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Return Path Specified Label Switched Path (LSP) Ping

Abstract

This document defines extensions to the data-plane failure-detection protocol for Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) known as "LSP ping". These extensions allow a selection of the LSP to be used for the echo reply return path. Enforcing a specific return path can be used to verify bidirectional connectivity and also increase LSP ping robustness.

Status of This Memo

This is an Internet Standards Track document.

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1. Introduction

This document defines extensions to the data-plane failure-detection protocol for Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) known as "LSP ping" [RFC4379] that can be used to specify the return paths for the echo reply message, increasing the robustness of LSP ping, reducing the opportunity for error, and improving the reliability of the echo reply message. A new Reply Mode, which is referred to as "Reply via Specified Path", is added and a new Type-Length-Value (TLV), which is referred to as "Reply Path (RP) TLV", is defined in this memo. The procedures defined in this document currently only apply to "ping" mode. The "traceroute" mode is out of scope for this document.

In this document, the term bidirectional LSP includes the co-routed bidirectional LSP defined in [RFC3945] and the associated bidirectional LSP that is constructed from a pair of unidirectional LSPs (one for each direction) that are associated with one another at the LSP's ingress/egress points [RFC5654]. The mechanisms defined in this document can apply to both IP/MPLS and MPLS Transport Profile (MPLS-TP) scenarios.

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 [RFC2119].

3. Problem Statements and Solution Overview

MPLS LSP ping is defined in [RFC4379]. It can be used to detect data-path failures in all MPLS LSPs.

LSPs are increasingly being deployed to provide bidirectional services. The co-routed bidirectional LSP is defined in [RFC3945], and the associated bidirectional LSP is defined in [RFC5654]. With the deployment of such services, operators have a desire to test both directions of a bidirectional LSP in a single operation.

Additionally, when testing a single direction of an LSP (either a unidirectional LSP or a single direction of a bidirectional LSP) using LSP ping, the validity of the result may be affected by the success of delivering the echo reply message. Failure to exchange these messages between the egress Label Switching Router (LSR) and the ingress LSR can lead to false negatives where the LSP under test is reported as "down" even though it is functioning correctly.

3.1. Limitations of Existing Mechanisms for Bidirectional LSPs

With the existing LSP ping mechanisms, as defined in [RFC4379], operators have to enable LSP detection on each of the two ends of a bidirectional LSP independently. This not only doubles the workload for the operators but may also bring additional difficulties when checking the backward direction of the LSP under the following condition:

The LSR that the operator logged on to perform the checking operations might not have out-of-band connectivity to the LSR at the far end of the LSP. That can mean it is not possible to check the return direction of a bidirectional LSP in a single operation -- the operator must log on to the LSR at the other end of the LSP to test the return direction.

Associated bidirectional LSPs have the same issues as those listed for co-routed bidirectional LSPs.

This document defines a mechanism to allow the operator to request that both directions of a bidirectional LSP be tested by a single LSP ping message exchange.

3.2. Limitations of Existing Mechanisms for Handling Unreliable Return Paths

[RFC4379] defines four Reply Modes:

1. Do not reply
2. Reply via an IPv4/IPv6 UDP packet
3. Reply via an IPv4/IPv6 UDP packet with Router Alert
4. Reply via application level control channel

Obviously, the issue of the reliability of the return path for an echo reply message does not apply in the first of these cases.

[RFC4379] states that the third mode may be used when the IP return path is deemed unreliable. This mode of operation requires that all intermediate nodes support the Router Alert option and understand how to forward MPLS echo replies. This is a rigorous requirement in deployed IP/MPLS networks, especially since the return path may be through legacy IP-only routers.

In any case, the use of Reply Modes 2 or 3 cannot guarantee the delivery of echo responses through an IP network that is fundamentally unreliable. The failure to deliver echo response messages can lead to false negatives, making it appear that the LSP has failed.

