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RFC 10018
Multicast and Ethernet VPN with Segment Routing Point-to-Multipoint (P2MP) and Ingress Replication

Abstract

A Point-to-Multipoint (P2MP) tree in a Segment Routing (SR) domain carries traffic from a Root to a set of Leaves. This document specifies extensions to BGP encodings and procedures for P2MP trees and Ingress Replication used in BGP/MPLS IP VPNs and Ethernet VPNs (EVPNs) in an SR domain. This document updates RFCs 6514 and 7988.

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1. Introduction

"Multicast in MPLS/BGP IP VPNs" [RFC6513] and "BGP Encodings and Procedures for Multicast in MPLS/BGP IP VPNs" [RFC6514] specify procedures that allow a network operator to provide Multicast VPN (MVPN) service to its customers. Multicast traffic from a customer is tunneled across the service provider network over Provider Tunnels (P-tunnels). P-tunnels can be instantiated using different transport mechanisms. For example, a service provider network that uses Segment Routing (SR) can use an SR Point-to-Multipoint (P2MP) tree defined by an SR P2MP Policy [RFC9960] or SR P2MP Ingress Replication (IR) to instantiate P-tunnels for MVPN. This document refers to a P-tunnel realized by an SR P2MP Policy as an SR P2MP P-tunnel. SR P2MP P-tunnels can be instantiated for both Segment Routing over MPLS (SR-MPLS) [RFC8660] and Segment Routing over IPv6 (SRv6) [RFC8986] [RFC8754].

An SR P2MP tree is defined by an SR P2MP Policy [RFC9960] and instantiated via a controller such as a Path Computation Element (PCE). An SR P2MP Policy consists of a Root, a set of Leaf nodes, and a set of candidate paths (CPs) with optional set of constraints and/or optimization objectives to be satisfied by the SR P2MP tree. A CP has zero or more P2MP tree instances (PTIs).

This document specifies extensions to BGP auto-discovery procedures specified in [RFC6514] for P-tunnels constructed with a PTI. Use of Protocol Independent Multicast (PIM) for auto-discovery is outside the scope of this document. Support for customer Bidirectional PIM (BIDIR-PIM) is also outside the scope of this document.

This document extends procedures in [RFC7988] for MVPN service with IR over an SR-MPLS data plane with a Service Level Agreement (SLA). New procedures are defined for MVPN service with IR over an SRv6 data plane with or without an SLA.

This document defines new SRv6 Endpoint behaviors [RFC8986] used for MVPN with SR P2MP and IR P-tunnels.

For BGP MPLS-Based EVPN specified in [RFC7432] and updated in [RFC9572], P-tunnels are advertised for handling multi-destination traffic. These P-tunnels can be instantiated by SR-MPLS or SRv6 P2MP trees.

The reader is expected to be familiar with [RFC6513] and [RFC6514] for MVPN procedures. For EVPN procedures, refer to [RFC7432].

Scalability, operational, and troubleshooting considerations for SR P2MP trees and Replication segments are described in [RFC9960] and [RFC9524], respectively. Operations, Administration, and Maintenance (OAM) ping and traceroute procedures for SR P2MP Policy using the SR-MPLS data plane are specified in [RFC9961].

1.1. Terminology

The following terms are used as defined in [RFC8402]:

- Segment Routing (SR)
- Segment Identifier (SID)
- SR domain
- SR-MPLS
- SRv6
- SRv6 SID

The following term is used as defined in [RFC8754]:

- Segment Routing Header (SRH)

The following terms are used as defined in [RFC9524]:

- Replication segment
- Replication-SID
- Root node
- Leaf node
- Bud node
- Intermediate Replication node

The following terms are used as defined in [RFC9960]:

- SR P2MP Policy
- Tree-ID
- Candidate path (CP)
- P2MP tree instance (PTI)
- Tree-SID

For MVPN, the following terms are used as defined in [RFC6513] and [RFC6514]:

- P-Multicast Service Interface (PMSI)
- P-tunnel
- PMSI Tunnel Attribute (PTA)

- Auto-Discovery (A-D) routes
- Intra-AS I-PMSI A-D
- Inter-AS I-PMSI A-D
- S-PMSI A-D
- Leaf A-D route

For EVPN, the following terms are used as defined in [RFC7432], [RFC9251], and [RFC9572]:

- EVPN Instance (EVI)
- Ethernet Segment (ES)
- Ethernet Segment Identifier (ESI)
- Inclusive Multicast Ethernet Tag (IMET) route
- Selective Multicast Ethernet Tag (SMET) route
- Broadcast, Unknown Unicast or Multicast (BUM)
- S-PMSI
- Leaf A-D route

1.2. Requirements Language

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. SR P2MP P-Tunnel

For MVPN or EVPN, Provider Edge (PE) routers can steer customer traffic into a P-tunnel realized by an SR-MPLS or SRv6 PTI. An SR PTI is instantiated by a CP of an SR P2MP Policy [RFC9960]. A P-tunnel is signaled in MVPN or EVPN A-D routes using the BGP PMSI Tunnel Attribute (PTA) [RFC6514]. The PTA identifies the P-tunnel that is used to instantiate a PMSI.

```
+---------------------------------+
|            INGRESS PE           |                   +------------+
|  +----------+      +----------+ |                   |            |
|  |          |      |  SR P2MP | |   PCEP/BGP/etc.   |            |
|  | MVPN/EVPN+----->|  Policy  | +------------------>| CONTROLLER |
|  |  Module  |      |  Module  | |                   |            |
|  +----------+      +----------+ |                   |            |
|                                 |                   +------------+
+---------------------------------+
```

