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Label Switching Router Self-Test

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Abstract

This document defines a means for a Label-Switching Router (LSR) to verify that its dataplane is functioning for certain key Multi-Protocol Label Switching (MPLS) applications, including unicast

forwarding based on LDP [LDP] and traffic engineering tunnels based on [RSVP-TE]. A new Loopback FEC type is defined to allow an upstream neighbor to assist in the testing at very low cost. MPLS Echo Request and MPLS Echo Reply messages [LSP-Ping] are extended to do the actual probing.

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1. Introduction

This document defines a means for a Label-Switching Router (LSR) to verify that its dataplane is functioning for certain key Multi-Protocol Label Switching (MPLS) applications, including unicast forwarding based on LDP [LDP] and traffic engineering tunnels based on [RSVP-TE]. MPLS Echo Request and MPLS Echo Reply messages [LSP-Ping] messages are extended to do the actual probing. The pings are sent to an upstream neighbor, looped back through the LSR under test and intercepted, by means of TTL expiration by a downstream neighbor. Extensions to LSP-Ping [LSP-Ping] are defined to allow the down stream neighbor to report the test results.

In order to minimize the load on upstream LSRs a new loopback FEC is defined. Receipt of a packet labeled with a loopback label will cause the advertising LSR to pop the label off the label stack and send the packet out the advertised interface.

Note that use of a loopback allows an LSR to test label entries for which the LSR is not currently some neighbor's next hop. In this way label entries can be verified prior to the occurrence of a routing change.

Some routing protocls, most notably OSPF have no means of exchanging the "Link Local Identifiers" used to identify unnumbered links and components of bundled links. These test procedures can be used to associate the neighbor's interfaces with the probing LSRs interfaces. This is achieved by simply having the TTL of the MPLS Ping expire one hop sooner, i.e. at the testing LSR itself.

1.1. Conventions

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 [KEYWORDS].

2. Loopback FEC

The Loopback FEC type is defined to enable an upstream neighbor to assist in LSR self-testing at very low cost. This FEC causes the loopback to occur in the dataplane without control plane involvement beyond the initial LDP exchange and dataplane setup. The FEC also carries information to indicate the desired encapsulation should it be the only label in a received label stack. Values are defined for IPv4 and IPv6.

An LSR uses a Loopback FEC to selectively advertise loopback labels to its neighbor LSRs. Each loopback label is bound to a particular interface. For multi-access links, a unique label for each neighbor is required, since the link-level address is derived from the label lookup. When an MPLS packet with its top label set to a loopback label is received from an interface over which that label was advertised, the loopback label is popped and the packet is sent on the interface to which the loopback label was bound. If the label-stack only contains the one loopback label, the encapsulation of the packet is determined by the FEC Type.

TTL treatment for loopback labels follows the Uniform model. I.e. the TTL carried in the loopback label is decremented and copied to the exposed label or IP header as the case may be.

2.1. IPv4 Loopback FEC Element

FEC element type 130 is used. The FEC element is encoded as follows: (note: 130 is provisionally assigned, the actual value will be assigned by IANA.)

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     130       |      Res      | If & Prot Type|   Id Length   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Interface Identifier                      |
|                             "                                 |
|                             "                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Reserved (Res)

Must be set to zero on transmission and ignored on receipt.

Interface & Protocol Type

#	Type	Interface Identifier
1	IPv4 Numbered	IPv4 Address
2	IPv4 Unnumbered	A 32 bit Link Identifier as defined in [RFC3477]
3	IPv6 Numbered	IPv6 Address
4	IPv6 Unnumbered	A 32 bit Link Identifier as defined in [RFC3477]

.in 9
Note that this type alos indicates the encapsulation type for payloads that have a label stack contain the one loopback label.

Identifier Length

Length of the interface identifier in octets. The length is 4 bytes for the unnumbered types and IPv4, 16 bytes for IPv6.

Address

An identifier encoded according to the Identifier Type field.

2.2. LDP Procedures

It is RECOMMENDED that loopback labels only be distributed in response to a Label Request message, irrespective of the label advertisement mode of the LDP session. However it is recognized that in certain cases such as OSPF with unnumbered links, the upstream LSR may not have sufficiently detailed information of the neighbor's link identifier to form the request. In these cases, the downstream LSR will need to be configured to make unsolicited advertisements.

