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Explicit Tracking with Wild Card Routes in Multicast VPN
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Abstract

The MVPN specifications provide procedures to allow a multicast ingress node to invoke "explicit tracking" for a multicast flow or set of flows, thus learning the egress nodes for that flow or set of flows. However, the specifications are not completely clear about how the explicit tracking procedures work in certain scenarios. This document provides the necessary clarifications. It also specifies a new, optimized explicit tracking procedure. This new procedure allows an ingress node, by sending a single message, to request explicit tracking of each of a set of flows, where the set of flows is specified using a wildcard mechanism. This document updates RFC6625.

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1. Introduction

[RFC6513] and [RFC6514] define the "Selective Provider Multicast Service Interface Auto-Discovery route" (S-PMSI A-D route). By originating one of these BGP routes, an ingress node advertises that it is transmitting a particular multicast flow. In the terminology of those RFCs, each flow is denoted by (C-S,C-G), where C-S is an IP source address and C-G is an IP multicast address, both in the address space of a VPN customer. The (C-S,C-G) of the multicast flow is encoded into the Network Layer Reachability Information (NLRI) of the S-PMSI A-D route.

Additionally, each S-PMSI A-D route contains a PMSI Tunnel attribute (PTA), which identifies a tunnel through the provider backbone network (a "P-tunnel"). If a P-tunnel is identified in the PTA of a given S-PMSI A-D route, the originator of that route is advertising that it will transmit the flow identified in the NLRI through the tunnel identified in the PTA.

[RFC6513] and [RFC6514] also define a procedure that allows an ingress node to determine the set of egress nodes that have requested to receive a particular flow from that ingress node. The ability of an ingress node to identify the egress nodes for a particular flow is known as "explicit tracking". An ingress node requests explicit tracking by setting a flag (the "Leaf Information Required" flag, or LIR) in the PTA. When an egress node receives an S-PMSI A-D route with LIR set, the egress node originates a Leaf A-D route whose NLRI contains the NLRI from the corresponding S-PMSI A-D route. In this way, the egress node advertises that it has requested to receive the particular flow identified in the NLRI of that S-PMSI A-D route.

[RFC6513] and [RFC6514] also allow an ingress node to originate an S-PMSI A-D route whose PTA has LIR set, but which does not identify any P-tunnel. This mechanism can be used when it is desired to do explicit tracking of a flow without at the same time binding that flow to a particular P-tunnel.

[RFC6625] (and other RFCs that update it) extends the specification of S-PMSI A-D routes, and allows an S-PMSI A-D route to encode a wildcard in its NLRI. Either the C-S or the C-G or both can be replaced by wildcards. These routes are known as (C-*,C-S) S-PMSI A-D routes, or as (C-S,C-*) S-PMSI A-D routes, or as (C-*,C-*) S-PMSI A-D routes, depending on whether the C-S or C-G or both have been replaced by wildcards. These routes are known jointly as "wildcard S-PMSI A-D routes".

One purpose of this document is to clarify the way that the explicit tracking procedures of [RFC6513] and [RFC6514] are applied when wildcard S-PMSI A-D routes are used.

In addition, this document addresses the following scenario, which is not addressed in [RFC6513], [RFC6514], or [RFC6625]. Suppose an ingress node originates an S-PMSI A-D route whose NLRI specifies, for example, (C-*,C-*) (i.e., both C-S and C-G are replaced by wildcards), and whose PTA identifies a particular P-tunnel. Now suppose that the ingress node wants explicit tracking for each individual flow that it transmits (following the procedures of [RFC6625] on that P-tunnel.

In this example, if the ingress node sets LIR in the PTA of the wildcard S-PMSI A-D route, each egress node that needs to receive a flow from the ingress node will respond with a Leaf A-D route whose NLRI specifies contains the (C-*,C-*) wildcard. This allows the ingress node to determine the set of egress nodes that are receiving flows from the ingress node. However, it does not allow the ingress node to determine which flows are being received by which egress nodes.

