Configure Performance Measurement

Network performance metrics is a critical measure for traffic engineering (TE) in service provider networks. Network performance metrics include the following:

- Packet loss
- Delay
- Delay variation
- Bandwidth utilization

These network performance metrics provide network operators information about the performance characteristics of their networks for performance evaluation and help to ensure compliance with service level agreements. The service-level agreements (SLAs) of service providers depend on the ability to measure and monitor these network performance metrics. Network operators can use Segment Routing Performance Measurement (SR-PM) feature to monitor the network metrics for links and end-to-end TE label switched paths (LSPs).

The following table explains the functionalities supported by performance measurement feature for measuring delay for links or SR policies.

Table 1: Performance Measurement Functionalities

Functionality	Details
Profiles	You can configure different default profiles for different types of delay measurements. Use the "interfaces" delay profile type for link-delay measurement. The "sr-policy" delay profile type is used for SR policy delay measurements. Delay profile allows you to schedule probe and configure metric advertisement parameters for delay measurement.
Protocols	Two-Way Active Measurement Protocol (TWAMP) Light (using RFC 5357 with IP/UDP encap).
Probe and burst scheduling	Schedule probes and configure metric advertisement parameters for delay measurement.
Metric advertisements	Advertise measured metrics periodically using configured thresholds. Also supports accelerated advertisements using configured thresholds.
Measurement history and counters	Maintain packet delay and loss measurement history, session counters, and packet advertisement counters.

Measurement Modes

The following table compares the different hardware and timing requirements for the measurement modes supported in SR PM.

Table 2: Measurement Mode Requirements

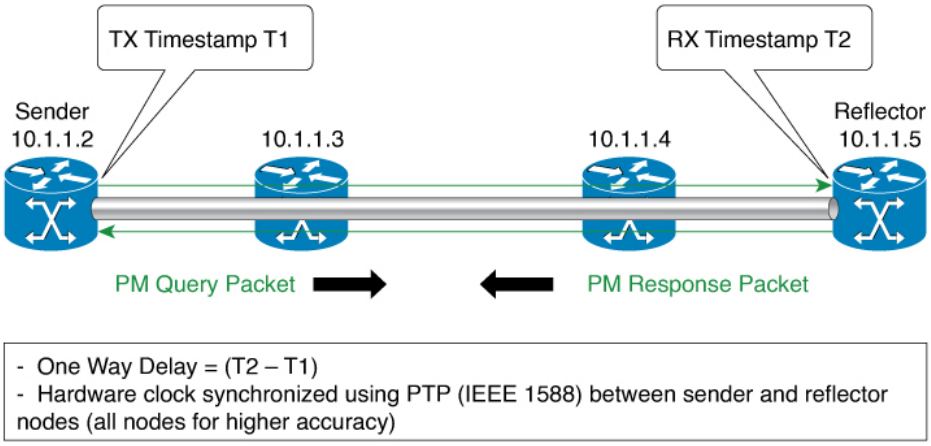
Measurement Mode	Sender: PTP-Capable HW and HW Timestamping	Reflector: PTP-Capable HW and HW Timestamping	PTP Clock Synchronization between Sender and Reflector
One-way	Required	Required	Required
Two-way	Required	Required	Not Required
Loopback	Required	Not Required	Not Required

One-Way Measurement Mode

One-way measurement mode provides the most precise form of one-way delay measurement. PTP-capable hardware and hardware timestamping are required on both Sender and Reflector, with PTP Clock Synchronization between Sender and Reflector.

Delay measurement in one-way mode is calculated as (T2 – T1).

Figure 1: One-Way



The PM query and response for one-way delay measurement can be described in the following steps:

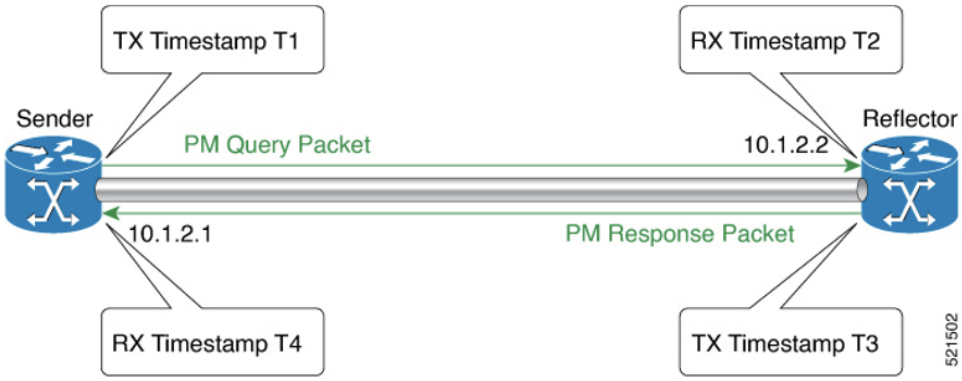
1. The local-end router sends PM query packets periodically to the remote side once the egress line card on the router applies timestamps on packets.
2. The ingress line card on the remote-end router applies time-stamps on packets as soon as they are received.
3. The remote-end router sends the PM packets containing time-stamps back to the local-end router.
4. One-way delay is measured using the time-stamp values in the PM packet.

Two-Way Measurement Mode

Two-way meaurement mode provides two-way measurements. PTP-capable hardware and hardware timestamping are required on both Sender and Reflector, but PTP clock synchronization between Sender and Reflector is not required.

Delay measurement in two-way mode is calculated as ((T4 – T1) – (T3 – T2))/2

Figure 2: Two-Way



The PM query and response for two-way delay measurement can be described in the following steps:

1. The local-end router sends PM query packets periodically to the remote side once the egress line card on the router applies timestamps on packets.
2. Ingress line card on the remote-end router applies time-stamps on packets as soon as they are received.
3. The remote-end router sends the PM packets containing time-stamps back to the local-end router. The remote-end router time-stamps the packet just before sending it for two-way measurement.
4. The local-end router time-stamps the packet as soon as the packet is received for two-way measurement.
5. Delay is measured using the time-stamp values in the PM packet.

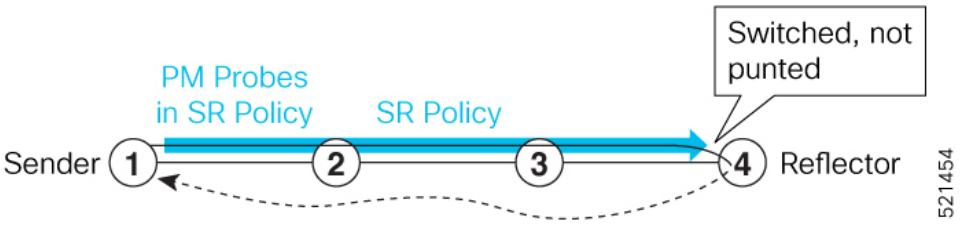
Loopback Measurement Mode

Loopback meaurement mode provides two-way and one-way measurements. PTP-capable hardware and hardware timestamping are required on the Sender, but are not required on the Reflector.

Delay measurements in Loopback mode are calculated as follows:

- Round-Trip Delay = (T4 – T1)
- One-Way Delay = Round-Trip Delay/2

Figure 3: Loopback



The PM query and response for Loopback delay measurement can be described in the following steps:

1. The local-end router sends PM probe packets periodically on the SR Policy.
2. The probe packets are loopback on the endpoint node (not punted), with no timestamping on endpoint node.
3. Round-trip Delay = T4 – T1.

Link Delay Measurement

Table 3: Feature History Table

Feature Name	Release Information	Feature Description
Link Delay Measurement with IPv6 Link Local Address	Release 7.3.1	The performance measurement for link delay determines the source and destination IP addresses used in the OAM packet based on the IP address of the interface, where the delay measurement operation is enabled. This feature enables using the IPv6 link-local address as the OAM packet source IP address, when no IPv4 or IPv6 address is configured in the interface.

Feature Name	Release Information	Feature Description
SR Performance Measurement Named Profiles	Release 7.3.1	You can use this feature to create specific performance measurement delay and liveness profiles, and associate it with an SR policy. This way, a delay or liveness profile can be associated with a policy for which the performance measurement probes are enabled, and performance measurement is precise, and enhanced. The **performance-measurement delay-profile sr-policy** command was updated with the **name** *profile* keyword-argument combination. The **performance-measurement liveness-profile sr-policy** command was updated with the **name** *profile* keyword-argument combination. The **performance-measurement delay-measurement** command was updated with **delay-profile name** *profile*. The **performance-measurement liveness-detection** command was updated with **liveness-profile name** *profile*

The PM for link delay uses the MPLS packet format defined in RFC 6374 for probes. The MPLS packet format requires the remote side line card to be MPLS capable. For link delay measurement, MPLS multicast MAC address is used to send delay measurement probe packets to next-hops. So, the user does not need to configure next-hop addresses for the links. The remote side line card needs to support the MPLS multicast MAC address.

Usage Guidelines and Restrictions for PM for Link Delay

The following restrictions and guidelines apply for the PM for link delay feature for different links.

