Implementing MPLS OAM

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IP-Less MPLS-TP Ping and MPLS-TP Traceroute

In Label Switched Path (LSP) ping or traceroute with IP encapsulation over ACH, IP encapsulated ping or traceroute packets are sent over the MPLS LSP using the control channel (ACH). The application-level control channel in this case is the reverse path of the LSP using ACH. The on-demand ping or traceroute echo response message is sent on the reverse path of the LSP. The response uses ACH and is IP encapsulated. The destination address in the IP header is set to that of the sender of the echo request message, and the source address in the IP header is set to a valid address of the replying node.

- the reply mode is 4
- the node does not have a return MPLS LSP path to the echo request source.

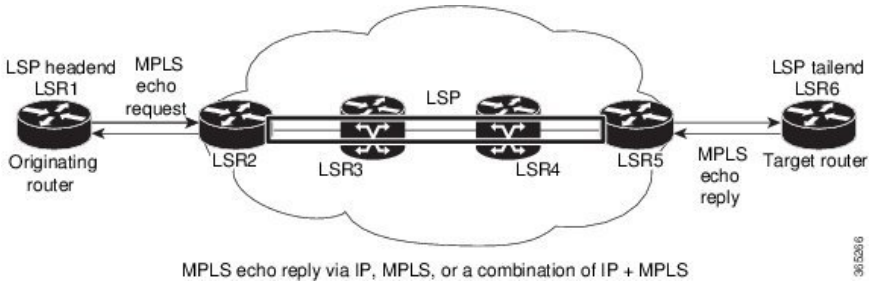
MPLS LSP Ping

The MPLS LSP Ping feature is used to check the connectivity between Ingress LSR and egress LSRs along an LSP. MPLS LSP ping uses MPLS echo request and reply messages, similar to Internet Control Message Protocol (ICMP) echo request and reply messages, to validate an LSP. While ICMP echo request and reply messages validate IP networks, MPLS echo and reply messages validate MPLS networks. The MPLS echo request packet is sent to a target router through the use of the appropriate label stack associated with the LSP to be validated. Use of the label stack causes the packet to be forwarded over the LSP itself. The destination IP address of the MPLS echo request packet is different from the address used to select the label stack. The destination IP address is defined as a 127.x.y.z/8 address and it prevents the IP packet from being IP switched to its destination, if the LSP is broken.

An MPLS echo reply is sent in response to an MPLS echo request. The reply is sent as an IP packet and it is forwarded using IP, MPLS, or a combination of both types of switching. The source address of the MPLS echo reply packet is an address obtained from the router generating the echo reply. The destination address is the source address of the router that originated the MPLS echo request packet. The MPLS echo reply destination port is set to the echo request source port.

The following figure shows MPLS LSP ping echo request and echo reply paths.

Figure 1: MPLS LSP Ping Echo Request and Reply Paths



By default, the **ping mpls ipv4** command tries to determine the Forwarding Equivalence Class (FEC) being used automatically. However, this is only applicable at head-end and works only if the FEC at the destination is same as the source. If the source and destination FEC types are not the same, the **ping mpls ipv4** command may fail to identify the targeted FEC type. You can overcome this limitation by specifying the FEC type in MPLS LSP ping using the **fec-type** command option. If the user is not sure about the FEC type at the transit or the destination, or it may change through network, use of the **generic** FEC type command option is recommended. Generic FEC is not coupled to a particular control plane and allows path verification when the advertising protocol is unknown, or may change during the path of the echo request. If you are aware of the destination FEC type, specify the target FEC as BGP or LDP.

Configuration Examples

This example shows how to use MPLS LSP ping to test the connectivity of an IPv4 LDP LSP. The destination is specified as a Label Distribution Protocol (LDP) IPv4 address.

```
RP/0/RP0/CPU0:router# ping mpls ipv4 10.1.1.2/32 verbose

Sun Nov 15 11:27:43.070 UTC

Sending 5, 100-byte MPLS Echos to 10.1.1.2/32,
      timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

!      size 100, reply addr 10.1.0.2, return code 3
!      size 100, reply addr 10.1.0.2, return code 3
!      size 100, reply addr 10.1.0.2, return code 3
!      size 100, reply addr 10.1.0.2, return code 3
!      size 100, reply addr 10.1.0.2, return code 3

Success rate is 100 percent (5/5), round-trip min/avg/max = 2/2/4 ms
```

In this example, the destination is specified as a Label Distribution Protocol (LDP) IPv4 prefix and Forwarding Equivalence Class (FEC) type is specified as generic.

```
RP/0/RP0/CPU0:router# ping mpls ipv4 10.1.1.2/32 fec-type generic

Wed Nov 25 03:36:33.143 UTC
```

```
Sending 5, 100-byte MPLS Echos to 10.1.1.2/32,
      timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 2/2/3 ms
```

In this example, the destination is specified as a Label Distribution Protocol (LDP) IPv4 prefix and the FEC type is specified as BGP.

