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**In-band Performance Measurement Using UDP Path  
for Segment Routing Networks  
draft-gandhi-spring-rfc6374-srpm-udp-00**

**Abstract**

Segment Routing (SR) is applicable to both Multiprotocol Label Switching (SR-MPLS) and IPv6 (SRv6) data planes. This document specifies procedures for using UDP path for sending and processing in-band probe query and response messages for Performance Measurement. The procedure uses the [RFC 6374](#) defined mechanisms for Delay and Loss performance measurement. The procedure specified is applicable to SR-MPLS and SRv6 data planes for both links and end-to-end measurement for SR Policies. In addition, this document defines Return Path TLV for two-way performance measurement and Block Number TLV for loss measurement.

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## [1.](#) Introduction

Segment Routing (SR) technology 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, 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 path 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. These protocols rely on control channel signaling to establish a test channel over an UDP path. These protocols lack support for IEEE 1588 timestamp [\[IEEE1588\]](#) format and direct-mode Loss Measurement (LM), which are required in SR networks [\[RFC6374\]](#). The Simple Two-way Active Measurement Protocol (STAMP) [\[I-D.ippm-stamp\]](#) alleviates the control channel signaling by using configuration data model to provision test channels. In addition, the STAMP supports IEEE 1588 timestamp format for Delay Measurement (DM). The TWAMP Light from broadband forum [\[BBF.TR-390\]](#) provides simplified mechanisms for active performance measurement in Customer Edge IP networks. [\[Y1731\]](#) specifies the mechanisms to carry OAM messages specifically for Ethernet networks that include Ethernet Frame Delay and Loss measurements.

[\[RFC6374\]](#) specifies protocol mechanisms to enable the efficient and accurate measurement of performance metrics and can be used in SR networks with MPLS data plane [\[I-D.spring-rfc6374-srpm-mpls\]](#). [\[RFC6374\]](#) addresses the limitations of the IP based performance measurement protocols as specified in [Section 1 of \[RFC6374\]](#). The [\[RFC6374\]](#) requires data plane to support MPLS Generic Associated Channel Label (GAL) and Generic Associated Channel (G-Ach), which may not be supported on all nodes in the network.

[\[RFC7876\]](#) specifies the procedures to be used when sending and processing out-of-band performance measurement probe response



messages over an UDP return path for [RFC 6374](#) based probe queries. [\[RFC7876\]](#) can be used to send out-of-band PM probe responses in both SR-MPLS and SRv6 networks for one-way performance measurement.

For SR Policies, there are ECMPs between the source and transit nodes, between transit nodes and between transit and destination nodes. Existing PM protocols (e.g. [RFC 6374](#)) do not define handling for ECMP forwarding paths in SR networks.

For two-way measurements for SR Policies, there is a need to specify a return path in the form of a Segment List in PM probe query messages without requiring any SR Policy state on the destination node. Existing protocols do not have such mechanisms to specify return path in the PM probe query messages.

This document specifies a procedure for using UDP path for sending and processing in-band probe query and response messages for Performance Measurement that does not require to bootstrap PM sessions. The procedure uses [RFC 6374](#) defined mechanisms for Delay and Loss PM and unless otherwise specified, the procedures from [RFC 6374](#) are not modified. The procedure specified is applicable to both SR-MPLS and SRv6 data planes. The procedure can be used for both SR links and end-to-end performance measurement for SR Policies. This document also defines mechanisms for handling Equal Cost Multipaths (ECMPs) of SR Policies for performance delay measurement. In addition, this document defines Return Path TLV for two-way performance measurement, Block Number TLV for loss measurement and Sequence Number TLV.

## **[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**

ACH: Associated Channel Header.

BSID: Binding Segment ID.

DFlag: Data Format Flag.

DM: Delay Measurement.



ECMP: Equal Cost Multi-Path.

G-ACh: Generic Associated Channel (G-ACh).

GAL: Generic Associated Channel (G-ACh) Label.

LM: Loss Measurement.

MPLS: Multiprotocol Label Switching.

NTP: Network Time Protocol.

OWAMP: One-Way Active Measurement Protocol.

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.

STAMP: Simple Two-way Active Measurement Protocol.