Figure 1: MVPN/EVPN Interaction with SR P2MP Policy

The figure above shows the interaction between the conceptual MVPN or EVPN module and SR P2MP Policy module on an ingress PE. The ingress PE participates in MVPN or EVPN AD procedures and interacts with the SR P2MP Policy module as shown above to create and update the SR P2MP Policy, CP, and the Leaf set of SR P2MP policies. The SR P2MP Policy module interacts with a controller using protocols such as the Path Computation Element Communication Protocol (PCEP) [SR-P2MP-PCEP], BGP, the Network Configuration Protocol (NETCONF), etc., which are outside the scope of this document.

An ingress PE creates a CP of an SR P2MP Policy in the SR P2MP Policy module upon provisioning of the MVPN or EVPN module for the SR P2MP P-tunnel or based on events or policy, such as mapping MVPN or EVPN flow to a new SR P2MP P-tunnel. This CP can have optional traffic engineering constraints and/or an optimization objective by provisioning or by a local policy. The SR P2MP Policy module signals the CP along with the constraints and optimization objective to the controller using one of the protocols mentioned above. The ingress PE deletes the CP of the SR P2MP Policy from the SR P2MP Policy module when the SR P2MP P-tunnel is not longer required. The SR P2MP Policy module signals deletion of the CP of the SR P2MP Policy to the controller.

An ingress PE participates in the MVPN or EVPN A-D procedures defined in this document to discover Leaf nodes of an SR P2MP P-tunnel via various A-D routes. The MVPN or EVPN module on the ingress PE updates the Leaf set of the SR P2MP Policy corresponding to the P-tunnel in the SR P2MP Policy module. The SR P2MP Policy module signals the updated Leaf set to the controller using one of the protocols mentioned above.

An egress PE associates an MVPN or EVPN A-D route with an MVPN or EVPN context and informs the SR P2MP Policy module to join the SR P2MP P-tunnel as a Leaf or a Bud node.

Given a Leaf set of an SR P2MP Policy and a CP with constraints and an optimization objective, the controller computes and instantiates the PTI on the nodes that are part of the tree by stitching Replication segments [RFC9524] at the Root (ingress PE) node, intermediate replication nodes, and Leaf nodes (egress PEs). A Replication segment of a PTI can be instantiated by various methods such as BGP, PCEP, NETCONF, etc., which are outside the scope of this document. This PTI of the SR P2MP Policy instantiates the P-tunnel advertised by the MVPN or EVPN A-D routes.

The Tree-SID is the unique data plane identifier of the PTI. The Root node encapsulates the payload in the Tree-SID to steer it into the PTI. The Provider (P) routers replicate the encapsulated payload using Replication segments towards the Leaf nodes of the PTI. The Leaf nodes of the PTI dispose the Tree-SID and deliver the payload. A Leaf node derives the MVPN or EVPN instance for delivering the payload from either the Tree-SID or another context encoded in the packet.

Note that an ingress PE can deliver an MVPN or EVPN payload to the egress PEs using IR over SR-MPLS or SRv6. The SR P2MP Policy module and controller do not participate in IR.

3. MVPN with SR

MVPN service can be provided using SR P2MP trees or IR over either an SR-MPLS or SRv6 data plane.

3.1. SRv6 Multicast Endpoint Behaviors

The following SRv6 Endpoint behaviors can be associated with the SRv6 Multicast Service SID used for MVPN with SR P2MP and IR P-tunnels.

3.1.1. End.DTMC4: Decapsulation and Specific IPv4 Multicast Table Lookup

The "Endpoint with Decapsulation and IPv4 Multicast Table Lookup" behavior (End.DTMC4 for short) is functionally identical to the End.DT4 behavior specified in [RFC8986], except that the forwarding lookup **MUST** be performed in the IPv4 multicast routing table rather than the IPv4 unicast routing table.

This behavior **MUST** only be associated with the SRv6 Multicast Service SID carried in AFI/SAFI 1/129 (MVPN-IPv4) A-D routes.

3.1.2. End.DTMC6: Decapsulation and Specific IPv6 Multicast Table Lookup

The "Endpoint with Decapsulation and IPv6 Multicast Table Lookup" behavior (End.DTMC6 for short) is functionally identical to the End.DT6 behavior specified in [RFC8986], except that the forwarding lookup **MUST** be performed in the IPv6 multicast routing table rather than the IPv6 unicast routing table.

This behavior **MUST** only be associated with the SRv6 Multicast Service SID carried in AFI/SAFI 2/129 (MVPN-IPv6) A-D routes.

3.1.3. End.DTMC46: Decapsulation and Specific IP Multicast Table Lookup

The "Endpoint with Decapsulation and IP Multicast Table Lookup" behavior (End.DTMC46 for short) is functionally identical to the End.DT4 and End.DT6 behaviors specified in [RFC8986], except that the forwarding lookup **MUST** be performed in the IP multicast routing table rather than in an IP unicast routing table.

