

SPRING Working Group  
Internet-Draft  
Intended Status: Standards Track  
Expires: March 18, 2019

R. Gandhi, Ed.  
C. Filsfils  
Cisco Systems, Inc.  
D. Voyer  
Bell Canada  
S. Salsano  
Universita di Roma "Tor Vergata"  
P. L. Ventre  
CNIT  
M. Chen  
Huawei  
September 14, 2018

UDP Path for In-band  
Performance Measurement for Segment Routing Networks  
draft-gandhi-spring-udp-pm-02

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. This document also defines mechanisms for handling Equal Cost Multipaths (ECMPs) for SR Policies. In addition, this document defines Return Path Segment List TLV for two-way performance measurement and Block Number TLV for loss measurement.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <http://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

Copyright Notice

Copyright (c) 2018 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (http://trustee.ietf.org/license-info) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

1. Introduction . . . . . 3
2. Conventions Used in This Document . . . . . 4
2.1. Requirements Language . . . . . 4
2.2. Abbreviations . . . . . 4
2.3. Reference Topology . . . . . 5
3. Probe Messages . . . . . 6
3.1. Probe Query Message . . . . . 6
3.1.1. Delay Measurement Probe Query Message . . . . . 6
3.1.2. Loss Measurement Probe Query Message . . . . . 7
3.1.2.1. Block Number TLV . . . . . 8
3.1.3. In-band Probe Query for SR Links . . . . . 8
3.1.4. In-band Probe Query for End-to-end Measurement of SR Policy . . . . . 8
3.1.4.1. In-band Probe Query Message for SR-MPLS Policy . . . . . 8
3.1.4.2. In-band Probe Query Message for SRv6 Policy . . . . . 9
3.2. Probe Response Message . . . . . 9
3.2.1. One-way Measurement for SR Link and end-to-end SR Policy . . . . . 10
3.2.1.1. Probe Response Message to Controller . . . . . 11
3.2.2. Two-way Measurement for SR Links . . . . . 11
3.2.3. Two-way End-to-end Measurement of SR Policy . . . . . 11
3.2.3.1. Return Path Segment List TLV . . . . . 11
3.2.3.2. In-band Probe Response Message for SR-MPLS Policy . . . . . 13
3.2.3.3. In-band Probe Response Message for SRv6 Policy . . . . . 13
4. Performance Measurement for P2MP SR Policies . . . . . 14
5. ECMP Support . . . . . 14
6. Sequence Number TLV . . . . . 14
7. Security Considerations . . . . . 15
8. IANA Considerations . . . . . 15

9. References . . . . . 16  
  9.1. Normative References . . . . . 16  
  9.2. Informative References . . . . . 16  
Acknowledgments . . . . . 19  
Contributors . . . . . 19  
Authors' Addresses . . . . . 19

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.

[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-sr-mpls-pm]. [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 does not require to bootstrap PM sessions and 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) for SR Policies. In addition, this document defines Return Path Segment List (RPSL) TLV for two-way performance measurement and Block Number TLV for loss measurement.

## 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.

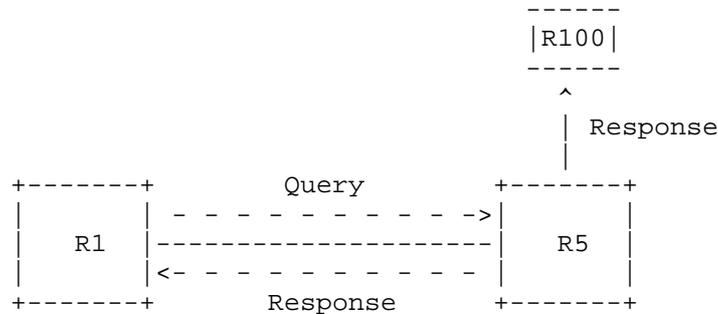
DM: Delay Measurement.

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.  
PTP: Precision Time Protocol.  
RPSL: Return Path Segment List.  
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.

