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LSP-Ping Mechanisms for EVPN and PBB-EVPN
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Abstract

LSP Ping is a widely deployed Operation, Administration, and Maintenance mechanism in MPLS networks. This document describes mechanisms for detecting data-plane failures using LSP Ping in MPLS based EVPN and PBB-EVPN networks.

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[1. Introduction](#)

[RFC7432] describes MPLS based Ethernet VPN (EVPN) technology. An EVPN comprises CE(s) connected to PE(s). The PEs provide layer 2 EVPN among the CE(s) over the MPLS core infrastructure. In EVPN networks, PEs advertise the MAC addresses learned from the locally connected CE(s), along with MPLS Label, to remote PE(s) in the control plane using multi-protocol BGP. EVPN enables multi-homing of CE(s) connected to multiple PEs and load balancing of traffic to and from multi-homed CE(s).

[RFC7623] describes the use of Provider Backbone Bridging [802.1ah] with EVPN. PBB-EVPN maintains the Customer MAC (C-MAC) learning in

data plane and only advertises Provider Backbone MAC (B-MAC) addresses in control plane using BGP.

Procedures for simple and efficient mechanisms to detect data-plane failures using LSP Ping in MPLS network are well defined in [\[RFC8029\]](#) and [\[RFC6425\]](#). The basic idea for the LSP Ping mechanism is to send a MPLS Echo Request packet along the same data path as data packets belonging to the same Forwarding Equivalent Class (FEC). The Echo Request packet carries the FEC being verified in the Target FEC Stack TLV. Once the Echo Request packet reaches the end of the MPLS path, it is sent to the control plane of the egress PE. Echo Request packet contains sufficient information to verify correctness of data plane operations and validate data plane against the control plane. Egress PE sends the results of the validation in Echo Reply packet to the originating PE of the Echo Request packet.

This document defines procedures to detect data-plane failures using LSP Ping in MPLS networks deploying EVPN and PBB-EVPN. This document defines four new Sub-TLVs for Target FEC Stack TLV with the purpose of identifying the FEC on the Egress PE.

2. 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 [\[RFC2119\]](#).

3. Terminology

AD: Auto Discovery

B-MAC: Backbone MAC Address

BUM: Broadcast, Unknown Unicast or Multicast

CE: Customer Edge Device

C-MAC: Customer MAC Address

DF: Designated Forwarder

ES: Ethernet Segment

ESI: Ethernet Segment Identifier

EVI: EVPN Instance Identifier that globally identifies the EVPN Instance

EVPN: Ethernet Virtual Private Network

FEC: Forwarding Equivalent Class

GAL: G-ACh Label

OAM: Operations, Administration, and Maintenance

P2MP: Point-to-Multipoint

PBB: Provider Backbone Bridge

PE: Provider Edge Device

4. Proposed Target FEC Stack Sub-TLVs

This document introduces four new Target FEC Stack Sub-TLVs that are included in the LSP-Ping Echo Request packet. The Echo Request packets are used for connectivity check in data-plane in EVPN and PBB-EVPN networks. The target FEC stack Sub-TLVs MAY be used to validate that an identifier for a given EVPN is programmed at the target node. These Target FEC Stack Sub-TLVs are described next.

4.1. EVPN MAC Sub-TLV

The EVPN MAC Sub-TLV identifies the MAC for an EVPN Instance Identifier (EVI) under test at a peer PE.

The EVPN MAC Sub-TLV fields are derived from the MAC/IP advertisement route defined in [\[RFC7432\] Section 7.2](#) and have the format as shown in Figure 1. This TLV is included in the Echo Request sent by a PE to a PBB-EVPN/EVPN Peer PE.