This behavior **MUST** only be associated with the SRv6 Multicast Service SID carried in AFI/SAFI 1/129 (MVPN-IPv4) or 2/129 (MVPN-IPv6) A-D routes.

3.2. MVPN with SR P2MP P-Tunnel

[RFC6514] defines procedures for discovering PEs participating in a given MVPN and binding customer multicast flows to specific P-tunnels. This section specifies modifications to these procedures for SR P2MP P-tunnels. The Intra-AS I-PMSI, Inter-AS I-PMSI, and S-PMSI A-D routes have the PTA that specifies the SR P2MP tree P-tunnel. In this section, the term "SR P2MP" refers to both SR-MPLS and SRv6 data planes.

3.2.1. PMSI Tunnel Attribute for SR P2MP P-Tunnel

A PTA for an SR P2MP P-tunnel is constructed as specified below.

- Tunnel Type: One of the following SR P2MP P-tunnel types (from the "P-Multicast Service Interface Tunnel (PMSI Tunnel) Tunnel Types" registry).
  - 0x0C for SR-MPLS P2MP Tree
  - 0x0D for SRv6 P2MP Tree
- Flags: See Section 3.2.2 for use of the "Leaf Information Required" flag.
- MPLS Label: See Section 4.1.1.1.
- Tunnel Identifier: The SR P2MP P-tunnel identifies an SR P2MP Policy with the identifier <Root, Tree-ID> [RFC9960] encoded in the exact order below:
  - Tree-ID: A 32-bit unsigned value that uniquely identifies an SR P2MP Policy at the Root.
  - Root: An IP address identifying the Root of the SR P2MP Policy. This can be either an IPv4 or IPv6 address. The address type can be inferred from the PTA length.

A PTA with a SR P2MP P-tunnel is provisioned with the Tunnel Type for SR-MPLS or SRv6 P2MP trees. An implementation **SHOULD** advertise a PTA with SR P2MP P-tunnel only when the underlying SR-MPLS or SRv6 data plane is supported. The procedures for provisioning and determination of data plane support for SR-MPLS or SRv6 are outside scope of this document.

A P-tunnel can be segmented or non-segmented (see Section 8 of [RFC6513]). When a P-tunnel is non-segmented, the PTA is created by PE router at the Root of an SR P2MP tree. For segmented P-tunnels, each segment can be instantiated by a different P-tunnel type. If a segment is instantiated using a P2MP tree, the router at the Root of an SR P2MP tree creates the PTA.

3.2.1.1. MPLS Label

When an SR P2MP P-tunnel is not shared across MVPNs, i.e., there is one-to-one association between an MVPN instance and an SR P2MP P-tunnel, the MPLS Label field is set to zero as per [RFC6514] for both SR-MPLS and SRv6. In this case, the SR-MPLS or SRv6 Tree-SID of the PTI of the SR P2MP Policy advertised in the P-tunnel is sufficient to identify the MVPN instance for delivering the payload.

[RFC6514] allows a PE to aggregate two or more MVPNs onto one SR P2MP P-tunnel by advertising the same P-tunnel in PTA of A-D routes of different MVPNs. In this case, the MPLS Label field of the PTA is filled to provide a context bound to a specific MVPN instance as described in sections below. The value in this field is used by egress PEs to identify the MVPN instance for delivering the payload encapsulated in SR-MPLS or SRv6.

3.2.1.1.1. SR-MPLS

When an SR P2MP P-tunnel is shared across two or more MVPNs in an SR-MPLS domain, the MPLS Label field of a PTA advertised in an A-D route **MUST** contain an upstream-assigned MPLS label [RFC5331] [RFC6513] or a label assigned from a global context, such as the Domain-wide Common Block (DCB) as specified in [RFC9573], that the advertising PE has bound to the MVPN.

When an ingress PE steers the payload into a shared SR P2MP P-tunnel PTI, this MPLS label **MUST** be imposed before the MPLS label representing the Tree-SID. The trade-off of sharing an SR P2MP P-tunnel across MVPNs is that two MPLS labels have to be imposed on ingress and disposed on egress.

The egress PEs of a shared SR P2MP P-tunnel use the MPLS label to determine the MVPN instance for delivering the payload.

3.2.1.1.2. SRv6

When an SR P2MP P-tunnel is shared across two or more MVPNs in an SRv6 domain [RFC8986], the MPLS Label field of a PTA advertised in an A-D route **MUST** contain an upstream-assigned SRv6 Multicast Service SID (Section 3.1) that the advertising PE has bound to the MVPN or an SRv6 Multicast Service SID assigned from a global context; this follows same concept of the DCB label as specified in [RFC9573]. The high-order 20 bits of the MPLS Label field carry the whole or a portion of the Function part of the SRv6 Multicast Service SID when the Transposition Scheme of encoding as defined in [RFC9252] is used. When using the Transposition Scheme, the Transposition Length of the SRv6 SID Structure Sub-Sub-TLV of the SRv6 Prefix-SID attribute (see below) **MUST** be less than or equal to 20 and less than or equal to the Function Length. When the Transposition Scheme is not used, the MPLS Label field **MUST** be set to zero as per [RFC6514], and Transposition Length **MUST** be zero.