3. Data Plane Self Test

A self test operation involves three LSRs, the LSR doing the test, an upstream neighbor and a downstream neighbor. We refer to these as LSRs T, U, and D respectively. In order to minimize the processing load on LSR-D, two new LSP Ping messages are defined, called the MPLS Data Plane Verification Request and the MPLS Data Plane Verification Reply. These messages are used to allow LSR-T to obtain the label stack, address and interface information of LSR-D.

If FEC verification is required, the MPLS Echo Request and Reply messages are used.

The packet flow is shown below. Although the figure shows LSR-D adjacent to LSR-T it may in some cases be an arbitrary number of hops away.

```
+-------+       +-------+       +-------+
|     ,-|-------|<DPVRq |       |       |
|     `-|-------|-------|-------|->     |
|       |       |       |       |       |
|       |       |     <-|-------|<DPVRp |
+-------+       +-------+       +-------+
  LSR-U           LSR-T           LSR-D

DPVRq: MPLS Data Plane Verification Request
DPVRp: MPLS Data Plane Verification Reply
```

Figure 1: Self Test Message Flow

In order to perform a test on an incoming label stack, LSR-T forms an MPLS Data Plane Verification Request. LSR-T prepends the packet with the incoming label stack being tested and the loopback label received from LSR-U. The TTL values are set such that they will expire at LSR-D. LSR-T then forwards the packet to LSR-U.

LSR-U receives the packet and performs normal MPLS forwarding. That is, the loopback label is popped, the TTL is decremented and propagated (in this case) to the exposed label.

LSR-T receives the packet and performs normal MPLS forwarding. If everything is functioning as expected this will cause the packet to arrive at LSR-D with a TTL of 1.

In this example, we assume that all is working properly. The TTL expires at LSR-D causing it to receive the packet. LSR-D notes the

the interface and the label stack on which the packet was received and records these in an Interface and Label Stack TLV. This Object is sent to LSR-T in an MPLS Data Plane Verification Reply message.

3.1. Data Plane Verification Request / Reply Messages

Two new LSP Ping messages are defined for LSR self test. The purpose of the new messages is three fold. First the timestamps are removed to minimize processing. Second the message type allows simple recognition that minimal processing is necessary to service this request. Third, the Verification Request message itself conveys the the request, thus a Verification Request message with no Objects is both legal and normal.

The definitions of all fields in the messages are identical to those found in [LSP-PING].

The new message types are: (Provisionally; to be assigned)

Type	Message
3	MPLS Data Plane Verification Request
4	MPLS Data Plane Verification Reply

The messages have the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Version Number        |         Must Be Zero          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Message Type |   Reply mode  |  Return Code  | Return Subcode|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sender's Handle                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            TLVs ...                           |
.                                                               .
.                                                               .
.                                                               .
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The MPLS Data Plane Verification Request message MAY contain the following objects:

Type #	Object
3	Pad
5	Vendor Enterprise Code
11 (provisional)	IPv4 Reply-to Object
12 (provisional)	IPv6 Reply-to Object

The MPLS Data Plane Verification Reply message MAY contain the following objects:

Type #	Object
3	Pad
4	Error Code
5	Vendor Enterprise Code
7	IPv4 Interface and Label Stack Object
8	IPv6 Interface and Label Stack Object

3.2. UDP Port

MPLS Data Plane Verification Request messages MAY be sent to port 3503 as is used for [LSP-PING]. However to aid implementations that wish to handle these messages at a lower level than MPLS Echo Request messages another UDP port, tbd, is provided. Port tbd SHOULD be used by default. The source UDP port, as in [LSP-PING] is chosen by the sender.

3.3. Reply-To Object

In order to perform detailed diagnostics of a particular failing flow in the face of ECMP, it is useful to be able to use the exact source and destination addresses of that flow. The Reply-To Object is an optional TLV in a MPLS Data Plane Verification Request message. The Object has two formats, type 11 for IPv4 and type 12 for IPv6 (to be assigned by IANA).

3.3.1. IPv4 Reply-To Object

The length of an IPv4 Reply-To Object is 4 octets; the value field has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Reply-to IPv4 Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Reply-to IPv4 Address

The address to which the MPLS Data Plane Verification Reply message is to be sent.

3.3.2. IPv6 Reply-To Object

The length of an IPv6 Reply-To Object is 16 octets; the value field has the following format:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Reply-to IPv6 Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Reply-to IPv6 Address (Cont.)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Reply-to IPv6 Address (Cont.)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Reply-to IPv6 Address (Cont.)                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Reply-to IPv6 Address

The address to which the MPLS Data Plane Verification Reply message is to be sent.

3.4. Sending procedures

In order to perform a test on an incoming labeled or unlabeled packet, an LSR first determines the expected outgoing label stack, next hop router and next hop interface.

