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 BGP prefix SIDs, IGP prefix and Flexible Algorithm SIDs, 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 BGP and 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
- Combinations of BGP and LDP signaled LSPs

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

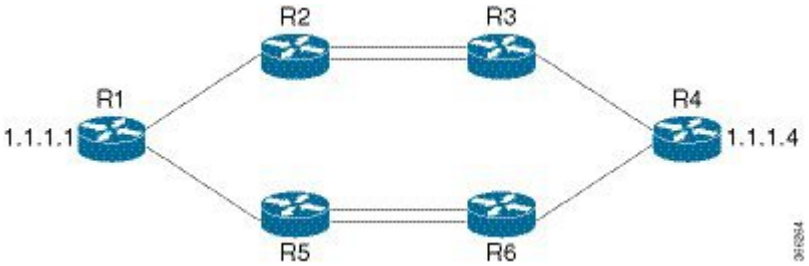
Live (TTL) value of the packet that carries the echo request. When the MPLS echo request message hits a transit node, it checks the TTL value and if it is expired, the packet is passed to the control plane, else the message is forwarded. If the echo message is passed to the control plane, a reply message is generated based on the contents of the request message.

The MPLS LSP Tree Trace (traceroute multipath) operation is also supported for BGP and 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 BGP and 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). The BGP IPv4 prefix sub-TLV contains the prefix SID and the prefix length.

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

These examples use the following topology:



MPLS Ping for Prefix-SID

```
RP/0/RP0/CPU0:router-arizona# ping mpls ipv4 10.1.1.4/32
Thu Dec 17 01:01:42.301 PST

Sending 5, 100-byte MPLS Echos to 10.1.1.4,
      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 Traceroute for Prefix-SID

```
RP/0/RP0/CPU0:router-arizona# traceroute mpls ipv4 10.1.1.4/32
Thu Dec 17 14:45:05.563 PST

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 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/RP0/CPU0:router-arizona# traceroute mpls multipath ipv4 10.1.1.4/32
Thu Dec 17 14:55:46.549 PST

Starting LSP Path Discovery for 10.1.1.4/32

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

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 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/RP0/CPU0:router-utah# 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
       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
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/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
```

Traceroute Nil FEC Target

```
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
```

Segment Routing Ping and Traceroute

Table 2: Feature History Table

Feature Name	Release Information	Feature Description
SR OAM for SR Policy (Policy Name / Binding SID / Custom label stack)	Release 7.3.1	This feature extends SR OAM ping and traceroute function for an SR policy (or binding SID)-LSP end-point combination. This addresses the limitations of the Nil-FEC LSP Ping and Traceroute function which cannot perform a ping operation to a segment list that is not associated with an installed SR policy. Also, it cannot validate egress device-specific SR policies.

Segment Routing Ping

The MPLS LSP ping feature is used to check the connectivity between ingress and egress of 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. Segment routing ping is an extension of the MPLS LSP ping to perform the connectivity verification on the segment routing control plane.

Note Segment routing ping can only be used when the originating device is running segment routing.

You can initiate the segment routing ping operation only when Segment Routing control plane is available at the originator, even if it is not preferred. This allows you to validate the SR path before directing traffic over the path. Segment Routing ping can use either generic FEC type or SR control-plane FEC type (SR-OSPF, SR-ISIS). In mixed networks, where some devices are running MPLS control plane (for example, LDP) or do not understand SR FEC, generic FEC type allows the device to successfully process and respond to the echo request. By default, generic FEC type is used in the target FEC stack of segment routing ping echo request. Generic FEC is not coupled to a particular control plane; it allows path verification when the advertising protocol is unknown or might change during the path of the echo request. If you need to specify the target FEC, you can select the FEC type as OSPF, IS-IS, or BGP. This ensures that only devices that are running segment routing control plane, and can therefore understand the segment routing IGP FEC, respond to the echo request.

Configuration Examples

These examples show how to use segment routing ping to test the connectivity of a segment routing control plane. In the first example, FEC type is not specified. You can also specify the FEC type as shown in the other examples.