The advertising ingress PE **MUST** attach a BGP Prefix-SID attribute [RFC8669] to Intra-AS I-PMSI, Inter-AS I-PMSI, or S-PMSI A-D routes with the SRv6 L3 Service TLV [RFC9252] to signal the SRv6 Multicast Service SID. The SRv6 SID Information Sub-TLV carries the SRv6 Multicast Service SID in the SRv6 SID Value field. The SRv6 Endpoint behavior of the SRv6 SID Information Sub-TLV encodes one of End.DTMC4, End.DTMC6, or End.DTMC46 code point values. The SRv6 SID Structure Sub-Sub-TLV encodes the structure of the SRv6 Multicast Service SID. If the Transposition Scheme is used, the offset and length of SRv6 Multicast Endpoint function of the SRv6 Multicast Service SID is set in the Transposition Length and Transposition Offset fields of this sub-sub-TLV. Otherwise, the Transposition Length and Offset fields **MUST** be set to zero. The locator (LOC) of an SRv6 Multicast Service SID, which is assigned from a global context, such as DCB, is outside the scope of this document.

The advertising ingress PE, which is the Root node of the shared SR P2MP P-tunnel, **MUST** encapsulate a payload in an outer IPv6 header with an SRH in which the SRv6 Multicast Service SID **MUST** be the last segment in the segment list (note the SRv6 Multicast Service SID may be the only segment in the SRH). If the Transposition Scheme is used, the ingress PE **MUST** merge the Function part of the MPLS Label field of the PTA with the SRv6 SID in the SRv6 SID Information Sub-TLV using the Transposition Offset and Length fields from the SRv6 SID Structure Sub-Sub-TLV to create the SRv6 Multicast Service SID.

An egress PE of the shared SR P2MP P-tunnel uses the SRv6 Multicast Service SID in the SRH to determine the MVPN instance in which the customer payload is to be delivered. The egress PE, in the role of Leaf or Bud node of the Replication segment associated with the shared SR P2MP P-tunnel tree, uses the "look at next SID in SRH" behavior [RFC9524] to process the SRv6 Multicast Service SID. An egress PE **MUST NOT** install the SRv6 Multicast Service SID in its Forwarding Information Base (FIB), i.e., it **MUST NOT** forward packets based on the Locator portion of the SRv6 Multicast Service SID because the SID is not significant on the ingress PE.

3.2.2. Auto-Discovery Procedures

MVPN A-D procedures specified in [RFC6514] are used to advertise an SR P2MP P-tunnel and discover the Leaf nodes of the SR P2MP Policy associated with the P-tunnel. This section describes the processing of MVPN A-D routes to create, update, and tear down an SR P2MP Policy of an SR P2MP P-tunnel as described in Section 2.

3.2.2.1. Creation of CP of SR P2MP Policy

A PE interacts with an SR P2MP Policy module to create a CP, with optional traffic engineering constraints and an optional optimization objective, of an SR P2MP Policy when it originates an Intra-AS I-PMSI A-D route [RFC6514], an Inter-AS I-PMSI A-D route for an intra-AS segment [RFC6514], an S-PMSI A-D route [RFC6514], or a "wildcard" S-PMSI A-D route [RFC6625] with a PTA that has an SR P2MP P-tunnel type.

The CP of the SR P2MP Policy associated with an SR P2MP P-tunnel is deleted from the SR P2MP Policy module when a PE withdraws the Intra-AS I-PMSI, Inter-AS I-PMSI, or S-PMSI A-D route advertising that P-tunnel.

When a PE originates an Inter-AS I-PMSI or an S-PMSI A-D route with a PTA that has an SR P2MP P-tunnel type, it **MUST** set the "Leaf Information Required" flag in the PTA.

3.2.2.2. Discovery of Leaf Nodes

An ingress PE that advertises an MVPN A-D route with a PTA that has an SR P2MP P-tunnel type discovers a Leaf node of the SR P2MP Policy associated with the SR P2MP P-tunnel when it imports an Intra-AS I-PMSI A-D route [RFC6514] or Leaf A-D route [RFC6514] from an egress PE. The ingress PE adds the egress PE as a Leaf node in the SR P2MP Policy module.

An ingress PE removes an egress PE from the Leaf set of the SR P2MP Policy when the egress PE withdraws the Intra-AS I-PMSI or the Leaf A-D route.

An egress PE informs the SR P2MP Policy module to join the SR P2MP Policy as a Leaf or Bud node when it imports an Intra-AS I-PMSI A-D route, an Inter-AS I-PMSI A-D route, or an S-PMSI A-D route from an ingress PE that has a PTA with an SR P2MP P-tunnel type. The egress PE **MUST** originate a Leaf A-D route if the "Leaf Information Required" flag is set in the PTA.

An egress PE withdraws itself as a Leaf or Bud node of the SR P2MP Policy when the ingress PE withdraws an Intra-AS I-PMSI, Inter-AS I-PMSI, or S-PMSI A-D route. The egress PE **MUST** withdraw the Leaf A-D it had originated earlier in response to the "Leaf Information Required" flag in the PTA.

3.3. MVPN with Ingress Replication over SR

A PE can provide MVPN service using IR over SR. The payload is encapsulated in SR-MPLS or SRv6 at an ingress PE and replicated with each copy sent to an egress PE via unicast.

