Performance Measurement Using TWAMP Light for Segment Routing Networks
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Abstract

Segment Routing (SR) leverages the source routing paradigm. SR is applicable to both Multiprotocol Label Switching (SR-MPLS) and IPv6 (SRv6) data planes. This document specifies procedure for sending and processing probe query and response messages for Performance Measurement (PM) in Segment Routing networks. The procedure uses the mechanisms defined in RFC 5357 (Two-Way Active Measurement Protocol (TWAMP) Light) for Delay Measurement, and also uses the mechanisms defined in this document for Loss Measurement. The procedure specified is applicable to SR-MPLS and SRv6 data planes and are used for both links and end-to-end SR Policies.

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1. Introduction

Segment Routing (SR) leverages the source routing paradigm and greatly simplifies network operations for Software Defined Networks (SDNs). SR is applicable to both Multiprotocol Label Switching (SR-MPLS) and IPv6 (SRv6) data planes. SR takes advantage of the Equal-Cost Multipaths (ECMPs) between source and transit nodes, between transit nodes and between transit and destination nodes. SR Policies as defined in [I-D.spring-segment-routing-policy] are used to steer traffic through a specific, user-defined paths using a stack of Segments. Built-in SR Performance Measurement (PM) is one of the essential requirements to provide Service Level Agreements (SLAs).

The One-Way Active Measurement Protocol (OWAMP) defined in [RFC4656] and Two-Way Active Measurement Protocol (TWAMP) defined in [RFC5357] provide capabilities for the measurement of various performance metrics in IP networks using probe messages. These protocols rely on control-channel signaling to establish a test-channel over an UDP path. These protocols lack support for direct-mode Loss Measurement (LM) to detect actual data traffic loss which is required in SR networks. The Simple Two-way Active Measurement Protocol (STAMP) [I-D.ippm-stamp] alleviates the control-channel signaling by using configuration data model to provision a test-channel. The TWAMP Light [Appendix I in RFC5357] [BBF.TR-390] provides simplified mechanisms for active performance measurement in Customer IP networks by provisioning UDP paths and eliminates the control-channel signaling.

This document specifies procedures for sending and processing probe query and response messages for Performance Measurement in SR networks. The procedure uses the mechanisms defined in [RFC5357] (TWAMP Light) for Delay Measurement (DM), and also uses the mechanisms defined in this document for Loss Measurement. The procedure specified is applicable to SR-MPLS and SRv6 data planes and are used for both links and end-to-end SR Policies. This document also defines mechanisms for handling ECMPs of SR Policies for performance delay measurements.
2. Conventions Used in This Document

2.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2.2. Abbreviations

BSID: Binding Segment ID.
DM: Delay Measurement.
ECMP: Equal Cost Multi-Path.
LM: Loss Measurement.
MPLS: Multiprotocol Label Switching.
PM: Performance Measurement.
PSID: Path Segment Identifier.
PTP: Precision Time Protocol.
SID: Segment ID.
SL: Segment List.
SR: Segment Routing.
SR-MPLS: Segment Routing with MPLS data plane.
SRv6: Segment Routing with IPv6 data plane.
TC: Traffic Class.
2.3. Reference Topology

In the reference topology shown below, the sender node R1 initiates a probe query for performance measurement and the responder node R5 sends a probe response for the query message received. The probe response is sent to the sender node R1. The nodes R1 and R5 may be directly connected via a link enabled with Segment Routing or there exists a Point-to-Point (P2P) SR Policy [I-D.spring-segment-routing-policy] on node R1 with destination to node R5. In case of Point-to-Multipoint (P2MP), SR Policy originating from source node R1 may terminate on multiple destination leaf nodes [I-D.spring-sr-p2mp-policy].

```
+-------+        Query        +-------+
|       | - - - - - - - - ->|       |
|   R1  |---------------------|   R5  |
|       |<- - - - - - - - - |       |
+-------+       Response      +-------+

Sender                       Responder
```

Reference Topology

3. Overview

For one-way, two-way and round-trip delay measurements in Segment Routing networks, the TWAMP Light procedures defined in Appendix I of [RFC5357] are used. For one-way and two-way direct-mode and inferred-mode loss measurements in Segment Routing networks, the procedures defined in this document are used. One-way loss measurement provides receive packet loss whereas two-way loss measurement provides both transmit and receive packet loss. Separate UDP destination port numbers are user-configured for delay and loss measurements from the range specified in [I-D.ippm-stamp]. The sender uses the UDP port number following the guidelines specified in Section 6 in [RFC6335]. For both links and end-to-end SR Policies, no PM session for delay or loss measurement is created on the responder node R5 [RFC5357].

