Inter-Area P2MP Segmented LSPs

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Abstract

This document describes procedures for building "inter-area P2MP segmented service LSPs" by using BGP to stitch intra-area segments of P2MP service LSP. The intra-area P2MP LSPs that are used to carry intra-area segments of P2MP service LSP may be signaled using P2MP RSVP-TE or P2MP LDP. The applications/services that use such an inter-area service LSP may be NGEN MVPN, VPLS multicast or Internet-multicast over MPLS.
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1. Specification of requirements

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].
2. Introduction

This document describes procedures for building "inter-area P2MP segmented service LSPs" by using BGP to stitch intra-area segments of P2MP service LSP. The intra-area P2MP LSPs that are used to carry intra-area segments of P2MP service LSP may be signaled using P2MP RSVP-TE or P2MP LDP. The applications/services that use such an inter-area service LSP may be NGEN MVPN, VPLS multicast or Internet-multicast over MPLS.

The primary use case of such segmented P2MP service LSPs is when the PEs are in different areas but in the same AS and thousands or more of PEs require P2MP connectivity. This may be the case when MPLS is pushed further to the metro edge and the metros are in different areas. Seamless MPLS is the industry term to address this case [SEAMLESS-MPLS]. Thus one of the applicabilities of this document is that it describes the multicast procedures for seamless MPLS.

It is to be noted that [BGP-MVPN], [VPLS-MCAST] already specify procedures for building segmented inter-AS P2MP service LSPs. This document complements those procedures as it extends the segmented tree model such that it is applicable to inter-area P2MP service LSPs as well. Infact an inter-AS deployment could use inter-AS segmented trees as specified in [BGP-MVPN, VPLS-MCAST] where each intra-AS segment is constructed using inter-area segmented trees as specified in this document.

3. General Assumptions and Terminology

Assume BGP is used as an inter-area routing and label distribution protocol for unicast /32 routes for the PEs. Assume ABRs act as Route Reflectors for these routes. Futhermore, assume ABRs set BGP Next Hop to self for these routes.

Within an AS a P2MP service LSP is partitioned into 3 segments: ingress area segment, backbone area segment, and egress area segment. Within each area a segment is carried over an intra-area P2MP LSP. There could be either 1:1 or n:1 mapping between segments and a given intra-area P2MP LSP. The latter is realized using P2MP LSP hierarchy with upstream-assigned labels. For simplicity we assume that P2MP LSP hierarchy is used even with 1:1 mapping, in which case the upstream-assigned label could be an implicit NULL.

The ingress area segment of a P2MP service LSP is rooted at PE (or at ASBR in the case where the P2MP service LSP spans multiple ASes). The leaves of this segment are other PEs and ABRs in the same area as the root PE. The backbone area segment is rooted at an ABR that is
connected to the ingress area (ingress ABR), and has as it leaves ABRs that are connected to the egress area(s). The egress area segment is rooted at an ABR in the egress area (egress ABR), and has as its leaves PEs and ASBR in that egress area. Note that for a given P2MP service LSP there may be more than one backbone segment, each rooted at its own ingress ABR, and more than one egress area segment, each rooted at its own egress ABR.

4. Discovering the P2MP FEC of the Inter-Area P2MP Service LSP

The P2MP FEC identifies the inter-area P2MP service LSP. The egress PEs need to learn this P2MP FEC in order to initiate the creation of the egress area segment of the P2MP inter-area service LSP. The P2MP FEC of the inter-area P2MP LSP is learned by the egress PEs either by configuration, or based on the application-specific procedures (e.g., MVPN-specific procedures, VPLS-specific procedures).

