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Updates on EVPN BUM Procedures
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Abstract

This document specifies procedure updates for broadcast, unknown unicast, and multicast (BUM) traffic in Ethernet VPNs (EVPN), including selective multicast, and provider tunnel segmentation.

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.

Status of This Memo

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1. Terminology

To be added

2. Introduction

RFC 7432 specifies procedures to handle broadcast, unknown unicast, and multicast (BUM) traffic in Section 11, 12 and 16, using Inclusive Multicast Ethernet Tag Route. A lot of details are referred to RFC

7117 (VPLS Multicast). In particular, selective multicast is briefly mentioned for Ingress Replication but referred to RFC 7117.

RFC 7117 specifies procedures for using both inclusive tunnels and selective tunnels, similar to MVPN procedures specified in RFC 6513 and RFC 6514. A new SAFI "MCAST-VPLS" is introduced, with two types of NLRIs that match MVPN's S-PMSI A-D routes and Leaf A-D routes. The same procedures can be applied to EVPN selective multicast for both Ingress Replication and other tunnel types, but new route types need to be defined under the same EVPN SAFI.

MVPN uses terms I-PMSI and S-PMSI A-D Routes. For consistency and convenience, this document will use the same I/S-PMSI terms for VPLS and EVPN. In particular, EVPN's Inclusive Multicast Ethernet Tag Route and VPLS's VPLS A-D route carrying PTA (PMSI Tunnel Attribute) for BUM traffic purpose will all be referred to as I-PMSI A-D routes. Depending on the context, they may be used interchangeably.

MVPN provider tunnels and EVPN/VPLS BUM provider tunnels, which are referred to as MVPN/EVPN/VPLS provider tunnels in this document for simplicity, can be segmented for technical or administrative reasons, which are summarized in Section 2.1 of this document. RFC 6513/6514 cover MVPN inter-as segmentation, RFC 7117 covers VPLS multicast inter-as segmentation, and RFC 7524 (Seamless MPLS Multicast) covers inter-area segmentation for both MVPN and VPLS.

There is a difference between MVPN and VPLS multicast inter-as segmentation. For simplicity, EVPN uses the same procedures as in MVPN. All ASBRs can re-advertise their choice of the best route. Each can become the root of its intra-AS segment and inject traffic it receives from its upstream, while each downstream PE/ASBR will only pick one of the upstream ASBRs as its upstream. This is also the behavior even for VPLS in case of inter-area segmentation.

For inter-area segmentation, RFC 7524 requires the use of Inter-area P2MP Segmented Next-Hop Extended Community (S-NH-EC), and the setting of "Leaf Information Required" (LIR) flag in PTA in certain situations. Either of these could be optional in case of EVPN. Removing these requirements would make the segmentation procedures transparent to ingress and egress PEs.

RFC 7524 assumes that segmentation happens at area borders. However, it could be at "regional" borders, where a region could be a sub-area, or even an entire AS plus its external links (Section 6). That would allow for more flexible deployment scenarios (e.g. for single-area provider networks).

This document specifies/clarifies/redefines certain/additional EVPN BUM procedures, with a salient goal that they're better aligned among MVPN, EVPN and VPLS. For brevity, only changes/additions to relevant RFC 7117 and RFC 7524 procedures are specified, instead of repeating the entire procedures. Note that these are to be applied to EVPN only, even though sometimes they may sound to be updates to RFC 7117/7524.

2.1. Reasons for Tunnel Segmentation

Tunnel segmentation may be required and/or desired because of administrative and/or technical reasons.

For example, an MVPN/VPLS/EVPN network may span multiple providers and Inter-AS Option-B has to be used, in which the end-to-end provider tunnels have to be segmented at and stitched by the ASBRs. Different providers may use different tunnel technologies (e.g., provider A uses Ingress Replication, provider B uses RSVP-TE P2MP while provider C uses mLDP). Even if they use the same tunnel technology like RSVP-TE P2MP, it may be impractical to set up the tunnels across provider boundaries.

The same situations may apply between the ASes and/or areas of a single provider. For example, the backbone area may use RSVP-TE P2MP tunnels while non-backbone areas may use mLDP tunnels.

Segmentation can also be used to divide an AS/area to smaller regions, so that control plane state and/or forwarding plane state/ burden can be limited to that of individual regions. For example, instead of Ingress Replicating to 100 PEs in the entire AS, with inter-area segmentation [RFC 7524] a PE only needs to replicate to local PEs and ABRs. The ABRs will further replicate to their downstream PEs and ABRs. This not only reduces the forwarding plane burden, but also reduces the leaf tracking burden in the control plane.