The LSR creates an MPLS Data Plane Verification Request message and includes a Data Plane Verification Object. Optionally a FEC Stack TLV may be included. In this case an MPLS Echo Request Message MUST be used.

In normal use, the source address is set to an address belonging to the LSR and the destination set to an address in the range of 127/8. The incoming label stack (if any) is prepended to the packet. The TTL of these labels and the packet header SHOULD be set to appropriate values - 2 for those labels and/or header which will be processed by this node when the packet is looped back; 1 for those labels and/or header which will be carried through. Finally the loopback label bound to the incoming interface is prepended to the packet. In the case of an otherwise unlabeled packet the label's FEC MUST indicate the appropriate IP version. The TTL is set such that it will have the value of 3 on the wire.

The packet is sent to the upstream neighbor on an interface for which the loopback label is valid.

In diagnostic situations, the source and destination addresses MAY be set to any value. In this case, a Reply-to IPv4 or IPv6 Object MUST be included. The IP TTL MUST be set to 1. The TTL of labels other than the loopback label MUST be set to appropriate values - 2 for those labels which will be process by this LSR when the packet is looped back; 1 for those labels which will be carried through.

In some MPLS deployments TTL hiding is used to make a providers network appear as a single hop. That is the TTL in the imposed label does not refect the TTL of the received packet. It is RECOMMENDED that testing of label imposition SHOULD NOT be performed in such circumstances as the Echo Request will in most case travel multiple hops.

3.5. Receiving procedures

An LSR X that receives an MPLS Verification Request message formats a MPLS Verification Reply message. The Sender's Handle and Sequence Number are copied from the Request message.

X then parses the packet to ensure that it is a well-formed packet, and that the TLVs that are not marked "Ignore" are understood. If not, X SHOULD send an MPLS echo reply with the Return Code set to "Malformed echo request received" or "TLV not understood" (as appropriate), and the Subcode set to zero. In the latter case, the misunderstood TLVs (only) are included in the reply.

If the echo request is good, X notes the interface I over which the echo was received, and the label stack with which it came. If the MPLS echo request contained a Downstream Verification object, then X must format this information as a Downstream Verification object and include it in its MPLS echo reply message.

The source address of the Reply message MUST be an address of the replying LSR. If the request included a Reply-to IPv4 or IPv6 Object, the MPLS Data Plane Verification Reply message MUST be sent to that address. Otherwise the Reply message is sent to the source address of the Verification Request message.

An LSR MUST be capable of filtering addresses that are to be replied to. If a filter has been invoked (i.e. configured) and an address does not pass the filter, then a reply MUST NOT be sent, and the event SHOULD be logged.

3.6. Upstream Neighbor Verification

To verify that an upstream neighbor is properly echoing packets an LSR may send an MPLS Data Plane Verification Request packet with the TTL set so that the packet will expire upon reaching reaching itself. This procedure not only tests that the neighbor is correctly processing the loopback label, it also allows the node to verify the neighbor's interface mapping.

```
                    +-------+       +-------+
                    |       |       |       |
                    |     ,-|-------|<DPVRq |
                    |     `-|-------|->     |
                    |       |       |       |
                    +-------+       +-------+
                      LSR-U           LSR-T

            DPVRq: MPLS Data Plane Verification Request
```

Figure 2: Upstream Neighbor Verification

No TLVs need to be included in the MPLS Data Plane Verification Request. By noting the Sender's Handle and Sequence Number, as well as the loopback label, LSR-T is able to detect that a) the packet was looped, and b) determine (or verify) the interface on which the packet was received.

4. Security Considerations

Were loopback labels widely known, they might be subject to abuse. It is therefore RECOMMENDED that loopback labels only be shared between trusted neighbors. Further, if the loopback labels are drawn from the Global Label Space, or any other label space shared across multiple LDP sessions, it is RECOMMENDED that all loopback labels be filtered from a session except those labels pertaining to interfaces directly connected to the neighbor participating in that session.

5. IANA Considerations

This document makes the following codepoint assigments (pending IANA action):

Registry	Codepoint	Purpose
UDP Port	tbd	MPLS Verification Request
LSP Ping Message Type	3	MPLS Data Plane Verification Request
LSP Ping Message Type	4	MPLS Data Plane Verification Reply
LSP Ping Object Type	11	IPv4 Reply-to Object

LSP Ping Object Type 12 IPv6 Reply-to Object

6. Acknowledgments

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7. References

7.1. Normative References

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8. Authors' Addresses

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