If the ingress node needs to determine which egress nodes are receiving which flows, it needs to originate an S-PMSI A-D route for each individual (C-S,C-G) flow that it is transmitting, and it needs to set LIR in the PTA of each such route. However, since all the flows are being sent through the tunnel identified in the (C-*,C-*) S-PMSI A-D route, there is no need to identify a tunnel in the PTA of each (C-S,C-G) S-PMSI A-D route. Per [RFC6514], the PTA of the (C-S,C-G) S-PMSI A-D routes can specify "no tunnel information". This procedure allows explicit tracking of individual flows, even though all those flows are assigned to tunnels in widlcard S-PMSI A-D routes.

Howver, this procedure requires several clarifications:

- The procedures of [RFC6625] do not clearly state how to handle an S-PMSI A-D route if its NLRI contains wild cards, but its PTA specifies "no tunnel info".

- If it is desired to send a set of flows through the same tunnel (where that tunnel is advertised in a wildcard S-PMSI A-D route), but it is also desired to explicitly track each individual flow transmitted over that tunnel, one has to send an S-PMSI A-D route (with LIR set in the PTA) for each individual flow. It would be more optimal if the ingress node could just send a single wildcard S-PMSI A-D route binding the set of flows to a particular tunnel, and have the egress nodes respond with Leaf A-D routes for each individual flow.

- [RFC6513] and [RFC6514] support the notion of "segmented P-tunnels", where "segmentation" occurs at ASBRs; [RFC7524] extends the notion segmented P-tunnels so that segmentation can occur at ABRs. One can think of a segmented P-tunnel as passing through a number of "segmentation domains". In each segmentation domain, a given P-tunnel has an ingress node and a set of egress nodes. The explicit tracking procedures allow an ingress node of a particular segmentation domain to determine, for a particular flow or set of flows, the egress nodes of that segmentation domain. This has given rise to two further problems:

  * The explicit tracking procedures do not allow an ingress node to "see" past the boundaries of the segmentation domain.

    This particular problem is not further addressed in this revision of this document.

  * The prior specifications do not make it very clear whether an egress node, upon receiving an S-PMSI A-D route whose PTA specifies "no tunnel information", is expected to forward the

S-PMSI A-D route, with the same PTA, to the next segmentation domain. This document provides the necessary clarifications.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL", when and only when appearing in all capital letters, are to be interpreted as described in [RFC2119].

2. The Explicit Tracking Flags

Prior specifications define one flag in the PTA, the "Leaf Info Required" (LIR) flag, that is used for explicit tracking.

This document defines a new flag in the flags field of the PMSI Tunnel attribute. This new flag is known as the "Leaf Info Required per Flow" bit (LIR-pF). This flag MAY be set in the PTA of a (C-*,C-*), (C-*,C-G), or (C-S,C-*) S-PMSI A-D route. (Use of this flag in a PTA carried by other routes is outside the scope of this document.) Support for this flag is OPTIONAL.

The action taken by an egress node when the LIR-pF bit is set is detailed in Section 5.

If the LIR-pF flag is set in a given PTA, the LIR flag of that PTA SHOULD also be set. (By setting LIR as well as LIR-pF, one forces a a response to be sent an egress node that does not support LIR-pF, and it is possible to tell from that response that the egress node does not support LIR-pF.)

3. Match for Tracking vs. Match for Reception

RFC6625 (and other RFCs or RFCs-to-be that update RFC6625) specify a set of rules for finding the S-PMSI A-D route that is the "match for reception" for a given (C-S,C-G) or (C-*,C-G) state. These rules do not take into account the fact that some S-PMSI A-D routes may not be carrying PTAs at all, or may be carrying PTAs that do not identify any P-tunnel. (A PTA that does not identify any P-tunnel is one whose "tunnel type" field has been set to "no tunnel information", as specified in Section 5 of [RFC6514].)