Smaller regions also have the benefit that, in case of tunnel aggregation, it is easier to find congruence among the segments of different constituent (service) tunnels and the resulting aggregation (base) tunnel in a region. This leads to better bandwidth efficiency, because the more congruent they are, the fewer leaves of the base tunnel need to discard traffic when a service tunnel's segment does not need to receive the traffic (yet it is receiving the traffic due to aggregation).

Another advantage of the smaller region is smaller BIER sub-domains. In this new multicast architecture BIER, packets carry a BitString, in which the bits correspond to edge routers that needs to receive

traffic. Smaller sub-domains means smaller BitStrings can be used without having to send multiple copies of the same packet.

3. Additional Route Types of EVPN NLRI

RFC 7432 defines the format of EVPN NLRI as the following:

```
+-----------------------------------+
|    Route Type (1 octet)           |
+-----------------------------------+
|     Length (1 octet)              |
+-----------------------------------+
| Route Type specific (variable)    |
+-----------------------------------+
```

So far five types have been defined:

+ 1 - Ethernet Auto-Discovery (A-D) route
+ 2 - MAC/IP Advertisement route
+ 3 - Inclusive Multicast Ethernet Tag route
+ 4 - Ethernet Segment route
+ 5 - IP Prefix Route

This document defines three additional route types:

+ 6 - Per-Region I-PMSI A-D route
+ 7 - S-PMSI A-D route
+ 8 - Leaf A-D route

The "Route Type specific" field of the type 6 and type 7 EVPN NLRIs starts with a type 1 RD, whose Administrative sub-field MUST match that of the RD in all the EVPN routes from the same advertising router for a given EVI, except the Leaf A-D route (Section 3.3).

3.1. Per-Region I-PMSI A-D route

The Per-region I-PMSI A-D route has the following format. Its usage is discussed in Section 6.2.

```
+-----------------------------------+
|      RD   (8 octets)              |
+-----------------------------------+
|  Ethernet Tag ID (4 octets)       |
+-----------------------------------+
| Extended Community (8 octets)     |
+-----------------------------------+
```

After Ethernet Tag ID, an Extended Community (EC) is used to identify the region. Various types and sub-types of ECs provide maximum flexibility. Note that this is not an EC Attribute, but an 8-octet field embedded in the NLRI itself, following EC encoding scheme.

3.2. S-PMSI A-D route

The S-PMSI A-D route has the following format:

```
+-----------------------------------+
|      RD   (8 octets)              |
+-----------------------------------+
|  Ethernet Tag ID (4 octets)       |
+-----------------------------------+
| Multicast Source Length (1 octet) |
+-----------------------------------+
|  Multicast Source (Variable)      |
+-----------------------------------+
|  Multicast Group Length (1 octet) |
+-----------------------------------+
|  Multicast Group   (Variable)     |
+-----------------------------------+
|   Originating Router's IP Addr    |
+-----------------------------------+
```

Other than the addition of Ethernet Tag ID, it is identical to the S-PMSI A-D route as defined in RFC 7117. The procedures in RFC 7117 also apply (including wildcard functionality), except that the granularity level is per Ethernet Tag.

3.3. Leaf-AD route

The Route Type specific field of a Leaf A-D route consists of the following:

```
+-----------------------------------+
|      Route Key (variable)         |
+-----------------------------------+
|   Originating Router's IP Addr    |
+-----------------------------------+
```

A Leaf A-D route is originated in response to a PMSI route, which could be an Inclusive Multicast Tag route, a per-region I-PMSI A-D route, an S-PMSI A-D route, or some other types of routes that may be defined in the future that triggers Leaf A-D routes. The Route Key is the "Route Type Specific" field of the route for which this Leaf A-D route is generated.

The general procedures of Leaf A-D route are first specified in RFC 6514 for MVPN. The principles apply to VPLS and EVPN as well. RFC 7117 has details for VPLS Multicast, and this document points out some specifics for EVPN, e.g. in Section 5.

4. Selective Multicast

RFC 7117 specifies Selective Multicast for VPLS. Other than that different route types and formats are specified with EVPN SAFI for S-PMSI A-D and Leaf A-D routes (Section 3), all procedures in RFC 7117 with respect to Selective Multicast apply to EVPN as well, including wildcard procedures.