```
RP/0/RP0/CPU0:router# ping sr-mpls 10.1.1.2/32

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 = 1/2/5 ms

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

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 = 1/1/2 ms


RP/0/RP0/CPU0:router# ping sr-mpls 10.1.1.2/32 fec-type igp ospf

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 = 1/1/2 ms


RP/0/RP0/CPU0:router# ping sr-mpls 10.1.1.2/32 fec-type igp isis

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 = 1/1/2 ms


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

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 = 1/1/2 ms
```

Ping for SR Policy

You can perform the ping operation for an SR policy (or binding SID), and LSP end-point combination. Use the **ping** command's **policy name lsp-end-point** and **policy binding-sid lsp-end-point** options to perform this task. You can instantiate the policy through the CLI, Netconf, PCEP or BGP-TE process.

IPv6 policies are not supported for SR OAM function.

Note As a prerequisite, you must enable the MPLS OAM function.

```
Router(config)# mpls oam
Router(config)# commit

Router# ping sr-mpls policy name srte_c_4_ep_10.0.0.1 lsp-end-point 209.165.201.1
Router# ping sr-mpls policy binding-sid 1000 lsp-end-point 209.165.201.1
```

Segment Routing Traceroute

The MPLS LSP traceroute 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. Segment routing traceroute feature extends the MPLS LSP traceroute functionality to segment routing networks.

Similar to segment routing ping, you can initiate the segment routing traceroute operation only when Segment Routing control plane is available at the originator, even if it is not preferred. Segment Routing traceroute can use either generic FEC type or SR control-plane FEC type (SR-OSPF, SR-ISIS). By default, generic FEC type is used in the target FEC stack of segment routing traceroute echo request. If you need to specify the target FEC, you can select the FEC type as OSPF, IS-IS, or BGP. This ensures that only devices that are running segment routing control plane, and can therefore understand the segment routing IGP FEC, respond to the echo request.

The existence of load balancing at routers in an MPLS network provides alternate paths for carrying MPLS traffic to a target router. The multipath segment routing traceroute feature provides a means to discover all possible paths of an LSP between the ingress and egress routers.

Configuration Examples

These examples show how to use segment routing traceroute to trace the LSP for a specified IPv4 prefix SID address. In the first example, FEC type is not specified. You can also specify the FEC type as shown in the other examples.

```
RP/0/RP0/CPU0:router# traceroute sr-mpls 10.1.1.2/32

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 3 ms


RP/0/RP0/CPU0:router# traceroute sr-mpls 10.1.1.2/32  fec-type generic

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


RP/0/RP0/CPU0:router# traceroute sr-mpls 10.1.1.2/32  fec-type  igp ospf

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
```

```
RP/0/RP0/CPU0:router# traceroute sr-mpls 10.1.1.2/32  fec-type  igp isis

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


RP/0/RP0/CPU0:router#traceroute sr-mpls 10.1.1.2/32 fec-type bgp


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/implicit-null Exp: 0/0]
! 1 10.12.12.2 2 ms
```

This example shows how to use multipath traceroute to discover all the possible paths for a IPv4 prefix SID.

```
RP/0/RP0/CPU0:router# traceroute sr-mpls multipath 10.1.1.2/32

Starting LSP Path Discovery for 10.1.1.2/32

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.

!
Path 0 found,
 output interface GigabitEthernet0/0/0/2 nexthop 10.13.13.2
source 10.13.13.1 destination 127.0.0.0
!
Path 1 found,
 output interface Bundle-Ether1 nexthop 10.12.12.2
source 10.12.12.1 destination 127.0.0.0

Paths (found/broken/unexplored) (2/0/0)
Echo Request (sent/fail) (2/0)
```

```
Echo Reply (received/timeout) (2/0)
Total Time Elapsed 14 ms
```

Traceroute for SR Policy

You can perform the traceroute operation for an SR policy (or binding SID), and LSP end-point combination. Use the **traceroute** command's **policy name lsp-end-point** and **policy binding-sid lsp-end-point** options to perform this task. You can instantiate the policy through the CLI, Netconf, PCEP or BGP-TE process.

IPv6 policies are not supported for SR OAM function.

Note As a prerequisite, you must enable the MPLS OAM function.