The definition of "match for reception" in [RFC6625] is hereby modified as follows:

> When finding the "match for reception" for a given (C-S,C-G) or (C-*,C-G), ignore any S-PMSI A-D route that has no PTA, or whose PTA specifying "no tunnel information".

We also introduce a new notion: the "match for tracking". This differs from the "match for reception" as follows:

> For a given C-flow ((C-S,C-G) or (C-*,C-G)) the "match for tracking" is chosen as follows. Ignore any S-PMSI A-D route that has no PTA. Also ignore any S-PMSI A-D route whose PTA specifies "no tunnel information", but does not have either LIR or LIR-pF set. (In particular, DO NOT ignore an S-PMSI A-D route that has a PTA specifying "no tunnel information", but whose LIR or LIR-pF bits are set). Then apply the rules (from [RFC6625] and other documents that that update it) for finding the "match for reception". The result (if any) is the match for tracking".

We will clarify this with a few examples. In these examples, we assume that there is only one segmentation domain. In this case, the ingress and egress nodes are Provider Edge (PE) routers.

Suppose a given PE router, PE1, has chosen PE2 as the "upstream PE" ([RFC6513]) for a given flow (C-S1,C-G1). And suppose PE1 has installed the following two routes that were originated by PE2:

- o Route1: A (C-*,C-*) S-PMSI A-D route, whose PTA specifies a tunnel.

- o Route2: A (C-S1,C-G1) S-PMSI A-D route, whose PTA specifies "no tunnel info" and has LIR set.

Route1 is (C-S1,C-G1)'s match for reception, and Route2 is (C-S1,C-G1)'s match for tracking.

Note that if there is no installed S-PMSI A-D route for (C-S2,C-G2), then Route1 would be (C-S2,C-G2)'s match for reception and also its match for tracking. Also note that if a match for tracking does not have the LIR flag or the LIR-pF flag set, no explicit tracking information will be generated. See Section 5.

As another example, suppose PE1 has installed the following two routes that were originated by PE2:

- o Route1: A (C-*,C-*) S-PMSI A-D route (irrespective of whether the PTA specifies a tunnel)

- o Route2: A (C-S1,C-G1) S-PMSI A-D route whose PTA specifies a tunnel.

Then Route2 is both the "match for reception" and the "match for tracking" for (C-S1,C-G1).

Note that for a particular C-flow, PE1's match for reception might be the same route as its match for tracking, or its match for reception might be a "less specific" route than its match for tracking. But its match for reception can never be a "more specific" route than its match for tracking.

4. Ingress Node Initiation of Tracking

An ingress node that needs to initiate explicit tracking for a particular flow or set of flows can do so by performing one of the following procedures:

1. An ingress node can initiate explicit tracking for (C-S1,C-G1) by originating an S-PMSI A-D route that identifies (C-S1,C-G1) in its NLRI, including a PTA in that route, and setting the LIR flag in that PTA. The PTA may specify a particular tunnel, or may specify "no tunnel info".

   However, the PTA of the (C-S1,C-G1) S-PMSI A-D route SHOULD NOT specify "no tunnel info" unless the ingress node also originates an A-D route carrying a PTA that specifies the tunnel to be used for carrying (C-S1,C-G1) traffic. Such a route could be an I-PMSI A-D route, a (C-*,C-G1) S-PMSI A-D route, a (C-S1,C-*) S-PMSI A-D route, or a (C-*,C-*) S-PMSI A-D route. (There is no point in requesting explicit tracking for a given flow if there is no tunnel on which the flow is being carried.)

   Further, if the ingress node originates a wildcard S-PMSI A-D route carrying a PTA specifying the tunnel to be used for carrying (C-S1,C-G1) traffic, and if that PTA has the LIR-pF bit set, then explicit tracking for (C-S1,C-G1) is requested by that S-PMSI A-D route. Thus the ingress node SHOULD NOT originate a (C-S1,C-G1) S-PMSI A-D route whose PTA specifies "no tunnel info"; such a route would not provide any additional functionality.