TC: Traffic Class.

TWAMP: Two-Way Active Measurement Protocol.

URO: UDP Return Object.

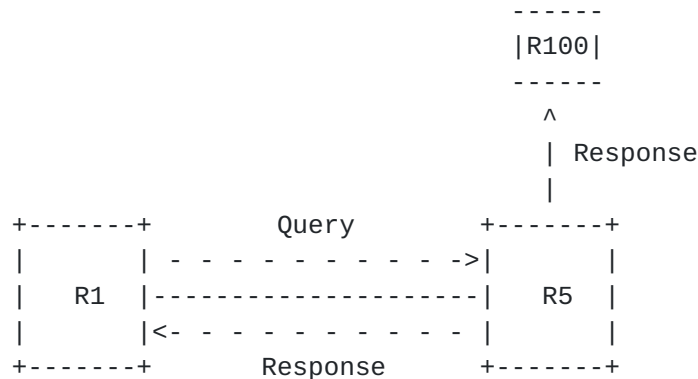
### **[2.3.](#)    Reference Topology**

In the reference topology, the querier 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 may be sent to the querier node R1 or to a controller node R100. 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](#)].



Reference Topology

Both Delay and Loss performance measurement is performed in-band for the traffic traversing between node R1 and node R5. One-way delay and two-way delay measurements are defined in [Section 2.4 of \[RFC6374\]](#). Transmit and Receive packet loss measurements are defined in [Section 2.2](#) and [Section 2.6 of \[RFC6374\]](#). One-way loss measurement provides receive packet loss whereas two-way loss measurement provides both transmit and receive packet loss.

## 2.4. In-band Probe Messages

For both Delay and Loss measurements for links and SR Policies, no PM session is created on the responder node. The probe messages for Delay measurement are sent in-band by the querier node to measure the delay experienced by the actual traffic flowing on the links and SR Policies. For Loss measurement, in-band probe messages are used to collect the traffic counter for the incoming link or incoming SID on which the probe query message is received at the responder node R5 as it has no PM session state present on the node. The performance measurement for Delay and Loss using out-of-band probe query messages are outside the scope of this document.

## 3. Probe Messages

### 3.1. Probe Query Message

In this document, UDP path is used for Delay and Loss measurements for SR links and end-to-end SR Policies. A user-configured UDP port is used for identifying PM probe packets that does not require to bootstrap PM sessions. A UDP port number from the Dynamic and/or



Private Ports range 49152-65535 is used as the destination UDP port. This approach is similar to the one defined in STAMP protocol [I-D.ippm-stamp]. The IPv4 TTL or IPv6 Hop Limit field of the IP header MUST be set to 255.

### 3.1.1. 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. The Source UDP port can be set to the same value for two-way delay measurement as indication of query and response is present in the message. The DM probe query message contains the payload for delay measurement defined in [Section 3.2 of \[RFC6374\]](#).

```

+-----+
| IP Header |
. Source IP Address = Querier IPv4 or IPv6 Address .
. Destination IP Address = Responder IPv4 or IPv6 Address .
. Protocol = UDP .
. Router Alert Option Not Set .
. .
+-----+
| UDP Header |
. Source Port = As chosen by Querier .
. Destination Port = User-configured Port for Delay Measurement.
. .
+-----+
| Payload = Message as specified in Section 3.2 of RFC 6374 |
. .
+-----+

```

Figure 1: DM Probe Query Message

### 3.1.2. Loss Measurement Probe Query Message

The message content for Loss measurement probe query message using UDP header [RFC768] is shown in Figure 2. As shown, the LM probe query message is sent with user-configured Destination UDP port number. The Source UDP port can be set to the same value for two-way loss measurement as indication of query and response is present in the message. The LM probe query message contains the payload for loss measurement defined in [Section 3.1 of \[RFC6374\]](#).

```

+-----+
| IP Header |
. Source IP Address = Querier IPv4 or IPv6 Address .