For Performance Measurement, probe query and response messages are sent as following:

- For Delay Measurement, the probe messages are sent on the congruent path of the data traffic by the sender node, and are used to measure the delay experienced by the actual data traffic flowing on the links and SR Policies.
For Loss Measurement, the probe messages are sent on the congruent path of the data traffic by the sender node, and are used to collect the receive traffic counters for the incoming link or incoming SID where the probe query messages are received at the responder node (incoming link or incoming SID needed since the responder node does not have PM session state present).

The In-Situ Operations, Administration, and Maintenance (IOAM) mechanisms for SR-MPLS defined in [I-D.spring-ioam-sr-mpls] and for SRv6 defined in [I-D.spring-ioam-srv6] are used to carry PM information such as timestamp in-band as part of the data packets, and are outside the scope of this document.

### 3.1. Example Provisioning Model

An example of a provisioning model and typical measurement parameters for performance delay and loss measurements using TWAMP Light is shown in the following Figure:

```
+------------+            +------------+  
| Controller |            | Measurement Protocol |  
+------------+            | Measurement Protocol |  
|          / \          / \  
| Destination UDP Port | Delay/Loss |  
|          / \          / \  
| Measurement Type | Measurement Type |  
|          / \          / \  
| Delay/Loss | Authentication Mode & Key |  
|          / \          / \  
| Authentication Mode & Key |  
|          / \          / \  
| Timestamp Format | Delay Measurement Mode |  
|          / \          / \  
| Delay Measurement Mode | Padding/MBZ Bytes |  
|          / \          / \  
| Padding/MBZ Bytes | Loss Measurement Mode |  
|          / \          / \  
| Loss Measurement Mode |  
|          / \          / \  
|          v \          v \  
| R1               R5          
|                   
+--++          +--++
| Sender        | Responder     
```

The responder node R5 uses the parameters for the timestamp format, delay measurement mode, padding size and loss measurement mode from the received probe query message.

The mechanisms to provision the sender and responder nodes are outside the scope of this document.
3.2. STAMP Applicability

The Simple Two-way Active Measurement Protocol (STAMP) [I-D.ippm-stamp] and the STAMP TLVs [I-D.ippm-stamp-option-tlv] are both equally applicable to the procedures specified in this document. This is because the delay measurement message formats defined for STAMP and STAMP TLVs are backwards compatible with the delay measurement message formats defined in [RFC5357]. Hence, the same user-configured destination UDP port for delay measurement can be used for STAMP and TWAMP Light messages. The STAMP with a TLV for "direct measurement" can be used for combined delay + loss measurement using a separate user-configured UDP destination port.

The loss measurement probe and query messages defined in this document are also equally applicable to STAMP and STAMP TLVs, by using the packet padding size of 30 octets as used by the STAMP payload.

4. Probe Messages

4.1. Probe Query Message

In this document, the probe messages defined in [RFC5357] are used for Delay and Loss measurements for SR links and end-to-end SR Policies. The user-configured destination UDP ports (separate UDP ports for different delay and loss message formats) are used for identifying the PM probe packets as described in Appendix I of [RFC5357].

4.1.1. Delay Measurement Probe Query Message

The message content for Delay Measurement probe query message using UDP header [RFC768] is shown in Figure 1. The DM probe query message is sent with user-configured Destination UDP port number for DM. The Destination UDP port cannot be used as Source port, since the message does not have any indication to distinguish between query and response. The DM probe query message contains the payload for delay measurement defined in Section 4.1.2 of [RFC5357]. For symmetrical size query and response messages [RFC6038], the DM probe query message contains the payload format defined in Section 4.2.1 of [RFC5357].

```plaintext
+---------------------------------------------------------------+
| IP Header                                                      |
| . Source IP Address = Sender IPv4 or IPv6 Address              |
| . Destination IP Address = Responder IPv4 or IPv6 Address      |
| . Protocol = UDP                                               |
```
Figure 1: DM Probe Query Message

Timestamp field is eight bytes. It is recommended to use the IEEE 1588v2 Precision Time Protocol (PTP) truncated 64-bit timestamp format [IEEE1588] as specified in [RFC8186].