   To terminate explicit tracking that has been initiated by an S-PMSI A-D route whose PTA specifies "no tunnel info", the ingress node withdraws the route.

   To terminate explicit tracking that has been initiated by an S-PMSI A-D route whose PTA specifies a tunnel, the ingress node re-originates the route without the LIR flag set.

2. The following procedure can be used if (and only if) it is known that the egress nodes support the optional LIR-pF flag. If the ingress node originates a wildcard S-PMSI A-D route, it can initiate explicit tracking for the individual flows that match

the wildcard route by setting the LIR-pF flag in the PTA of the wildcard route. If an egress node needs to receive one or more flows for which that wildcard route is a match for tracking, the egress node will originate a Leaf A-D route for each such flow, as specified in Section 5.2).

When following this procedure, the PTA of the S-PMSI A-D route may specify a tunnel, or may specify "no tunnel info". The choice between these two options is determined by considerations that are outside the scope of this document.

To terminate explicit tracking that has been initiated by an S-PMSI A-D route whose PTA specifies "no tunnel info", the ingress node withdraws the route.

To terminate explicit tracking that has been initiated by an S-PMSI A-D route whose PTA specifies a tunnel, the ingress node re-originates the route without the LIR flag set

5. Egress Node Response to the Match for Tracking

5.1. General Egress Node Procedures

There are four cases to consider:

1. With regard to a particular (C-S,C-G) or (C-*,C-G) multicast state, the egress node's match for tracking is same as its match for reception, and neither LIR nor LIR-pF flags are on.

   In this case, the egress node does not originate a Leaf A-D route in response to the match for reception/tracking, and there is no explicit tracking of the flow. This document specifies no new procedures for this case.

2. With regard to a particular (C-S,C-G) or (C-*,C-G) multicast state, the egress node's match for tracking is the same as its match for reception, LIR is set, but LIR-pF is not set.

   In this case, a Leaf A-D route is originated by the egress node, corresponding to the S-PMSI A-D route that is the match for reception/tracking. Construction of the Leaf A-D route is as specified in [RFC6514]; this document specifies no new procedures for this case.

3. With regard to a particular (C-S,C-G) or (C-*,C-G) multicast state, the egress node's match for tracking is the same as its match for reception, and LIR-pF is set. The egress PE MUST follow whatever procedures are required by other specifications,

based on the match for reception. If the egress PE supports the LIR-pF flag, it MUST also follow the procedures of Section 5.2.

4. With regard to a particular (C-S,C-G) or (C-*,C-G) multicast state, the egress node's match for tracking is not the same as its match for reception. This can only happen if the match for tracking has a PTA specifying "no tunnel info", with either LIR or LIR-pF set. In this case, the egress node must respond, separately, BOTH to the match for tracking and to the match for reception.

   When responding to the match for reception, the egress node MUST ignore the LIR-pF flag. However, the LIR flag is processed normally per the procedures for the match for reception.

   If the match for tracking has LIR set and if either (a) the egress node does not support LIR-pF, or (b) LIR-pF is not set, then the egress node must respond to the match for tracking, following procedures specified in other documents for the case where LIR is set.

   If the match for tracking has LIR-pF set, and the egress node supports the LIR-pF flag, the egress node must originate one or more Leaf A-D routes, as specified in Section 5.2.

   Note that if LIR is set in the PTA of the match for reception, the egress node may need to originate one or more Leaf A-D routes corresponding to the match for tracking, as well as originating a Leaf A-D route corresponding to the match for reception.

5.2. Responding to the LIR-pF Flag

To respond to a match for tracking that has LIR-pF set, an egress node originates one or more Leaf A-D routes.