Allowing the ingress LSR to control the path used for echo reply messages enables an operator to apply an extra level of deterministic process to the LSP ping test. For example, when testing an LSP, Reply Mode 2 is used at the beginning but no echo reply is received. When failure of the return path is suspected, the operator can initiate another LSP ping with the Reply Mode defined in this document and specify a different return path that is deemed workable to complete the test.

This document defines extensions to LSP ping that can be used to specify the return paths of the echo reply message in an echo request message.

4. Extensions

LSP ping, defined in [RFC4379], is carried out by sending an echo request message. It carries the Forwarding Equivalence Class (FEC) information of the LSP being tested. The FEC information indicates which MPLS path is being verified along the same data path as other normal data packets belonging to the FEC.

LSP ping [RFC4379] defines four Reply Modes that are used to direct the egress LSR in how to send back an echo reply. This document defines a new Reply Mode, the "Reply via Specified Path" mode. This new mode is used to direct the egress LSR of the tested LSP to send the echo reply message back along the path specified in the echo request message.

In addition, two new TLVs, the "Reply Path (RP) TLV" and "Reply Traffic Class (TC) TLV" [RFC5462], are defined in this document. The Reply Path TLV contains one or more nested sub-TLVs that can be used to carry the specified return path information to be used by the echo reply message.

4.1. Reply via Specified Path Mode

A new Reply Mode is defined to be carried in the Reply Mode field of the echo request message.

The value of the Reply via Specified Path mode is 5 (This has been allocated by IANA using early allocation and is to be confirmed by IANA).

Value	Meaning
-----	-----
5	Reply via Specified Path

The Reply via Specified Path mode is used to request that the remote LSR receiving the echo request message sends back the echo reply message along the specified paths carried in the Reply Path TLV.

4.2. Reply Path (RP) TLV

The Reply Path (RP) TLV is an optional TLV within the LSP ping protocol. However, if the Reply via Specified Path mode requested, as described in Section 4.1, the Reply Path (RP) TLV MUST be included in an echo request message, and its absence is treated as a malformed echo request, as described in [RFC4379]. Furthermore, if a Reply Path (RP) TLV is included in an echo request message, a Reply Path (RP) TLV MUST be included in the corresponding echo reply message sent by an implementation that is conformant to this specification.

The Reply Path (RP) TLV carries the specified return path that the echo reply message is required to follow. The format of Reply Path TLV is as follows:

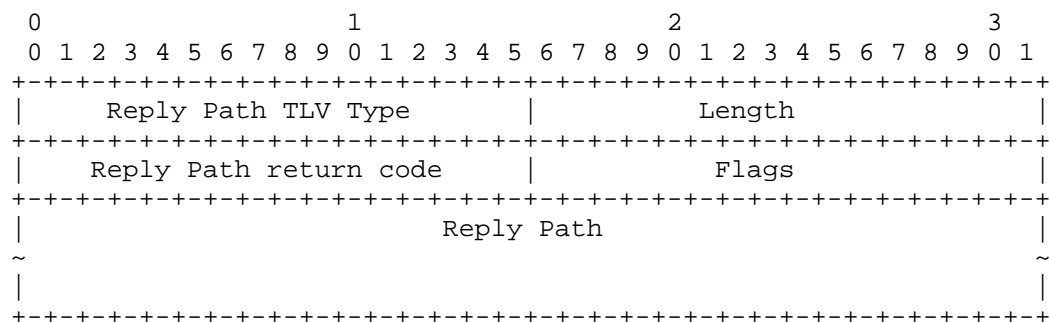


Figure 1: Reply Path TLV

Reply Path TLV Type: It is 2 octets in length, and the type value is 21.

Length: It is 2 octets in length. It defines the length in octets of the Reply Path return code, Flags, and Reply Path fields.