"Ingress Replication Tunnels in Multicast VPN" [RFC7988] specifies procedures that can be reused to provide MVPN service with IR in an SR domain. A PE advertises Intra-AS I-PMSI A-D, Inter-AS I-PMSI A-D, or Selective PMSI A-D and Leaf A-D routes with the PTA for IR. Egress PEs join as Leaf nodes using Intra-AS I-PMSI A-D or Leaf A-D routes. The procedures of [RFC7988] provide an MVPN IR service with best-effort unicast connectivity.

This document adds procedures for providing an MVPN IR service with an SLA from an ingress PE to an egress PE both for SR-MPLS and SRv6. This document extends the BGP Update message of AFI/SAFI 1/129 (MVPN-IPv4) and 2/129 (MVPN-IPv6) to carry the Color Extended Community as specified in [RFC9012] and the Color-Only Type extension specified in Section 3 of [RFC9830]. An egress PE colors the Leaf or Intra-AS I-PMSI A-D route with a Color Extended Community. The ingress PE replicates MVPN customer payload to the egress PE by steering it into an SR-TE policy according to Section 8 of [RFC9256]. The ingress PE encapsulates the payload packet into a segment list of the matching SR-TE policy to the egress PE along with the IR MPLS label or SRv6 Multicast Service SID received from the egress PE.

Note that the Color Extended Community is not used with an MVPN SR P2MP P-tunnel. For MVPN with an SR P2MP P-tunnel, the ingress PE dictates the traffic engineering treatment by specifying the constraints and the metric optimization in the CP of the SR P2MP Policy corresponding to the P-tunnel on the ingress PE. This is necessary because packets are replicated in the PTI; therefore, it is not possible to have differing traffic engineering treatment towards each egress PE (Leaf node) of the PTI.

3.3.1. SR-MPLS

The PTA carried in Intra-AS I-PMSI A-D, Inter-AS I-PMSI A-D, S-PMSI A-D, and Leaf A-D routes is constructed as specified in [RFC7988].

MVPN IR service with SLA over SR-MPLS data plane can be provided by using the Color Extended Community as described above. Suppose an egress PE, say PE2, sends Leaf A-D route with Extended Color Community C1 with Color-Only Type 0 and IR label L10 to the ingress PE1. Assume the segment list of SR-TE policy (C1, PE2) at ingress PE1 is <L1, L2, L3>. PE1 will encapsulate the MVPN payload into the MPLS label stack <L1, L2, L3, L10> with L10 as the Bottom-of-Stack (BoS) label.

3.3.2. SRv6

The procedures specified in [RFC7988], with the modifications defined in this section, are used to provide MVPN IR service over SRv6.

The PTA carried in Intra-AS I-PMSI A-D, Inter-AS I-PMSI A-D, Selective PMSI A-D, and Leaf A-D routes is constructed as specified in [RFC7988] with the following modifications:

- Tunnel Type: "Ingress Replication" as per [RFC6514].
- MPLS Label: The high-order 20 bits of this field carry the whole or a portion of the Function part of the SRv6 Multicast Service SID when the Transposition Scheme is used for encoding as defined in [RFC9252]. When using the Transposition Scheme, the Transposition Length of the SRv6 SID Structure Sub-Sub-TLV of the SRv6 Prefix-SID attribute (see below) **MUST** be less than or equal to 20 and less than or equal to the Function Length. When the Transposition Scheme is not used, the MPLS Label field **MUST** be set to zero, and Transposition Length **MUST** be zero.

Sections 6 and 7 of [RFC7988] describe considerations and procedures for allocating MPLS labels for IR P-tunnels. These considerations also apply to allocation of a SRv6 Multicast Service SID for SRv6 IR.

To join an SRv6 IR P-tunnel advertised in the PTA of Intra-AS I-PMSI A-D, Inter-AS I-PMSI A-D, or Selective S-PMSI A-D routes, an egress PE constructs a Leaf A-D or Intra-AS I-PMSI A-D route as described in [RFC7988] with the modified PTA above. The egress PE **MUST** attach a BGP Prefix-SID attribute [RFC8669] with a Leaf A-D or Intra-AS I-PMSI A-D route with the SRv6 L3 Service TLV [RFC9252] to signal the SRv6 Multicast Service SID (Section 3.1). The SRv6 SID Information Sub-TLV carries the SRv6 Multicast Service SID in the SRv6 SID Value field. The SRv6 Endpoint behavior of the SRv6 SID Information Sub-TLV **MUST** encode one of the End.DTMC4, End.DTMC6, or End.DTMC46 code point values. The SRv6 SID Structure Sub-Sub-TLV encodes the structure of the SRv6 Multicast Service SID. If the Transposition Scheme is used, the offset and length of SRv6 Multicast Endpoint function of the SRv6 Multicast Service SID is set in the Transposition Length and Transposition Offset fields of this sub-sub-TLV. Otherwise, the Transposition Length and Offset fields **MUST** be set to zero. The BGP Prefix SID attribute with the SRv6 L3 Service TLV in an Intra-AS I-PMSI or Leaf A-D route indicates to the ingress PE that the egress PE supports SRv6.