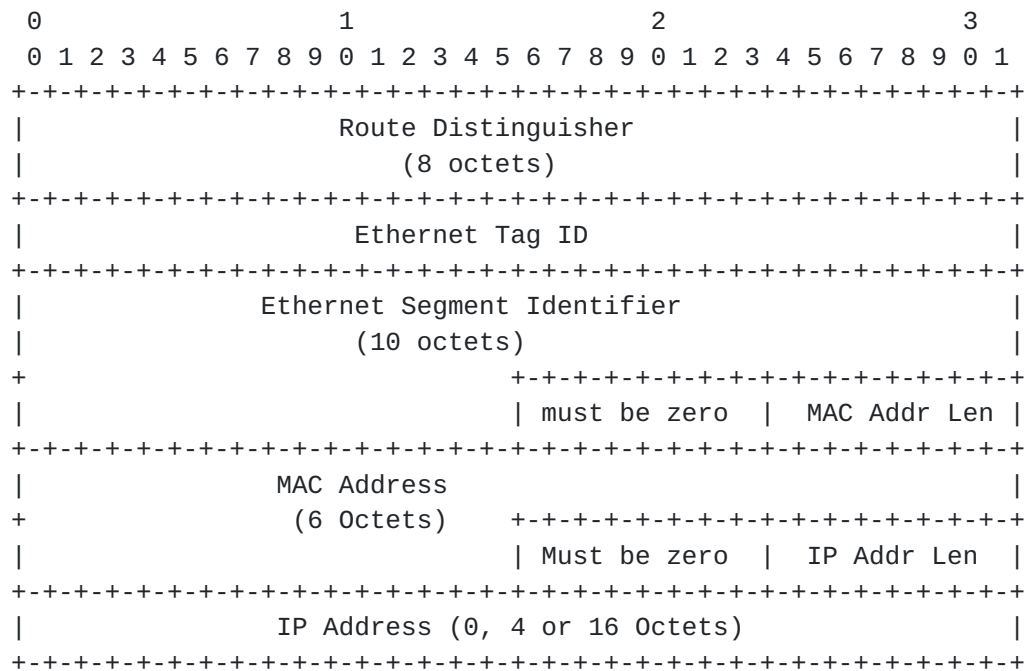


Figure 1: EVPN MAC Sub-TLV format

The LSP Echo Request is sent using the EVPN MPLS label(s) associated with the MAC route announced by a remote PE and the MPLS transport label(s) to reach the remote PE.

4.2. EVPN Inclusive Multicast Sub-TLV

The EVPN Inclusive Multicast Sub-TLV fields are based on the EVPN Inclusive Multicast route defined in [\[RFC7432\] Section 7.3](#).

The EVPN Inclusive Multicast Sub-TLV has the format as shown in Figure 2. This TLV is included in the Echo request sent to the EVPN peer PE by the originator of request to verify the multicast connectivity state on the peer PE(s) in EVPN and PBB-EVPN networks.