```
Router(config)# mpls oam
Router(config)# commit

Router# traceroute sr-mpls policy name srte_c_4_ep_10.0.0.1 lsp-end-point 209.165.201.1
Router# traceroute sr-mpls policy binding-sid 1000 lsp-end-point 209.165.201.1
```

Segment Routing Treetrace Enhancements

Table 3: Feature History Table

Feature Name	Release	Description
Segment Routing Treetrace Enhancements	Release 7.3.2	The OAM Treetrace operation provides enhanced traceroute functionality to validate ECMP paths between two endpoints. This feature augments the Treetrace operation to support SR policies, SR NIL FEC, SR Flex Algo, or a custom list of labels.

The SR-OAM Treetrace (multipath traceroute) operation provides enhanced traceroute functionality to validate ECMP paths between two endpoints.

The Segment Routing Treetrace enhancements augment the Treetrace operation to support SR policies, Flex Algo labels, or a custom list of labels.

- Use the **traceroute sr-mpls multipath policy** EXEC command to specify the target SR policy.
- Use the **traceroute sr-mpls multipath labels** EXEC command to specify the target custom list of labels:
  - The custom list can have 1 to 12 prefix-SID labels.
  - A label can be Algo 0 or Flex Algo prefix-SID label.
- Use the **traceroute sr-mpls multipath nil-fec** EXEC command to specify the target custom list of labels and outgoing information or the target SR policy, to be verified using Nil FEC.

Note As a prerequisite, you must enable the MPLS OAM function.

```
Router(config)# mpls oam
Router(config-oam)# commit
```

Example 1: Treetrace Operation for an SR Policy

```
Router# traceroute sr-mpls multipath policy name srte_c_10_ep_192.168.0.3 lsp-endpoint
192.168.0.3

 Starting LSP Path Discovery for SR Policy with name [srte_c_10_ep_192.168.0.3]

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.

L!
Path 0 found,
 output interface GigabitEthernet0/0/0/0 nexthop 10.10.10.2
 source 10.10.10.1 destination 127.0.0.0
L!
Path 1 found,
 output interface GigabitEthernet0/0/0/1 nexthop 11.11.11.2
 source 11.11.11.1 destination 127.0.0.0

Paths (found/broken/unexplored) (2/0/0)
 Echo Request (sent/fail) (4/0)
 Echo Reply (received/timeout) (4/0)
 Total Time Elapsed 14 ms
```

Example 2: Treetrace Operation for an SR Policy with Nil FEC

```
Router# traceroute sr-mpls multipath nil-fec policy name srte_c_10_ep_192.168.0.3

 Starting LSP Path Discovery for SR Policy with name [srte_c_10_ep_192.168.0.3]

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.

L!
Path 0 found,
 output interface GigabitEthernet0/0/0/0 nexthop 10.10.10.2
 source 10.10.10.1 destination 127.0.0.0
L!
Path 1 found,
 output interface GigabitEthernet0/0/0/1 nexthop 11.11.11.2
```

```
 source 11.11.11.1 destination 127.0.0.0

Paths (found/broken/unexplored) (2/0/0)
 Echo Request (sent/fail) (4/0)
 Echo Reply (received/timeout) (4/0)
 Total Time Elapsed 14 ms
```

Example 3: Treetrace Operation for a Custom List of Labels with SR Label FEC

```
Router# traceroute sr-mpls multipath labels 16128 lsp-end-point 10.1.1.5

Starting LSP Path Discovery for SR Label FEC with lsp end point 10.1.1.5, SID Label(s)
[16128]

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 GigabitEthernet0/0/0/0 nexthop 10.10.10.2
source 10.10.10.1 destination 127.0.0.0
LL!
Path 1 found,
 output interface GigabitEthernet0/0/0/1 nexthop 11.11.11.2
source 11.11.11.1 destination 127.0.0.0

Paths (found/broken/unexplored) (2/0/0)
Echo Request (sent/fail) (6/0)
Echo Reply (received/timeout) (6/0)
Total Time Elapsed 30 ms
```

Example 4: Treetrace Operation for a Custom List of Labels with Nil FEC

```
Router# traceroute sr-mpls multipath labels 16004,16005 output interface GigabitEthernet
0/0/0/2 nexthop 12.12.12.3

Starting LSP Path Discovery for Nil FEC with labels [16004,16005]

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 GigabitEthernet0/0/0/2 nexthop 12.12.12.3
 source 12.12.12.1 destination 127.0.0.2
!
Path 1 found,
 output interface GigabitEthernet0/0/0/2 nexthop 12.12.12.3
 source 12.12.12.1 destination 127.0.0.0
```

```
Paths (found/broken/unexplored) (2/0/0)
 Echo Request (sent/fail) (4/0)
 Echo Reply (received/timeout) (4/0)
 Total Time Elapsed 30 ms
```

Segment Routing Ping and Traceroute for Flexible Algorithm

Flexible Algorithm validation method is based on segment identifier (SID) label and label switched path (LSP) destination, instead of being based on IP address. The assigner is validated against the topology prefix information provided by SR-PCE database. If the assigner is valid, then the label given is also validated against the SR-PCE database. On the egress side, the destination label is contained in a new SR Label sub-TLV. This label is verified against a SID list provided by SR-PCE.

Note Observe the following guidelines and restrictions:

- All routers within an area must share the same Flexible Algorithm definition for a Flexible Algorithm to be valid.
- All routers within the domain must be configured with the same SRGB range of values.
- BGP-LS must be enabled.
- Only prefix SIDs and Flexible Algorithm SIDs are supported.
- Only single label stack is supported.

Segment Routing Ping for Flexible Algorithm