4.1.1.1. Delay Measurement Authentication Mode

When using the authenticated mode for delay measurement, the matching authentication type (e.g. HMAC-SHA-256) and key are user-configured on both the sender and responder nodes. A separate user-configured destination UDP port is used for the delay measurement in authentication mode due to the different probe message format.

4.1.2. Loss Measurement Probe Query Message

In this document, new probe query message formats are defined for loss measurement as shown in Figure 3A and Figure 3B. The message formats are hardware efficient due to the small size payload and well-known locations of counters. They are similar to the delay measurement message formats and do not require any backwards compatibility and support for the existing DM message formats from [RFC5357].

The message content for Loss Measurement probe query message using UDP header [RFC768] is shown in Figure 2. The LM probe query message is sent with user-configured Destination UDP port number for LM. Separate Destination UDP ports are used for direct-mode and inferred-mode loss measurements. The Destination UDP port cannot be used as Source port, since the message does not have any indication to distinguish between query and response. The LM probe query message contains the payload for loss measurement as defined in Figure 3A and Figure 3B. For symmetrical size query and response messages [RFC6038], the LM probe query message contains the payload format defined in Figure 7A and Figure 7B for loss measurement.
Figure 2: DM Probe Query Message

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Transmit Counter                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|X|B|I|  Reserved               |         Block Number          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                                                               |
|                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                               |      Checksum Complement      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3A: LM Probe Query Message

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MBZ (12 octets)                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
Figure 3B: LM Probe Query Message - Authenticated Mode

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----------------------------------------------+
<table>
<thead>
<tr>
<th>Sequence Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------------------------------------------</td>
</tr>
</tbody>
</table>
+-----------------------------------------------+

Figure 3C: LM Probe Query Message for STAMP

```

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----------------------------------------------+
|          Sequence Number                      |
+-----------------------------------------------+
```
Sequence Number (32-bit): As defined in [RFC5357].

Transmit Counter (64-bit): The number of packets sent by the sender node in the query message and by the responder node in the response message. The counter is always written at the fixed location in the probe query and response messages.

Receive Counter (64-bit): The number of packets received at the responder node. It is written by the responder node in the probe response message.

Sender Counter (64-bit): This is the exact copy of the transmit counter from the received query message. It is written by the responder node in the probe response message.

Sender Sequence Number (32-bit): As defined in [RFC5357].

Sender TTL: As defined in [RFC5357].

Flag: The meanings of the Flag bits are:

X: Extended counter format indicator. Indicates the use of extended (64-bit) counter values. Initialized to 1 upon creation (and prior to transmission) of an LM Query and copied from an LM Query to an LM response. Set to 0 when the LM message is
transmitted or received over an interface that writes 32-bit counter values.

B: Octet (byte) count. When set to 1, indicates that the Counter 1-4 fields represent octet counts. The octet count applies to all packets within the LM scope, and the octet count of a packet sent or received includes the total length of that packet (but excludes headers, labels, or framing of the channel itself). When set to 0, indicates that the Counter fields represent packet counts.

I: Inferred Mode Loss Measurement: When set to 1, indicates that inferred-mode of loss measurement is used. When set to 0, it indicates direct-mode of loss measurement is used.

Block Number (16-bit): The Loss Measurement using Alternate-Marking method defined in [RFC8321] requires to identify the Block Number (or color) of the traffic counters. The probe query and response messages carry Block Number for the traffic counters for loss measurement. In both probe query and response messages, the counters MUST belong to the same Block Number.

HMAC: The PM probe packet in authenticated mode includes a key Hashed Message Authentication Code (HMAC) ([RFC2104]) hash. Each probe query and response messages are authenticated by adding Sequence Number with Hashed Message Authentication Code (HMAC) TLV. It can use HMAC-SHA-256 truncated to 128 bits (similarly to the use of it in IPSec defined in [RFC4868]); hence the length of the HMAC field is 16 octets.