The SRv6 Multicast Service SID **MUST** be routable within the AS of the egress PE. As per [RFC7988], the ingress PE uses the Tunnel Identifier of PTA to determine the unicast tunnel to use in order to send data to the egress PE. For SRv6 IR, the ingress PE **MUST** use the SRv6 Multicast Service SID to determine the unicast tunnel to be used. For best-effort MVPN IR service or SLA-based MVPN IR service using the IGP Flexible Algorithm, the ingress PE **MUST** encapsulate the payload in an outer IPv6 header, with the SRv6 Multicast Service SID provided by the egress PE used as the destination address. If the Transposition Scheme is used, the ingress PE **MUST** merge the Function part of the MPLS Label field of the PTA with SRv6 SID in the SRv6 SID Information Sub-TLV using the Transposition Offset and Length fields from the SRv6 SID Structure Sub-Sub-TLV to create the SRv6 Multicast Service SID.

MVPN IR service with SLA over SRv6 can be provided by using the Color Extended Community as described above. Suppose an egress PE, say PE2, sends Leaf A-D route with Extended Color community C1 with Color-Only Type 0 and SRv6 Multicast Service SID S10 to ingress PE1. Assume the segment list of the SR-TE policy (C1, PE2) at ingress PE1 is <S1, S2, S3>. PE1 will encapsulate a payload into an IPv6 header with SRH (PE1, S1) (S10, S3, S2; SL=3) (payload).

4. EVPN with SR

BGP MPLS-Based EVPN, specified in [RFC7432], specifies the IMET route to support BUM traffic. This IMET route is the equivalent of the MVPN Intra-AS I-PMSI route and is advertised with a PTA as specified in [RFC6514] to advertise the inclusive P-tunnels. [RFC9252] specifies procedures for IMET routes with IR over SRv6.

[RFC9572] updates the EVPN BUM procedures to support selective P-tunnels. It defines new BGP route types that are advertised with a PTA, including the S-PMSI A-D and Leaf A-D routes. The S-PMSI and Leaf A-D routes of [RFC9572] are analogous to MVPN S-PMSI and Leaf A-D routes [RFC6514]. Note that support of Inter-AS and Inter-Region segmentation procedures in [RFC9572] with SR P2MP P-tunnels are out of scope of this document.

Inclusive and selective P-tunnels can be instantiated using SR P2MP trees or IR over SR.

4.1. EVPN with SR P2MP P-Tunnel

This section specifies modifications to procedures of [RFC7432] and [RFC9572] for SR P2MP P-tunnels. The IMET, S-PMSI, and Leaf A-D routes have the PTA that specifies the SR P2MP tree P-tunnel. In this section, the term "SR P2MP" refers to both SR-MPLS and SRv6 data planes.

4.1.1. PMSI Tunnel Attribute for SR P2MP P-Tunnel

A PTA for an SR P2MP P-tunnel is constructed as specified in Section 3.2.1, except the MPLS Label and Flags fields are filled as specified in Sections 4.1.1.1 and 4.1.3, respectively.

4.1.1.1. MPLS Label

4.1.1.1.1. SR-MPLS

When an SR P2MP P-tunnel is not shared across MVPNs, i.e., there is one-to-one association between an EVI and an SR P2MP P-tunnel, the MPLS Label field is set to zero as per [RFC6514]. In this case, the SR-MPLS Tree-SID of the PTI of the SR P2MP Policy advertised in the P-tunnel is sufficient to identify the MVPN instance for delivering the payload.

[RFC7432] and [RFC9572] allow a PE to aggregate two or more EVIs onto one SR P2MP P-tunnel by advertising the same P-tunnel in the PTA of A-D routes of different EVIs. When an SR P2MP P-tunnel is shared across two or more EVIs in an SR-MPLS domain, the MPLS Label field of a PTA advertised in an EVPN A-D route **MUST** contain an upstream-assigned MPLS label [RFC5331] [RFC6513] or a label assigned from a global context, such as DCB as specified in [RFC9573], that the advertising PE has bound to the EVI. The egress PE uses this label as context to identify the specific EVI for delivering the EVPN payload encapsulated in SR-MPLS. When an ingress PE steers the payload into a shared SR P2MP P-tunnel PTI, this MPLS label **MUST** be imposed before the MPLS label representing the Tree-SID.

4.1.1.1.2. SRv6

For SRv6 P2MP, an EVI is identified by an SRv6 SID encoded in the SRH of an IPv6-encapsulated packet from the ingress PE as described later in this section. This is required even if the SR P2MP P-tunnel is not shared across EVIs.

The advertising ingress PE **MUST** attach a BGP Prefix-SID attribute [RFC8669] to IMET [RFC9252] or S-PMSI [RFC9572] A-D routes with the SRv6 L2 Service TLV [RFC9252]. The SRv6 SID Information Sub-TLV carries the SID in the SRv6 SID Value field. The SRv6 Endpoint behavior of the SRv6 SID Information Sub-TLV **SHOULD** be END.DT2M [RFC8986] as per Section 6.3 of [RFC9252]. The SRv6 SID Structure Sub-Sub-TLV encodes the structure of SID. If the Transposition Scheme is used, the offset and length of the SID is set in the Transposition Length and Transposition Offset fields of this sub-sub-TLV. Otherwise, the Transposition Length and Offset fields **MUST** be set to zero. The LOC of a SID, which is assigned from a global context, such as DCB, is outside the scope of this document.