- For protocol pm-mpls, remote-end line card needs to be MPLS-capable.
- For broadcast links, only point-to-point (P2P) links are supported. P2P configuration on IGP is required for flooding the value.
- For link bundles, the hashing function may select a member link for forwarding but the reply may come from the remote line card on a different member link of the bundle.
- For one-way delay measurement, clocks should be synchronized on two end-point nodes of the link using PTP.

- Link delay measurement is supported on IPv4 unnumbered interfaces. An IPv4 unnumbered interface is identified by a node ID (a loopback address) and the local SNMP index assigned to the interface. Note that the reply messages could be received on any interface, since the packets are routed at the responder based on the loopback address used to identify the link.

Configuration Example: PM for Link Delay

This example shows how to configure performance-measurement functionalities for link delay as a global default profile. The default values for the different parameters in the PM for link delay is given as follows:

- **probe measurement mode**: The default measurement mode for probe is two-way delay measurement. If you are configuring one-way delay measurement, hardware clocks must be synchronized between the local-end and remote-end routers using precision time protocol (PTP). See Measurement Modes, on page 2 for more information.
- **protocol**:
  - **twamp-light**: Interface delay measurement using RFC 5357 with IP/UDP encap. This is the default protocol.
  - **pm-mpls**: Interface delay measurement using RFC6374 with MPLS encap.
- **burst interval**: Interval for sending probe packet. The default value is 3000 milliseconds and the range is from 30 to 15000 milliseconds.
- **computation interval**: Interval for metric computation. Default is 30 seconds; range is 1 to 3600 seconds.
- **periodic advertisement**: Periodic advertisement is enabled by default.
- **periodic-advertisement interval**: The default value is 120 seconds and the interval range is from 30 to 3600 seconds.
- **periodic-advertisement threshold**: Checks the minimum-delay metric change for threshold crossing for periodic advertisement. The default value is 10 percent and the range is from 0 to 100 percent.
- **periodic-advertisement minimum change**: The default value is 1000 microseconds (usec) and the range is from 0 to 100000 microseconds.
- **accelerated advertisement**: Accelerated advertisement is disabled by default.
- **accelerated-advertisement threshold**: Checks the minimum-delay metric change for threshold crossing for accelerated advertisement. The default value is 20 percent and the range is from 0 to 100 percent.
- **accelerated-advertisement minimum change**: The default value is 500 microseconds and the range is from 0 to 100000 microseconds.

```
RP/0/0/CPU0:router(config)# performance-measurement delay-profile interfaces
RP/0/0/CPU0:router(config-pm-dm-intf)# probe
RP/0/0/CPU0:router(config-pm-dm-intf-probe)# measurement-mode one-way
RP/0/0/CPU0:router(config-pm-dm-intf-probe)# burst-interval 60
RP/0/0/CPU0:router(config-pm-dm-intf-probe)# computation-interval 60
RP/0/0/CPU0:router(config-pm-dm-intf-probe)# exit

RP/0/0/CPU0:router(config-pm-dm-intf)# advertisement periodic
RP/0/0/CPU0:router(config-pm-dm-intf-adv-per)# interval 120
RP/0/0/CPU0:router(config-pm-dm-intf-adv-per)# threshold 20
RP/0/0/CPU0:router(config-pm-dm-intf-adv-per)# minimum-change 1000
RP/0/0/CPU0:router(config-pm-dm-intf-adv-per)# exit
```

```
RP/0/0/CPU0:router(config-pm-dm-intf)# advertisement accelerated
RP/0/0/CPU0:router(config-pm-dm-intf-adv-acc)# threshold 30
RP/0/0/CPU0:router(config-pm-dm-intf-adv-acc)# minimum-change 1000
RP/0/0/CPU0:router(config-pm-dm-intf-adv-per)# exit
```

Configure the UDP Destination Port

Configuring the UDP port for TWAMP-Light protocol is optional. By default, PM uses port 862 as the TWAMP-reserved UDP destination port for delay.

The UDP port is configured for each PM measurement probe type (delay, loss, protocol, authentication mode, etc.) on querier and responder nodes. If you configure a different UDP port, the UDP port for each PM measurement probe type must match on the querier and the responder nodes.

Note The same UDP destination port is used for delay measurement for links and SR Policy.

This example shows how to configure the UDP destination port for delay.

```
Router(config)# performance-measurement

Router(config-perf-meas)# protocol twamp-light

Router(config-pm-protocol)# measurement delay unauthenticated
Router(config-pm-proto-mode)# querier-dst-port 12000
```

Enable PM for Link Delay Over an Interface

This example shows how to enable PM for link delay over an interface.

```
RP/0/0/CPU0:router(config)# performance-measurement
RP/0/0/CPU0:router(config-perf-meas)# interface TenGigE0/0/0/0
RP/0/0/CPU0:router(config-pm-intf)# next-hop ipv4 10.10.10.2 // Optional IPv4 or IPv6
next-hop address
RP/0/0/CPU0:router(config-pm-intf)# delay-measurement
RP/0/0/CPU0:router(config-pm-intf-dm)# exit
```

The source and destination IP addresses used in the OAM packet are determined by the IP address present on the interface where the delay-measurement operation is enabled and the setting of the optional **next-hop** address.

When the **next-hop** address is not specified, the following rules apply to determine the source and destination IP addresses used in the OAM packet:

- If an IPv4 address is configured under the interface, then:
  - OAM packet source IP address = Interface's IPv4 address
  - OAM packet destination IP address = 127.0.0.0
- Else, if an IPv6 global address is configured under the interface, then:
  - OAM packet source IP address = Interface's IPv6 global address
  - OAM packet destination IP address = 0::ff:127.0.0.0

- Else, if an IPv6 link-local address is assigned to the interface, then:
  - OAM packet source IP address = Interface's IPv6 link-local address
  - OAM packet destination IP address = 0::ff:127.0.0.0

When the **next-hop** {**ipv4** | **ipv6**} address is configured, the following rules apply to determine the source and destination IP addresses used in the OAM packet:

- If a next-hop IPv4 address is configured, then:
  - OAM packet source IP address = Interface's IPv4 address
  - OAM packet destination IP address = Configured next-hop IPv4 address

Note If there is no IPv4 address configured under the interface, then the delay-measurement probe does not send OAM packets.

- If a next-hop IPv6 address is configured, then:
  - OAM packet source IP address = Interface's IPv6 global address
  - OAM packet destination IP address = Configured next-hop IPv6 address

Note If there is no IPv6 global address configured under the interface, then the delay-measurement probe does not send OAM packets.

This example shows how to enable PM for link delay over an interface with IPv4 address configured:

```
interface TenGigE0/0/0/0
 ipv4 address 10.10.10.1 255.255.255.0

performance-measurement
 interface TenGigE0/0/0/0
  delay-measurement
```

This example shows how to enable PM for link delay over an interface IPv6 address configured:

```
interface TenGigE0/0/0/0
 ipv6 address 10:10:10::1/64

performance-measurement
 interface TenGigE0/0/0/0
  delay-measurement
```

This example shows how to enable PM for link delay over an interface with a specified next-hop IPv4 address:

```
interface TenGigE0/0/0/0
 ipv4 address 10.10.10.1 255.255.255.0
```

```
performance-measurement
 interface TenGigE0/0/0/0
  next-hop ipv4 10.10.10.2
  delay-measurement
```

This example shows how to enable PM for link delay over an interface with a specified next-hop IPv6 address:

```
interface TenGigE0/0/0/0
 ipv6 address 10:10:10::1/64

performance-measurement
 interface TenGigE0/0/0/0
  next-hop ipv6 10:10:10::2
  delay-measurement
```

This example shows how to enable PM for link delay over an interface with only IPv6 link-local address:

```
interface TenGigE0/0/0/0
 ipv6 enable

performance-measurement
 interface TenGigE0/0/0/0
  delay-measurement
```