### 3. Probe Messages

#### 3.1. Probe Query Message

In this document, UDP path is defined for sending and processing PM probe query messages for Delay and Loss measurements for SR links and end-to-end SR Policies as described in the following Sections. As well-known UDP port is used for identifying PM probe packets, bootstrapping of the PM session [RFC5357] is not required. The TTL / Hop Limit field of the IP header MUST be set to 1.

##### 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. As shown, the DM probe query message is sent with Destination UDP port number TBA1 defined in this document. The Source UDP port may optionally be set to TBA1 for two-way delay measurement. 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 .
. IP TTL = 1 .
. Router Alert Option Not Set .
.
+-----+
| UDP Header |
. Source Port = As chosen by Querier .
. Destination Port = TBA1 by IANA 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 Destination UDP port number TBA2 defined in this document. The Source UDP port may optionally be set to TBA2 for two-way loss measurement. 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 .
. IP TTL = 1 .
. Router Alert Option Not Set .
.
+-----+
| UDP Header |
. Source Port = As chosen by Querier .
. Destination Port = TBA2 by IANA for Loss Measurement .
.
+-----+
| Payload = Message as specified in Section 3.1 of RFC 6374 |
.
+-----+

```

Figure 2: LM Probe Query Message

The path segment identifier [I-D.spring-mpls-path-segment] [I-D.pce-sr-path-segment] of the SR Policy is required 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 (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 TBA8) 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:

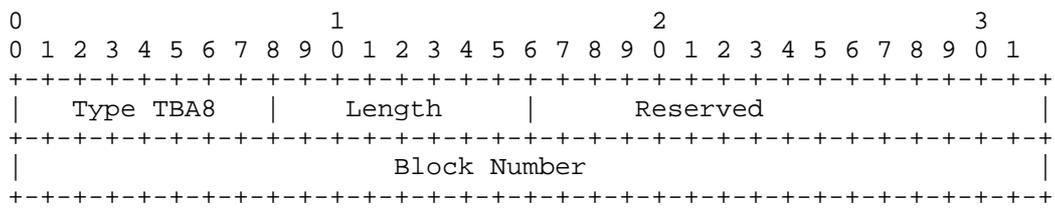


Figure 11: Block Number TLV

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. In-band 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. In-band Probe Query for End-to-end Measurement of SR Policy

3.1.4.1. In-band 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.

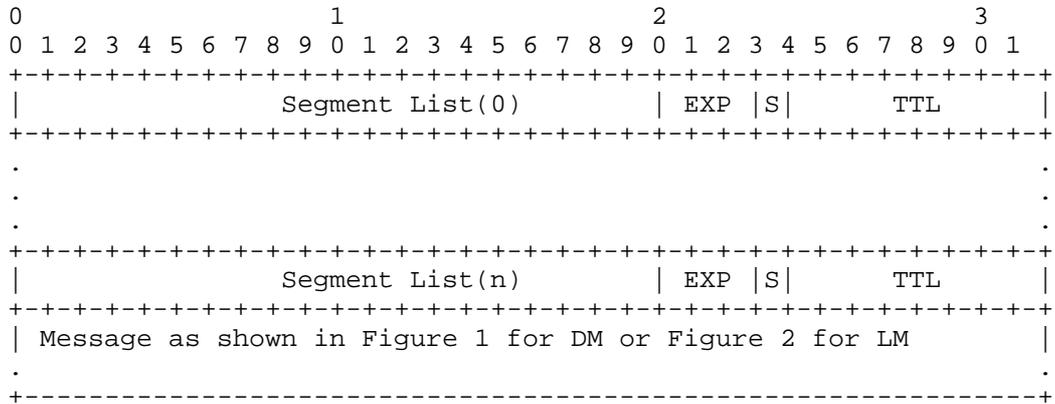


Figure 3: In-band Probe Query Message for SR-MPLS Policy

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

3.1.4.2. In-band 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.

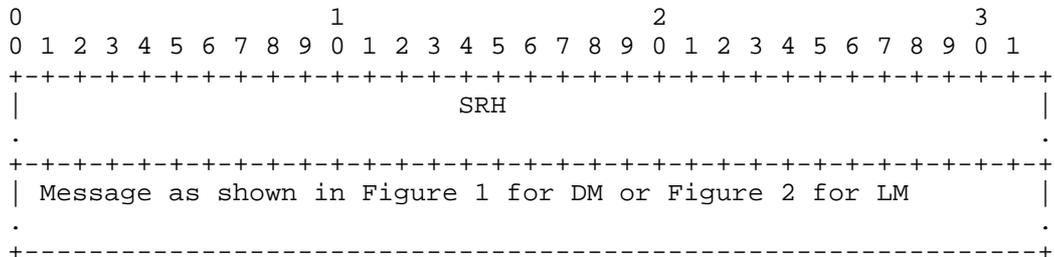


Figure 4: In-band Probe Query Message for SRv6 Policy

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 the 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 = URO.Address .