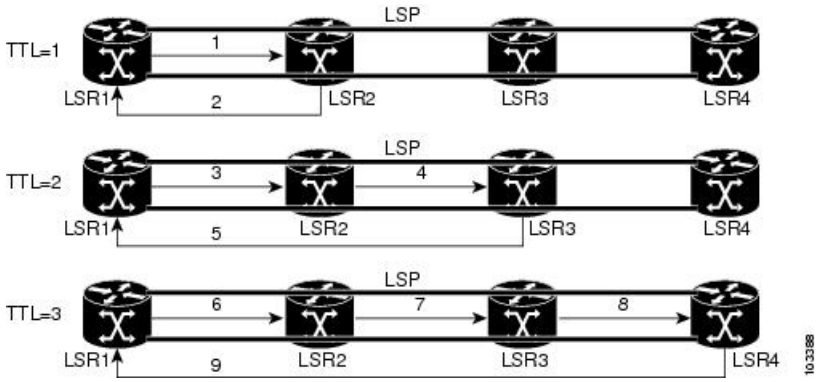
```
RP/0/RP0/CPU0:router# ping mpls ipv4 10.1.1.2/32 fec-type bgp

Wed Nov 25 03:38:33.143 UTC
Sending 5, 100-byte MPLS Echos to 10.1.1.2/32,
      timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 2/2/3 ms
```

MPLS LSP Traceroute

The MPLS LSP Traceroute feature is used to isolate the failure point of an LSP. It is used for hop-by-hop fault localization and path tracing. The MPLS LSP Traceroute feature relies on the expiration of the Time to Live (TTL) value of the packet that carries the echo request. When the MPLS echo request message hits a transit node, it checks the TTL value and if it is expired, the packet is passed to the control plane, else the message is forwarded. If the echo message is passed to the control plane, a reply message is generated based on the contents of the request message.

The following figure shows an MPLS LSP traceroute example with an LSP from LSR1 to LSR4.

Figure 2: MPLS LSP Traceroute



By default, the **traceroute mpls ipv4** command tries to determine the Forwarding Equivalence Class (FEC) being used automatically. However, this is only applicable at head-end and works only if the FEC at the destination is same as the source. If the source and destination FEC types are not the same, the **traceroute mpls ipv4** command may fail to identify the targeted FEC type. You can overcome this limitation by specifying the FEC type in MPLS LSP traceroute using the **fec-type** command option. If the user is not sure about the FEC type at the transit or the destination, or it may change through network, use of the **generic** FEC type command option is recommended. Generic FEC is not coupled to a particular control plane and allows path verification when the advertising protocol is unknown, or may change during the path of the echo request. If you are aware of the destination FEC type, specify the target FEC as BGP or LDP.

Configuration Examples

This example shows how to use the **traceroute** command to trace to a destination.

```
RP/0/RP0/CPU0:router# traceroute mpls ipv4 10.1.1.2/32 destination 127.0.0.3 127.0.0.6 2
Sat Jan 27 03:50:23.746 UTC

Tracing MPLS Label Switched Path to 10.1.1.2/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

Destination address 127.0.0.3
  0 10.2.1.2 MRU 1500 [Labels: 24000 Exp: 0]
L 1 10.2.1.1 MRU 1500 [Labels: implicit-null Exp: 0] 8 ms
! 2 10.1.0.2 3 ms

Destination address 127.0.0.5
  0 10.2.1.2 MRU 1500 [Labels: 24000 Exp: 0]
L 1 10.2.1.1 MRU 1500 [Labels: implicit-null Exp: 0] 5 ms
! 2 10.1.0.2 2 ms
```

This example shows how to use the **traceroute** command and how to specify the maximum number of hops for the traceroute to traverse by specifying the **ttl** value.

```
RP/0/RP0/CPU0:router# traceroute mpls ipv4 10.1.1.2/32 ttl 1
Sun Nov 15 12:20:14.145 UTC
Tracing MPLS Label Switched Path to 10.1.1.2/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.

  0 10.1.0.1 MRU 1500 [Labels: implicit-null Exp: 0]
! 1 10.1.0.2 3 ms
```

This example shows how to use the **traceroute** command to trace to a destination and FEC type is specified as generic.

```
RP/0/RP0/CPU0:router# traceroute mpls ipv4 10.1.1.2/32 fec-type generic
Sun Nov 15 12:25:14.145 UTC
Tracing MPLS Label Switched Path to 10.1.1.2/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
Type escape sequence to abort.
0 10.12.12.1 MRU 1500 [Labels: implicit-null Exp: 0]
! 1 10.12.12.2 2 ms
```