Verification

```
RP/0/0/CPU0:router# show performance-measurement profile interface
Thu Dec 12 14:13:16.029 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------
Interface Delay-Measurement:
  Profile configuration:
    Measurement Type                          : Two-Way
    Probe computation interval                : 30 (effective: 30) seconds
    Type of services                          : Traffic Class: 6, DSCP: 48
    Burst interval                            : 3000 (effective: 3000) mSec
    Burst count                               : 10 packets
    Encap mode                                : UDP
    Payload Type                              : TWAMP-light
    Destination sweeping mode                 : Disabled
    Periodic advertisement                    : Enabled
      Interval                                : 120 (effective: 120) sec
      Threshold                               : 10%
      Minimum-Change                          : 500 uSec
    Advertisement accelerated                 : Disabled
    Threshold crossing check                  : Minimum-delay

RP/0/0/CPU0:router# show performance-measurement summary detail location 0/2/CPU0

Thu Dec 12 14:09:59.162 PST

------------------------------------------------------------------------------
0/2/CPU0
------------------------------------------------------------------------------
Total interfaces                              : 1
Total SR Policies                             : 0
Total RSVP-TE tunnels                         : 0
```

```
Total Maximum PPS                              : 2000 pkts/sec
Total Interfaces PPS                           : 0 pkts/sec
Maximum Allowed Multi-hop PPS                  : 2000 pkts/sec
Multi Hop Requested PPS                        : 0 pkts/sec (0% of max allowed)
Dampened Multi Hop Requested PPS               : 0% of max allowed
Inuse Burst Interval Adjustment Factor         : 100% of configuration


Interface Delay-Measurement:
  Total active sessions                        : 1
  Counters:
    Packets:
      Total sent                               : 26
      Total received                           : 26
    Errors:
        TX:
          Reason interface down                : 0
          Reason no MPLS caps                  : 0
          Reason no IP address                 : 0
          Reason other                         : 0
        RX:
          Reason negative delay                : 0
          Reason delay threshold exceeded      : 0
          Reason missing TX timestamp          : 0
          Reason missing RX timestamp          : 0
          Reason probe full                    : 0
          Reason probe not started             : 0
          Reason control code error            : 0
          Reason control code notif            : 0
    Probes:
      Total started                            : 3
      Total completed                          : 2
      Total incomplete                         : 0
      Total advertisements                     : 0

SR Policy Delay-Measurement:
  Total active sessions                        : 0
  Counters:
    Packets:
      Total sent                               : 0
      Total received                           : 0
    Errors:
        TX:
          Reason interface down                : 0
          Reason no MPLS caps                  : 0
          Reason no IP address                 : 0
          Reason other                         : 0
        RX:
          Reason negative delay                : 0
          Reason delay threshold exceeded      : 0
          Reason missing TX timestamp          : 0
          Reason missing RX timestamp          : 0
          Reason probe full                    : 0
          Reason probe not started             : 0
          Reason control code error            : 0
          Reason control code notif            : 0
    Probes:
      Total started                            : 0
      Total completed                          : 0
      Total incomplete                         : 0
      Total advertisements                     : 0

RSVP-TE Delay-Measurement:
  Total active sessions                        : 0
```

```
  Counters:
    Packets:
      Total sent                            : 0
      Total received                        : 0
    Errors:
        TX:
          Reason interface down             : 0
          Reason no MPLS caps               : 0
          Reason no IP address              : 0
          Reason other                      : 0
        RX:
          Reason negative delay             : 0
          Reason delay threshold exceeded   : 0
          Reason missing TX timestamp       : 0
          Reason missing RX timestamp       : 0
          Reason probe full                 : 0
          Reason probe not started          : 0
          Reason control code error         : 0
          Reason control code notif         : 0
    Probes:
      Total started                         : 0
      Total completed                       : 0
      Total incomplete                      : 0
      Total advertisements                  : 0

Global Delay Counters:
  Total packets sent                        : 26
  Total query packets received              : 26
  Total invalid session id                  : 0
  Total missing session                     : 0

RP/0/0/CPU0:router# show performance-measurement interfaces detail
Thu Dec 12 14:16:09.692 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------

------------------------------------------------------------------------------
0/2/CPU0
------------------------------------------------------------------------------

Interface Name: GigabitEthernet0/2/0/0 (ifh: 0x1004060)
  Delay-Measurement                 : Enabled
  Loss-Measurement                  : Disabled
  Configured IPv4 Address           : 10.10.10.2
  Configured IPv6 Address           : 10:10:10::2
  Link Local IPv6 Address           : fe80::3a:6fff:fec9:cd6b
  Configured Next-hop Address       : Unknown
  Local MAC Address                 : 023a.6fc9.cd6b
  Next-hop MAC Address              : 0291.e460.6707
  Primary VLAN Tag                  : None
  Secondary VLAN Tag                : None
  State                             : Up

  Delay Measurement session:
    Session ID          : 1

    Last advertisement:
      Advertised at: Dec 12 2019 14:10:43.138 (326.782 seconds ago)
      Advertised reason: First advertisement
      Advertised delays (uSec): avg: 839, min: 587, max: 8209, variance: 297

    Next advertisement:
      Threshold check scheduled in 1 more probe (roughly every 120 seconds)
```

```
  Aggregated delays (uSec): avg: 751, min: 589, max: 905, variance: 112
  Rolling average (uSec): 756

Current Probe:
  Started at Dec 12 2019 14:15:43.154 (26.766 seconds ago)
  Packets Sent: 9, received: 9
  Measured delays (uSec): avg: 795, min: 631, max: 1199, variance: 164
  Next probe scheduled at Dec 12 2019 14:16:13.132 (in 3.212 seconds)
  Next burst packet will be sent in 0.212 seconds
  Burst packet sent every 3.0 seconds
  Probe samples:
    Packet Rx Timestamp       Measured Delay (nsec)
    Dec 12 2019 14:15:43.156          689223
    Dec 12 2019 14:15:46.156          876561
    Dec 12 2019 14:15:49.156          913548
    Dec 12 2019 14:15:52.157         1199620
    Dec 12 2019 14:15:55.156          794008
    Dec 12 2019 14:15:58.156          631437
    Dec 12 2019 14:16:01.157          656440
    Dec 12 2019 14:16:04.157          658267
    Dec 12 2019 14:16:07.157          736880
```

You can also use the following commands for verifying the PM for link delay on the local-end router.

Command	Description
show performance-measurement history probe interfaces [*interface*]	Displays the PM link-delay probe history for interfaces.
show performance-measurement history aggregated interfaces [*interface*]	Displays the PM link-delay aggregated history for interfaces.
show performance-measurement history advertisement interfaces [*interface*]	Displays the PM link-delay advertisement history for interfaces.
show performance-measurement counters [interface *interface*] [location *location-name*]	Displays the PM link-delay session counters.

You can also use the following commands for verifying the PM for link-delay configuration on the remote-end router.

Command	Description
show performance-measurement responder summary [**location** *location-name*]	Displays the PM for link-delay summary on the remote-end router (responder).
show performance-measurement responder interfaces [*interface*]	Displays PM for link-delay for interfaces on the remote-end router.
show performance-measurement responder counters [**interface** *interface*] [**location** *location-name*]	Displays the PM link-delay session counters on the remote-end router.

Configure a Static Delay Value on an Interface

You can configure an interface to advertise a static delay value, instead of the measured delay value. When you configure a static delay value, the advertisement is triggered immediately. The average, minimum, and maximum advertised values will use the static delay value, with a variance of 0.

Scheduled probes will continue, and measured delay metrics will be aggregated and stored in history buffer. However, advertisement threshold checks are suppressed so that there are no advertisements of the actual measured delay values. If the configured static delay value is removed, the next scheduled advertisement threshold check will update the advertised measured delay values.

The static delay value can be configured from 1 to 16777215 microseconds (16.7 seconds).

This example shows how to configure a static delay of 1000 microseconds:

```
RP/0/0/CPU0:router(config)# performance-measurement
RP/0/0/CPU0:router(config-perf-meas)# interface TenGigE0/0/0/0
RP/0/0/CPU0:router(config-pm-intf)# delay-measurement
RP/0/0/CPU0:router(config-pm-intf-dm)# advertise-delay 1000
```

Running Configuration

```
performance-measurement
 interface GigabitEthernet0/0/0/0
  delay-measurement
   advertise-delay 1000
  !
 !
!
```

Verification

```
RP/0/RSP0/CPU0:ios# show performance-measurement interfaces detail

-------------------------------------------------------------------------------
0/0/CPU0
-------------------------------------------------------------------------------

Interface Name: GigabitEthernet0/0/0/0 (ifh: 0x0)
  Delay-Measurement                : Enabled

. . .

    Last advertisement:
      Advertised at: Nov 29 2021 21:53:00.656 (7.940 seconds ago)
      Advertised reason: Advertise delay config
      Advertised delays (uSec): avg: 1000, min: 1000, max: 1000, variance: 0

. . .
```

SR Performance Measurement Named Profiles

You can create a named performance measurement profile for delay or liveness.