. Protocol = UDP .
. Router Alert Option Not Set .
. .
+-----+
| UDP Header |
. Source Port = As chosen by Responder .
. Destination Port = URO.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 URO from Probe Query Message

### 3.2.1.1. 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 URO TLV in the probe query message and setting its own IP address in the IP Address in the URO 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 URO TLV in the probe query message and sets the IP address of R100 in the IP Address field and UDP port TBA1 for DM and TBA2 for LM in the UDP-Destination-Port field of the URO 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 of 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 [I-D.spring-mpls-path-segment] [I-D.pce-sr-path-segment] of the forward SR Policy can be used to find the reverse SR Policy to send the probe response message in the absence of RPSL TLV defined in the following Section.

##### 3.2.3.1. Return Path Segment List 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 Types are defined in this document for Return Path Segment List (RPSL) to carry reverse SR path for probe response messages. The format of the RPSL TLV is shown in Figure 7:

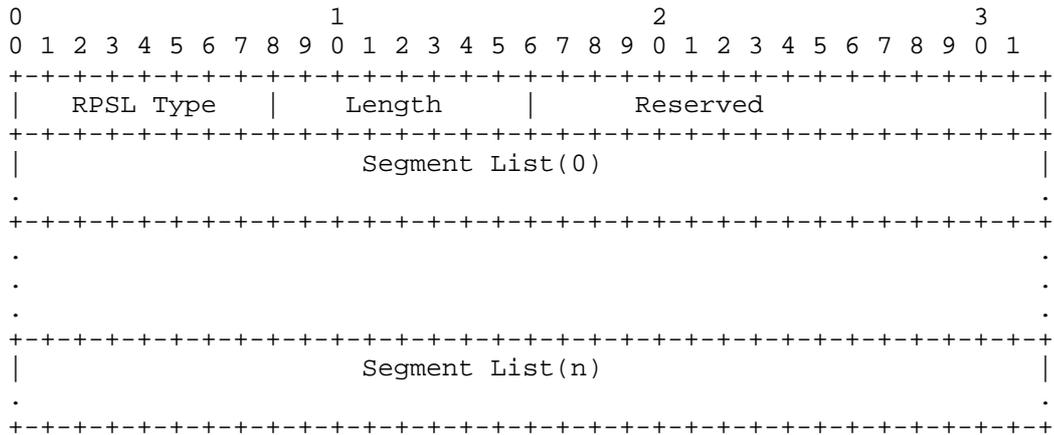


Figure 7: Return Path Segment List TLV

The RPSL can be one of following Types:

- o RPSL Type (value TBA3): SR-MPLS Label Stack of the Reverse SR Policy
- o RPSL Type (value TBA4): SRv6 Segment List of the Reverse SR Policy
- o RPSL Type (value TBA5): SR-MPLS Binding SID [I-D.pce-binding-label-sid] of the Reverse SR Policy
- o RPSL Type (value TBA6): SRv6 Binding SID [I-D.pce-binding-label-sid] of the Reverse SR Policy

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 RPSL TLV is optional. The PM querier node MUST only insert one RPSL TLV in the probe query message and the responder node MUST only process the first RPSL TLV in the probe query message and ignore

other RPSL TLVs if present. The responder node MUST send probe response message back on the reverse path specified in the RPSL TLV and MUST NOT add RPSL TLV in the probe response message.

3.2.3.2. In-band 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 RPSL TLV in the probe query message.

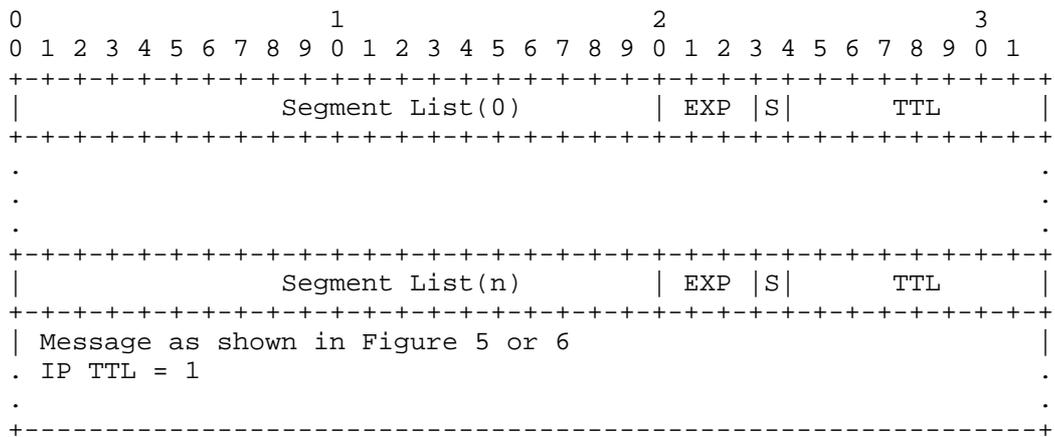


Figure 8: In-band Probe Response Message for SR-MPLS Policy