5. Inter-AS Segmentation

5.1. Changes to Section 7.2.2 of RFC 7117

The first paragraph of Section 7.2.2.2 of RFC 7117 says:

> "... The best route procedures ensure that if multiple ASBRs, in an AS, receive the same Inter-AS A-D route from their EBGP neighbors, only one of these ASBRs propagates this route in Internal BGP (IBGP). This ASBR becomes the root of the intra-AS segment of the inter-AS tree and ensures that this is the only ASBR that accepts traffic into this AS from the inter-AS tree."

The above VPLS behavior requires complicated VPLS specific procedures for the ASBRs to reach agreement. For EVPN, a different approach is used and the above quoted text is not applicable to EVPN.

The Leaf A-D based procedure is used for each ASBR who re-advertises into the AS to discover the leaves on the segment rooted at itself. This is the same as the procedures for S-PMSI in RFC 7117 itself.

The following text at the end of the second bullet:

> "... If, in order to instantiate the segment, the ASBR needs to know the leaves of the tree, then the ASBR obtains this information from the A-D routes received from other PEs/ASBRs in the ASBR's own AS."

is changed to the following:

"... If, in order to instantiate the segment, the ASBR needs to know the leaves of the tree, then the ASBR MUST set the LIR flag to 1 in the PTA to trigger Leaf A-D routes from egress PEs and downstream ASBRs. It MUST be (auto-)configured with an import RT, which controls acceptance of leaf A-D routes by the ASBR."

Accordingly, the following paragraph in Section 7.2.2.4:

"If the received Inter-AS A-D route carries the PMSI Tunnel attribute with the Tunnel Identifier set to RSVP-TE P2MP LSP, then the ASBR that originated the route MUST establish an RSVP-TE P2MP LSP with the local PE/ASBR as a leaf. This LSP MAY have been established before the local PE/ASBR receives the route, or it MAY be established after the local PE receives the route."

is changed to the following:

"If the received Inter-AS A-D route has the LIR flag set in its PTA, then a receiving PE must originate a corresponding Leaf A-D route, and a receiving ASBR must originate a corresponding Leaf A-D route if and only if it received and imported one or more corresponding Leaf A-D routes from its downstream IBGP or EBGP peers, or it has non-null downstream forwarding state for the PIM/mLDP tunnel that instantiates its downstream intra-AS segment. The ASBR that (re-)advertised the Inter-AS A-D route then establishes a tunnel to the leaves discovered by the Leaf A-D routes."

5.2. I-PMSI Leaf Tracking

An ingress PE does not set the LIR flag in its I-PMSI's PTA, even with Ingress Replication or RSVP-TE P2MP tunnels. It does not rely on the Leaf A-D routes to discover leaves in its AS, and Section 11.2 of RFC 7432 explicitly states that the LIR flag must be set to zero.

An implementation of RFC 7432 might have used the Originating Router's IP Address field of the Inclusive Multicast Ethernet Tag routes to determine the leaves, or might have used the Next Hop field instead. Within the same AS, both will lead to the same result.

With segmentation, an ingress PE MUST determine the leaves in its AS from the BGP next hops in all its received I-PMSI A-D routes, so it does not have to set the LIR bit set to request Leaf A-D routes. PEs within the same AS will all have different next hops in their I-PMSI A-D routes (hence will all be considered as leaves), and PEs from other ASes will have the next hop in their I-PMSI A-D routes set to addresses of ASBRs in this local AS, hence only those ASBRs will be considered as leaves (as proxies for those PEs in other ASes). Note

that in case of Ingress Replication, when an ASBR re-advertises IBGP I-PMSI A-D routes, it MUST advertise the same label for all those for the same Ethernet Tag ID and the same EVI. When an ingress PE builds its flooding list, multiple routes may have the same (nexthop, label) tuple and they will only be added as a single branch in the flooding list.

5.3. Backward Compatibility

The above procedures assume that all PEs are upgraded to support the segmentation procedures:

- o An ingress PE uses the Next Hop instead of Originating Router's IP Address to determine leaves for the I-PMSI tunnel.
- o An egress PE sends Leaf A-D routes in response to I-PMSI routes, if the PTA has the LIR flag set (by the re-advertising ASBRs).
- o In case of Ingress Replication, when an ingress PE builds its flooding list, multiple I-PMSI routes may have the same (nexthop, label) tuple and only a single branch for those will be added in the flooding list.

If a deployment has legacy PEs that does not support the above, then a legacy ingress PE would include all PEs (including those in remote ASes) as leaves of the inclusive tunnel and try to send traffic to them directly (no segmentation), which is either undesired or not possible; a legacy egress PE would not send Leaf A-D routes so the ASBRs would not know to send external traffic to them.