Delay Profile

This example shows how to create a named SR performance measurement delay profile.

```
Router(config)# performance-measurement delay-profile sr-policy profile2
Router(config-pm-dm-srpolicy)# probe
Router(config-pm-dm-srpolicy-probe)# burst-interval 60
Router(config-pm-dm-srpolicy-probe)# computation-interval 60
Router(config-pm-dm-srpolicy-probe)# protocol twamp-light
Router(config-pm-dm-srpolicy-probe)# tos dscp 63

Router(config-pm-dm-srpolicy)# advertisement
Router(config-pm-dm-srpolicy-adv)# periodic
Router(config-pm-dm-srpolicy-adv-per)# interval 60
```

```
Router(config-pm-dm-srpolicy-adv-per)# minimum-change 1000
Router(config-pm-dm-srpolicy-adv-per)# threshold 20
Router(config-pm-dm-srpolicy-adv-per)# commit
```

Apply the delay profile for an SR Policy.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy TEST
Router(config-sr-te-policy)# color 4 end-point ipv4 10.10.10.10
Router(config-sr-te-policy)# performance-measurement
Router(config-sr-te-policy-perf-meas)# delay-measurement delay-profile name profile2

Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 100
Router(config-sr-te-policy-path-pref)# explicit segment-list LIST1
Router(config-sr-te-pp-info)# weight 2

Router(config-sr-te-policy-path-pref)# explicit segment-list LIST2
Router(config-sr-te-pp-info)# weight 3
```

Running Configuration

```
Router# show run segment-routing traffic-eng policy TEST

segment-routing
 traffic-eng
  policy TEST
   color 4 end-point ipv4 10.10.10.10
   candidate-paths
    preference 100
     explicit segment-list LIST1
      weight 2
     !
     explicit segment-list LIST2
      weight 3
     !
    !
   !
   performance-measurement
    delay-measurement
     delay-profile name profile2
```

Verification

```
Router# show performance-measurement profile named-profile delay sr-policy name profile2

----------------------------
0/RSP0/CPU0
----------------------------
SR Policy Delay Measurement Profile Name: profile2
  Profile configuration:
    Measurement mode                          : One-way
    Protocol type                             : TWAMP-light
    Encap mode                                : UDP
    Type of service:
      PM-MPLS traffic class                   : 6
      TWAMP-light DSCP                        : 63
    Probe computation interval                : 60 (effective: 60) seconds
    Burst interval                            : 60 (effective: 60) mSec
    Packets per computation interval          : 1000
    Periodic advertisement                    : Enabled
      Interval                                : 60 (effective: 60) sec
      Threshold                               : 20%
      Minimum-change                          : 1000 uSec
    Advertisement accelerated                 : Disabled
```

```
    Advertisement logging:
      Delay exceeded                          : Disabled (default)
    Threshold crossing check                  : Maximum-delay
    Router alert                              : Disabled (default)
    Destination sweeping mode                 : Disabled
    Liveness detection parameters:
      Multiplier                              : 3
      Logging state change                    : Disabled
```

On-Demand SR Policy

```
Router(config-sr-te)# on-demand color 20
Router(config-sr-te-color)# performance-measurement delay-measurement
Router(config-sr-te-color-delay-meas)# delay-profile name profile2
Router(config-sr-te-color-delay-meas)# commit
```

Running Configuration

```
Router# show run segment-routing traffic-eng on-demand color 20

segment-routing
 traffic-eng
  on-demand color 20
   performance-measurement
    delay-measurement
     delay-profile name profile2
```

Liveness Profile

This example shows how to create a *named* SR performance measurement liveness profile.

```
Router(config)# performance-measurement liveness-profile sr-policy name profile3
Router(config-pm-ld-srpolicy)# probe
Router(config-pm-ld-srpolicy-probe)# burst-interval 60
Router(config-pm-ld-srpolicy-probe)# measurement-mode loopback
Router(config-pm-ld-srpolicy-probe)# tos dscp 10
Router(config-pm-ld-srpolicy-probe)# liveness-detection
Router(config-pm-ld-srpolicy-probe)# multiplier 5
Router(config-pm-ld-srpolicy-probe)# commit
```

Apply the Liveness Profile for the SR Policy

This example shows how to enable PM for SR policy liveness for a specific policy.

For the same policy, you cannot enable delay-measurement (delay-profile) and liveness-detection (liveness-profile) at the same time. For example, if delay measurement is enabled, use the **no delay-measurement** command to disable it, and then enable the following command for enabling liveness detection.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy TRST2
Router(config-sr-te-policy)# color 40 end-point ipv4 20.20.20.20
Router(config-sr-te-policy)# candidate-paths
Router(config-sr-te-policy-path)# preference 50
Router(config-sr-te-policy-path-pref)# explicit segment-list LIST3
Router(config-sr-te-pp-info)# weight 2

Router(config-sr-te-policy-path-pref)# explicit segment-list LIST4
Router(config-sr-te-pp-info)# weight 3

Router(config-sr-te-policy)# performance-measurement
Router(config-sr-te-policy-perf-meas)# liveness-detection liveness-profile name profile3
```

Running Configuration

```
Router# show run segment-routing traffic-eng policy TRST2

segment-routing
 traffic-eng
  policy TRST2
   color 40 end-point ipv4 20.20.20.20
   candidate-paths
    preference 50
     explicit segment-list LIST3
      weight 2
     !
     explicit segment-list LIST4
      weight 3
     !
    !
   !
   performance-measurement
    liveness-detection
     liveness-profile name profile3
    !
```

Verification

```
Router# show performance-measurement profile named-profile delay

-----------
0/RSP0/CPU0
-----------

SR Policy Liveness Detection Profile Name: profile1
  Profile configuration:
    Measurement mode                          : Loopback
    Protocol type                             : TWAMP-light
    Type of service:
      TWAMP-light DSCP                        : 10
    Burst interval                            : 60 (effective: 60) mSec
    Destination sweeping mode                 : Disabled
    Liveness detection parameters:
      Multiplier                              : 3
      Logging state change                    : Disabled

SR Policy Liveness Detection Profile Name: profile3
  Profile configuration:
    Measurement mode                          : Loopback
    Protocol type                             : TWAMP-light
    Type of service:
      TWAMP-light DSCP                        : 10
    Burst interval                            : 60 (effective: 60) mSec
    Destination sweeping mode                 : Disabled
    Liveness detection parameters:
      Multiplier                              : 3
      Logging state change                    : Disabled
```

On-Demand SR Policy

For the same policy, you cannot enable delay-measurement (delay-profile) and liveness-detection (liveness-profile) at the same time. For example, to disable delay measurement, use the **no delay-measurement** command, and then enable the following command for enabling liveness detection.

```
Router(config-sr-te)# on-demand color 30
Router(config-sr-te-color)# performance-measurement
Router(config-sr-te-color-pm)# liveness-detection liveness-profile name profile1
Router(config-sr-te-color-delay-meas)# commit
```

Running Configuration

```
Router# show run segment-routing traffic-eng on-demand color 30

segment-routing
 traffic-eng
  on-demand color 30
   performance-measurement
    liveness-detection
     liveness-profile name profile1
    !
```

Verification

```
Router# show performance-measurement profile named-profile liveness sr-policy name profile1

--------------------
0/RSP0/CPU0
--------------------
SR Policy Liveness Detection Profile Name: profile1
  Profile configuration:
    Measurement mode                          : Loopback
    Protocol type                             : TWAMP-light
    Type of service:
      TWAMP-light DSCP                        : 10
    Burst interval                            : 60 (effective: 60) mSec
    Destination sweeping mode                 : Disabled
    Liveness detection parameters:
      Multiplier                              : 3
      Logging state change                    : Disabled
```

Delay Normalization

Table 4: Feature History Table

Feature Name	Release Information	Feature Description
SR-TE Delay Normalization for OSPF	Release 7.3.1	This feature extends the current Delay Normalization feature to support OSPF.

Performance measurement (PM) measures various link characteristics like packet loss and delay. Such characteristics can be used by IS-IS as a metric for Flexible Algorithm computation. Low latency routing using dynamic delay measurement is one of the primary use cases for Flexible Algorithm technology.

Delay is measured in microseconds. If delay values are taken as measured and used as link metrics during the IS-IS topology computation, some valid ECMP paths might be unused because of the negligible difference in the link delay.

The Delay Normalization feature computes a normalized delay value and uses the normalized value instead. This value is advertised and used as a metric during the Flexible Algorithm computation.

The normalization is performed when the delay is received from the delay measurement component. When the next value is received, it is normalized and compared to the previous saved normalized value. If the values are different, then the LSP generation is triggered.

The following formula is used to calculate the normalized value:

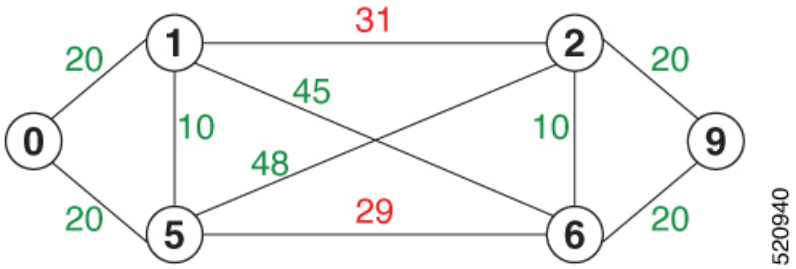
- **Dm** – measured Delay
- **Int** – configured normalized Interval

- **Off** – configured normalized Offset (must be less than the normalized interval Int)
- **Dn** – normalized Delay
- **a** = Dm / Int (rounded down)
- **b** = a * Int + Off

If the measured delay (Dm) is less than or equal to **b**, then the normalized delay (Dn) is equal to **b**. Otherwise, Dn is **b + Int**.

Example

The following example shows a low-latency service. The intent is to avoid high-latency links (1-6, 5-2). Links 1-2 and 5-6 are both low-latency links. The measured latency is not equal, but the difference is insignificant.