4.1. BGP MVPN

Egress PEs discover the P2MP FEC when the application is BGP MVPN, using the I-PMSI or S-PMSI A-D routes that are originated by the ingress PEs or ASBRs following the procedures of [BGP-MVPN]. The NLRI of such routes encodes the P2MP FEC. The procedures in this document assume all ABRs act as Route Reflectors for MVPN auto-discovery (A-D) routes. The "Leaf Information Required" flag MUST be set in the P-Tunnel attribute carried in such routes. Before any Leaf auto discovery route is advertised by a PE or ABR in the same area, as described in the following sections, an I-/S-PMSI autodiscovery route is advertised either with an explicit tunnel type in the PMSI Tunnel Attribute, if a tunnel identifier has already been assigned, or possibly with a special tunnel type of "No tunnel information present.

To avoid requiring ABRs to participate in the propagation of C-multicast routes, this document requires ABRs NOT to modify BGP Next Hop when re-advertising I-PMSI/S-PMSI A-D routes. The egress PEs may advertise the C-multicast routes to RRs that are different than the ABRs. However ABRs still can be configured to be the Route Reflectors for C-multicast routes, in which case they will participate in the propagation of C-multicast routes.
4.2. BGP VPLS or LDP VPLS with BGP A-D

Egress PEs discover the P2MP FEC when the application is VPLS, using the VPLS A-D routes that are originated by the ingress PEs [BGP-VPLS, VPLS-AD] or S-PMSI A-D routes that are originated by the ingress PE [VPLS-P2MP]. The NLRI of such routes encodes the P2MP FEC. The "Leaf Information Required" flag MUST be set in the P-Tunnel attribute carried in such routes. Before any Leaf auto discovery route is advertised by a PE or ABR in the same area, as described in the following sections, an VPLS/S-PMSI autodiscovery route is advertised either with an explicit tunnel type in the PMSI Tunnel Attribute, if a tunnel identifier has already been assigned, or possibly with a special tunnel type of "No tunnel information present."

The procedures in this document assume all ABRs act as Route Reflectors for VPLS auto-discovery (A-D) routes. These ABRs/RRs do NOT modify BGP Next Hop when re-advertising these A-D routes.

4.3. Internet Multicast

This section describes how the egress PEs discover the P2MP FEC when the application is internet multicast.

An egress PE learns the (S/*, G) of a multicast stream as a result of receiving IGMP or PIM messages on one of its IP multicast interfaces. This (S/*, G) forms the P2MP FEC of the inter-area P2MP service LSP. Therefore, an ABR maintains LFIB state for each (S,G) tree traversing that ABR. That is for a given (S,G) both the ingress PE and the ingress ABR have to allocate a distinct upstream-assigned label.

5. Procedures

5.1. Egress PEs

Once an egress PE discovers the P2MP FEC of an inter-area segmented P2MP service LSP, it MUST propagate this P2MP FEC in BGP in order to construct the segmented inter-area P2MP service LSP.

5.1.1. Determining the Ingress PE/ASBR

The egress PE discovers the P2MP FEC of an inter-area P2MP Segmented Service LSP as described in section 3. When an egress PE discovers this P2MP FEC it MUST first determine the ingress PE/ASBR of such a FEC as follows.
If the application is MVPN or VPLS the ingress PE/ASBR’s address is the BGP next-hop of the MVPN or VPLS A-D route from which the P2MP FEC is derived.

If the application is internet multicast then the unicast routes to multicast sources/RPs SHOULD carry the VRF Route Import Extended Community [BGP MVPN] where the IP address in the Global Administrator field is set to the IP address of PE advertising the unicast route. The Local Administrator field of this community MUST be set to 0. If it is not desirable to advertise the VRF Route Import Extended Community in unicast routes, then unicast routes to multicast sources MUST be advertised using the multicast SAFI i.e. SAFI 2 and the VRF Route Import Extended Community MUST be carried in such routes. The ingress PE address as determined by the egress PE is the IP address determined from the VRF Route Import Extended community, that is present in the best route to reach S/RP.

5.1.2. Originating a Leaf Auto-Discovery Route

If the P2MP FEC was derived from a MVPN or VPLS A-D route then the egress PE MUST originate a Leaf auto-discovery (A-D) route if the MVPN or VPLS A-D route carries a P-Tunnel Attribute with the "Leaf Information Required" flag set.