Reply Path return code: The Reply Path return code field is 2 octets in length. It is defined for the egress LSR of the forward LSP to report the results of Reply Path TLV processing and return path selection. This field MUST be set to zero in a Reply Path TLV carried on an echo request message and MUST be ignored on receipt. This document defines the following Reply Path return codes for inclusion in a Reply Path TLV carried on an echo reply:

Value	Meaning
-----	-----
0x0000	Reserved, MUST NOT be used
0x0001	Malformed Reply Path TLV was received
0x0002	One or more of the sub-TLVs in the Reply Path TLV were not understood
0x0003	The echo reply was sent successfully using the specified Reply Path
0x0004	The specified Reply Path was not found, the echo reply was sent via another LSP
0x0005	The specified Reply Path was not found, the echo reply was sent via pure IP forwarding (non-MPLS) path
0x0006-0xffffb	Unassigned
0xffffc-0xfffff	Experimental Use

Flags: It is also 2 octets in length, it is used to notify the egress how to process the Reply Paths field when performing return path selection. The Flags field is a bit vector and has following format:

```

+---+---+---+---+---+---+---+---+---+---+
|           MUST be zero           |A|B|
+---+---+---+---+---+---+---+---+

```

Figure 2: Flags

A (Alternative path): the egress LSR MUST select a non-default path as the return path. This is very useful when reverse default path problems are suspected that can be confirmed when the echo reply is forced to follow a non-default return path. Here, the default path refers to the path that the egress LSR will use to send the echo reply when Reply Mode 2 or 3 is used. If A bit is set, there is no need to carry any specific reply path sub-TLVs, and when received, the sub-TLVs SHOULD be ignored.

B (Bidirectional): the return path is required to follow the reverse direction of the tested bidirectional LSP. If B bit is set, there is no need to carry any specific reply path sub-TLVs, and when received, the sub-TLVs SHOULD be ignored.

The A flag and B flag MUST NOT both be set, otherwise, an echo reply with the RP return code set to "Malformed Reply Path TLV was received" MUST be returned.

Reply Path: It is used to describe the return path that an echo reply will be send along. It is variable in length and can contain zero, one or more Target FEC sub-TLVs [RFC4379]. In an echo request, it carries sub-TLVs that describe the specified path that the echo reply message is required to follow. In an echo reply, the sub-TLVs describe the FEC Stack information of the return path (when the return path is an MPLS path) that the echo reply will be sent along.

4.3. Tunnel Sub-TLVs

[RFC4379] has already defined several Target FEC sub-TLVs, the Target FEC sub-TLVs provide a good way to identify a specific return path. The Reply Path TLV can carry any (existing and future defined) sub-TLV defined for use in the Target FEC Stack TLV to specify the return path.

This document defines three new Target FEC sub-TLVs: IPv4 RSVP Tunnel sub-TLV, IPv6 RSVP Tunnel sub-TLV, and Static Tunnel sub-TLV. One usage of these generic RSVP Tunnel sub-TLVs is when LSP ping is used to periodically verify the control plane against the data plane [RFC5884], using a Tunnel other than a particular LSP can avoid the impact of an LSP identifier changing when Make-Before-Break (MBB) is deployed. These sub-TLVs also can be used in the Reply Path TLV to allow the operator to specify a more generic tunnel FEC other than a particular LSP as the return path.

No assignments of sub-TLVs are made directly for TLV Type 21, the sub-TLV space and assignments for TLV Type 21 will be the same as that for TLV Type 1. Sub-types for TLV Type 1 and TLV Type 21 MUST be kept the same. Any new sub-type added to TLV Type 1 MUST apply to the TLV Type 21 as well.

With the Return Path TLV flags and the sub-TLVs defined for the Target FEC Stack TLV and in this document, it could provide the following options for return paths specifying:

1. a particular LSP as return path
 - use those sub-TLVs defined for the Target FEC Stack TLV
2. a more generic tunnel FEC as return path
 - use the IPv4/IPv6 RSVP and Static Tunnel sub-TLVs defined in Sections Section 4.3.1, Section 4.3.2, and Section 4.3.3 of this document
3. the reverse path of the bidirectional LSP as return path
 - use B bit defined in Section 4.2 of this document.
4. Force return path to non-default path
 - use A bit defined in Section 4.2 of this document.