The MPLS Label field of a PTA advertised in an A-D route **MUST** contain an upstream-assigned SRv6 SID that the advertising PE has bound to the EVI or an SRv6 SID assigned from a global context; this follows same concept of the DCB label as specified in [RFC9573]. The high-order 20 bits of the MPLS Label field carry the whole or a portion of the Function part of the SRv6 SID when the Transposition Scheme of encoding as defined in [RFC9252] is used. When using the Transposition Scheme, the Transposition Length of the SRv6 SID Structure Sub-Sub-TLV of the SRv6 Prefix-SID attribute **MUST** be less than or equal to 20 and less than or equal to the Function Length. When the Transposition Scheme is not used, the MPLS Label field **MUST** be set to zero as per [RFC6514], and Transposition Length **MUST** be zero.

The advertising ingress PE, which is the Root node of the SR P2MP P-tunnel, **MUST** encapsulate a payload in an outer IPv6 header with an SRH in which the SRv6 SID (advertised in the BGP Prefix-SID attribute) **MUST** be the last segment in the segment list (note the SRv6 SID may be the only segment in the SRH). If the Transposition Scheme is used, the ingress PE **MUST** merge the Function part of the MPLS Label field of the PTA with the SRv6 SID in the SRv6 SID Information Sub-TLV using the Transposition Offset and Length fields from the SRv6 SID Structure Sub-Sub-TLV to create the SRv6 SID. When ESI-based split-horizon filtering is used, the Arg.FE2 (see Section 4.1.2.2) **SHOULD** be merged with the SRv6 SID by doing a bitwise logical OR operation to create the complete SRv6 SID encoded in the SRH on the ingress PE.

An egress PE of the SR P2MP P-tunnel uses the SRv6 SID in the SRH to determine the EVI in which the customer payload is to be delivered. The egress PE, in role of Leaf or Bud node of the Replication segment associated with the SR P2MP P-tunnel tree, uses "look at next SID in SRH" [RFC9524] behavior to process the SRv6 SID. An egress PE **MUST NOT** install the SRv6 SID in its FIB, i.e., it **MUST NOT** forward packets based on the Locator portion of the SRv6 SID. The Arg.FE2 of the SID, if present, is used for ESI-based split-horizon filtering as specified in Section 4.1.2.2.

4.1.2. Split-Horizon Filtering for ES Multihoming

EVPN requires split-horizon filtering with ES multihoming in order to prevent duplicate BUM traffic as described in Section 8.3 of [RFC7432]. This section describes split-horizon filtering procedures with SR P2MP P-tunnels.

4.1.2.1. SR-MPLS Filtering

The split-horizon procedures specified for P2MP MPLS Label Switched Paths (LSPs) in Section 8.3.1.2 of [RFC7432] are sufficient for SR P2MP P-tunnels. Note for shared SR P2MP P-tunnels, the ESI label is at the bottom of the label stack, followed by an EVI context label and finally the Tree-SID label of the PTI associated with P-tunnel at the top in SR-MPLS encapsulation.

4.1.2.2. SRv6 Filtering

For SRv6, the Arg.FE2 argument of End.DT2M SRv6 Endpoint behavior [RFC8986] is used for ESI-based split-horizon filtering. For an SR P2MP P-tunnel, the Arg.FE2 SID argument is an upstream-assigned value assigned by an ingress PE and identifies an ES of origin. This SID Argument is analogous to the upstream-assigned ESI MPLS label specified in Section 8.3 of [RFC7432]. The Arg.FE2 is signaled in the ESI Label field of the ESI Label extended community [RFC7432] and a BGP Prefix-SID attribute with an Ethernet A-D per ES route as specified in Section 6.1.1 of [RFC9252] and expanded further in [RFC9819].

The advertised Arg.FE2 is encoded with the SRv6 SID in the SRH by the ingress PE as described in Section 4.1.1.1.2. The egress PE uses the Arg.FE2 of the SRv6 SID, if present, to perform ESI-based split-horizon filtering as specified for the End.DT2M forwarding behavior in Section 4.12 of [RFC8986].

4.1.3. Auto-Discovery Procedures

EVPN A-D procedures specified in [RFC7432] and [RFC9572] are used to advertise an SR P2MP P-tunnel and discover the Leaf nodes of the SR P2MP Policy associated with the P-tunnel. This section describes the processing of EVPN A-D routes to create, update, and tear down an SR P2MP Policy of an SR P2MP P-tunnel as described in Section 2.

4.1.3.1. Creation of CP of SR P2MP Policy

A PE interacts with an SR P2MP Policy module to create a CP, with optional traffic engineering constraints and an optional optimization objective, of an SR P2MP Policy when it originates an IMET A-D route [RFC7432] or an S-PMSI A-D route [RFC9572], with a PTA that has an SR P2MP P-tunnel type.

The CP of the SR P2MP Policy associated with an SR P2MP P-tunnel is deleted from the SR P2MP Policy module when a PE withdraws the IMET or S-PMSI A-D route advertising that P-tunnel.

When a PE originates an S-PMSI A-D route with a PTA that has an SR P2MP P-tunnel type, it **MUST** set the "Leaf Information Required" flag in the PTA.

4.1.3.2. Discovery of Leaf Nodes

An ingress PE that advertises an EVPN A-D route with a PTA that has an SR P2MP P-tunnel type discovers a Leaf node of the SR P2MP Policy associated with the SR P2MP P-tunnel when it imports an IMET A-D route [RFC7432] or Leaf A-D route [RFC9572] from an egress PE. The ingress PE adds the egress PE as a Leaf node in the SR P2MP Policy module.