Suppose the egress node has multicast state for a (C-S,C-G) or a (C-*,C-G) flow, and has determined a particular S-PMSI A-D route, which has the LIR-pF flag set, to be the match for tracking for that flow. Then if the egress node supports the LIR-pF flag, it MUST originate a Leaf A-D route whose NLRI identifies that particular flow. Note that if a single S-PMSI A-D route (with wild cards) is the match for tracking for multiple flows, the egress PE may need to originate multiple Leaf A-D routes, one for each such flow. We say that, from the perspective of a given egress node, a given S-PMSI A-D route tracks the set of flows for which it is the match for tracking. Each of the Leaf A-D routes originated in response to that S-PMSI A-D route tracks a single such flow.

The NLRI of each the Leaf A-D route that tracks a particular flow is constructed as follows. The "route key" field of the NLRI will have the following format:

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

Figure 1: NLRI of S-PMSI A-D Route

- o The "ingress PE" address is taken from the "originating router" field of the NLRI of the S-PMSI A-D route that is the match for tracking.

- o The multicast source and group fields specify the S and G of one of the flow being tracked by this Leaf A-D route. If a (C-*,C-G) is being tracked by this Leaf A-D route, the source field is omitted, and its length is set to 0.

- o The RD field is constructed as follows:

  * Take the RD value from the NLRI of the S-PMSI A-D route.

  * Add 16 to the second octet of the RD.

Note that, per RFC4364, every RD begins with a two-octet type field that is either 0, 1, or 2. By adding 16 to the second octet of the RD, we force the type field to be 16, 17, or 18. The presence of one of these values will indicate that the Leaf A-D route was constructed in response to a less specific S-PMSI A-D route that had the LIR-pF bit set. (That is, it distinguishes the routes from "ordinary" MVPN Leaf A-D routes.)

The encoding of these Leaf A-D routes is similar to the encoding of the Leaf A-D routes described in section 6.2.2 of [RFC7524], which were designed for the support of "global table multicast". However,

that document sets the RD to either 0 or -1; following the procedures of this document, the RD will never be 0 or -1. Therefore Leaf A-D routes constructed according to the procedures of this section can always be distinguished from the Leaf A-D routes constructed according to the procedures of section 6.2.2 of [RFC7524]. Also, Leaf A-D routes constructed according to the procedures of this section are VPN-specific routes, and will always carry an IP-address-specific Route Target, as specified in [RFC6514].

If a Leaf A-D route is originated as a response to a match for tracking whose PTA specifies "no tunnel info", a PTA SHOULD NOT be attached to the Leaf A-D route; if a PTA is attached, it MUST specify "no tunnel info".

In the case where the match for tracking and the match for reception are the same, the PTA of the match may have both the LIR and the LIR-pF flags set. This may cause the egress node to originate one Leaf A-D route in response to the LIR bit, and one or more Leaf A-D routes in response to the LIR-pF bit. A PTA SHOULD NOT be attached to the Leaf A-D routes that are originated in response to the LIR-pF bit.

When a Leaf A-D route constructed according to the procedures of this section is received, it MUST be processed by the node identified in its IP-address-specific Route Target, even though its "route key" field does not correspond to the NLRI of any S-PMSI A-D route.

Of course, an egress node that originates such Leaf A-D routes needs to remember which S-PMSI A-D route caused these Leaf A-D routes to be originated; if that S-PMSI A-D route is withdrawn, those Leaf A-D routes MUST be withdrawn.

Similarly, a Leaf A-D route needs to be withdrawn (either implicitly or explicitly) if the egress node changes its Upstream Multicast Hop (UMH) ([RFC6513]) for the flow that is identified in the Leaf A-D route's NLRI, or if the egress node that originated the route no longer needs to receive the flow identified in the NLRI of the route.