4.3.1. IPv4 RSVP Tunnel Sub-TLV

The format of the IPv4 RSVP Tunnel sub-TLV is as follows:

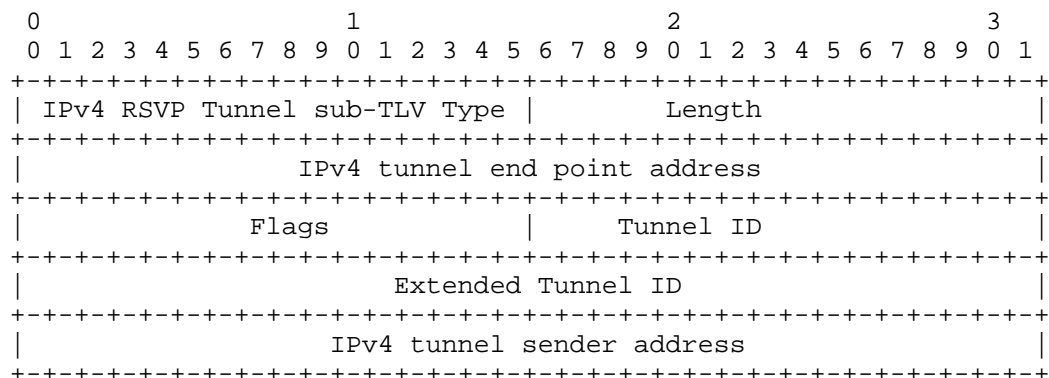


Figure 3: IPv4 RSVP Tunnel Sub-TLV

The IPv4 RSVP Tunnel sub-TLV is derived from the RSVP IPv4 FEC TLV that is defined in Section 3.2.3 of [RFC4379]. All fields have the same semantics as defined in [RFC4379] except that the LSP-ID field is omitted and a new Flags field is defined.

The IPv4 RSVP Tunnel sub-TLV Type field is 2 octets in length, and the recommended type value is 26.

The Flags field is 2 octets in length, it is used to notify the egress LSR how to choose the return path. The Flags field is a bit vector and has following format:

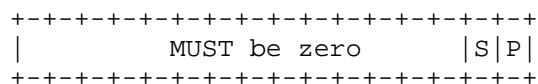


Figure 4: Tunnel Flags

P (Primary): the return path MUST be chosen from the LSPs that belong to the specified Tunnel and the LSP MUST be the primary LSP.

S (Secondary): the return path MUST be chosen from the LSPs that belong to the specified Tunnel and the LSP MUST be the secondary LSP. Primary and secondary LSPs are defined in [RFC4872].

P bit and S bit MUST NOT both be set, otherwise, an echo reply with the RP return code set to "Malformed Reply Path TLV was received" SHOULD be returned. If P bit and S bit are both not set, the return path could be any one of the LSPs from the same Tunnel.

4.3.2. IPv6 RSVP Tunnel Sub-TLV

The format of the IPv6 RSVP Tunnel sub-TLV is as follows:

