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H. Chen
Futurewei
M. Toy
Verizon
A. Wang
China Telecom
Z. Li
China Mobile
L. Liu
Fujitsu
X. Liu
Volta Networks
October 31, 2020

SR Path Ingress Protection
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Abstract

This document describes extensions to Path Computation Element (PCE) communication Protocol (PCEP) for protecting the ingress node of a Segment Routing (SR) tunnel or path.

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 RFC 2119 [RFC2119].

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1. Introduction

The fast protection of a transit node of a Segment Routing (SR) path or tunnel is described in [I-D.bashandy-rtgwg-segment-routing-ti-lfa] and [I-D.hu-spring-segment-routing-proxy-forwarding]. [RFC8424] presents extensions to RSVP-TE for the fast protection of the ingress node of a traffic engineering (TE) Label Switching Path (LSP). However, these documents do not discuss any protocol extensions for the fast protection of the ingress node of an SR path or tunnel.

This document fills that void and specifies protocol extensions to Path Computation Element (PCE) communication Protocol (PCEP) for the fast protection of the ingress node of an SR path or tunnel. Ingress

node and ingress, fast protection and protection as well as SR path and SR tunnel will be used exchangeably in the following sections.

2. Terminologies

The following terminologies are used in this document.

SR: Segment Routing

SRv6: SR for IPv6

SRH: Segment Routing Header

SID: Segment Identifier

CE: Customer Edge

PE: Provider Edge

LFA: Loop-Free Alternate

TI-LFA: Topology Independent LFA

TE: Traffic Engineering

BFD: Bidirectional Forwarding Detection

VPN: Virtual Private Network

L3VPN: Layer 3 VPN

FIB: Forwarding Information Base

PLR: Point of Local Repair

BGP: Border Gateway Protocol

IGP: Interior Gateway Protocol

OSPF: Open Shortest Path First

IS-IS: Intermediate System to Intermediate System

3. SR Path Ingress Protection Example

Figure 1 shows an example of protecting ingress PE1 of a SR path, which is from ingress PE1 to egress PE3.

```
                *******  *******
            [PE1]-----[P1]-----[PE3]            PE1 Ingress
            / |        |& &&&&&  | \            PEx Provider Edge
           /  |        |&        |  \           CEx Customer Edge
      [CE1]   |        |&        |   [CE2]      Px  Non Provider Edge
           \  |        |&        |  /           *** SR Path
            \ |  &&&&& |&        | /            &&& Backup Path
            [PE2]-----[P2]-----[PE4]
```

Figure 1: Protecting Ingress PE1 of SR Path

In normal operations, CE1 sends the traffic with destination PE3 to ingress PE1, which imports the traffic into the SR path.

When CE1 detects the failure of ingress PE1, it switches the traffic to backup ingress PE2, which imports the traffic from CE1 into a backup SR path. The backup path is from the backup ingress PE2 to the egress PE3. When the traffic is imported into the backup path, it is sent to the egress PE3 along the path.

4. Behavior after Ingress Failure

After failure of the ingress of an SR path happens, there are a couple of different ways to detect the failure. In each way, there may be some specific behavior for the traffic source (e.g., CE1) and the backup ingress (e.g., PE2).

In one way, the traffic source (e.g., CE1) is responsible for fast detecting the failure of the ingress (e.g., PE1) of an SR path. Fast detecting the failure means detecting the failure in a few or tens of milliseconds. The backup ingress (e.g., PE2) is ready to import the traffic from the traffic source into the backup SR path installed.

In normal operations, the source sends the traffic to the ingress of the SR path. When the source detects the failure of the ingress, it switches the traffic to the backup ingress, which delivers the traffic to the egress of the SR path via the backup SR path.

In another way, both the backup ingress and the traffic source are concurrently responsible for fast detecting the failure of the ingress of an SR path.

In normal operations, the source (e.g., CE1) sends the traffic to the ingress (e.g., PE1). It switches the traffic to the backup ingress (e.g., PE2) when it detects the failure of the ingress.

The backup ingress does not import any traffic from the source into the backup SR path in normal operations. When it detects the failure

of the ingress, it imports the traffic from the source into the backup SR path.

5. Extensions to PCEP

PCC runs on each of the edge nodes of a network normally. PCE runs on a server as a controller to communicate with PCCs. PCE and PCCs work together to support protection for the ingress of a SR path.