```



```

. Destination IP Address = Responder IPv4 or IPv6 Address .
. Protocol = UDP .
. Router Alert Option Not Set .
. .
+-----+
| UDP Header |
. Source Port = As chosen by Querier .
. Destination Port = User-configured Port for Loss Measurement .
. .
+-----+
| Payload = Message as specified in Section 3.1 of RFC 6374 |
. .
+-----+

```

Figure 2: LM Probe Query Message

The Path Segment Identifier (PSID) [[I-D.spring-mpls-path-segment](#)] of the SR Policy is used for accounting received traffic on the egress node for loss measurement.

### [3.1.2.1](#). Block Number TLV

The Loss Measurement using Alternate-Marking method defined in [[RFC8321](#)] requires to identify the Block Number (or color) of the traffic counters carried by the probe query and response messages. Probe query and response messages specified in [[RFC6374](#)] for Loss Measurement do not define any means to carry the Block Number.

[[RFC6374](#)] defines probe query and response messages that can include one or more optional TLVs. New TLV Type (value TBA2) is defined in this document to carry Block Number (32-bit) for the traffic counters in the probe query and response messages for loss measurement. The format of the Block Number TLV is shown in Figure 11:

```

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 TBA2  |   Length   |   Reserved   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Block Number                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Figure 11: Block Number TLV

The Block Number TLV is optional. The PM querier node SHOULD only insert one Block Number TLV in the probe query message and the responder node in the probe response message SHOULD return the first Block Number TLV from the probe query messages and ignore other Block



Number TLVs if present. In both probe query and response messages, the counters **MUST** belong to the same Block Number.

### 3.1.3. Probe Query for SR Links

The probe query message as defined in Figure 1 is sent in-band for Delay measurement. The probe query message as defined in Figure 2 is sent in-band for Loss measurement.

#### **3.1.4. Probe Query for End-to-end Measurement for SR Policy**

#### 3.1.4.1. Probe Query Message for SR-MPLS Policy

The message content for in-band probe query message using UDP header for end-to-end performance measurement of SR-MPLS Policy is shown in Figure 3.

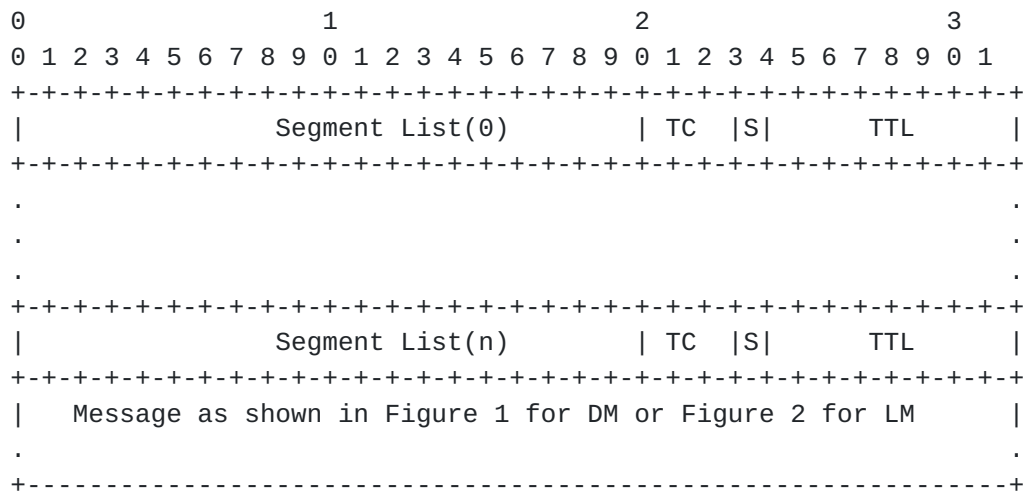
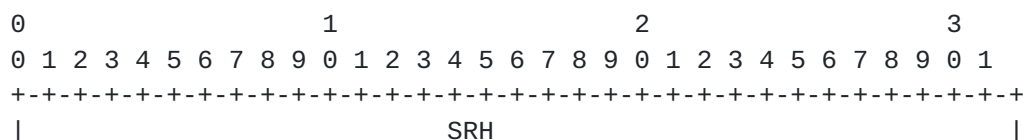


Figure 3: Probe Query Message for SR-MPLS Policy

The Segment List (SL) can be empty to indicate Implicit NULL label case.

#### 3.1.4.2. Probe Query Message for SRv6 Policy

The in-band probe query messages using UDP header for end-to-end performance measurement of an SRv6 Policy is sent using SRv6 Segment Routing Header (SRH) and Segment List of the SRv6 Policy as defined in [I-D.6man-segment-routing-header] and is shown in Figure 4.