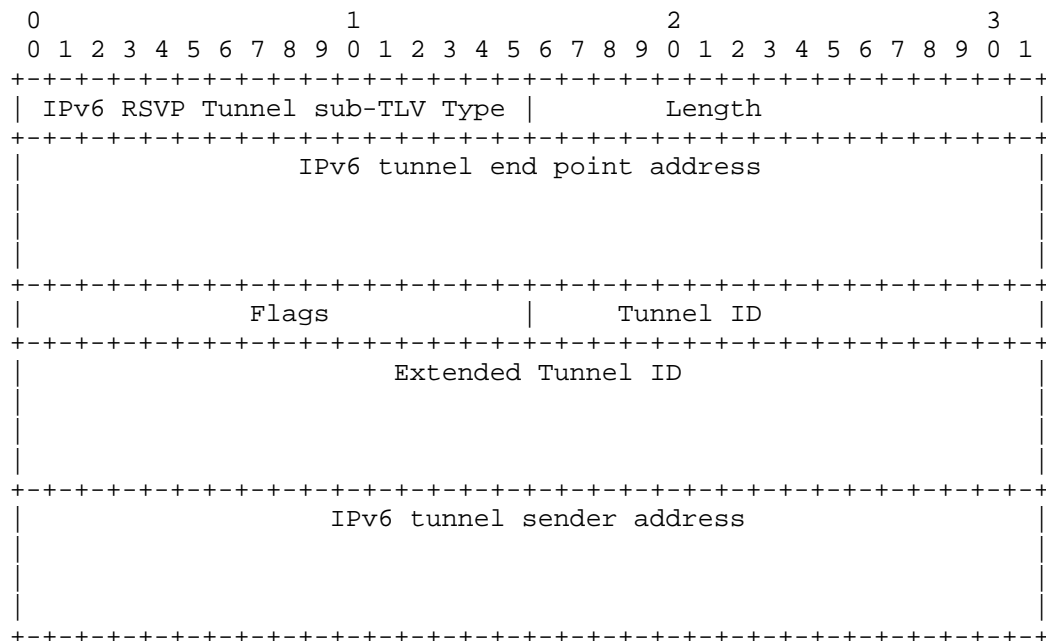


Figure 5: IPv6 RSVP Tunnel Sub-TLV

The IPv6 RSVP Tunnel sub-TLV is derived from the RSVP IPv6 FEC TLV that is defined in Section 3.2.4 of [RFC4379]. All fields have the same semantics as defined in [RFC4379] except that the LSP-ID field is omitted and a new Flags field is defined.

The IPv6 RSVP Tunnel sub-TLV Type field is 2 octets in length, and the type value is 27.

The Flags field is 2 octets in length and is identical to that described in Section 4.3.1.

4.3.3. Static Tunnel Sub-TLV

The format of the Static RSVP Tunnel sub-TLV is as follows. The value fields are taken from the definitions in [RFC6370].

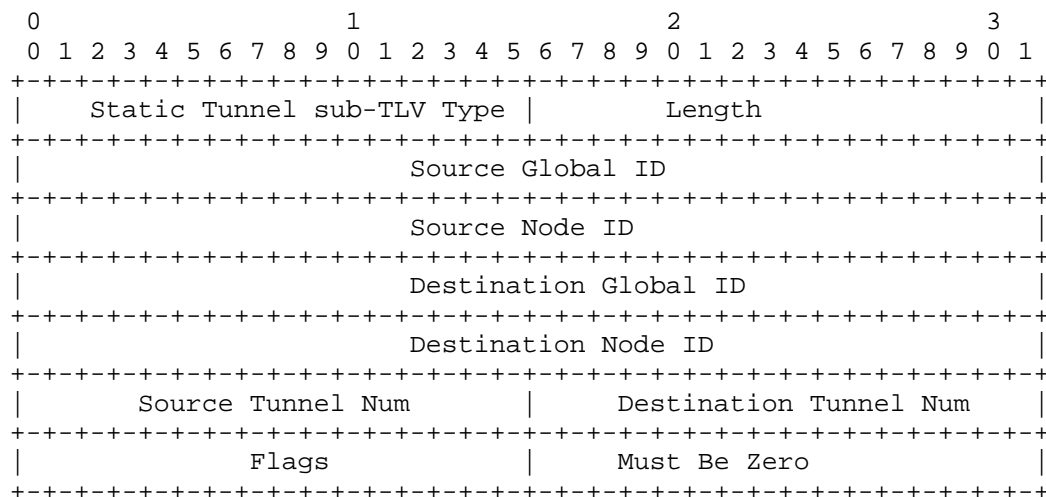


Figure 6: Static Tunnel Sub-TLV

The Flags field is 2 octets in length and is identical to that described in Section 4.3.1.

The sub-TLV type value is 28.

