibility is for the ingress to poll the path to each egress in turn, but this may be inefficient, undesirable, or (in the case of multicast LDP LSPs) illegal.

The Downstream Mapping TLV that MUST be included in the echo response indicates the next hop from each responding LSR, and this information supplied by a non-branch LSR can be pieced together by the ingress to

reconstruct the P2MP tree although it may be necessary to refer to the routing information distributed by the IGP to correlate next hop addresses and LSR reporting addresses in subsequent echo responses.

In order to facilitate more easy correlation of echo responses, the Downstream Mapping TLV can also contain Multipath Information as described in [RFC4379] to identify to which egress/egresses the echo response applies, and indicates. This information:

- MUST NOT be present for multicast LDP LSPs

- SHOULD be present for P2MP MPLS TE LSPs when the echo request applies to all egresses

- is RECCOMMENDED to be present for P2MP MPLS TE LSPs when the echo request is limited to a single egress.

The format of the information in the Downstream Mapping TLV for P2MP MPLS LSPs is described in section 3.3.5 and 3.3.6.

3.3.2. Traceroute Responses at Branch Nodes

A branch node may need to identify more than one downstream interface in a traceroute echo response if some of the egresses that are being traced lie on different branches. This will always be the case for any branch node if all egresses are being traced.

[RFC4379] describes how multiple Downstream Mapping TLVs should be included in an echo response, each identifying exactly one downstream interface that is applicable to the LSP.

A branch node MUST follow the procedures described in Section 3.3.1 to determine whether it should respond to an echo request. The branch node MUST add a Downstream Mapping TLV to the echo response for each outgoing branch that it reports, but it MUST NOT report branches that do not lie on the path to one of the destinations being traced. Thus a branch node may sometimes only need to respond with a single Downstream Mapping TLV, for example, consider the case where the traceroute is directed to only a single egress node. Therefore, the presence of only one Downstream Mapping TLV in an echo response does not guarantee that the reporting LSR is not a branch node.

To report on the fact that an LSR is a branch node for the P2MP MPLS LSP a new B-flag is added to the Downstream Mapping TLV. The flag is set to zero to indicate that the reporting LSR is not a branch for this LSP, and is set to one to indicate that it is a branch. The flag is placed in the fourth byte of the TLV that was previously reserved.

The format of the information in the Downstream Mapping TLV for P2MP MPLS LSPs is described in section 3.3.5 and 3.3.6.

3.3.2.1. Correlating Traceroute Responses

Just as with non-branches, it is important that the echo responses from branch nodes provide correlation information that will allow the ingress to work out to which branch of the LSP the response applies.

The P2MP tree can be determined by the ingress using the identity of the reporting node and the next hop information from the previous echo response, just as with echo responses from non-branch nodes.

As with non-branch nodes, in order to facilitate more easy correlation of echo responses, the Downstream Mapping TLV can also contain Multipath Information as described in [RFC4379] to identify to which egress/egresses the echo response applies, and indicates. This information:

- MUST NOT be present for multicast LDP LSPs

- SHOULD be present for P2MP MPLS TE LSPs when the echo request applies to all egresses

- is RECCOMMENDED to be present for P2MP MPLS TE LSPs when the echo request is limited to a single egress.

The format of the information in the Downstream Mapping TLV for P2MP MPLS LSPs is described in section 3.3.5 and 3.3.6.

3.3.3. Traceroute Responses at Bud Nodes

Some nodes on a P2MP MPLS LSP may be egresses, but also have downstream LSRs. Such LSRs are known as bud nodes [RFC4461].

A bud node MUST respond to a traceroute echo request just as a branch node would, but it MUST also indicates to the ingress that it is an egress in its own right. This is achieved through the use of a new E-flag in the Downstream Mapping TLV that indicates that the reporting LSR is not a bud for this LSP (cleared to zero) or is a bud (set to one). A normal egress MUST NOT set this flag.

The flag is placed in the fourth byte of the TLV that was previously reserved.