3.2.3.3. In-band 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 RPSL TLV in the probe query message.

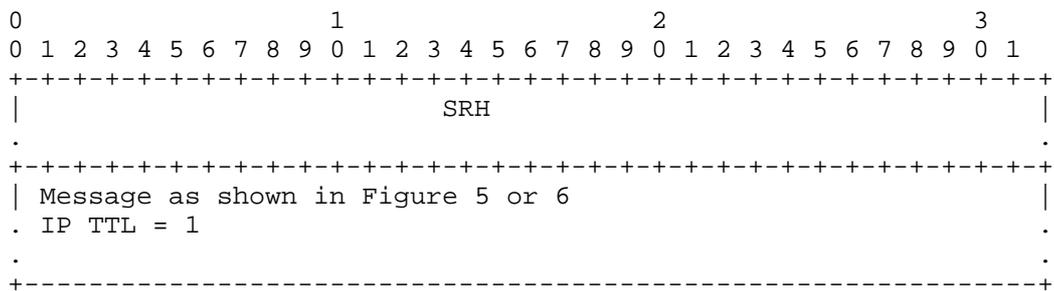


Figure 9: In-band Probe Response Message for SRv6 Policy

#### 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, between transit nodes and between transit and destination nodes. The PM probe messages can be sent to traverse different ECMP paths to measure performance 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.

- o The mechanisms described in [RFC8029] [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 0:0:0:0:0:FFFF:7F00/104 range for IPv6 can be used to exercise a particular ECMP path. In addition, different Source Addresses or different Source UDP ports can be used for this purpose. As specified in [RFC6437], 3-tuple of Flow Label, Source Address and Destination Address fields in the IPv6 header can also be used.
- o For SR-MPLS, entropy label [RFC6790] in the PM probe messages can be used.
- o For SRv6, Flow Label in SRH [I-D.6man-segment-routing-header] of the PM probe messages can be used.

#### 6. Sequence Number TLV

The message formats for DM and LM [RFC6374] do not contain sequence number for probe query packets. Sequence numbers can be useful when some probe query messages are lost or they arrive out of order.

[RFC6374] defines DM and LM probe query and response messages that can include one or more optional TLVs. New TLV Type (value TBA7) is defined in this document to carry sequence number for probe query and response messages for delay and loss measurement. The format of the

Sequence Number TLV is shown in Figure 10:

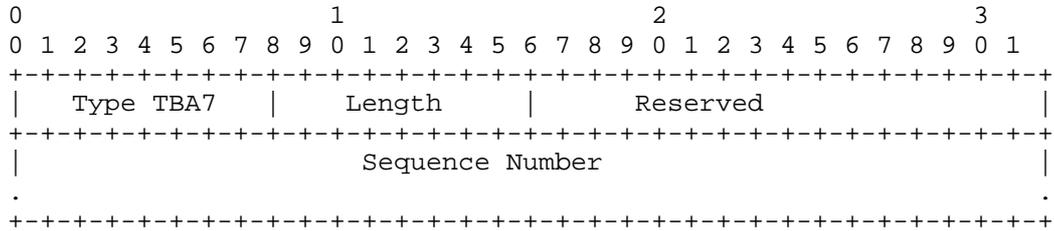


Figure 10: Sequence Number TLV

The sequence numbers start with 0 and are incremented by one for each subsequent probe query packet. The sequence number can be of any length determined by the querier node. The Sequence Number TLV is optional. 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 other Sequence Number TLVs if present.

7. Security Considerations

The performance measurement is intended for deployment in well-managed private and service provider networks. The security considerations described in Section 8 of [RFC6374] are applicable to this specification, and particular attention should be paid to the last two paragraphs. Cryptographic measures may be enhanced by the correct configuration of access-control lists and firewalls.

8. IANA Considerations