HMAC uses its own key and the mechanism to distribute the HMAC key is outside the scope of this document.

In authenticated mode, only the sequence number is encrypted, and the other payload fields are sent in clear text. The probe packet MAY include Comp.MBZ (Must Be Zero) variable length field to align the packet on 16 octets boundary.

4.1.2.1. Loss Measurement Authentication Mode

When using the authenticated mode for loss measurement, the matching authentication type (e.g. HMAC-SHA-256) and key are user-configured on both the sender and responder nodes. A separate user-configured destination UDP port is used for the loss measurement in authentication mode due to the different message format.

4.1.3. Probe Query for SR Links
The probe query message as defined in Figure 1 is sent on the congruent path of the data traffic for Delay measurement. The probe query message as defined in Figure 2 is sent on the congruent path of the data traffic for Loss measurement.

4.1.4. Probe Query for End-to-end Measurement for SR Policy

The performance delay and loss measurement for segment routing is applicable to both SR-MPLS and SRv6 Policies.

4.1.4.1. Probe Query Message for SR-MPLS Policy

The probe query messages for end-to-end performance measurement of an SR-MPLS Policy is sent using its SR-MPLS header containing the MPLS segment list as shown in Figure 4.

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Segment List(1)        | TC  |S|      TTL      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
         0                   1                   2                   3
9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Segment List(n)        | TC  |S|      TTL      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                PSID                   | TC  |S|      TTL      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Message as shown in Figure 1 for DM or Figure 2 for LM      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Probe Query Message for SR-MPLS Policy

The Segment List (SL) can be empty to indicate Implicit NULL label case for a single-hop SR Policy.

The Path Segment Identifier (PSID) [I-D.spring-mpls-path-segment] of the SR-MPLS Policy is used for accounting received traffic on the egress node for loss measurement. The PSID is not required for end-to-end SR Policy delay measurement.

4.1.4.2. Probe Query Message for SRv6 Policy

An SRv6 Policy setup using the SRv6 Segment Routing Header (SRH) and a Segment List as defined in [I-D.6man-segment-routing-header]. The probe query messages for end-to-end performance measurement of an
SRv6 Policy is sent using its SRv6 Segment Routing Header (SRH) and Segment List as shown in Figure 5.

+---------------------------------------------------------------+   SRH
|   END.OTP (DM) or END.OP (LM) with Target SRv6 SID           |
|                                                               |
+---------------------------------------------------------------+
| Message as shown in Figure 1 for DM or Figure 2 for LM       |
| (Using IPv6 Source and Destination Addresses)                |
|                                                               |
+---------------------------------------------------------------+

Figure 5: Probe Query Message for SRv6 Policy

For delay measurement of SRv6 Policy using SRH, END function END.OTP [I-D.6man-srv6-oam] is used with the target SRv6 SID to punt probe messages on the target node, as shown in Figure 5. Similarly, for loss measurement of SRv6 Policy, END function END.OP [I-D.6man-srv6-oam] is used with target SRv6 SID to punt probe messages on the target node.

4.2. Probe Response Message

The probe response message is sent using the IP/UDP information from the received probe query message. The content of the probe response message is shown in Figure 6.

+---------------------------------------------------------------+   IP Header
|   Source IP Address = Responder IPv4 or IPv6 Address          |
|   Destination IP Address = Source IP Address from Query      |
|   Protocol = UDP                                            |
|                                                               |
+---------------------------------------------------------------+
|   UDP Header                                                |
|   Source Port = As chosen by Responder                      |
|   Destination Port = Source Port from Query                 |
|                                                               |
+---------------------------------------------------------------+
|   DM Payload as specified in Section 4.2.1 of RFC 5357, or   |
|   LM Payload as specified in Figure 7A or 7B in this document |
|                                                               |
+---------------------------------------------------------------+

Figure 6: Probe Response Message
In this document, new probe response message formats are defined for loss measurement as shown in Figure 7A and Figure 7B. The message formats are hardware efficient due to the small size payload and well known locations of the counters. They are also similar to the delay measurement message formats.