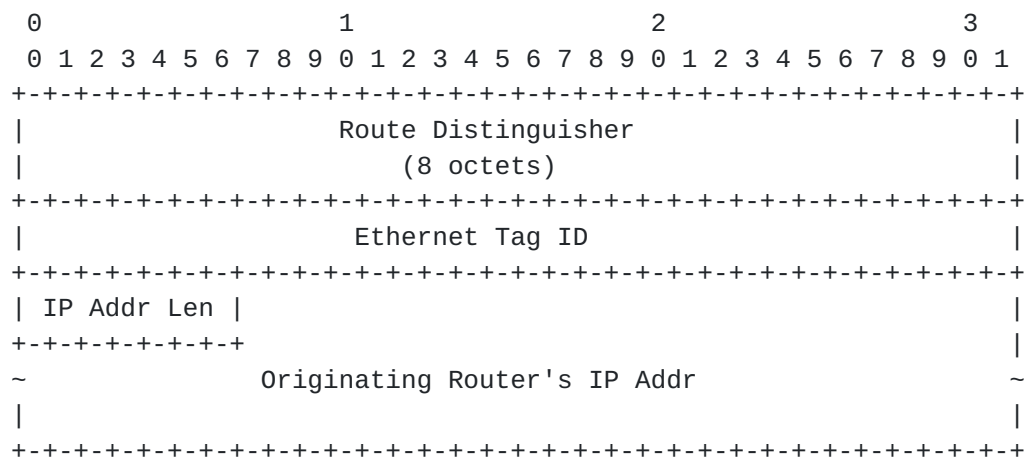


Figure 2: EVPN Inclusive Multicast Sub-TLV format

Broadcast, unknown unicast or multicast (BUM) traffic can be sent using ingress replication or P2MP P-tree in EVPN and PBB-EVPN network. In case of ingress replication, the Echo Request is sent using a label stack of [Transport label, Inclusive Multicast label] to each remote PE participating in EVPN or PBB-EVPN. The inclusive multicast label is the downstream assigned label announced by the remote PE to which the Echo Request is being sent. The Inclusive Multicast label is the inner label in the MPLS label stack.

When using P2MP P-tree in EVPN or PBB-EVPN, the Echo Request is sent using P2MP P-tree transport label for inclusive P-tree arrangement or using a label stack of [P2MP P-tree transport label, upstream assigned EVPN Inclusive Multicast label] for the aggregate inclusive P2MP P-tree arrangement as described in [Section 6](#).

In case of EVPN, to emulate traffic coming from a multi-homed site, an additional EVPN Ethernet Auto-Discovery Sub-TLV in the Target FEC stack TLV and ESI Split Horizon Group MPLS label as the bottom label, are also included in the Echo Request packet. When using P2MP P-tree, the ESI Split Horizon Group MPLS label is upstream assigned. Please see [Section 6.2.2](#) for operations using P2MP P-trees.

4.3. EVPN Ethernet Auto-Discovery Sub-TLV

The EVPN Ethernet Auto-Discovery (AD) Sub-TLV fields are based on the EVPN Ethernet Auto-Discovery route advertisement defined in [\[RFC7432\]](#) [Section 7.1](#). EVPN Ethernet AD Sub-TLV applies to only EVPN.

The EVPN Ethernet AD Sub-TLV has the format shown in Figure 3.

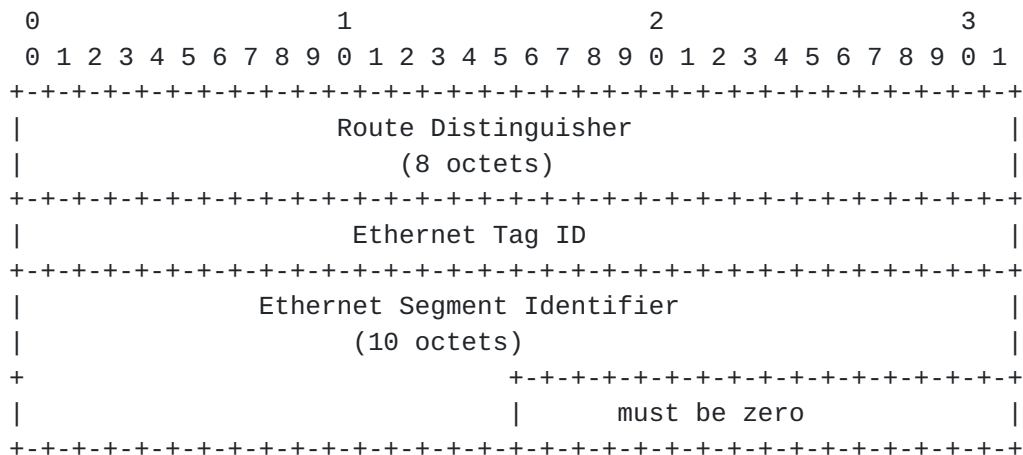


Figure 3: EVPN Ethernet Auto-Discovery Sub-TLV format

EVPN Ethernet AD Sub-TLV can be sent in the context of per-Ethernet Segement (ES) or per-EVI. When an operator performs a connectivity check for the BUM L2 service, Echo Request packet sent, MAY contain EVPN Ethernet AD Sub-TLV to emulate traffic coming from a multi-homed site. In this case, the EVPN Ethernet AD Sub-TLV is added in per-ES context. When Echo Request packet is sent for the connectivity check for EVPN Aliasing state, the context for the EVPN Ethernet AD Sub-TLV is per-EVI.