IANA is requested to allocate following UDP ports for performance measurements:

- o UDP Port TBA1: Delay Performance Measurement
- o UDP Port TBA2: Loss Performance Measurement

IANA is also requested to allocate values for the following Return Path Segment List TLV Types for RFC 6374 to be carried in PM probe query messages:

- o Type TBA3: SR-MPLS Label Stack of the Reverse SR Policy

- o Type TBA4: SRv6 Segment List of the Reverse SR Policy
- o Type TBA5: SR-MPLS Binding SID of the Reverse SR Policy
- o Type TBA6: SRv6 Binding SID of the Reverse SR Policy

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

- o Type TBA7: Sequence Number TLV

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 TBA8: Block Number TLV

## 9. References

### 9.1. Normative References

- [RFC768] Postel, J., "User Datagram Protocol", STD 6, RFC 768, August 1980.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", RFC 2119, March 1997.
- [RFC6374] Frost, D. and S. Bryant, "Packet Loss and Delay Measurement for MPLS networks", RFC 6374, September 2011.
- [RFC7876] Bryant, S., Sivabalan, S., and Soni, S., "UDP Return Path for Packet Loss and Delay Measurement for MPLS Networks", RFC 7876, July 2016.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", RFC 8174, May 2017.

### 9.2. Informative References

- [IEEE1588] IEEE, "1588-2008 IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems", March 2008.

- [RFC4656] Shalunov, S., Teitelbaum, B., Karp, A., Boote, J., and M. Zekauskas, "A One-way Active Measurement Protocol (OWAMP)", RFC 4656, September 2006.
- [RFC5357] Hedayat, K., Krzanowski, R., Morton, A., Yum, K., and J. Babiarz, "A Two-Way Active Measurement Protocol (TWAMP)", RFC 5357, October 2008.
- [RFC5884] Aggarwal, R., Kompella, K., Nadeau, T., and G. Swallow, "Bidirectional Forwarding Detection (BFD) for MPLS Label Switched Paths (LSPs)", RFC 5884, DOI 10.17487/RFC5884, June 2010.
- [RFC6437] Amante, S., Carpenter, B., Jiang, S., and J. Rajahalme, "IPv6 Flow Label Specification", RFC 6437, November 2011.
- [RFC6790] Kompella, K., Drake, J., Amante, S., Henderickx, W., and L. Yong, "The Use of Entropy Labels in MPLS Forwarding", RFC 6790, November 2012.
- [RFC8029] Kompella, K., Swallow, G., Pignataro, C., Kumar, N., Aldrin, S. and M. Chen, "Detecting Multiprotocol Label Switched (MPLS) Data-Plane Failures", RFC 8029, March 2017.
- [RFC8321] Fioccola, G. Ed., "Alternate-Marking Method for Passive and Hybrid Performance Monitoring", RFC 8321, January 2018.