5.1. Capability for SR Path Ingress Protection

When a PCE and a PCC establish a PCEP session between them, they exchange their capabilities of supporting protection for the ingress node of an SR path/tunnel.

A new sub-TLV called SR_INGRESS_PROTECTION_CAPABILITY is defined. It is included in the PATH_SETUP_TYPE_CAPABILITY TLV with PST = TBD1 (suggested value 2 for backup SR path/tunnel) in the OPEN object, which is exchanged in Open messages when a PCC and a PCE establish a PCEP session between them. Its format is illustrated below.

```
 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 = TBD2          |           Length=4            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Reserved            |        Flags              |D|A|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: SR_INGRESS_PROTECTION_CAPABILITY sub-TLV

Type: TBD2 is to be assigned by IANA.

Length: 4.

Reserved: 2 octets. Must be set to zero in transmission and ignored on reception.

Flags: 2 octets. Two flags are defined.

- o D flag: A PCC sets this flag to 1 to indicate that it is able to detect its adjacent node's failure quickly.

- o A flag: A PCE sets this flag to 1 to request a PCC to let the forwarding entry for the backup SR path/tunnel be Active.

A PCC, which supports ingress protection for a SR tunnel/path, sends a PCE an Open message containing SR_INGRESS_PROTECTION_CAPABILITY

sub-TLV. This sub-TLV indicates that the PCC is capable of supporting the ingress protection for a SR tunnel/path.

A PCE, which supports ingress protection for a SR tunnel/path, sends a PCC an Open message containing SR_INGRESS_PROTECTION_CAPABILITY sub-TLV. This sub-TLV indicates that the PCE is capable of supporting the ingress protection for a SR tunnel/path.

Assume that both a PCC and a PCE support SR_PCE_CAPABILITY, that is that each of the Open messages sent by the PCC and PCE contains PATH-SETUP-TYPE-CAPABILITY TLV with a PST list containing PST=1 and a SR-PCE-CAPABILITY sub-TLV.

If a PCE receives an Open message without a SR_INGRESS_PROTECTION_CAPABILITY sub-TLV from a PCC, then the PCE MUST not send the PCC any request for ingress protection of a SR path/tunnel.

If a PCC receives an Open message without a SR_INGRESS_PROTECTION_CAPABILITY sub-TLV from a PCE, then the PCC MUST ignore any request for ingress protection of a SR path/tunnel from the PCE.

If a PCC sets D flag to zero, then the PCE SHOULD send the PCC an Open message with A flag set to one. When the PCE sends the PCC a message for initiating a backup SR path/tunnel, the PCC SHOULD let the forwarding entry for the backup SR path/tunnel be Active.

5.2. SR Path Ingress Protection

A new sub-TLV called SR_INGRESS_PROTECTION is defined. When a PCE sends a PCC a PCInitiate message for initiating a backup SR path/tunnel to protect the primary ingress node of a primary SR path/tunnel, the message contains this TLV in the RP/SRP object. Its format is illustrated below.

```
 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 = TBD3           |        Length (variable)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Reserved            |        Flags                |A|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                                                               ~
~                        sub-TLVs (optional)                    ~
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: SR_INGRESS_PROTECTION sub-TLV

Type: TBD3 is to be assigned by IANA.

Length: Variable.

Reserved: 2 octets. Must be set to zero in transmission and ignored on reception.

Flags: 2 octets. One flag is defined.

- o A flag: A PCE sets this flag to 1 to request a PCC to let the forwarding entry for the backup SR path/tunnel be Active.

Three optional sub-TLVs are defined.

5.2.1. Traffic-Description sub-TLV

A Traffic-Description sub-TLV describes the traffic to be imported into a backup SR path/tunnel. Its format is illustrated below.

```
 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 = TBD4           |        Length (variable)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                                                               ~
~                        sub-TLVs (optional)                    ~
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Traffic-Description sub-TLV

Type: TBD4 is to be assigned by IANA.

Length: Variable.

Two optional sub-TLVs are defined. One is FEC sub-TLV and the other interface sub-TLV.

A FEC sub-TLV describes the traffic to be imported into the backup SR path/tunnel. It is an IP prefix with an optional virtual network ID. It has two formats: one for IPv4 and the other for IPv6, which are illustrated below.

```
 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 = TBD5           |        Length (variable)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|IPv4 Prefix Len|          IPv4 Prefix                          ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~   (Optional) Virtual Network ID (2 octets)                    ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: IPv4 FEC sub-TLV

Type: TBD5 is to be assigned by IANA.

Length: Variable.