This example shows how to use the **traceroute** command to trace to a destination and FEC type is specified as BGP.

```
RP/0/RP0/CPU0:router# traceroute mpls ipv4 10.1.1.2/32 fec-type bgp
Sun Nov 15 12:25:14.145 UTC
Tracing MPLS Label Switched Path to 10.1.1.2/32, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'B' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlvs, 'N' - no rx label,
'P' - no rx intf label prot, 'p' - premature termination of LSP,
'R' - transit router, 'I' - unknown upstream index,
'X' - unknown return code, 'x' - return code 0
Type escape sequence to abort.
0 10.12.12.1 MRU 1500 [Labels: implicit-null Exp: 0]
! 1 10.12.12.2 2 ms
```

MPLS OAM Using Nil FEC

The Nil-FEC LSP ping and traceroute operations are extensions of regular MPLS ping and traceroute. MPLS ping and traceroute requires at least one forwarding equivalence class (FEC) in the target FEC stack. In Nil-FEC ping and traceroute operations, an explicit FEC is not associated with the label. Nil-FEC LSP ping and traceroute support MPLS static LSPs and also act as an additional diagnostic tool for all other LSP types.

Nil-FEC LSP ping and traceroute allow network operators to provide the ability to freely test any label stack by allowing them to specify the following:

- label stack
- outgoing interface
- nexthop address

The following table shows the syntax for the ping and traceroute commands.

Table 1: LSP Ping and Traceroute Nil FEC Commands

Command Syntax
ping mpls nil-fec labels {*label*[**,***label*]} [**output** {**interface** *tx-interface*} [**nexthop** *nexthop-ip-addr*]]
traceroute mpls nil-fec labels {*label*[**,***label*]} [**output** {**interface** *tx-interface*} [**nexthop** *nexthop-ip-addr*]]

Examples: LSP Ping Nil FEC and LSP Traceroute Nil FEC

The examples in this section use the following topology:

```
Node loopback IP address: 172.18.1.3   172.18.1.4   172.18.1.5   172.18.1.7
Node label:               16003        16004        16005        16007
Nodes:                    Arizona ---- Utah ------- Wyoming ---- Texas

Interface:            GigabitEthernet0/2/0/1   GigabitEthernet0/2/0/1
Interface IP address:         10.1.1.3              10.1.1.4
```

```
RP/0/RP0/CPU0:router-arizona# show mpls forwarding

Tue May  2 13:44:31.999 EDT
Local  Outgoing    Prefix            Outgoing     Next Hop        Bytes
Label  Label       or ID             Interface                    Switched
------ ----------- ----------------- ------------ --------------- ------------
16004  Pop         No ID             Gi0/2/0/1    10.1.1.4        1392
       Pop         No ID             Gi0/2/0/2    10.1.2.2        0
16005  16005       No ID             Gi0/2/0/0    10.1.1.4        0
       16005       No ID             Gi0/2/0/1    10.1.2.2        0
16007  16007       No ID             Gi0/2/0/0    10.1.1.4        4752
       16007       No ID             Gi0/2/0/1    10.1.2.2        0
```

This example shows how to use Nil-FEC LSP ping to test a label stack.

```
RP/0/RP0/CPU0:router-arizona# ping mpls nil-fec labels 16005,16007 output interface
GigabitEthernet 0/2/0/1 nexthop 10.1.1.4 repeat 1
Sending 1, 72-byte MPLS Echos with Nil FEC labels 16005,16007,
     timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
```

```
  'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
!
Success rate is 100 percent (1/1), round-trip min/avg/max = 1/1/1 ms
 Total Time Elapsed 0 ms
```

This example shows how to use Nil-FEC LSP traceroute for a label stack.

```
RP/0/RP0/CPU0:router-arizona# traceroute mpls nil-fec labels 16005,16007 output interface
GigabitEthernet 0/2/0/1 nexthop 10.1.1.4
Tracing MPLS Label Switched Path with Nil FEC labels 16005,16007, timeout is 2 seconds

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
  'L' - labeled output interface, 'B' - unlabeled output interface,
  'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
  'M' - malformed request, 'm' - unsupported tlvs, 'N' - no label entry,
  'P' - no rx intf label prot, 'p' - premature termination of LSP,
  'R' - transit router, 'I' - unknown upstream index,
  'd' - see DDMAP for return code,
  'X' - unknown return code, 'x' - return code 0

Type escape sequence to abort.
  0 10.1.1.3 MRU 1500 [Labels: 16005/16007/explicit-null Exp: 0/0/0]
L 1 10.1.1.4 MRU 1500 [Labels: implicit-null/16007/explicit-null Exp: 0/0/0] 1 ms
L 2 10.1.1.5 MRU 1500 [Labels: implicit-null/explicit-null Exp: 0/0] 1 ms
! 3 10.1.1.7 1 ms
```