```
Router# ping sr-mpls labels 16131 lsp-end-point 10.1.1.5
Fri Dec 13 19:26:29.517 IST

Sending 5, 100-byte MPLS Echos with SR Label FEC with lsp end point 10.1.1.5, SID Label(s)
 [16131],
      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 = 4/4/6 ms
```

Segment Routing Traceroute for Flexible Algorithm

```
Router# traceroute sr-mpls labels 16130 lsp-end-point 10.1.1.5
Fri Dec 13 19:26:59.368 IST

Tracing MPLS Label Switched Path to SR Label FEC with lsp end point 10.1.1.5, SID Label(s)
 [16130], 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 13.13.13.1 MRU 1500 [Labels: 16130 Exp: 0]
L 1 13.13.13.3 MRU 1500 [Labels: 16130 Exp: 0] 5 ms
L 2 16.16.16.4 MRU 1500 [Labels: implicit-null Exp: 0] 4 ms
! 3 18.18.18.5 4 ms
```

Segment Routing over IPv6 OAM

Segment Routing over IPv6 data plane (SRv6) implementation adds a new type of routing extension header. Hence, the existing ICMPv6 mechanisms including ping and traceroute can be used in the SRv6 network. There is no change in the way ping and traceroute operations work for IPv6- or SRv6-capable nodes in an SRv6 network.

Restrictions and Usage Guidelines

The following restriction applies for SRv6 OAM:

- Ping to an SRv6 SID is not supported.

Examples: SRv6 OAM

The following example shows using ping in an SRv6 network.

```
RP/0/RP0/CPU0:Router# ping ipv6 2001::33:33:33:33
Mon Sep 17 20:04:10.068 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2001::33:33:33:33, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/4 ms
```

The following example shows using traceroute in an SRv6 network.

```
RP/0/RP0/CPU0:Router# traceroute ipv6 2001::33:33:33:33 probe 1 timeout 0 srv6
Fri Sep 14 15:59:25.170 UTC
Type escape sequence to abort.
Tracing the route to 2001::33:33:33:33
 1  2001::22:22:22:22[IP tunnel: DA=cafe:0:0:a4:1:::: SRH =(2001::33:33:33:33   ,SL=1)] 2
msec
 2  2001::2:2:2:2[IP tunnel: DA=cafe:0:0:a4:1:::: SRH =(2001::33:33:33:33   ,SL=1)] 2 msec
 3  2001::44:44:44:44 2 msec
```

```
 4  2001::33:33:33:33 3 msec
```

The following example shows using traceroute in an SRv6 network without an SRH.

```
RP/0/RSP1/CPU0:Router# traceroute ipv6 2001::44:44:44:44 srv6
Wed Jan 16 14:35:27.511 UTC
Type escape sequence to abort.
Tracing the route to 2001::44:44:44:44
 1 2001::2:2:2:2 3 msec 2 msec 2 msec
 2 2001::44:44:44:44 3 msec 3 msec 3 msec
```

The following example shows using ping for a specified IP address in the VRF.

```
RP/0/RP0/CPU0:Router# ping 10.15.15.1 vrf red
Mon Sep 17 20:07:10.085 UTC
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.15.15.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```

The following example shows using traceroute for a specified IP address in the VRF.

```
RP/0/RP0/CPU0:Router# traceroute 10.15.15.1 vrf red
Mon Sep 17 20:07:18.478 UTC

Type escape sequence to abort.
Tracing the route to 10.15.15.1
 1  10.15.15.1 3 msec  2 msec  2 msec
```

The following example shows using traceroute for CE1 (4.4.4.5) to CE2 (5.5.5.5) in the VRF:

```
RP/0/RP0/CPU0:Router# traceroute 5.5.5.5 vrf a
Wed Jan 16 15:08:46.264 UTC

Type escape sequence to abort.
Tracing the route to 5.5.5.5
 1  14.14.14.1 5 msec 1 msec 1 msec
 2  15.15.15.1 3 msec 2 msec 2 msec
 3  15.15.15.2 2 msec * 3 msec
```