We can normalize the measured latency before it is advertised and used by IS-IS. Consider a scenario with the following:

- Interval = 10
- Offset = 3

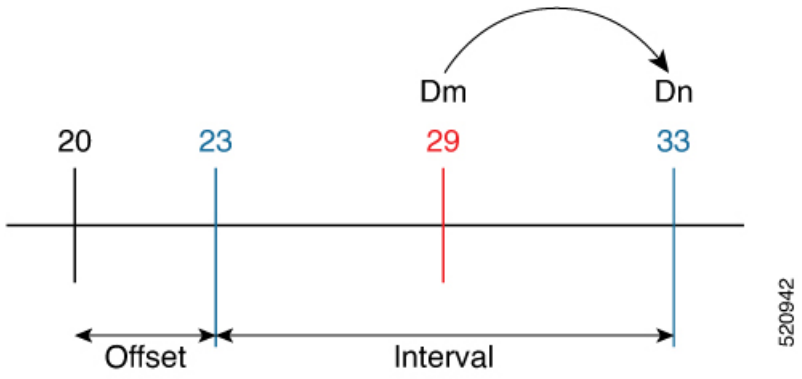
The measured delays will be normalized as follows:

- **Dm** = 29

  a = 29 / 10 = 2 (2.9, rounded down to 2)

  b = 2 * 10 + 3 = 23

  In this case, **Dm** (29) is greater than **b** (23); so **Dn** is equal to **b**+**I** (23 + 10) = **33**

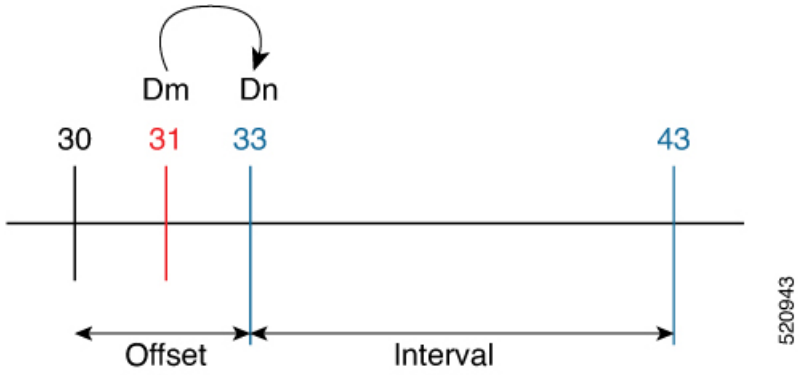


- **Dm** = 31

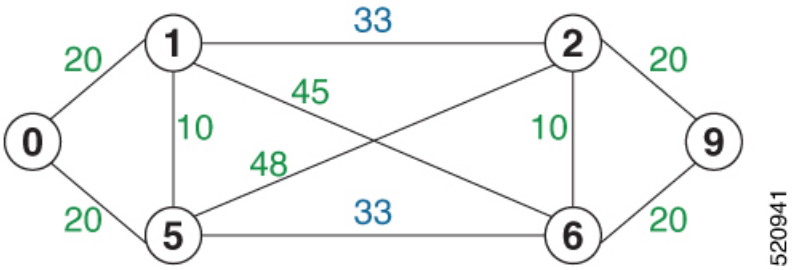
  a = 31 / 10 = 3 (3.1, rounded down to 3)

b = 3 * 10 + 3 = 33

In this case, **Dm** (31) is less than **b** (33); so **Dn** is **b** = **33**



The link delay between 1-2 and 5-6 is normalized to 33.



Configuration

Delay normalization is disabled by default. To enable and configure delay normalization, use the **delay normalize interval** *interval* [**offset** *offset*] command.

- *interval* – The value of the normalize interval in microseconds.
- *offset* – The value of the normalized offset in microseconds. This value must be smaller than the value of normalized interval.

IS-IS Configuration

```
router isis 1
 interface GigEth 0/0/0/0
  delay normalize interval 10 offset 3
  address-family ipv4 unicast
   metric 77
```

OSPF Configuration

```
router ospf 1
 area 0
  interface GigabitEthernet0/0/0/0
   delay normalize interval 10 offset 3
  !
 !
!
```

SR Policy End-to-End Delay Measurement

Table 5: Feature History Table

Feature Name	Release	Description
Segment Routing Performance Measurement for Link Delay and SR Policy Delay Using RFC 5357 (TWAMP Light) Encoding	Release 7.2.2	This feature introduces support for Two-Way Active Measurement Protocol (TWAMP) Light (RFC 5357) for link delay and SR policy delay measurement. TWAMP Light adds two-way or round-trip measurement capabilities. Network performance data such as packet loss, delay and delay variation, and bandwidth utilization is a critical measure for Traffic Engineering (TE). This data provides service providers the characteristics of their networks for performance evaluation that is required to ensure the Service Level Agreements (SLAs). The performance measurement and delay variation feature allows you to measure those metrics and advertise them through IGP extensions as extended TE metrics.

The PM for SR Policy uses the MPLS packet format defined in RFC 6374 or IP/UDP packet format defined in RFC 5357 (TWAMP-Light) for probes. The MPLS packet format requires the remote-side line card to be MPLS-capable.

The PM for SR Policy uses the IP/UDP packet format defined in RFC 5357 (TWAMP-Light) for probes. Two-Way Active Measurement Protocol (TWAMP) adds two-way or round-trip measurement capabilities. TWAMP employs time stamps applied at the echo destination (reflector) to enable greater accuracy. In the case of TWAMP Light, the Session-Reflector doesn't necessarily know about the session state. The Session-Reflector simply copies the Sequence Number of the received packet to the Sequence Number field of the reflected packet. The controller receives the reflected test packets and collects two-way metrics. This architecture allows for collection of two-way metrics.

The extended TE link delay metric (minimum-delay value) can be used to compute paths for SR policies as an optimization metric or as an accumulated delay bound.

There is a need to monitor the end-to-end delay experienced by the traffic sent over an SR policy to ensure that the delay does not exceed the requested "upper-bound" and violate SLAs. You can verify the end-to-end delay values before activating the candidate-path or the segment lists of the SR policy in forwarding table, or to deactivate the active candidate-path or the segment lists of the SR policy in forwarding table.

Note The end-to-end delay value of an SR policy will be different than the path computation result (for example, the sum of TE link delay metrics) due to several factors, such as queuing delay within the routers.

Restrictions and Usage Guidelines for PM for SR Policy Delay

Hardware clocks must be synchronized between the querier and the responder nodes of the link using PTP for one-way delay measurement.

Configuring Performance Measurement Parameters

This example shows how to configure performance-measurement parameters for SR policy delay as a global default profile. The default values for the different parameters in the PM for SR policy delay is given as follows:

- **probe**: The default mode for probe is one-way delay measurement. Two-way delay and loopback modes are supported. See Measurement Modes, on page 2 for more information.
- **burst interval**: Interval for sending probe packet. The default value is 3000 milliseconds and the range is from 30 to 15000 milliseconds.
- **computation interval**: Interval for metric computation. Default is 30 seconds; range is 1 to 3600 seconds.
- **protocol**:
  - **twamp-light**: SR Policy delay measurement using RFC 5357 with IP/UDP encap. This is the default protocol.
- **tos**: Type of Service
  - **dscp** *value*: The default value is 48 and the range is from 0 to 63.
  - **traffic-class** *value*: The default value is 6 and the range is from 0 to 7.
- **advertisement threshold-check**: minimum-delay/maximum-delay - The default value of periodic advertisement threshold-check is maximum-delay.
- **periodic advertisement**: Periodic advertisement is enabled by default.
- **periodic-advertisement interval**: The default value is 120 seconds and the interval range is from 30 to 3600 seconds.
- **periodic-advertisement threshold**: Checks the minimum-delay metric change for threshold crossing for periodic advertisement. The default value is 10 percent and the range is from 0 to 100 percent.
- **periodic-advertisement minimum-change**: The default value is 500 microseconds (usec) and the range is from 0 to 100000 microseconds.
- **accelerated advertisement**: Accelerated advertisement is disabled by default.
- **accelerated-advertisement threshold**: Checks the minimum-delay metric change for threshold crossing for accelerated advertisement. The default value is 20 percent and the range is from 0 to 100 percent.
- **accelerated-advertisement minimum**: The default value is 500 microseconds and the range is from 1 to 100000 microseconds.

```
Router(config)# performance-measurement delay-profile sr-policy
Router(config-pm-dm-srpolicy)# probe
Router(config-pm-dm-srpolicy-probe)# burst-interval 60
Router(config-pm-dm-srpolicy-probe)# computation-interval 60
Router(config-pm-dm-srpolicy-probe)# protocol twamp-light
Router(config-pm-dm-srpolicy-probe)# tos dscp 63
Router(config-pm-dm-srpolicy-probe)# exit

Router(config-pm-dm-srpolicy)# advertisement
Router(config-pm-dm-srpolicy-adv)# periodic
Router(config-pm-dm-srpolicy-adv-per)# interval 60
Router(config-pm-dm-srpolicy-adv-per)# minimum-change 1000
Router(config-pm-dm-srpolicy-adv-per)# threshold 20
Router(config-pm-dm-srpolicy-adv-per)# exit

Router(config-pm-dm-srpolicy-adv)# accelerated
Router(config-pm-dm-srpolicy-adv-acc)# minimum-change 1000
Router(config-pm-dm-srpolicy-adv-acc)# threshold 10
Router(config-pm-dm-srpolicy-adv-acc)# exit

Router(config-pm-dm-srpolicy-adv)# threshold-check minimum-delay
Router(config-pm-dm-srpolicy-adv)# exit
Router(config-pm-dm-srpolicy)#
```

Configure the UDP Destination Port

Configuring the UDP port for TWAMP-Light protocol is optional. By default, PM uses port 862 as the TWAMP-reserved UDP destination port for delay.