Ethernet Tag field value in EVPN Ethernet AD Sub-TLV, MUST be set according to the context:

- o For per-ES context, the Ethernet Tag field in the sub-TLV MUST be set to the reserved MAX-ET value [[RFC7432](#)]
- o For per-EVI context, the Ethernet Tag field in the sub-TLV MUST be set to the non-reserved value

[Section 8.2 of \[RFC7432\]](#) specifies that a per-ES EVPN AD route for a given multi-homed ES, may be advertised more than once with different RD values because many EVIs may be associated with the same ES and Route Targets for all these EVIs may not fit in a single BGP Update message. In this case, the RD value used in the EVPN Ethernet AD Sub-TLV, MUST be the RD value received for the EVI in the per-ES EVPN AD Route.

4.4. EVPN IP Prefix Sub-TLV

The EVPN IP Prefix Sub-TLV identifies the IP Prefix for an EVI under test at a peer PE.

The EVPN IP Prefix Sub-TLV fields are derived from the IP Prefix Route (RT-5) advertisement defined in [RFC9136] and has the format as shown in Figure 4. This TLV is included in the Echo Request sent by a PE to a EVPN peer PE.

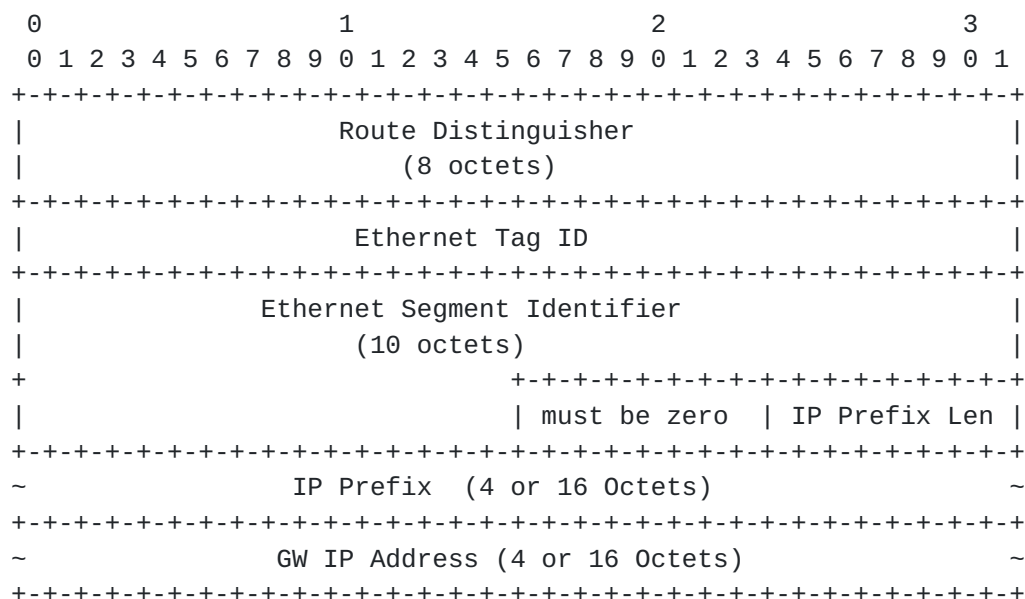


Figure 4: EVPN IP Prefix Sub-TLV format

The LSP Echo Request is sent using the EVPN MPLS label(s) associated with the IP Prefix route announced by a remote PE and the MPLS transport label(s) to reach the remote PE.

5. Encapsulation of OAM Ping Packets

The LSP Ping Echo request IP/UDP packets MUST be encapsulated with the Transport and EVPN Label(s) followed by the Generic Associated Channel Label (GAL) [RFC5586] which is the bottom most label. The GAL is followed by a Generic Associated Channel Header (G-ACH) carrying IPv4(0x0021) or IPv6(0x0057) Channel Type. The code points for ipv4 and ipv6 channels are defined in Generic Associated Channel (G-ACH) Parameters by IANA.