Figure 7A: LM Probe Response Message

![Diagram showing the message format with fields labeled: Sequence Number, Transmit Counter, MBZ (12 octets), Transmit Counter, Block Number, Receive Counter, Sender Sequence Number, Sender Counter, Sender Block Number, Sender TTL, Packet Padding, Checksum Complement]
4.2.1. One-way Measurement Mode

Figure 7B: LM Probe Response Message - Authenticated Mode
In one-way performance measurement mode, the probe response message as defined in Figure 6 is sent back out of band to the sender node, for both SR links and SR Policies.

4.2.2. Two-way Measurement Mode

In two-way performance measurement mode, when using a bidirectional path, the probe response message as defined in Figure 6 is sent back on the congruent path of the data traffic to the sender node, for both SR links and SR Policies.

4.2.2.1. Return Path TLV

For two-way performance measurement, the responder node needs to send the probe response message on a specific reverse path. This way the destination node does not require any additional state. The sender node can request in the probe query message to the responder node to send a response back on a given reverse path (e.g. co-routed path for two-way measurement).

[I-D.ippm-stamp-option-tlv] defines STAMP probe query messages that can include one or more optional TLVs. New TLV Type (TBA1) is defined in this document for Return Path to carry reverse path for probe response messages (in the payload of the message). The format of the Return Path TLV is shown in Figure 8A and Figure 8B:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type = TBA1  |    Length     |      Reserved                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Return Path Sub-TLVs                       |
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8A: Return Path TLV