Note The same UDP destination port is used for delay measurement for links and SR Policy.

This example shows how to configure the UDP destination port for delay.

```
Router(config)# performance-measurement

Router(config-perf-meas)# protocol twamp-light

Router(config-pm-protocol)# measurement delay unauthenticated
Router(config-pm-proto-mode)# querier-dst-port 12000
```

Enable Performance Measurement for SR Policy

This example shows how to enable PM for SR policy delay for a specific policy.

```
Router(config)# segment-routing traffic-eng
Router(config-sr-te)# policy foo
Router(config-sr-te-policy)# performance-measurement
Router(config-sr-te-policy-perf-meas)# delay-measurement
```

SR Policy Probe IP/UDP ECMP Hashing Configuration

This example shows how to configure SR Policy ECMP IP-hashing mode.

- The destination IPv4 address 127.x.x.x – 127.y.y.y is used in the Probe messages to take advantages of 3-tuple IP hashing (source-address, destination-address, and local router ID) for ECMP paths of SR-MPLS Policy.

Note The destination IPv4 address must be 127/8 range (loopback), otherwise it will be rejected.

- One PM session is always created for the actual endpoint address of the SR Policy.
- You can specify the number of IP addresses to sweep. The range is from 0 (default, no sweeping) to 128.
- Platforms may have a limitation for large label stack size to not check IP address for hashing.

```
Router(config)# performance-measurement delay-profile sr-policy
Router(config-pm-dm-srpolicy)# probe
Router(config-pm-dm-srpolicy-probe)# sweep
Router(config-pm-dm-srpolicy-probe-sweep)# destination ipv4 127.0.0.1 range 28
```

Verification

```
Router# show performance-measurement sr-policy
Mon Jan 20 18:48:41.002 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------

Policy Name                LSP ID Tx/Rx         Avg/Min/Max/Variance
 ---------------------------------------------------------------------------
srte_c_10_ep_192.168.0.4   2      6/6           27012/26906/27203/106

Router# show performance-measurement sr-policy name srte_c_10_ep_192.168.0.4 detail verbose
Mon Jan 20 18:44:22.400 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------
SR Policy name: srte_c_10_ep_192.168.0.4
  Color                       : 10
  Endpoint                    : 192.168.0.4
  Number of candidate-paths   : 1

  Candidate-Path:
    Instance                  : 2
    Preference                : 100
    Protocol-origin           : Configured
    Discriminator             : 100
    Source address            : 192.168.0.2
    Reverse path label        : Not configured
    Number of segment-lists   : 1
    Last advertisement:
      No advertisements have occured
    Next advertisement:
      Check scheduled at the end of the current probe (roughly every 30 seconds)
      Aggregated delays (uSec): avg: 45218, min: 26512, max: 82600, variance: 18706
      Rolling average (uSec): 45218
    Last probe:
      Packets Sent: 9, received: 9
      Measured delays (uSec): avg: 45218, min: 26512, max: 82600, variance: 18706
    Current Probe:
      Started at Jan 20 2020 18:44:19.170 (3.453 seconds ago)
      Packets Sent: 3, received: 3
```

```
  Measured delays (uSec): avg: 26588, min: 26558, max: 26630, variance: 30
Next probe scheduled at Jan 20 2020 18:44:34.166 (in 11.543 seconds)
Next burst packet will be sent in 1.543 seconds
Burst packet sent every 5.0 seconds
Liveness Detection: Disabled

Segment-List              : R4
    16004
  Number of atomic paths  : 3
  Last advertisement:
    No advertisements have occured
  Next advertisement:
    Aggregated delays (uSec): avg: 45218, min: 26512, max: 82600, variance: 18706
    Rolling average (uSec): 45218
  Last probe:
    Packets Sent: 9, received: 9
    Measured delays (uSec): avg: 45218, min: 26512, max: 82600, variance: 18706
  Current probe:
    Packets Sent: 3, received: 3
    Measured delays (uSec): avg: 26588, min: 26558, max: 26630, variance: 30
  Liveness Detection: Disabled

  Atomic path:
    Hops                  : 127.0.0.0
    Session ID            : 33554434
    Last advertisement:
      No advertisements have occured
    Next advertisement:
      Aggregated delays (uSec): avg: 45407, min: 26629, max: 82600, variance: 18778
      Rolling average (uSec): 45407
    Last Probe:
      Packets Sent: 3, received: 3
      Measured delays (uSec): avg: 45407, min: 26629, max: 82600, variance: 18778
    Current Probe:
      Packets Sent: 1, received: 1
      Measured delays (uSec): avg: 26630, min: 26630, max: 26630, variance: 0
    Probe samples:
      Packet Rx Timestamp       Measured Delay (nsec)
      Jan 20 2020 18:44:19.198        26630730
    Liveness Detection: Disabled

  Atomic path:
    Hops                  : 127.0.0.1
    Session ID            : 33554435
    Last advertisement:
      No advertisements have occured
    Next advertisement:
      Aggregated delays (uSec): avg: 45128, min: 26521, max: 81961, variance: 18607
      Rolling average (uSec): 45128
    Last Probe:
      Packets Sent: 3, received: 3
      Measured delays (uSec): avg: 45128, min: 26521, max: 81961, variance: 18607
    Current Probe:
      Packets Sent: 1, received: 1
      Measured delays (uSec): avg: 26576, min: 26576, max: 26576, variance: 0
    Probe samples:
      Packet Rx Timestamp       Measured Delay (nsec)
      Jan 20 2020 18:44:19.198        26576938
    Liveness Detection: Disabled

  Atomic path:
    Hops                  : 192.168.0.4
    Session ID            : 33554433
    Last advertisement:
```

```
        No advertisements have occured
      Next advertisement:
        Aggregated delays (uSec): avg: 45119, min: 26512, max: 81956, variance: 18607
        Rolling average (uSec): 45119
      Last Probe:
        Packets Sent: 3, received: 3
        Measured delays (uSec): avg: 45119, min: 26512, max: 81956, variance: 18607
      Current Probe:
        Packets Sent: 1, received: 1
        Measured delays (uSec): avg: 26558, min: 26558, max: 26558, variance: 0
      Probe samples:
        Packet Rx Timestamp       Measured Delay (nsec)
        Jan 20 2020 18:44:19.198        26558375
      Liveness Detection: Disabled

Router# show performance-measurement history probe sr-policy
Mon Jan 20 18:46:55.445 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------

SR Policy name: srte_c_10_ep_192.168.0.4
  Color                      : 10
  Endpoint                   : 192.168.0.4

  Candidate-Path:
    Preference               : 100
    Protocol-origin          : Configured
    Discriminator            : 100
    Delay-Measurement history (uSec):
      Probe Start Timestamp     Pkt(TX/RX)   Average       Min       Max
      Jan 20 2020 18:46:34.174         9/9     26880     26684     27070
      Jan 20 2020 18:46:19.174         9/9     26899     26822     27004
      Jan 20 2020 18:46:04.173         9/9     26813     26571     27164
      Jan 20 2020 18:45:49.172         9/9     26985     26713     27293
      Jan 20 2020 18:45:34.172         9/9     26744     26557     27005
      Jan 20 2020 18:45:19.171         9/9     26740     26435     27093
     Jan 20 2020 18:45:04.171         9/9     27115     26938     27591
      Jan 20 2020 18:44:49.171         9/9     26878     26539     27143
      Jan 20 2020 18:44:34.171         9/9     26824     26562     27265
      Jan 20 2020 18:44:19.170         9/9     26944     26558     27422
      Jan 20 2020 18:44:06.543         9/9     45218     26512     82600

    Segment-List             : R4
      16004
      Delay-Measurement history (uSec):
        Probe Start Timestamp     Pkt(TX/RX)   Average       Min       Max
        Jan 20 2020 18:46:34.174         9/9     26880     26684     27070
        Jan 20 2020 18:46:19.174         9/9     26899     26822     27004
        Jan 20 2020 18:46:04.173         9/9     26813     26571     27164
        Jan 20 2020 18:45:49.172         9/9     26985     26713     27293
        Jan 20 2020 18:45:34.172         9/9     26744     26557     27005
        Jan 20 2020 18:45:19.171         9/9     26740     26435     27093
        Jan 20 2020 18:45:04.171         9/9     27115     26938     27591
        Jan 20 2020 18:44:49.171         9/9     26878     26539     27143
        Jan 20 2020 18:44:34.171         9/9     26824     26562     27265
        Jan 20 2020 18:44:19.170         9/9     26944     26558     27422
        Jan 20 2020 18:44:06.543         9/9     45218     26512     82600

      Atomic path:
        Hops                 : 127.0.0.0
        Delay-Measurement history (uSec):
          Probe Start Timestamp     Pkt(TX/RX)   Average       Min       Max
```

```
        Jan 20 2020 18:46:34.174         3/3     26927     26747     27070
        Jan 20 2020 18:46:19.174         3/3     26982     26970     27004
        Jan 20 2020 18:46:04.173         3/3     26895     26647     27164
        Jan 20 2020 18:45:49.172         3/3     27054     26764     27293
        Jan 20 2020 18:45:34.172         3/3     26801     26694     27005
        Jan 20 2020 18:45:19.171         3/3     26807     26524     27093
        Jan 20 2020 18:45:04.171         3/3     27226     26938     27591
        Jan 20 2020 18:44:49.171         3/3     26976     26644     27143
        Jan 20 2020 18:44:34.171         3/3     26880     26679     27265
        Jan 20 2020 18:44:19.170         3/3     26994     26630     27422
        Jan 20 2020 18:44:06.543         3/3     45407     26629     82600

    Atomic path:
      Hops                    : 127.0.0.1
      Delay-Measurement history (uSec):
        Probe Start Timestamp     Pkt(TX/RX)   Average       Min       Max
        Jan 20 2020 18:46:34.174         3/3     26865     26705     26988
        Jan 20 2020 18:46:19.174         3/3     26846     26822     26881
        Jan 20 2020 18:46:04.173         3/3     26787     26581     26939
        Jan 20 2020 18:45:49.172         3/3     26954     26728     27180
        Jan 20 2020 18:45:34.172         3/3     26724     26577     26957
        Jan 20 2020 18:45:19.171         3/3     26705     26452     27032
        Jan 20 2020 18:45:04.171         3/3     27043     26972     27124
        Jan 20 2020 18:44:49.171         3/3     26848     26550     27062
        Jan 20 2020 18:44:34.171         3/3     26800     26562     27204
        Jan 20 2020 18:44:19.170         3/3     26927     26576     27327
        Jan 20 2020 18:44:06.543         3/3     45128     26521     81961

    Atomic path:
      Hops                    : 192.168.0.4
      Delay-Measurement history (uSec):
        Probe Start Timestamp     Pkt(TX/RX)   Average       Min       Max
        Jan 20 2020 18:46:34.174         3/3     26848     26684     26967
        Jan 20 2020 18:46:19.174         3/3     26871     26833     26913
        Jan 20 2020 18:46:04.173         3/3     26759     26571     26876
        Jan 20 2020 18:45:49.172         3/3     26947     26713     27163
        Jan 20 2020 18:45:34.172         3/3     26708     26557     26939
        Jan 20 2020 18:45:19.171         3/3     26708     26435     27075
        Jan 20 2020 18:45:04.171         3/3     27078     27016     27138
        Jan 20 2020 18:44:49.171         3/3     26812     26539     27043
        Jan 20 2020 18:44:34.171         3/3     26793     26582     27181
        Jan 20 2020 18:44:19.170         3/3     26911     26558     27308
        Jan 20 2020 18:44:06.543         3/3     45119     26512     81956

Router# show performance-measurement counters sr-policy name srte_c_10_ep_192.168.0.4
Mon Jan 20 18:47:55.499 PST

------------------------------------------------------------------------------
0/0/CPU0
------------------------------------------------------------------------------
SR Policy name: srte_c_10_ep_192.168.0.4
  Candidate-Path:
    Instance                : 2
    Preference              : 100
    Protocol-origin         : Configured
    Discriminator           : 100
    Packets:
      Total sent                            : 141
      Total received                        : 141
    Errors:
      Total sent errors                     : 0
      Total received errors                 : 0
    Probes:
      Total started                         : 16
```

```
    Total completed                          : 15
    Total incomplete                         : 0
    Total advertisements                     : 2
  Segment-List              : R4
    16004
    Packets:
      Total sent                             : 141
      Total received                         : 141
    Errors:
      Total sent errors                      : 0
      Total received errors                  : 0
    Probes:
      Total started                          : 16
      Total completed                        : 15
      Total incomplete                       : 0
      Total advertisements                   : 2
```