IPv4 Prefix Len: Indicates the length of the IPv4 Prefix.

IPv4 Prefix: IPv4 Prefix rounded to octets.

Virtual Network ID: 2 octets. This is optional. It indicates the ID of a virtual network.

```
 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 = TBD6           |        Length (variable)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|IPv6 Prefix Len|          IPv6 Prefix                          ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~   Optional Virtual Network ID (2 octets)                      ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: IPv6 FEC sub-TLV

Type: TBD6 is to be assigned by IANA.

Length: Variable.

IPv6 Prefix Len: Indicates the length of the IPv6 Prefix.

IPv6 Prefix: IPv6 Prefix rounded to octets.

Virtual Network ID: 2 octets. This is optional. It indicates the ID of a virtual network.

An Interface sub-TLV indicates the interface from which the traffic is received and imported into the backup SR path/tunnel. It has three formats: one for interface index, the other two for IPv4 and IPv6 address, which are illustrated below.

```
 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 = TBD7           |          Length (4)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Interface Index (4 octets)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Interface Index sub-TLV

Type: TBD7 is to be assigned by IANA.

Length: 4.

Interface Index: 4 octets. It indicates the index of an interface.

```
 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 = TBD8           |          Length (4)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Interface IPv4 Address (4 octets)               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 8: Interface IPv4 Address sub-TLV

Type: TBD8 is to be assigned by IANA.

Length: 4.

Interface IPv4 Address: 4 octets. It represents the IPv4 address of an interface.

```
 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 = TBD9           |         Length (16)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Interface IPv6 Address (16 octets)              |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 9: Interface IPv6 Address sub-TLV

Type: TBD9 is to be assigned by IANA.

Length: 16.

Interface IPv6 Address: 16 octets. It represents the IPv6 address of an interface.

5.2.2. Primary-Ingress sub-TLV

A Primary-Ingress sub-TLV indicates the IP address of the primary ingress node of a primary SR path/tunnel. It has two formats: one for primary ingress node IPv4 address and the other for primary ingress node IPv6 address, which are illustrated below.

```
 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 = TBDa           |          Length (4)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Primary Ingress IPv4 Address (4 octets)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 10: Primary Ingress IPv4 Address sub-TLV

Type: TBDa is to be assigned by IANA.

Length: 4.

Primary Ingress IPv4 Address: 4 octets. It represents an IPv4 host address of the primary ingress node of a SR path/tunnel.

```
 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 = TBDb           |         Length (16)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Primary Ingress IPv6 Address (16 octets)           |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 11: Primary Ingress IPv6 Address sub-TLV

Type: TBDb is to be assigned by IANA.

Length: 16.

Primary Ingress IPv6 Address: 16 octets. It represents an IPv6 host address of the primary ingress node of a SR path/tunnel.

5.2.3. Service sub-TLV

A Service sub-TLV contains a service ID or label to be added into a packet to be carried by a SR path/tunnel. It has two formats: one for the service identified by a label and the other for the service identified by a service identifier (ID) of 32 or 128 bits, which are illustrated below.

```
 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 = TBDc           |          Length (4)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        zero           |       Service Label (20 bits)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 12: Service Label sub-TLV

Type: TBDc is to be assigned by IANA.

Length: 4.

Service Label: the least significant 20 bits. It represents a label of 20 bits.

```
 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 = TBDd           |         Length (4/16)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Service ID (4 or 16 octets)            |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 13: Service ID sub-TLV

Type: TBDd is to be assigned by IANA.

Length: 4 or 16.

Service ID: 4 or 16 octets. It represents Identifier (ID) of a service in 4 or 16 octets.

6. Security Considerations

TBD

7. Acknowledgements

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8. IANA Considerations

TBD

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Authors' Addresses

Huaimo Chen
Futurewei
Boston, MA
USA

Email: Huaimo.chen@futurewei.com

Mehmet Toy
Verizon
USA

Email: mehmet.toy@verizon.com

Aijun Wang
China Telecom
Beiqijia Town, Changping District
Beijing, 102209
China

Email: wangaj3@chinatelecom.cn

Zhenqiang Li
China Mobile
32 Xuanwumen West Ave, Xicheng District
Beijing, 100053
China

Email: lizhengqiang@chinamobile.com

Lei Liu
Fujitsu

USA

Email: liulei.kddi@gmail.com

Xufeng Liu
Volta Networks

McLean, VA
USA

Email: xufeng.liu.ietf@gmail.com