- [I-D.spring-segment-routing-policy] Filsfils, C., et al., "Segment Routing Policy Architecture", draft-ietf-spring-segment-routing-policy, work in progress.
- [I-D.spring-sr-p2mp-policy] Voyer, D. Ed., et al., "SR Replication Policy for P2MP Service Delivery", draft-voyer-spring-sr-p2mp-policy, work in progress.
- [I-D.6man-segment-routing-header] Filsfils, C., et al., "IPv6 Segment Routing Header (SRH)", draft-ietf-6man-segment-routing-header, work in progress.
- [I-D.spring-sr-mpls-pm] Filsfils, C., Gandhi, R. Ed., et al. "Performance Measurement in Segment Routing Networks with MPLS Data Plane", draft-gandhi-spring-sr-mpls-pm, work in progress.
- [I-D.pce-binding-label-sid] Filsfils, C., et al., "Carrying Binding

Label Segment-ID in PCE-based Networks",  
draft-sivabalan-pce-binding-label-sid, work in progress.

[I-D.spring-mpls-path-segment] Cheng, W., et al., "Path Segment in  
MPLS Based Segment Routing Network",  
draft-cheng-spring-mpls-path-segment, work in progress.

[I-D.pce-sr-path-segment] Li, C., et al., "Path Computation Element  
Communication Protocol (PCEP) Extension for Path  
Identification in Segment Routing (SR)",  
draft-li-pce-sr-path-segment, work in progress.

[I-D.ippm-stamp] Mirsky, G. et al. "Simple Two-way Active  
Measurement Protocol", draft-ietf-ippm-stamp, work in  
progress.

[BBF.TR-390] "Performance Measurement from IP Edge to Customer  
Equipment using TWAMP Light", BBF TR-390, May 2017.

#### Acknowledgments

The authors would like to thank Nagendra Kumar and Carlos Pignataro for the discussion on SRv6 Performance Measurement.

#### Contributors

Sagar Soni  
Cisco Systems, Inc.  
Email: sagsoni@cisco.com

Patrick Khordoc  
Cisco Systems, Inc.  
Email: pkhordoc@cisco.com

Zafar Ali  
Cisco Systems, Inc.  
Email: zali@cisco.com

Daniel Bernier  
Bell Canada  
Email: daniel.bernier@bell.ca

Dirk Steinberg  
Steinberg Consulting  
Germany  
Email: dws@dirksteinberg.de

#### Authors' Addresses

Rakesh Gandhi (editor)  
Cisco Systems, Inc.  
Canada  
Email: rgandhi@cisco.com

Clarence Filsfils  
Cisco Systems, Inc.  
Email: cfilsfil@cisco.com

Daniel Voyer

Bell Canada  
Email: daniel.voyer@bell.ca

Stefano Salsano  
Universita di Roma "Tor Vergata"  
Italy  
Email: stefano.salsano@uniroma2.it

Pier Luigi Ventre  
CNIT  
Italy  
Email: pierluigi.ventre@cnit.it

Mach(Guoyi) Chen  
Huawei  
Email: mach.chen@huawei.com