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |      Reserved                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Segment List(1)                            |
.                                                               .
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
.                                                               .
```

The Segment List Sub-TLV in the Return Path TLV can be one of the following Types:

- Type (value 1): Respond back on Incoming Interface (Layer-3 and Layer-2) (Segment List is Empty)
- Type (value 2): SR-MPLS Segment List (Label Stack) of the Reverse SR Path
- Type (value 3): SR-MPLS Binding SID [I-D.pce-binding-label-sid] of the Reverse SR Policy
- Type (value 4): SRv6 Segment List of the Reverse SR Path
- Type (value 5): SRv6 Binding SID [I-D.pce-binding-label-sid] of the Reverse SR Policy

The Return Path TLV is optional. The PM sender node MUST only insert one Return Path TLV in the probe query message and the responder node MUST only process the first Return Path TLV in the probe query message and ignore other Return Path TLVs if present. The responder node MUST send probe response message back on the reverse path specified in the Return Path TLV and MUST NOT add Return Path TLV in the probe response message.

4.2.2.2. Probe Response Message for SR-MPLS Policy

The message content for sending probe response message for two-way end-to-end performance measurement of an SR-MPLS Policy is shown in Figure 9.

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Segment List(1)        | TC  |S|      TTL      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
4.2.2.3. Probe Response Message for SRv6 Policy

The message content for sending probe response message on the congruent path of the data traffic for two-way end-to-end performance measurement of an SRv6 Policy with SRH is shown in Figure 10.

Figure 10: Probe Response Message for SRv6 Policy

4.2.3. Loopback Measurement Mode

The Loopback measurement mode can be used to measure round-trip delay for a bidirectional SR Path. The IP header of the probe query message contains the destination address equals to the sender address and the source address equals to the responder address. Optionally, the probe query message can carry the reverse path information (e.g. reverse path label stack for SR-MPLS) as part of the SR header. The responder node does not process the PM probe messages and generate response messages.

5. Performance Measurement for P2MP SR Policies
The procedures for delay and loss measurement described in this document for Point-to-Point (P2P) SR Policies [I-D.spring-segment-routing-policy] are also equally applicable to the Point-to-Multipoint (P2MP) SR Policies [I-D.spring-sr-p2mp-policy] as following:

- The sender root node sends probe query messages using either Spray P2MP segment or TreeSID P2MP segment defined in [I-D.spring-sr-p2mp-policy] over the P2MP SR Policy as shown in Figure 1.
- Each responder leaf node sends its IP address in the Source Address of the probe response messages. This allows the sender root node to identify the responder leaf nodes of the P2MP SR Policy.
- The P2MP root node measures the end-to-end delay and loss performance for each P2MP leaf node.

Figure 11: With P2MP Segment Identifier for SR-MPLS Policy

6. ECMP Support for SR Policies

An SR Policy can have ECMPs between the source and transit nodes, between transit nodes and between transit and destination nodes. Usage of Anycast SID [RFC8402] by an SR Policy can result in ECMP paths via transit nodes part of that Anycast group. The PM probe messages need to be sent to traverse different ECMP paths to measure performance delay of an SR Policy.

Forwarding plane has various hashing functions available to forward packets on specific ECMP paths. Following mechanisms can be used in PM probe messages to take advantage of the hashing function in forwarding plane to influence the path taken by them.

- The mechanisms described in [RFC8029] and [RFC5884] for handling ECMPs are also applicable to the performance measurement. In the IP/UDP header of the PM probe messages, Destination Addresses in...
127/8 range for IPv4 or 0:0:0:0:FFFF:7F00/104 range for IPv6 can be used to exercise a particular ECMP path. As specified in [RFC6437], 3-tuple of Flow Label, Source Address and Destination Address fields in the IPv6 header can also be used.

- For SR-MPLS Policy, entropy label [RFC6790] can be used in the PM probe messages.
- For SRv6 Policy using SRH, Flow Label in the SRH [I-D.6man-segment-routing-header] of the PM probe messages can be used.

7. Additional Message Processing Rules

7.1. TTL Value

The TTL or the Hop Limit field in the IP, MPLS and SRH headers of the probe query messages are set to 255 [RFC5357].

When using the Destination IPv4 Address from the 127/8 range, the TTL in the IPv4 header is set to 1 [RFC8029]. Similarly, when using the Destination IPv6 Address from the 0:0:0:0:FFFF:7F00/104 range, the Hop Limit field in the inner IPv6 header is set to 1 whereas in the outer IPv6 header is set to 255.

7.2. Router Alert Option

The Router Alert IP option is not set when using the routable Destination IP Address in the probe messages.

When using the Destination IPv4 Address from the 127/8 range, the Router Alert IP Option of value 0x0 [RFC2113] for IPv4 is set in the IP header [RFC8029]. Similarly, when using the Destination IPv6 Address from the 0:0:0:0:FFFF:7F00/104 range, the Router Alert IP Option of value 69 [RFC7506] for IPv6 is set in the IP header.

7.3. UDP Checksum

The Checksum Complement for delay and loss measurement messages follows the procedure defined in [RFC7820] and can be optionally used with the procedures defined in this document.

For IPv4 and IPv6 probe messages, where the hardware is not capable of re-computing the UDP checksum or adding checksum complement [RFC7820], the sender node sets the UDP checksum to 0 [RFC6936] [RFC8085]. The receiving node bypasses the checksum validation and accepts the packets with UDP checksum of 0 for the UDP port being
8. Security Considerations

The performance measurement is intended for deployment in well-managed private and service provider networks. As such, it assumes that a node involved in a measurement operation has previously verified the integrity of the path and the identity of the far end responder node.

If desired, attacks can be mitigated by performing basic validation and sanity checks, at the sender, of the counter or timestamp fields in received measurement response messages. The minimal state associated with these protocols also limits the extent of measurement disruption that can be caused by a corrupt or invalid message to a single query/response cycle.

Use of HMAC-SHA-256 in the authenticated mode protects the data integrity of the probe messages. SRv6 has HMAC protection authentication defined for SRH [I-D.6man-segment-routing-header]. Hence, PM probe messages for SRv6 may not need authentication mode. Cryptographic measures may be enhanced by the correct configuration of access-control lists and firewalls.

9. IANA Considerations

IANA is requested to allocate value for the following Return Path TLV Type for [I-D.ippm-stamp-option-tlv] to be carried in PM probe query messages:

- Type TBA1: Return Path TLV

IANA is also requested to allocate the values for the following Sub-TLV Types for the Return Path TLV.

- Type (value 1): Respond back on Incoming Interface (Layer-3 and Layer-2) (Segment List is Empty)

- Type (value 2): SR-MPLS Segment List (Label Stack) of the Reverse SR Path

- Type (value 3): SR-MPLS Binding SID [I-D.pce-binding-label-sid] of the Reverse SR Policy

- Type (value 4): SRv6 Segment List of the Reverse SR Path
10. References

10.1. Normative References


10.2. Informative References


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