If the P2MP FEC was derived from an Internet Multicast S/*, G and the ingress PE’s address is not the same as the egress PE, then the egress PE MUST originate a Leaf auto-discovery (A-D) route.

5.1.2.1. Leaf A-D Route for MVPN and VPLS

If the P2MP FEC was derived from MVPN or VPLS A-D routes then the Route Key field of the Leaf A-D route contains the NLRI of the A-D route from which the P2MP FEC was derived. This follows procedures described in [BGP-MVPN, VPLS-P2MP].

5.1.2.2. Leaf A-D Route for Internet Multicast

If the application is internet multicast then the MCAST-VPN NLRI of the Leaf A-D route is constructed as follows:

The Route Key field of MCAST-VPN NLRI has the following format:

```
+-----------------------------------+  
|      RD   (8 octets)              |  
+-----------------------------------+  
```
RD is set to 0 for (S,G) state and all 1s for (*,G) state, Multicast Source is set to S for (S,G) state or RP for (*,G) state, Multicast Group is set to G, Multicast Source Length and Multicast Group Length is set to either 4 or 16 (depending on whether S/RP and G are IPv4 or IPv6 addresses), and Ingress PE IP Address is set to the address carried in the BGP Next Hop of the route to S/RP.

The Originating Router’s IP address field of MCAST-VPN NLRI is set to the address of the local PE (PE that originates the route).

Thus the whole MCAST-VPN NLRI of the route has the following format:

```
+-----------------------------------+
|      RD   (8 octets)              |
+-----------------------------------+
| Multicast Source Length (1 octet) |
+-----------------------------------+
|  Multicast Source (Variable)      |
+-----------------------------------+
|  Multicast Group Length (1 octet) |
+-----------------------------------+
|   Multicast Group   (Variable)    |
+-----------------------------------+
|    Ingress PE IP Addr            |
+-----------------------------------+
| Originating Router’s IP address   |
+-----------------------------------+
```

When the PE deletes (S,G)/(*,G) state that was created as a result of receiving PIM messages on one of its IP multicast interfaces, if the PE previously originated a Leaf auto-discovery route for that state, then the PE SHOULD withdraw that route.

The support of PIM-SM in ASM mode requires further details and they will be provided in the next revision.
5.1.2.3. Constructing Rest of the Leaf A-D Route

The Next Hop field of the MP_REACH_NLRI attribute of the route SHOULD be set to the same IP address as the one carried in the Originating Router’s IP Address field of the route.

To constrain distribution of this route, the originating PE constructs an IP-based Route Target community by placing the IP address of the egress ABR in the Global Administrator field of the community, with the Local Administrator field of this community set to 0. The originating PE then adds this Route Target Extended Community to this Leaf auto-discovery route. The egress ABR’s address is the BGP next-hop of the BGP route to reach the ingress PE/ASBR.

The PE then advertises this route to the (egress) ABR/RR.

5.2. Egress ABR

When an egress ABR receives a Leaf auto-discovery route, or a withdraw of a previously received Leaf auto-discovery route, and the Route Target extended community carried by the route contains the IP address of this ABR, then the following procedures will be executed.

The egress ABR originates a Leaf A-D route, whose MCAST-VPN NLRI is constructed as follows.

The Route Key field of MCAST-VPN NLRI is the same as the Route Key field of MCAST-VPN NLRI of the received Leaf A-D route. The Originating Router’s IP address field of MCAST-VPN NLRI is set to the address of the local ABR (the ABR that originates the route).

The Next Hop field of the MP_REACH_NLRI attribute of the route SHOULD be set to the same IP address as the one carried in the Originating Router’s IP Address field of the route.