```

.   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 Addresses)                               .
.
+-----+

```

Figure 4: Probe Query Message for SRv6 Policy

For delay measurement of SRv6 Policy, END function END.OTP [[I-D.spring-srv6-oam](#)] is used with the target SRv6 SID to punt probe messages on the target node, as shown in Figure 4. Similarly, for loss measurement of SRv6 Policy, END function END.OP [[I-D.spring-srv6-oam](#)] is used with target SRv6 SID to punt probe messages on the target node.

### 3.2. Probe Response Message

When the received probe query message does not contain any UDP Return Object (URO) TLV [[RFC7876](#)], the probe response message is sent using the IP/UDP information from the probe query message. The content of the probe response message is shown in Figure 5.

```

+-----+
| IP Header                                     |
.   Source IP Address = Responder IPv4 or IPv6 Address   .
.   Destination IP Address = Source IP Address from Query .
.   Protocol = UDP                                       .
.   Router Alert Option Not Set                         .
.
+-----+
| UDP Header                                     |
.   Source Port = As chosen by Responder                 .
.   Destination Port = Source Port from Query            .
.
+-----+
| Message as specified in Section 3.2 of RFC 6374 for DM, or |
.   Message as specified in Section 3.1 of RFC 6374 for LM   .
.
+-----+

```

Figure 5: Probe Response Message

When the received probe query message contains UDP Return Object (URO) TLV [[RFC7876](#)], the probe response message uses the IP/UDP information from the URO in the 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 = UR0.Address .
. Protocol = UDP .
. Router Alert Option Not Set .
.
+-----+
| UDP Header                                     |
. Source Port = As chosen by Responder .
. Destination Port = UR0.UDP-Destination-Port .
.
+-----+
| Message as specified in Section 3.2 of RFC 6374 for DM, or |
. Message as specified in Section 3.1 of RFC 6374 for LM .
.
+-----+

```

Figure 6: Probe Response Message Using UR0 from Probe Query Message

### **[3.2.1.](#) One-way Measurement for SR Link and end-to-end SR Policy**

For one-way performance measurement, the probe response message as defined in Figure 5 or Figure 6 is sent out-of-band for both SR links and SR Policies.

The PM querier node can receive probe response message back by properly setting its own IP address as Source Address of the header or by adding UR0 TLV in the probe query message and setting its own IP address in the IP Address in the UR0 TLV (Type=131) [[RFC7876](#)]. In addition, the "control code" in the probe query message is set to "out-of-band response requested". The "Source Address" TLV (Type 130), and "Return Address" TLV (Type 1), if present in the probe query message, are not used to send probe response message.

#### **[3.2.1.1.](#) Probe Response Message to Controller**

As shown in the Reference Topology, if the querier node requires the probe response message to be sent to the controller R100, it adds UR0 TLV in the probe query message and sets the IP address of R100 in the IP Address field and user-configured UDP port for DM and for LM in the UDP-Destination-Port field of the UR0 TLV (Type=131) [[RFC7876](#)].

### **[3.2.2.](#) Two-way Measurement for SR Links**

For two-way performance measurement, when using a bidirectional channel, the probe response message as defined in Figure 5 or Figure 6 is sent back in-band to the querier node for SR links. In this



case, the "control code" in the probe query message is set to "in-band response requested" [[RFC6374](#)].

### 3.2.3. Two-way End-to-end Measurement for SR Policy

For two-way performance measurement, when using a bidirectional channel, the probe response message is sent back in-band to the querier node for end-to-end measurement of SR Policies. In this case, the "control code" in the probe query message is set to "in-band response requested" [[RFC6374](#)].

The Path Segment Identifier (PSID) [[I-D.spring-mpls-path-segment](#)] of the forward SR Policy can be used to find the reverse SR Policy to send the probe response message for two-way measurement in the absence of Return Path TLV defined in the following Section.