To address this backward compatibility problem, the following procedure can be used (see Section 6.2 for per-PE/AS/region I-PMSI A-D routes):

- o An upgraded PE indicates in its per-PE I-PMSI A-D route that it supports the new procedures. Details will be provided in a future revision.
- o All per-PE I-PMSI A-D routes are restricted to the local AS and not propagated to external peers.
- o The ASBRs in an AS originate per-region I-PMSI A-D routes and advertise to their external peers to advertise tunnels used to carry traffic from the local AS to other ASes. Depending on the types of tunnels being used, the LIR flag in the PTA may be set, in which case the downstream ASBRs and upgraded PEs will send Leaf A-D routes to pull traffic from their upstream ASBRs. In a particular downstream AS, one of the ASBRs is elected, based on

the per-region I-PMSI A-D routes for a particular source AS, to send traffic from that source AS to legacy PEs in the downstream AS. The traffic arrives at the elected ASBR on the tunnel announced in the best per-region I-PMSI A-D route for the source AS, that the ASBR has selected of all those that it received over EBGP or IBGP sessions. Details of the election procedure will be provided in a future revision.

- In an ingress AS, if and only if an ASBR has active downstream receivers (PEs and ASBRs), which are learned either explicitly via Leaf AD routes or implicitly via PIM join or mLDP label mapping, the ASBR originates a per-PE I-PMSI A-D route (i.e., regular Inclusive Multicast Ethernet Tag route) into the local AS, and stitches incoming per-PE I-PMSI tunnels into its per-region I-PMSI tunnel. With this, it gets traffic from local PEs and send to other ASes via the tunnel announced in its per-region I-PMSI A-D route.

Note that, even if there is no backward compatibility issue, the above procedures have the benefit of keeping all per-PE I-PMSI A-D routes in their local ASes, greatly reducing the flooding of the routes and their corresponding Leaf A-D routes (when needed), and the number of inter-as tunnels.

6. Inter-Region Segmentation

6.1. Area vs. Region

RFC 7524 is for MVPN/VPLS inter-area segmentation and does not explicitly cover EVPN. However, if "area" is replaced by "region" and "ABR" is replaced by "RBR" (Regional Border Router) then everything still works, and can be applied to EVPN as well.

A region can be a sub-area, or can be an entire AS including its external links. Instead of automatic region definition based on IGP areas, a region would be defined as a BGP peer group. In fact, even with IGP area based region definition, a BGP peer group listing the PEs and ABRs in an area is still needed.

Consider the following example diagram:

```
             ---------           ------            ---------
            /         \         /      \          /         \
           /           \       /        \        /           \
          | PE1 o    ASBR1 -- ASBR2    ASBR3 -- ASBR4    o PE2 |
           \           /       \        /        \           /
            \         /         \      /          \         /
             ---------           ------            ---------
             AS 100              AS 200              AS 300
          |-----------|--------|---------|--------|------------|
             segment1  segment2 segment3  segment4  segment5
```

The inter-as segmentation procedures specified so far (RFC 6513/6514, 7117, and Section 5 of this document) requires all ASBRs to be involved, and Ingress Replication is used between two ASBRs in different ASes.

In the above diagram, it's possible that ASBR1/4 does not support segmentation, and the provider tunnels in AS 100/300 can actually extend across the external link. In the case, the inter-region segmentation procedures can be used instead - a region is the entire (AS100 + ASBR1-ASBR2 link) or (AS300 + ASBR3-ASBR4 link). ASBR2/3 would be the RBRs, and ASBR1/4 will just be a transit core router with respect to provider tunnels.

As illustrated in the diagram below, ASBR2/3 will establish a multihop EBGP session with either a RR or directly with PEs in the neighboring AS. I/S-PMSI A-D routes from ingress PEs will not be processed by ASBR1/4. When ASBR2 re-advertises the routes into AS 200, it changes the next hop to its own address and changes PTA to specify the tunnel type/identification in its own AS. When ASBR3 re-advertises I/S-PMSI A-D routes into the neighboring AS 300, it changes the next hop to its own address and changes PTA to specify the tunnel type/identification in the neighboring region 3. Now the segment is rooted at ASBR3 and extends across the external link to PEs.

```
             ---------           ------            ---------
            /   RR....\.mh-ebpg /      \    mh-ebgp/....RR   \
           /    :      \    `. /        \ .'      /      :    \
          | PE1 o    ASBR1 -- ASBR2    ASBR3 -- ASBR4    o PE2 |
           \           /       \        /        \           /
            \         /         \      /          \         /
             ---------           ------            ---------
             AS 100              AS 200              AS 300
          |-------------------|----------|---------------------|
             segment 1          segment 2         segment 3
```