4.4. Reply TC TLV

Reply TOS Byte TLV [RFC4379] is used by the originator of the echo request to request that an echo reply be sent with the IP header TOS byte set to the value specified in the TLV. Similarly, in this document, a new TLV, Reply TC TLV, is defined and MAY be used by the originator of the echo request to request that an echo reply be sent with the TC bits of the return path LSP set to the value specified in this TLV. The Reply TC TLV is not limited to the Reply Mode specified in this document (Reply via Specified Path) but may be used in all the other Reply Modes as well. The format of Reply TC TLV is as follows:

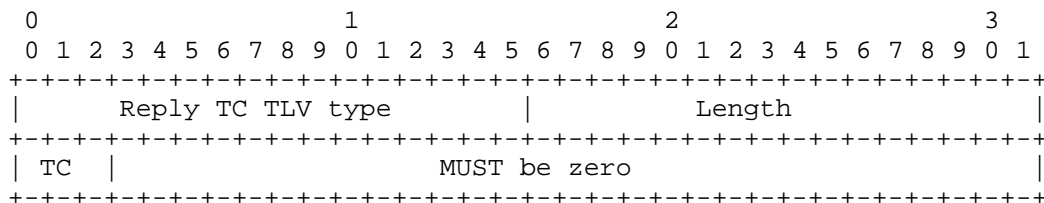


Figure 7: Reply TC TLV

The Reply TC TLV Type field is 2 octets in length, and the type value is 22.

The Length field is 2 octets in length, the value of length field is fixed 4 octets.

5. Theory of Operation

The procedures defined in this document currently only apply to "ping" mode. The "traceroute" mode is out of scope for this document.

In [RFC4379], the echo reply is used to report the LSP checking result to the LSP ping initiator. This document defines a new Reply Mode and a new TLV (Reply Path TLV) that enable the LSP ping initiator to specify or constrain the return path of the echo reply. Similarly, the behavior of echo reply is extended to detect the requested return path by looking at a specified path FEC TLV. This enables LSP ping to detect failures in both directions of a path with a single operation; of course, this cuts in half the operational steps required to verify the end-to-end bidirectional connectivity and integrity of an LSP.

When the return path is an MPLS path, the echo reply MUST carry the FEC Stack information in a Reply Path TLV to test the return MPLS LSP path. The destination IP address of the echo reply message MUST never be used in a forwarding decision. To avoid this possibility the destination IP address of the echo reply message that is transmitted along the specified return path MUST be set to numbers from the range 127/8 for IPv4 or 0:0:0:0:0:FFFF:127.0.0.0/104 for IPv6, and the IP Time to Live (TTL) MUST be set 1, and the TTL in the outermost label MUST be set to 255.

When the return path is a pure IP forwarding path, the procedures defined in [RFC4379] (the destination IP address is copied from the source IP address) apply unchanged.

5.1. Sending an Echo Request

When sending an echo request, in addition to the rules and procedures defined in Section 4.3 of [RFC4379], the Reply Mode of the echo request MUST be set to "Reply via Specified Path", and a Reply Path TLV MUST be carried in the echo request message correspondingly. The Reply Path TLV includes one or several reply path sub-TLV(s) to identify the return path(s) the egress LSR should use for its reply.

For a bidirectional LSP, since the ingress LSR and egress LSR of a bidirectional LSP are aware of the relationship between the forward and backward direction LSPs, only the B bit SHOULD be set in the Reply Path TLV. If the operator wants the echo reply to be sent along a path other than the reverse direction of the bidirectional LSP, the A bit SHOULD be set or another FEC sub-TLV SHOULD be carried in the Reply Path TLV instead, and the B bit MUST be clear.

In some cases, operators may want to treat two unidirectional LSPs (one for each direction) as a pair. There may not be any binding relationship between the two LSPs. Using the mechanism defined in this document, operators can run LSP ping one time from one end to complete the failure detection on both unidirectional LSPs. To accomplish this, the echo request message MUST carry (in the Reply Path TLV) a FEC sub-TLV that belongs to the backward LSP.