3.3.4. Non-Response to Traceroute Echo Requests

The nature of P2MP MPLS TE LSPs in the data plane means that traceroute echo requests may be delivered to the control plane of LSRs that must not reply to the request because, although they lie on the P2MP tree, they do not lie on the path to the egress that is being traced.

Thus, an LSR on a P2MP MPLS LSP MUST NOT respond to an echo request when the TTL has expired if any of the following applies:

- The Reply Type indicates that no reply is required

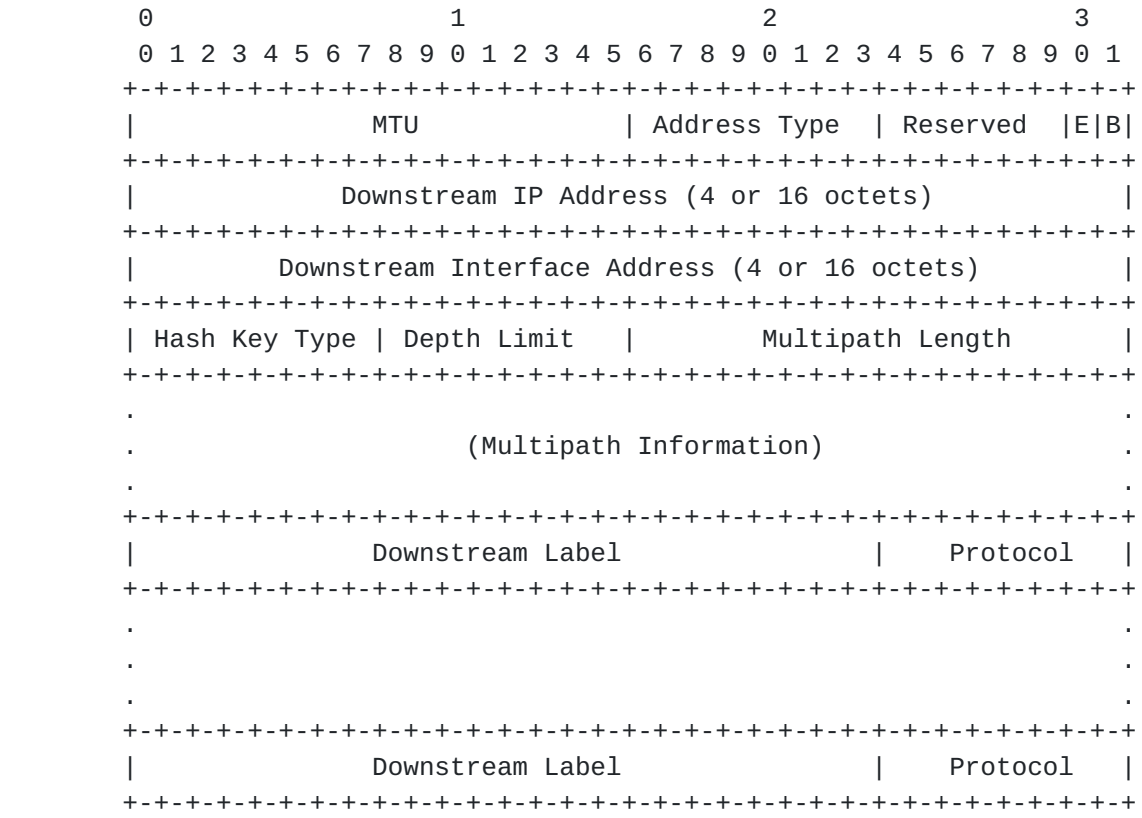
- There is a P2MP Egress Identifier TLV present on the echo request (which means that the LSP is a P2MP MPLS TE LSP), but the address does not identify an egress that is reached through this LSR for this particular P2MP MPLS LSP.

3.3.5. Modifications to the Downstream Mapping TLV

A new B-flag is added to the Downstream Mapping TLV to indicate that the reporting LSR is not a branch for this LSP (cleared to zero) or is a branch (set to one).

A new E-flag is added to the Downstream Mapping TLV to indicate that the reporting LSR is not a bud node for this LSP (cleared to zero) or is a bud node (set to one).