To constrain distribution of this route, the originating PE constructs an IP-based Route Target community by placing the IP address of the ingress ABR in the Global Administrator field of the community, with the Local Administrator field of this community set to 0, and sets the Extended Communities attribute of this Leaf auto-discovery route to that community. The ingress ABR is the BGP Next Hop of the route to the ingress PE/ASBR. If the RD of the received Leaf A-D route is 0, then the Ingress PE address is determined from the the received Leaf A-D route. If the RD of the received Leaf A-D route is not 0, the ABR finds an MVPN I-PMSI/S-PMSI A-D route or VPLS A-D or S-PMSI A-D route whose NLRI has the same value as the Route Key field of the the Leaf A-D route. The BGP next-hop of this NLRI is...
the address of the ingress PE.

To carry information identifying the upstream PE/ABR that has to process this Leaf Auto-Discovery route, the originating PE constructs an IP-based Route Target community by placing the IP address of the ingress ABR in the Global Administrator field of the community, with the Local Administrator field of this community set to 0, and sets the Extended Communities attribute of this Leaf auto-discovery route to that community. The ingress ABR is the BGP Next Hop of the route to the ingress PE/ASBR. If the RD of the received Leaf A-D route is 0, then the Ingress PE address is determined from the received Leaf A-D route. If the RD of the received Leaf A-D route is not 0, the ABR finds an MVPN I-PMSI/S-PMSI A-D route or VPLS A-D or S-PMSI A-D route whose NLRI has the same value as the Route Key field of the Leaf A-D route. The BGP next-hop of this NLRI is the address of the ingress PE. The ABR then advertises this Leaf A-D route to the ABRs in the backbone area.

Mechanisms specific in RFC4684 for constrained BGP route distribution can be used along with this specification to ensure that only the needed PE/ABR will have to process a said Leaf auto-discovery route.

5.2.1. P2MP RSVP-TE LSP as the Intra-Area P2MP LSP in the Egress Area

If P2MP RSVP-TE LSP is used as the the intra-area LSP in the egress area, then the egress ABR can either (a) graft the leaf (whose IP address is specified in the received Leaf auto-discovery route) into an existing P2MP LSP rooted at the egress ABR, and use that LSP for carrying traffic for the inter-area segmented P2MP service LSP, or (b) originate a new P2MP LSP to be used for carrying (S,G).

Note that an existing intra-area P2MP LSP may be used solely for that particular inter-area P2MP service LSP, or for other inter-area P2MP service LSPs as well. The choice between the two options is purely local to the egress ABR. The first option provides one-to-one mapping between inter-area P2MP service LSPs and intra-area P2MP LSPs; the second option provides many-to-one mapping, thus allowing to aggregate forwarding state.

When the RD of the received Leaf A-D route is not set to zero then the ABR MUST re-advertise in the egress area the MVPN/VPLS A-D route, that matches the Leaf A-D route to signal the binding of the intra-area P2MP RSVP-TE LSP to the inter-area P2MP service LSP. This must be done ONLY if a) such a binding hasn’t already been advertised or b) The binding has changed. The PMSI Tunnel attribute of the re-advertised route specifies an intra-area P2MP RSVP-TE LSP rooted at the ABR and MUST also carry an upstream assigned MPLS label. The
upstream-assigned MPLS label MUST be set to implicit NULL if the mapping between the inter-area P2MP service LSP and the intra-area P2MP LSP is one-to-one. If the mapping is many-to-one the intra-area segment of the inter-area P2MP service LSP (referred to as the "inner" P2MP LSP) is constructed by nesting the inter-area P2MP service LSP in an intra-area P2MP LSP (referred to as the "outer" intra-area P2MP LSP), by using P2MP LSP hierarchy based on upstream-assigned MPLS labels [RFC 5332].

If the RD of the received Leaf A-D route is zero, then the egress ABR need not advertise any auto-discovery routes. As this is the case of inter-area P2MP service LSP being associated with the Internet multicast service. In this case the egress PEs do not require the binding of the intra-area P2MP LSP to the inter-area P2MP service LSP. If an egress PE receives multicast packets over an intra-area P2MP LSP, with no MPLS label in the stack to identify the inter-area P2MP service LSP, the egress PE must forward the packets using its internet multicast forwarding table.