#### 3.2.3.1. Return Path TLV

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

[RFC6374] defines DM and LM 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 SR path for probe response messages (in the payload of the message). The format of the Return Path TLV is shown in Figure 7A and 7B:

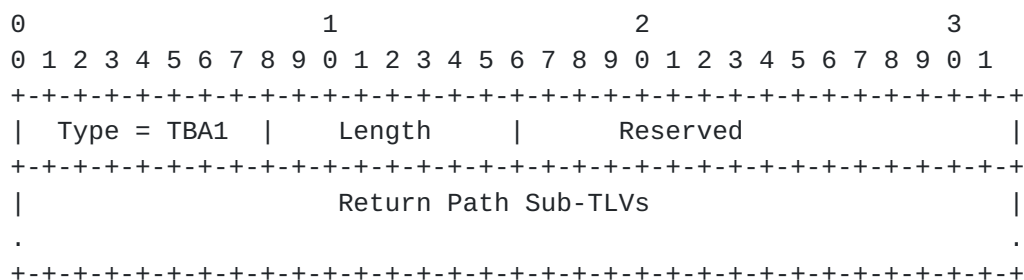
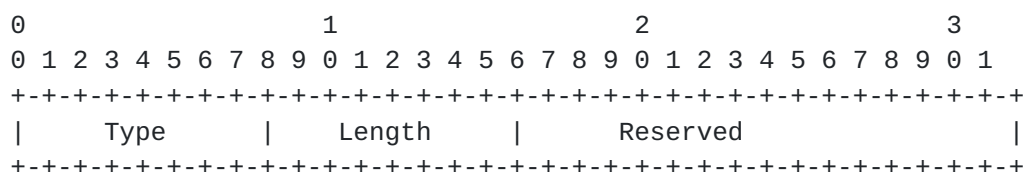


Figure 7A: Return Path TLV





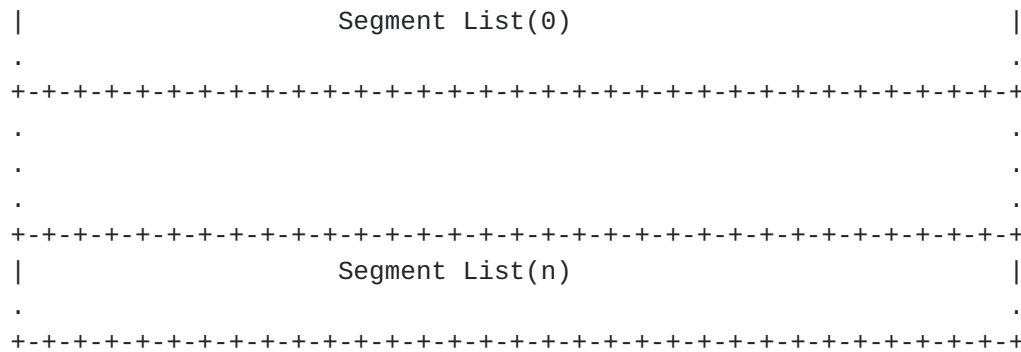


Figure 7B: Segment List Sub-TLV in Return Path TLV

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

- o Type (value 1): SR-MPLS Label Stack of the Reverse SR Policy
- o Type (value 2): SR-MPLS Binding SID [[I-D.pce-binding-label-sid](#)] of the Reverse SR Policy
- o Type (value 3): SRv6 Segment List of the Reverse SR Policy
- o Type (value 4): SRv6 Binding SID [[I-D.pce-binding-label-sid](#)] of the Reverse SR Policy

With sub-TLV Type 1, the Segment List(0) can be used by the responder node to compute the next-hop IP address and outgoing interface to send the probe response messages.

The Return Path TLV is optional. The PM querier 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.

#### 3.2.3.2. Probe Response Message for SR-MPLS Policy

The message content for sending probe response message in-band using UDP header for two-way end-to-end performance measurement of an SR-MPLS Policy is shown in Figure 8. The SR-MPLS label stack in the packet header is built using the Segment List received in the Return Path TLV in the probe query message.