The flags are placed in the fourth byte of the TLV that was previously reserved as shown below. All other fields are unchanged from their definitions in [RFC4379] except for the additional information that can be carried in the Multipath Information (see Section 3.3.6).



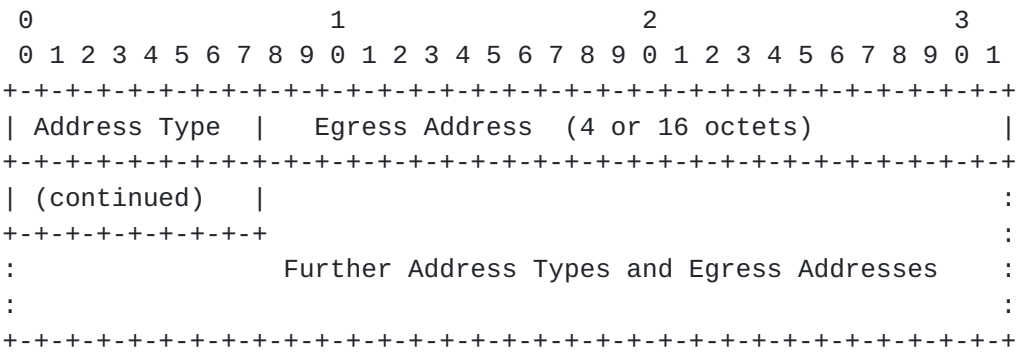
3.3.6. Additions to Downstream Mapping Multipath Information

A new value for the Multipath Type is defined to indicate that the reported Multipath Information applies to a P2MP MPLS TE LSP and may contain a list of egress identifiers that indicate the egress nodes that can be reached through the reported interface. This Multipath Type MUST NOT be used for a multicast LDP LSP.

Type #	Address Type	Multipath Information
TBD	P2MP egresses	List of P2MP egresses

Note that a list of egresses may include IPv4 and IPv6 identifiers since these may be mixed in the P2MP MPLS TE LSP.

The Multipath Length field continues to identify the length of the Multipath Information just as in [RFC4379] (that is, not including the downstream labels), and the downstream label (or potential stack thereof) is also handled just as in [RFC4379]. The format of the Multipath Information for a Multipath Type of P2MP Egresses is as follows.



Address Type

This field indicates whether the egress address that follows is an IPv4 or IPv6 address, and so implicitly encodes the length of the address.

Two values are defined and mirror the values used in the Address Type field of the Downstream Mapping TLV itself.

Type #	Address Type
1	IPv4
3	IPv6

Egress Address

An egress of this P2MP MPLS TE LSP that is reached through the

interface indicated by the Downstream Mapping TLV and for which the traceroute echo request was enquiring.

4. Operation of LSP Ping for Bootstrapping Other OAM Mechanisms

Bootstrapping of other OAM procedures can be achieved using the MPLS Echo Request/Response messages. The LSP(s) under test are identified using the RSVP P2MP IPv4 or IPv6 Session Sub-TLVs (see Section 3.1.1) or the Multicast LDP FEC Stack Sub-TLV (see Section 3.1.2).

Other Sub-TLVs may be defined in other specifications to indicate the OAM procedures being bootstrapped, and to describe the bootstrap parameters. Further details of the bootstrapping processes and the bootstrapped OAM processes are described in other documents. For example, see [MPLS-BFD] and [MCAST-CV].

5. Non-compliant Routers

If an egress for a P2MP LSP does not support MPLS LSP ping, then no reply will be sent, resulting in a "false negative" result. There is no protection for this situation, and operators may wish to ensure that end points for P2MP LSPs are all equally capable of supporting this function. Alternatively, the traceroute option can be used to verify the LSP nearly all the way to the egress, leaving the final hop to be verified manually.

If, in "traceroute" mode, a transit LSR does not support LSP ping, then no reply will be forthcoming from that LSR for some TTL, say n. The LSR originating the echo request SHOULD continue to send echo requests with TTL=n+1, n+2, ..., n+k in the hope that some transit LSR further downstream may support MPLS echo requests and reply. In such a case, the echo request for TTL > n MUST NOT have Downstream Mapping TLVs, until a reply is received with a Downstream Mapping.