If the mapping between the inter-area P2MP service LSP for Internet multicast service and the intra-area P2MP LSP is many-to-one then an egress PE must be able to determine whether a given multicast packet for a particular (S, G) is received from the "expected" upstream PE/ABR. The expected PE/ABR is the PE/ABR to which the Leaf A-D route is sent by the egress PE. Packets received from another PE/ABR for that (S, G) MUST be dropped. To allow the egress PE to determine the sender, the intra-area P2MP LSP must be signaled with no PHP, when the mapping between the inter-area P2MP service LSP for Internet multicast service and the intra-area P2MP LSP is many-to-one.

This document assumes that a single S-PMSI service LSP carries only a single (C-S,C-G). Thus if segments of multiple MVPN or VPLS S-PMSI service LSPs are carried over a given intra-area P2MP LSP, each of these segments would require a distinct upstream-assigned label, even if all these service LSPs are for (C-S, C-G)s from the same MVPN/VPLS. Therefore, an ABR maintains an LFIB state for each of the (C-S, C-G)s carried over S-PMSIs traversing this ABR (that applies to both the ingress and the egress ABRs).

Note also that the SESSION object that the egress ABR would use for the intra-area P2MP LSP need not encode the P2MP FEC from the received Leaf auto-discovery route.
5.2.2. P2MP mLDP LSP as the intra-area LSP in the egress area

If P2MP mLDP LSP is used as the intra-area LSP in the egress area, and the RD of the received Leaf A-D route is set to 0 then the egress ABR constructs an S-PMSI A-D. The PMSI Tunnel attribute of the route contains the identity of the intra-area P2MP LSP. Note that the PMSI Tunnel attribute does not carry an upstream assigned label. The RD, Multicast Source Length, Multicast Source, Multicast Group Length (1 octet), and Multicast Group fields of the NLRI of this route are the same as of the Leaf A-D route. The egress ABR advertises this route into the egress area. The forwarding considerations including the determination of whether packets are received from an expected sender are the same as the ones above with P2MP RSVP-TE.

If P2MP mLDP LSP is used as the intra-area LSP in the egress area, and the RD of the received Leaf A-D route is not set to 0, ABR MUST re-advertise the MVPN/VPLS A-D route, that matches the Leaf A-D route to signal the binding of the intra-area P2MP RSVP-TE LSP to the inter-area P2MP service LSP. This must be done ONLY if a) such a binding hasn’t already been advertised or b) The binding has changed. The PMSI Tunnel attribute of the re-advertised route specifies an intra-area P2MP RSVP-TE LSP rooted at the ABR and MUST also carry an upstream assigned MPLS label. The upstream-assigned MPLS label MUST be set to implicit NULL if the mapping between the inter-area P2MP service LSP and the intra-area P2MP LSP is one-to-one.

The egress PEs MUST join the intra-area P2MP LDP LSP that is encoded in the PMSI Tunnel Attribute of the A-D routes that carry the binding of the inter-area P2MP service LSP to the intra-area P2MP LDP LSP.

5.3. Ingress ABR

When an ingress ABR receives a Leaf auto-discovery route, or a withdraw of a previously received Leaf auto-discovery route from an (egress) ABR, and the Route Target extended community carried by the route contains the IP address of this ABR, then the following procedures will be executed.

The ingress ABR originates a Leaf A-D route towards the ingress PE/ASBR, whose MCAST-VPN-NLRI is constructed using procedures in section 4.2 with the difference that the IP based RT contains the ingress PE/ASBR address and not the ingress ABR address.
5.3.1. P2MP RSVP-TE LSP as the intra-area LSP in the backbone area

If the RD of the received Leaf A-D route is not zero, and P2MP RSVP-TE LSP is used as the the intra-area LSP in the backbone area, then the procedures for binding the backbone area segment of the inter-area P2MP LSP to the intra-area P2MP LSP in the backbone area, are the same as in section 4.2.1.

