Using Segment Routing OAM

Segment Routing Operations, Administration, and Maintenance (OAM) helps service providers to monitor label-switched paths (LSPs) and quickly isolate forwarding problems to assist with fault detection and troubleshooting in the network. The Segment Routing OAM feature provides support for IGP prefix SID and Nil-FEC (forwarding equivalence classes) LSP Ping and Traceroute functionality.

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MPLS Ping and Traceroute for BGP and IGP Prefix-SID

MPLS Ping and Traceroute operations for Prefix SID are supported for various IGP scenarios, for example:

- Within an IS-IS level or OSPF area
- Across IS-IS levels or OSPF areas
- Route redistribution from IS-IS to OSPF and from OSPF to IS-IS
- Anycast Prefix SID

The MPLS LSP Ping feature is used to check the connectivity between ingress Label Switch Routers (LSRs) 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. 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.

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 MPLS LSP Tree Trace (traceroute multipath) operation is also supported for IGP Prefix SID. MPLS LSP Tree Trace provides the means to discover all possible equal-cost multipath (ECMP) routing paths of an LSP to reach a destination Prefix SID. It uses multipath data encoded in echo request packets to query for the
load-balancing information that may allow the originator to exercise each ECMP. When the packet TTL expires at the responding node, the node returns the list of downstream paths, as well as the multipath information that can lead the operator to exercise each path in the MPLS echo reply. This operation is performed repeatedly for each hop of each path with increasing TTL values until all ECMP are discovered and validated.

MPLS echo request packets carry Target FEC Stack sub-TLVs. The Target FEC sub-TLVs are used by the responder for FEC validation. The IGP IPv4 prefix sub-TLV has been added to the Target FEC Stack sub-TLV. The IGP IPv4 prefix sub-TLV contains the prefix SID, the prefix length, and the protocol (IS-IS or OSPF).

**Examples: MPLS Ping, Traceroute, and Tree Trace for Prefix-SID**

These examples use the following topology:

![Topology Diagram]

**MPLS Ping for Prefix-SID**

RP/0/RSP0/CPU0:router-arizona# ping mpls ipv4 1.1.1.4/32
Thu Dec 17 01:01:42.301 PST

Sending 5, 100-byte MPLS Echos to 1.1.1.4,
timeout is 2 seconds, send interval is 0 msec:

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'U' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlv's, '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 Traceroute for Prefix-SID**

RP/0/RSP0/CPU0:router-arizona# traceroute mpls ipv4 1.1.1.4/32
Thu Dec 17 14:45:05.563 PST

Codes: '!' - success, 'Q' - request not sent, '.' - timeout,
'L' - labeled output interface, 'U' - unlabeled output interface,
'D' - DS Map mismatch, 'F' - no FEC mapping, 'f' - FEC mismatch,
'M' - malformed request, 'm' - unsupported tlv's, '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 12.12.12.1 MRU 4470 [Labels: 16004 Exp: 0]
L 1 12.12.12.2 MRU 4470 [Labels: 16004 Exp: 0] 3 ms
L 2 23.23.23.3 MRU 4470 [Labels: implicit-null Exp: 0] 3 ms
! 3 34.34.34.4 11 ms

**MPLS Tree Trace for Prefix-SID**

RP/0/RSP0/CPU0:router-arizona# traceroute mpls multipath ipv4 1.1.1.4/32
Thu Dec 17 14:55:46.549 PST
Starting LSP Path Discovery for 1.1.1.4/32

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.

LL!
Path 0 found,
output interface TenGigE0/0/0/0 nexthop 12.12.12.2 source 12.12.12.1 destination 127.0.0.0
L!
Path 1 found,
output interface TenGigE0/0/0/0 nexthop 12.12.12.2 source 12.12.12.1 destination 127.0.0.2
LL!
Path 2 found,
output interface TenGigE0/0/0/1 nexthop 15.15.15.5 source 15.15.15.1 destination 127.0.0.1
L!
Path 3 found,
output interface TenGigE0/0/0/1 nexthop 15.15.15.5 source 15.15.15.1 destination 127.0.0.0

Paths (found/broken/unexplored) (4/0/0)
Echo Request (sent/fail) (10/0)
Echo Reply (received/timeout) (10/0)
Total Time Elapsed 53 ms

**MPLS LSP Ping and Traceroute Nil FEC Target**

The Nil-FEC LSP ping and traceroute operations are extensions of regular MPLS ping and traceroute.

Nil-FEC LSP Ping/Traceroute functionality supports segment routing and MPLS Static. It also acts as an additional diagnostic tool for all other LSP types. This feature allows operators to provide the ability to freely test any label stack by allowing them to specify the following:

- label stack
- outgoing interface
- nexthop address
In the case of segment routing, each segment nodal label and adjacency label along the routing path is put into the label stack of an echo request message from the initiator Label Switch Router (LSR); MPLS data plane forwards this packet to the label stack target, and the label stack target sends the echo message back.

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

**Table 1: LSP Ping and Traceroute Nil FEC Commands**

<table>
<thead>
<tr>
<th>Command Syntax</th>
<th></th>
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<tbody>
<tr>
<td>ping mpls nil-fec labels {label[,label]} [output {interface tx-interface} [nexthop nexthop-ip-addr]]</td>
<td></td>
</tr>
<tr>
<td>traceroute mpls nil-fec labels {label[,label]} [output {interface tx-interface} [nexthop nexthop-ip-addr]]</td>
<td></td>
</tr>
</tbody>
</table>

**Examples: LSP Ping and Traceroute for Nil_FEC Target**

These examples 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: 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/RSP0/CPU0# show mpls forwarding
Tue Jul 5 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
16005 No ID Gi0/2/0/2 10.1.2.2 0
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
24000 Pop SR Adj (idx 0) Gi0/2/0/0 10.1.1.4 0
24001 Pop SR Adj (idx 2) Gi0/2/0/0 10.1.1.4 0
24002 Pop SR Adj (idx 0) Gi0/2/0/1 10.1.2.2 0
24003 Pop SR Adj (idx 2) Gi0/2/0/1 10.1.2.2 0
24004 Pop No ID tt10 point2point 0
24005 Pop No ID tt11 point2point 0
24006 Pop No ID tt12 point2point 0
24007 Pop No ID tt13 point2point 0
24008 Pop No ID tt30 point2point 0
```

**Ping Nil FEC Target**

```
RP/0/RSP0/CPU0# 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:
```

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

Traceroute Nil FEC Target

RP/0/RSP0/CPU0# 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


Type escape sequence to abort.

0 10.1.1.3 MRU 1500 [Labels: 16005/16007/explicit-null Exp: 0/0/0]
1 10.1.1.4 MRU 1500 [Labels: implicit-null/16007/explicit-null Exp: 0/0/0] 1 ms
2 10.1.1.5 MRU 1500 [Labels: implicit-null/explicit-null Exp: 0/0] 1 ms
! 3 10.1.1.7 1 ms
Examples: LSP Ping and Traceroute for Nil_FEC Target