SR Policy Liveness Monitoring

Table 6: Feature History Table

Feature Name	Release Information	Feature Description
SR Policy Liveness Monitoring	Release 7.3.1	This feature allows you to verify end-to-end traffic forwarding over an SR Policy candidate path by periodically sending performance monitoring packets.

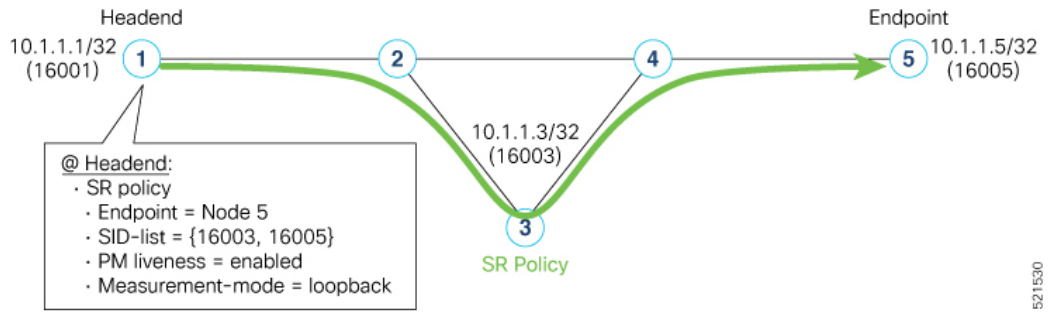
SR Policy liveness monitoring allows you to verify end-to-end traffic forwarding over an SR Policy candidate path by periodically sending performance monitoring (PM) packets. The head-end router sends PM packets to the SR policy's endpoint router, which sends them back to the head-end without any control-plane dependency on the endpoint router.

The following are benefits to using SR-PM liveness monitoring:

- Allows both liveness monitoring and delay measurement using a single-set of PM packets as opposed to running separate monitoring sessions for each purpose. This improves the overall scale by reducing the number of PM sessions required.
- Eliminates network and device complexity by reducing the number of monitoring protocols on the network (for example, no need for Bidirectional Failure Detection [BFD]). It also simplifies the network and device operations by not requiring any signaling to bootstrap the performance monitoring session.
- Improves interoperability with third-party nodes because signaling protocols aren't required. In addition, it leverages the commonly supported TWAMP protocol for packet encoding.
- Improves liveness detection time because PM packets aren't punted on remote nodes
- Provides a common solution that applies to data-planes besides MPLS, including IPv4, IPv6, and SRv6.

The workflow associated with liveness detection over SR policy is described in the following sequence.

Consider an SR policy programmed at head-end node router 1 towards end-point node router 5. This SR policy is enabled for liveness detection using the loopback measurement-mode.



- **A**: The head-end node creates and transmits the PM probe packets.

  The IP destination address (DA) on the probe packets is set to the loopback value of the head-end node itself.

  A transmit (Tx) timestamp is added to the payload.

  Optionally, the head-end node may also insert extra encapsulation (labels) to enforce the reverse path at the endpoint node.

  Finally, the packet is injected into the data-plane using the same encapsulation (label stack) of that of the SR policy being monitored.

- **B**: The network delivers the PM probe packets as it would user traffic over the SR policy.

- **C**: The end-point node receives the PM probe packets.

  Packets are switched back based on the forwarding entry associated with the IP DA of the packet. This would typically translate to the end-point node pushing the prefix SID label associated with the head-end node.

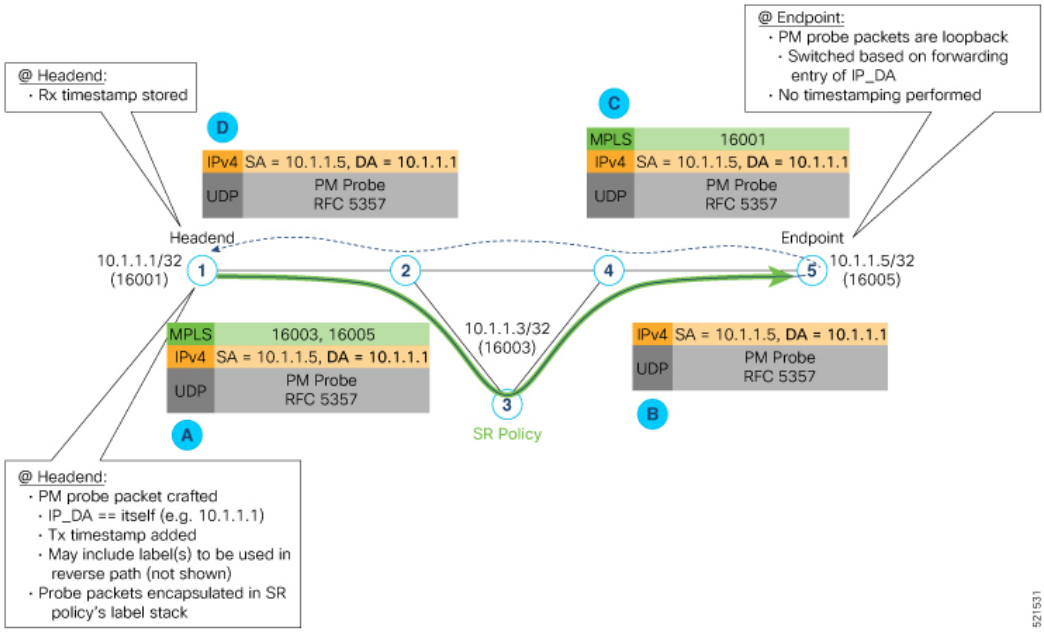
  If the head-end node inserted label(s) for the reverse path, then the packets are switched back at the end-point node based on the forwarding entry associated with the top-most reverse path label.