6.2. Per-region Aggregation

Notice that every I/S-PMSI route from each PE will be propagated throughout all the ASes or regions. They may also trigger corresponding Leaf A-D routes depending on the types of tunnels used in each region. This may become too many - routes and corresponding tunnels. To address this concern, the I-PMSI routes from all PEs in a AS/region can be aggregated into a single I-PMSI route originated from the RBRs, and traffic from all those individual I-PMSI tunnels will be switched into the single I-PMSI tunnel. This is like the MVPN Inter-AS I-PMSI route originated by ASBRs.

The MVPN Inter-AS I-PMSI A-D route can be better called as per-AS I-PMSI A-D route, to be compared against the (per-PE) Intra-AS I-PMSI A-D routes originated by each PE. In this document we will call it as per-region I-PMSI A-D route, in case we want to apply the aggregation at regional level. The per-PE I-PMSI routes will not be propagated to other regions. If multiple RBRs are connected to a region, then each will advertise such a route, with the same route key (Section 3.1). Similar to the per-PE I-PMSI A-D routes, RBRs/PEs in a downstream region will each select a best one from all those re-advertised by the upstream RBRs, hence will only receive traffic injected by one of them.

MVPN does not aggregate S-PMSI routes from all PEs in an AS like it does for I-PMSIs routes, because the number of PEs that will advertise S-PMSI routes for the same (s,g) or (*,g) is small. This is also the case for EVPN, i.e., there is no per-region S-PMSI routes.

Notice that per-region I-PMSI routes can also be used to address backwards compatibility issue, as discussed in Section 5.3.

The per-region I-PMSI route uses an embedded EC in NLRI to identify a region. As long as it uniquely identifies the region and the RBRs for the same region uses the same EC it is permitted. In the case where an AS number or area ID is needed, the following can be used:

- o For a two-octet AS number, a Transitive Two-Octet AS-Specific EC of sub-type 0x09 (Source AS), with the Global Administrator sub-field set to the AS number and the Local Administrator sub-field set to 0.

- o For a four-octet AS number, a Transitive Four-Octet AS-Specific EC of sub-type 0x09 (Source AS), with the Global Administrator sub-field set to the AS number and the Local Administrator sub-field set to 0.

o For an area ID, a Transitive IPv4-Address-Specific EC of any sub-type.

Uses of other particular ECs may be specified in other documents.

6.3. Use of S-NH-EC

RFC 7524 specifies the use of S-NH-EC because it does not allow ABRs to change the BGP next hop when they re-advertise I/S-PMSI AD routes to downstream areas. That is only to be consistent with the MVPN Inter-AS I-PMSI A-D routes, whose next hop must not be changed when they're re-advertised by the segmenting ABRs for reasons specific to MVPN. For EVPN, it is perfectly fine to change the next hop when RBRs re-advertise the I/S-PMSI A-D routes, instead of relying on S-NH-EC. As a result, this document specifies that RBRs change the BGP next hop when they re-advertise I/S-PMSI A-D routes and do not use S-NH-EC. if a downstream PE/RBR needs to originate Leaf A-D routes, it simply uses the BGP next hop in the corresponding I/S-PMSI A-D routes to construct Route Targets.

The advantage of this is that neither ingress nor egress PEs need to understand/use S-NH-EC, and consistent procedure (based on BGP next hop) is used for both inter-as and inter-region segmentation.

6.4. Ingress PE's I-PMSI Leaf Tracking

RFC 7524 specifies that when an ingress PE/ASBR (re-)advertises an VPLS I-PMSI A-D route, it sets the LIR flag to 1 in the route's PTA. Similar to the inter-as case, this is actually not really needed for EVPN. To be consistent with the inter-as case, the ingress PE does not set the LIR flag in its originated I-PMSI A-D routes, and determines the leaves based on the BGP next hops in its received I-PMSI A-D routes, as specified in Section 5.2.

The same backward compatibility issue exists, and the same solution as in the inter-as case applies, as specified in Section 5.3.

7. Multi-homing Support

If multi-homing does not span across different ASes or regions, existing procedures work with segmentation. If an ES is multi-homed to PEs in different ASes or regions, additional procedures are needed to work with segmentation. The procedures are well understood but omitted here until the requirement becomes clear.

8. Security Considerations

This document does not seem to introduce new security risks, though this may be revised after further review and scrutiny.

9. Acknowledgements

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