Note that an egress node may acquire (C-S,C-G) state or (C-*,C-G) state after it has already received the S-PMSI A-D that is the match for tracking for that state. In this case, a Leaf A-D route needs to be originated at that time, and the egress node must remember that the new Leaf A-D route corresponds to that match for tracking.

Note that if a particular S-PMSI A-D route is a match for tracking but not a match for reception, the LIR bit in its PTA is ignored if the LIR-pF bit is set.

5.3. When the Egress Node is an ABR or ASBR

When segmented P-tunnels are used, the ingress and egress nodes may be ABRs or ASBRs. An egress ABR/ASBR that receives and installs an S-PMSI A-D route also forwards that route. If the PTA of an installed S-PMSI A-D route specifies a tunnel, the egress ABR/ASBR MAY change the PTA to specify a different tunnel type (as discussed in [RFC6514] and/or [RFC7524]).

However, if the PTA of the installed S-PMSI A-D route specifies "no tunnel info", the egress ABR/ASBR MUST pass the PTA along unchanged when it forwards the S-PMSI A-D route. (That is, a PTA specifying "no tunnel info" MUST NOT be changed into a PTA specifying a tunnel.) Furthermore, if the PTA specifies "no tunnel info", the LIR and LIR-pF flags in the PTA MUST be passed along unchanged.

In the case where the egress node is a PE, it will know whether it needs to receive a given flow by virtue of its having received a PIM or IGMP Join for that flow from a CE. In the case where the egress node is not a PE, but rather an ABR or ASBR, it will not know whether it needs to receive a given flow unless it receives a Leaf A-D route whose NLRI specifies that flow and whose IP-address-specific RT specifies an address of the egress node. Therefore an egress ABR/ASBR MUST NOT originate a Leaf A-D route for a given flow UNLESS it has an installed Leaf A-D route for that flow, received from further downstream.

This will ensure that an egress ABR/ASBR only sends a Leaf A-D route in response to a "match for tracking" if it is on the path to an egress PE for the flow(s) identified in the corresponding S-PMSI A-D route.

Then we can establish the following rule for egress ABRs/ASBRs. Suppose an egress ABR/ASBR receives an S-PMSI A-D route whose NLRI is X, and whose PTA (a) specifies "no tunnel info" and (b) has LIR set. The egress ABR/ASBR should not immediately originate a Leaf A-D route in response. Rather it should wait until it receives a Leaf A-D route whose NLRI contains X in the "route key" field. If it receives such a Leaf A-D route, it redistributes that route, but first it changes that route's RT. The "global administrator" field of the modified RT will be set to the IP address taken either from the S-PMSI A-D route's next hop field, or from its Segmented P2MP Next Hop Extended Community. (This is the same rule that is used for when the PTA does specify a tunnel type.)

6. Acknowledgments

The authors wish to thank Robert Kebler for his ideas and comments.

7. IANA Considerations

The LIR-pF flag needs to be added to the "P-Multicast Service Interface Tunnel (PMSI Tunnel) Attribute Flags" in the "Border Gateway Protocol (BGP) Parameters" registry. This registry is defined in [PTA_Flags]. The requested value is Bit Position 2. This document should be the reference.

IANA is requested to allocate three new types from the Route Distinguisher Type Field registry:

- o Administrator field is two-byte Autonomous System Number. To be used only in certain MCAST-VPN Leaf A-D routes.

- o Administrator field is four-byte IP Address. To be used only in certain MCAST-VPN Leaf A-D routes.

- o Administrator field is four-byte Autonomous System Number. To be used only in certain MCAST-VPN Leaf A-D routes.

The requested values are 16, 17, and 18 respectively.

8. Security Considerations

The Security Considerations of [RFC6513] and [RFC6514] apply.

By setting the LIR-pF flag in a single wildcard S-PMSI A-D route, a large number of Leaf A-D routes can be elicited. If this flag is set when not desired (through either error or malfeasance), a significant increase in control plane overhead can result.

9. References

9.1. Normative References

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