An ingress PE removes an egress PE from the Leaf set of the SR P2MP Policy when the egress PE withdraws the IMET A-D or the Leaf A-D route.

An egress PE informs the SR P2MP Policy module to join the SR P2MP Policy as a Leaf or Bud node when it imports an IMET A-D route or an S-PMSI A-D route from an ingress PE that has a PTA with an SR P2MP P-tunnel type. The egress PE **MUST** originate a Leaf A-D route if the "Leaf Information Required" flag is set in the PTA.

An egress PE withdraws itself as a Leaf or Bud node of the SR P2MP Policy when the ingress PE withdraws an IMET or an S-PMSI A-D route. The egress PE **MUST** withdraw the Leaf A-D it had originated earlier in response to the "Leaf Information Required" flag in the PTA.

4.2. EVPN with Ingress Replication over SR

A PE can provide EVPN service using IR over SR. The EVPN payload is encapsulated in SR-MPLS or SRv6 at an ingress PE and replicated with each copy sent to an egress PE via unicast. IR procedures for MPLS are specified for the IMET A-D route in [RFC7432] and the SMET A-D route in [RFC9251]. Procedures for EVPN IR over SRv6 for the IMET A-D route are specified in [RFC9252]. These procedures provide an EVPN IR service with best-effort unicast connectivity.

This document adds procedures for providing an EVPN IR service with an SLA from an ingress PE to an egress PE both for SR-MPLS and SRv6. This document extends the BGP Update message of AFI/SAFI 25/70 (L2VPN-EVPN) to carry the Color Extended Community as specified in [RFC9012] and the Color-Only Type extension specified in Section 3 of [RFC9830]. An egress PE colors the IMET with a Color Extended Community. The ingress PE replicates EVPN customer payload to the egress PE by steering it into an SR-TE policy according to Section 8 of [RFC9256]. The ingress PE encapsulates the payload packet into a segment list of the matching SR-TE policy to the egress PE along with IR MPLS label or SRv6 End.DT2M SID received from the egress PE.

Note that the Color Extended Community is not used with an EVPN SR P2MP P-tunnel. For EVPN with an SR P2MP P-tunnel, the ingress PE dictates the traffic engineering treatment by specifying the constraints and the metric optimization in the CP of the SR P2MP Policy corresponding to the P-tunnel on the ingress PE. This is necessary because packets are replicated in the PTI; therefore, it is not possible to have differing traffic engineering treatment towards each egress PE (Leaf node) of the PTI.

4.2.1. SR-MPLS

EVPN IR procedures for MPLS specified in [RFC7432] and [RFC9251] can be extended for EVPN IR over SR-MPLS.

EVPN IR service with an SLA over SR-MPLS data plane can be provided by using the Color Extended Community as described above. Suppose an egress PE, say PE2, sends an IMET A-D route with Extended Color Community C1 with Color-Only Type 0 and EVPN BUM label L10 to ingress PE1. Assume the segment list of SR-TE policy (C1, PE2) at ingress PE1 is <L1, L2, L3>. PE1 will encapsulate the MVPN payload into the MPLS label stack <L1, L2, L3, L10> with L10 as the BoS label. Note that the MPLS label stack may have the ESI label at the bottom of the label stack if ESI-based split-horizon filtering is used.

4.2.2. SRv6

EVPN IR procedures for SRv6 are specified in Section 6.3 of [RFC9252] for the IMET A-D route.

A PE can provide EVPN IR service with SLA over SRv6 using the Color Extended Community as described above. Suppose an egress PE, say PE2, sends an IMET A-D route with Extended Color community C1 with Color-Only Type 0 and SRv6 End.DT2M SID S10 to ingress PE1. Assume the segment list of the SR-TE policy (C1, PE2) at ingress PE1 is <S1, S2, S3>. PE1 will encapsulate a payload into an IPv6 header with SRH (PE1, S1) (S10, S3, S2; SL=3) (payload). Note that the End.DT2M SID S10 may also have an Arg.FE2 Argument if ESI-based split-horizon filtering is used.

5. IANA Considerations

IANA has assigned the following values in the "P-Multicast Service Interface Tunnel (PMSI Tunnel) Tunnel Types" registry [RFC7385] within the "Border Gateway Protocol (BGP) Parameters" registry group <https://www.iana.org/assignments/bgp-parameters>.

Value	Meaning	Reference
0x0C	SR-MPLS P2MP Tree	RFC 10018
0x0D	SRv6 P2MP Tree	RFC 10018

Table 1: PMSI Tunnel Types

IANA has allocated the following code points in the "SRv6 Endpoint Behaviors" registry [RFC8986] within the "Segment Routing" registry group <https://www.iana.org/assignments/segment-routing>.

Value	Hex	Endpoint Behavior	Reference	Change Controller
76	0x004C	End.DTMC4	RFC 10018	IETF
77	0x004D	End.DTMC6	RFC 10018	IETF
78	0x004E	End.DTMC46	RFC 10018	IETF

Table 2: SRv6 Endpoint Behaviors

6. Security Considerations

The procedures in this document do not introduce any additional security considerations beyond those mentioned in [RFC6513], [RFC6514], [RFC7432], and [RFC9572]. For general security considerations applicable to SR P2MP Policy and Replication segments, please refer to [RFC9960] and [RFC9524], respectively.

7. References

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