5.2. Receiving an Echo Request

"Ping" mode processing, as defined in Section 4.4 of [RFC4379], applies in this document. In addition, when an echo request is received, if the egress LSR does not know the Reply Mode defined in this document, an echo reply with the return code set to "Malformed echo request received" and the Subcode set to zero will be sent back to the ingress LSR according to the rules of [RFC4379]. If the egress LSR knows the Reply Mode, according to the Reply Path TLV, it SHOULD find and select the desired return path. If there is a matched path, an echo reply with a Reply Path TLV that identifies the return path SHOULD be sent back to the ingress LSR, the Reply Path return code SHOULD be set to "The echo reply was sent successfully using the specified Reply Path". If there is no such path, an echo reply with the Reply Path TLV SHOULD be sent back to the ingress LSR, the Reply Path return code SHOULD be set to the relevant code (defined in Section 4.2) for the real situation to reflect the result of Reply Path TLV processing and return path selection. For example, if the specified LSP is not found, the egress then chooses another LSP as the return path to send the echo reply, the Reply Path return code SHOULD be set to "The specified reply path was not found, the echo reply was sent via another LSP", and if the egress chooses an IP path to send the echo reply, the Reply Path return code SHOULD be set

to "The specified Reply Path was not found, the echo reply was sent via pure IP forwarding (non-MPLS) path". If there is an unknown sub-TLV in the received Reply Path TLV, the Reply Path return code SHOULD be set to "One or more of the sub-TLVs in the Reply Path TLV were not understood".

If the A bit of the Reply Path TLV in a received echo request message is set, the egress LSR SHOULD send the echo reply along a non-default return path.

If the B bit of the Reply Path TLV in a received echo request message is set, the egress LSR SHOULD send the echo reply along the reverse direction of the bidirectional LSP.

In addition, the FEC validate results of the forward path LSP SHOULD NOT affect the egress LSR continue to test return path LSP.

5.3. Sending an Echo Reply

As described in [RFC4379], the echo reply message is a UDP packet, and it MUST be sent only in response to an MPLS echo request. The source IP address is a valid IP address of the replier, the source UDP port is the well-know UDP port for LSP ping.

When the return path is an MPLS LSP, the destination IP address of the echo reply message is copied from the destination IP address of the echo request, and the destination UDP port is copied from the source UDP port of the echo request. The IP TTL MUST be set to 1, the TTL in the outermost label MUST be set to 255.

When the return path is a pure IP forwarding path, the same as defined in [RFC4379], the destination IP address and UDP port are copied from the source IP address and source UDP port of the echo request.

When sending the echo reply, a Reply Path TLV that identifies the return path MUST be carried, the Reply Path return code SHOULD be set to relevant code that reflects results about how the egress processes the Reply Path TLV in a previous received echo request message and return path selection. By carrying the Reply Path TLV in an echo reply, it gives the ingress LSR enough information about the reverse direction of the tested path to verify the consistency of the data plane against control plane. Thus, a single LSP ping could achieve both directions of a path test. If the return path is pure IP path, no sub-TLVs are carried in the Reply Path TLV.

5.4. Receiving an Echo Reply

The rules and process defined in Section 4.6 of [RFC4379] apply here. When an echo reply is received, if the Reply Mode is "Reply via Specified Path" and the Reply Path return code is "The echo reply was sent successfully using the specified Reply Path", and if the return path is an MPLS LSP. The ingress LSR MUST perform FEC validation (based on the FEC Stack information of the return path carried in the Reply Path TLV) as an egress LSR does when receiving an echo request, the FEC validation process (relevant to "ping" mode) defined in Section 4.4.1 of [RFC4379] applies here.

When an echo reply is received with return code set to "Malformed echo request received" and the Subcode set to zero. It is possible that the egress LSR may not know the "Reply via Specified Path" Reply Mode, the operator may choose to re-perform another LSP ping by using one of the four Reply Modes defined [RFC4379].