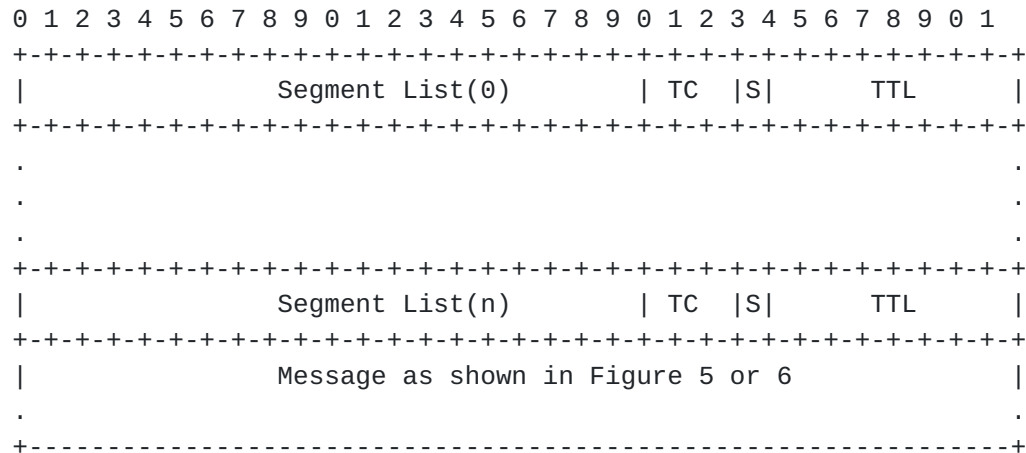


Figure 8: Probe Response Message for SR-MPLS Policy

### 3.2.3.3. Probe Response Message for SRv6 Policy

The message content for sending probe response message in-band using UDP header for two-way end-to-end performance measurement of an SRv6 Policy is shown in Figure 9. For SRv6 Policy, the SRv6 SID list in the SRH of the probe response message is built using the SRv6 Segment List received in the Return Path TLV in the probe query message.

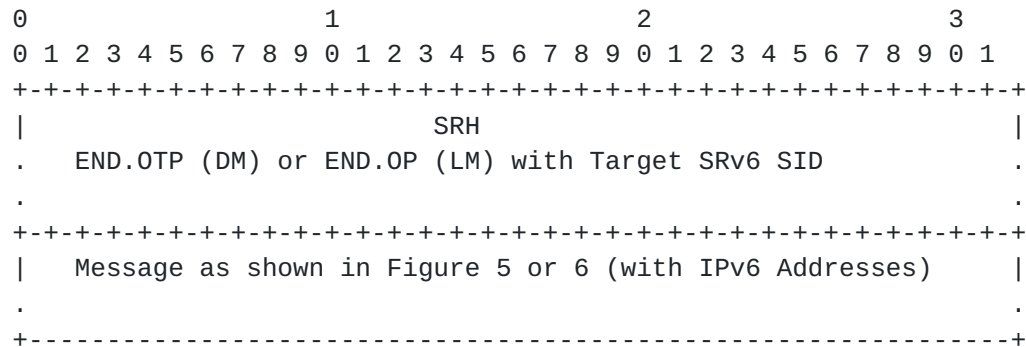


Figure 9: Probe Response Message for SRv6 Policy

## 4. Performance Measurement for P2MP SR Policies

The procedures for delay and loss measurement described in this document for Point-to-Point (P2P) SR-MPLS Policies are also equally applicable to the Point-to-Multipoint (P2MP) SR Policies.

## 5. ECMP Support

An SR Policy can have ECMPs between the source and transit nodes,







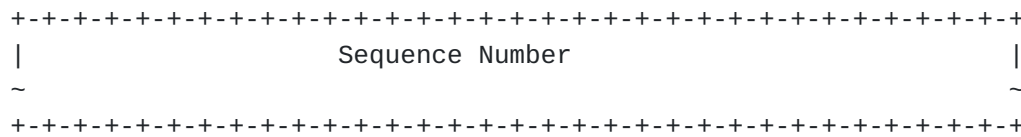


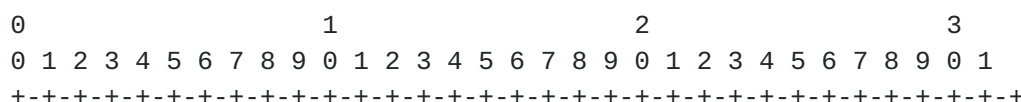
Figure 10: Sequence Number TLV - Unauthenticated Mode