Note that the settings of the new bit flags in the Downstream Mapping TLV are such that a legacy LSR would return them with value zero which most closely matches the likely default behavior of a legacy LSR.

6. OAM Considerations

The procedures in this document provide OAM functions for P2MP MPLS LSPs and may be used to enable bootstrapping of other OAM procedures.

In order to be fully operational several considerations must be made.

- Scaling concerns dictate that only cautious use of LSP Ping should be made. In particular, sending an LSP Ping to all egresses of a P2MP MPLS LSP could result in congestion at or near the ingress

when the responses arrive.

Further, incautious use of timers to generate LSP Ping echo requests either in ping mode or especially in traceroute may lead to significant degradation of network performance.

- Management interfaces should allow an operator full control over the operation of LSP Ping. In particular, it SHOULD provide the ability to limit the scope of an LSP Ping echo request for a P2MP MPLS LSP to a single egress.

  Such an interface SHOULD also provide the ability to disable all active LSP Ping operations to provide a quick escape if the network becomes congested.

- A MIB module is required for the control and management of LSP Ping operations, and to enable the reported information to be inspected.

  There is no reason to believe this should not be a simple extension of the LSP Ping MIB module used for P2P LSPs.

7. IANA Considerations

7.1. New Sub-TLV Types

Three new Sub-TLV types are defined for inclusion within the LSP Ping [RFC4379] Target FEC Stack TLV (TLV type 1).

IANA is requested to assign sub-type values to the following Sub-TLVs from the Multiprotocol Label Switching Architecture (MPLS) Label Switched Paths (LSPs) Parameters - TLVs registry.

RSVP P2MP IPv4 Session (see Section 3.1.1)
RSVP P2MP IPv6 Session (see Section 3.1.1)
Multicast LDP FEC Stack (see Section 3.1.2)

7.2. New Multipath Type

Section 3.3 of [RFC4379] defines a set of values for the LSP Ping Multipath Type. These values are currently not tracked by IANA.

A new value for the LSP Ping Multipath Type is defined in Section 3.3.6 of this document to indicate that the reported Multipath Information applies to a P2MP MPLS TE LSP.

IANA is requested to create a new registry as follows:

Multiprotocol Label Switching Architecture (MPLS) Label Switched Paths (LSPs) - Multipath Types

Key	Type	Multipath Information	
0	no multipath	Empty (Multipath Length = 0)	[RFC4379]
2	IP address	IP addresses	[RFC4379]
4	IP address range	low/high address pairs	[RFC4379]
8	Bit-masked IP address set	IP address prefix and bit mask	[RFC4379]
9	Bit-masked label set	Label prefix and bit mask	[RFC4379]
xx	P2MP egress IP addresses	List of P2MP egresses	[thisDoc]

A suggested value of xx is TBD by the MPLS Working Group.

New values from this registry are to be assigned only by Standards Action.

7.3. New TLVs

Two new LSP Ping TLV types are defined for inclusion in LSP Ping messages.

IANA is reuqested to assign a new value from the Multiprotocol Label Switching Architecture (MPLS) Label Switched Paths (LSPs) Parameters - TLVs registry as follows using a Standards Action value.

P2MP Egress Identifier TLV (see Section 3.2.4)
Two sub-TLVs are defined
- Type 1: IPv4 P2MP Egress Identifier (see Section 3.2.4)
- Type 2: IPv6 P2MP Egress Identifier (see Section 3.2.4)

Echo Jitter TLV (see Section 3.2.5)

8. Security Considerations

This document does not introduce security concerns over and above those described in [RFC4379]. Note that because of the scalability implications of many egresses to P2MP MPLS LSPs, there is a stronger concern to regulate the LSP Ping traffic passed to the control plane by the use of a rate limiter applied to the LSP Ping well-known UDP port. Note that this rate limiting might lead to false positives.

9. Acknowledgements

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11. Normative References

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