On receipt of an echo reply with Reply Path return code in the Reply Path TLV set to "The specified reply path was not found, ...", it means that the egress LSR could not find a matched return path as specified. Operators may choose to specify another LSP as the return path or use other methods to detect the path further.

5.5. Non-IP Encapsulation for MPLS-TP LSPs

In some MPLS-TP deployment scenarios, IP addressing might not be available or the use of some form of non-IP encapsulation might be preferred. In such scenarios, the Non-IP encapsulation defined in [RFC6426] applies here. The LSP Ping Reply Mode in the echo request and echo reply is set to 5. The return path of the echo reply is as specified in the Reply Path TLV.

6. Security Considerations

Security considerations discussed in [RFC4379] apply to this document.

In addition, the extensions defined in this document may be used for potential "proxying" attacks. For example, an echo request initiator may specify a return path that has a destination different from that of the initiator. But normally, such attacks will not happen in an MPLS domain where the initiators and receivers belong to the same domain. Even this, in order to prevent using the extension defined in this document for proxying any possible attacks, the return path LSP should have destination to the same node where the forward path is from. The receiver may drop the echo request when it cannot determine whether the return path LSP has the destination to the

initiator. That means, when sending echo request, the initiator should choose a proper source address according the specified return path LSP to help the receiver to make the decision.

7. IANA Considerations

7.1. TLVs

IANA has assigned the value 21 for the Reply Path TLV and assigned the value 22 for Reply TC TLV from the "Multiprotocol Label Switching Architecture (MPLS) Label Switched Paths (LSPs) Ping Parameters" registry, "TLVs" subregistry.

Value	Meaning	Reference
-----	-----	-----
21	Reply Path TLV	this document (Section 4.2)
22	Reply TC TLV	this document (Section 4.4)

The sub-TLV space and assignments for the Reply Path TLV will be the same as that for the Target FEC Stack TLV. Sub-types for the Target FEC Stack TLV and the Reply Path TLV MUST be kept the same. Any new sub-type added to the Target FEC Stack TLV MUST apply to the Reply Path TLV as well.

7.2. New Target FEC Stack Sub-TLVs

IANA has assigned three new sub-TLV types from the "Multiprotocol Label Switching Architecture (MPLS) Label Switched Paths (LSPs) Ping Parameters - TLVs" registry, "Sub-TLVs for TLV Types 1, 16, and 21" subregistry.

Sub-Type	Sub-TLV Name	Reference
-----	-----	-----
26	IPv4 RSVP Tunnel	this document (Section 4.3.1)
27	IPv6 RSVP Tunnel	this document (Section 4.3.2)
28	Static Tunnel	this document (Section 4.3.3)

7.3. New Reply Mode

IANA has allocated (5 - Reply via Specified Path) from the "Multi-Protocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" registry, the "Reply Modes" subregistry.

Value	Meaning	Reference
-----	-----	-----
5	Reply via Specified Path	this document (Section 4.1)

7.4. Reply Path Return Code

IANA has created a new subregistry for the "Multi-Protocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" for Reply Path return codes.

This document (Section 4.2) defines the following return codes:

Value	Meaning
-----	-----
0x0000	No return code
0x0001	Malformed Reply Path TLV was received
0x0002	One or more of the sub-TLVs in the Reply Path TLV were not understood
0x0003	The echo reply was sent successfully using the specified Reply Path
0x0004	The specified Reply Path was not found, the echo reply was sent via another LSP
0x0005	The specified Reply Path was not found, the echo reply was sent via pure IP forwarding (non-MPLS) path
0x0006-0xffffb	Unassigned
0xffffc-0xfffff	Reserved for Experimental Use

The range of 0x0006-0xffffb is not allocated and reserved for future extensions and is allocated via Standard Action; the range of 0xffffc-0xfffff is for Experimental Use.

8. Contributors

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