- **D**: Headend node receives the PM probe packets.

  A received (Rx) timestamp stored.

  If the head-end node receives the PM probe packets, the head-end node assume that the SR policy active candidate path is up and working.

  If the head-end node doesn't receive the specified number of consecutive probe packets (based on configured multiplier), the head-end node assumes the candidate path is down and a configured action is trigerred.



Usage Guidelines and Limitations

The following usage guidelines and limitations apply:

Configuring SR Policy Liveness Monitoring

Configuring SR Policy liveness monitoring involves the following steps:

- Configuring a performance measurement liveness profile to customize generic probe parameters
- Enabling liveness monitoring under SR Policy by associating a liveness profile, and customizing SR policy-specific probe parameters

Configuring Performance Measurement Liveness Profile

Liveness monitoring parameters are configured under **performance-measurement liveness-profile** sub-mode. The following parameters are configurable:

- **liveness-profile sr-policy {default | name** *name*}

  Parameters defined under the **sr-policy default** liveneness-profile apply to any SR policy with liveness monitoring enabled and that does not reference a non-default (named) liveneness-profile.

- **probe**: Configure the probe parameters.
- **measurement-mode**: Liveness detection must use loopback mode (see Measurement Modes, on page 2).
- **burst interval**: Interval for sending probe packet. The default value is 3000 milliseconds and the range is from 30 to 15000 milliseconds.
- **tos dscp** *value*: The default value is 48 and the range is from 0 to 63. You can modify the DSCP value of the probe packets, and use this value to priortize the probe packets from headend to tailend.

- **sweep destination ipv4 127.*x.x.x* range** *range*: Configure SR Policy ECMP IP-hashing mode. Specifiy the number of IP addresses to sweep. The range is from 0 (default, no sweeping) to 128. The option is applicable to IPv4 packets.

Note The destination IPv4 headendaddress 127.x.x.x – 127.y.y.y is used in the Probe messages to take advantages of 3-tuple IP hashing (source-address, destination-address, and local router ID) for ECMP paths of SR-MPLS Policy.

The destination IPv4 address must be 127/8 range (loopback), otherwise it will be rejected.

Note One PM session is always created for the actual endpoint address of the SR Policy.

- **liveness-detection**: Configure the liveness-detection parameters:
- **multiplier**: Number of consecutive missed probe packets before the PM session is declared as down. The range is from 2 to 10, and the default is 3.

Note The detection-interval is equal to (burst-interval * multiplier).

Enabling Liveness Monitoring under SR Policy

Enable liveness monitoring under SR Policy, associate a liveness-profile, and configure SR Policy-specific probe parameters under the **segment-routing traffic-eng policy performance-measurement** sub-mode. The following parameters are configurable:

- **liveness-detection**: Enables end-to-end SR Policy Liveness Detection for all segment-lists of the active and standby candidate-path that are in the forwarding table.
- **liveness-profile name** *name*: Specifies the profile name for named profiles.
- **invalidation-action {down | none}**:
  - **Down (default)**: When the PM liveness session goes down, the candidate path is immediately operationally brought down.
  - **None**: When the PM liveness session goes down, no action is taken. If logging is enabled, the failure is logged but the SR Policy operational state isn't modified.
- **logging session-state-change**: Enables Syslog messages when the session state changes.
- **reverse-path label** {*BSID-value* | *NODE-SID-value*}: Specifies the MPLS label to be used for the reverse path for the reply. If you configured liveness detection with ECMP hashing, you must specify the reverse path. The default reverse path uses IP Reply.
  - *BSID-value*: The Binding SID (BSID) label for the reverse SR Policy. (This is practical for manual SR policies with a manual BSID.)

- *NODE-SID-value*: The absolute SID label of the (local) Sender Node to be used for the reverse path for the reply.

Configuration Examples

Configure a Default SR-Policy PM Liveness-Profile

The following example shows a default sr-policy liveness-profile:

```
RP/0/RSP0/CPU0:ios(config)# performance-measurement
RP/0/RSP0/CPU0:ios(config-perf-meas)# liveness-profile sr-policy default
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# probe
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# measurement-mode loopback
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# burst-interval 1500
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# tos dscp 52
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# exit
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# liveness-detection
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-ld)# multiplier 5
```

Running Configuration:

```
performance-measurement
 liveness-profile sr-policy default
  liveness-detection
   multiplier 5
  !
  probe
   tos dscp 52
   measurement-mode loopback
   burst-interval 1500
  !
 !
!
end
```

Configure a Named (Non-Default) SR-Policy PM Liveness-Profile

The following example shows a named sr-policy liveness-profile:

```
RP/0/RSP0/CPU0:ios(config)# performance-measurement
RP/0/RSP0/CPU0:ios(config-perf-meas)# liveness-profile name sample-profile
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# probe
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# measurement-mode loopback
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# burst-interval 1500
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# tos dscp 52
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# exit
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# liveness-detection
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-ld)# multiplier 5
```

Running Configuration:

```
performance-measurement
 liveness-profile sr-policy name sample-profile
  liveness-detection
   multiplier 5
  !
  probe
   tos dscp 52
   measurement-mode loopback
   burst-interval 1500
  !
```

```
 !
!
end
```

Configure a SR-Policy PM Liveness-Profile with Sweep Parameters

The following example shows a named liveness-profile with sweep parameters:

```
RP/0/RSP0/CPU0:ios(config)# performance-measurement
RP/0/RSP0/CPU0:ios(config-perf-meas)# liveness-profile name sample-profile
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# probe
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# measurement-mode loopback
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# burst-interval 1500
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# tos dscp 52
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# sweep
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe-sweep)# destination ipv4 127.0.0.1 range 25
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe-sweep)# exit
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-probe)# exit
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy)# liveness-detection
RP/0/RSP0/CPU0:ios(config-pm-ld-srpolicy-ld)# multiplier 5
```

Running Configuration

```
performance-measurement
 liveness-profile sr-policy name sample-profile
  liveness-detection
   multiplier 5
  !
  probe
   tos dscp 52
   sweep
    destination ipv4 127.0.0.1 range 25
   !
   measurement-mode loopback
   burst-interval 1500
  !
 !
!
end
```

Enable Liveness Monitoring Under SR Policy

The following example shows how to enable liveness monitoring under SR Policy, associate a liveness-profile, and configure the invalidation action:

```
RP/0/RSP0/CPU0:ios(config)# segment-routing traffic-eng
RP/0/RSP0/CPU0:ios(config-sr-te)# policy FOO
RP/0/RSP0/CPU0:ios(config-sr-te-policy)# performance-measurement
RP/0/RSP0/CPU0:ios(config-sr-te-policy-perf-meas)# liveness-detection
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# liveness-profile name sample-profile
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# invalidation-action none
```

Running Config

```
segment-routing
 traffic-eng
  policy FOO
   performance-measurement
    liveness-detection
     liveness-profile name sample-profile
     invalidation-action none
    !
   !
  !
 !
```

```
!
end
```

Enable Liveness Monitoring under SR Policy with Optional Parameters

The following example shows how to enable liveness monitoring under SR Policy, associate a liveness-profile, and configure reverse path label and session logging:

```
RP/0/RSP0/CPU0:ios(config)# segment-routing traffic-eng
RP/0/RSP0/CPU0:ios(config-sr-te)# policy BAA
RP/0/RSP0/CPU0:ios(config-sr-te-policy)# performance-measurement
RP/0/RSP0/CPU0:ios(config-sr-te-policy-perf-meas)# liveness-detection
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# liveness-profile name sample-profile
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# invalidation-action down
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# logging session-state-change
RP/0/RSP0/CPU0:ios(config-sr-te-policy-live-detect)# exit
RP/0/RSP0/CPU0:ios(config-sr-te-policy-perf-meas)# reverse-path label 16001
```

Running Config

```
segment-routing
 traffic-eng
  policy BAA
   performance-measurement
    liveness-detection
     logging
      session-state-change
     !
     liveness-profile name sample-profile
     invalidation-action down
    !
    reverse-path
     label 16001
    !
   !
  !
 !
!
end
```