- o The sequence numbers start with 0 and are incremented by one for each subsequent probe query packet.
- o The sequence number are independent for DM and LM messages.
- o The sequence number can be of any length determined by the querier node.
- o The Sequence Number TLV is optional.
- o The PM querier node SHOULD only insert one Sequence Number TLV in the probe query message and the responder node in the probe response message SHOULD return the first Sequence Number TLV from the probe query message and ignore the other Sequence Number TLVs if present.
- o When Sequence Number TLV is added, the DM and LM messages SHOULD NOT carry sequence number in the timestamp field of the message.

## 6.2. Sequence Number TLV in Authenticated Mode

The PM probe query and reply packet format in authenticated mode includes a key Hashed Message Authentication Code (HMAC) ([[RFC2104](#)]) hash. Each probe query and reply messages are authenticated by adding Sequence Number with Hashed Message Authentication Code (HMAC) TLV. It uses 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 own key and the definition of 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.





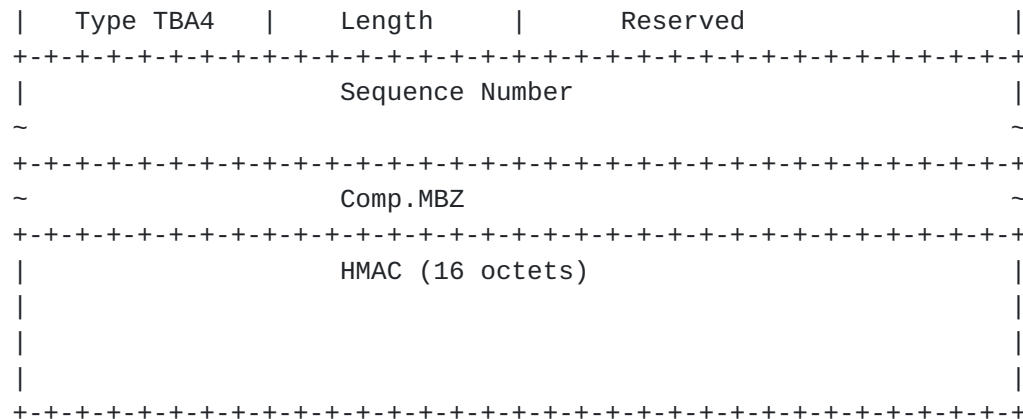


Figure 11: Sequence Number TLV - Authenticated Mode

- o This TLV is mandatory in the authenticated mode.
- o The node MUST discard the probe message if HMAC is invalid.
- o The Sequence Number follows the same processing rule as defined in the unauthenticated mode.

## 7. 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. The security considerations described in [Section 8 of \[RFC6374\]](#) are applicable to this specification, and particular attention should be paid to the last three paragraphs.

Use of HMAC-SHA-256 in the authenticated mode defined in this document 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.

## 8. IANA Considerations

IANA is requested to allocate values for the following Return Path TLV Type for [RFC 6374](#) to be carried in PM probe query messages:





- o Type TBA1: Return Path TLV

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

- o Type 1: SR-MPLS Label Stack of the Reverse SR Policy
- o Type 2: SR-MPLS Binding SID of the Reverse SR Policy
- o Type 3: SRv6 Segment List of the Reverse SR Policy
- o Type 4: SRv6 Binding SID of the Reverse SR Policy

IANA is also requested to allocate a value for the following Block Number TLV Type for [RFC 6374](#) to be carried in the PM probe query and response messages for loss measurement:

- o Type TBA2: Block Number TLV

IANA is also requested to allocate a value for the following Sequence Number TLV Types for [RFC 6374](#) to be carried in the PM probe query and response messages for delay and loss measurement:

- o Type TBA3: Sequence Number TLV in Unauthenticated Mode
- o Type TBA4: Sequence Number TLV in Authenticated Mode

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