When the RD of the received Leaf A-D route is zero, as is the case where the inter-area service P2MP LSP is associated with the Internet multicast service, then in addition to the procedures in section 4.2.1 the ingress ABR MUST originate a S-PMSI A-D route. The PMSI Tunnel attribute of the route contains the identity of the intra-area P2MP LSP and a distinct upstream assigned MPLS label. The RD, Multicast Source Length, Multicast Source, Multicast Group Length (1 octet), and Multicast Group fields of the NLRI of this route are the same as of the Leaf A-D route. The ingress ABR advertises this route into the backbone area.

5.3.2. P2MP mLDP LSP as the intra-area LSP in the backbone area

If the RD of the received Leaf A-D route is not zero, and P2MP mLDP LSP is used as the the intra-area LSP in the backbone area, then the procedures for binding the backbone area segment of the inter-area P2MP LSP to the intra-area P2MP LSP in the backbone area, are the same as in section 4.2.2.

When the RD of the received Leaf A-D route is zero then in addition to the procedures in section 4.2.2 the S-PMSI A-D route’s PMSI Tunnel Attribute MUST carry an upstream assigned MPLS label.

5.4. Ingress PE/ASBR

When an ingress PE/ASBR receives a Leaf auto-discovery route, or a withdraw of a previously received Leaf auto-discovery route, and the Route Target extended community carried by the route contains the IP address of this PE, then the following procedures will be executed.

If the RD of the received Leaf A-D route is 0, as is the case when the inter-area service P2MP LSP is associated with the Internet multicast service, the information carried in the MCAST-VPN NLRI of the route MUST be decoded. The PIM implementation should set its upstream (S/RP,G) state machine in Joined state for the (S/RP, G) received via a Leaf auto-discovery route. Likewise, the PIM implementation should set its upstream (S/RP, G) state machine in
Pruned state for the \((S/RP, G)\) received via a Leaf auto-discovery route.

If the RD of the received Leaf A-D route is not 0, the ingress PE/ASBR finds an MVPN I-PMSI/S-PMSI A-D route or VPLS A-D or S-PMSI A-D route whose NLRI has the same value as the Route Key field of the the Leaf A-D route.

5.4.1. P2MP RSVP-TE LSP as the intra-area LSP in the ingress area

If the RD of the received Leaf A-D route is not zero, and P2MP RSVP-TE LSP is used as the the intra-area LSP in the ingress area, then the procedures for binding the ingress segment of the inter-area P2MP LSP to the intra-area P2MP LSP in the ingress area, are the same as in section 4.2.1.

When the RD of the received Leaf A-D route is zero than in addition to the procedures in section 4.2.1 the ingress PE MUST originate a S-PMSI A-D route. The PMSI Tunnel attribute of the route contains the identity of the intra-area P2MP LSP and an upstream assigned MPLS label. The RD, Multicast Source Length, Multicast Source, Multicast Group Length (1 octet), and Multicast Group fields of the NLRI of this route are the same as of the Leaf A-D route. The ingress PE advertises this route into the ingress area.

5.4.2. P2MP mLDP LSP as the intra-area LSP in the ingress area

If the RD of the received Leaf A-D route is not zero, and P2MP RSVP-TE LSP is used as the the intra-area LSP in the ingress area, then the procedures for binding the ingress segment of the inter-area P2MP LSP to the intra-area P2MP LSP in the ingress area, are the same as in section 4.2.2.

When the RD of the received Leaf A-D route is zero than in addition to the procedures in section 4.2.2 the S-PMSI A-D route’s PMSI Tunnel Attribute MUST carry an upstream assigned MPLS label.
6. IANA Considerations

These will be spelled out in the next revision.

7. Security Considerations

These will be spelled out in a future revision.

8. References

8.1. Normative References


[RFC2119] "Key words for use in RFCs to Indicate Requirement Levels.", Bradner, March 1997


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