6. Operations

6.1. Unicast Data-plane connectivity checks

Figure 5 is an example of a PBB-EVPN network. CE1 is dual-homed to PE1 and PE2. Assume, PE1 announced a MAC route with RD 1.1.1.1:00 and B-MAC 00aa.00bb.00cc and with MPLS label 16001 for EVI 10. Similarly, PE2 announced a MAC route with RD 2.2.2.2:00 and B-MAC 00aa.00bb.00cc and with MPLS label 16002.

On PE3, when an operator performs a connectivity check for the B-MAC address 00aa.00bb.00cc on PE1, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN MAC Sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {Transport Label(s) to reach PE1, EVPN Label = 16001, GAL} MPLS label stack and IP ACH Channel header. Once the Echo Request packet reaches PE1, PE1 will use the GAL and the IP ACH Channel header to determine that the packet is IPv4 OAM Packet. The PE1 will process the packet and perform checks for the EVPN MAC Sub-TLV present in the Target FEC Stack TLV as described in [Section 4.4 in \[RFC8029\]](#) and respond according to [\[RFC8029\]](#) processing rules.

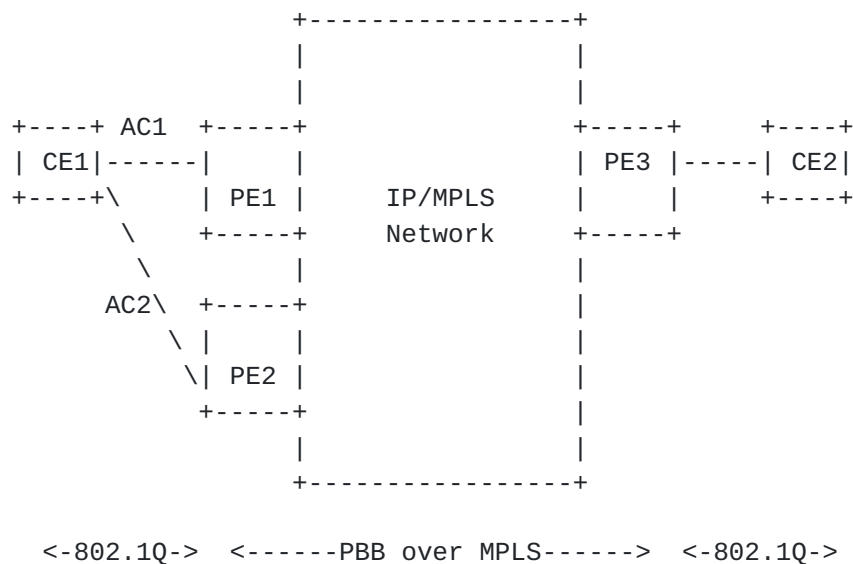


Figure 5: PBB-EVPN network

Similarly, on PE3, when an operator performs a connectivity check for the B-MAC address 00aa.00bb.00cc on PE2, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN MAC

Sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {MPLS transport Label(s) to reach PE2, EVPN Label = 16002, GAL} MPLS label stack and IP ACH Channel header.

LSP Ping operation for unicast data-plane connectivity checks in E-VPN, are similar to those described above for PBB-EVPN except that the checks are for C-MAC addresses instead of B-MAC addresses.

6.2. Inclusive Multicast Data-plane Connectivity Checks

6.2.1. Ingress Replication

Assume PE1 announced an Inclusive Multicast route for EVI 10, with RD 1.1.1.1:00, Ethernet Tag (ISID 10), PMSI tunnel attribute Tunnel type set to ingress replication and downstream assigned inclusive multicast MPLS label 17001. Similarly, PE2 announced an Inclusive Multicast route for EVI 10, with RD 2.2.2.2:00, Ethernet Tag (ISID 10), PMSI tunnel attribute Tunnel type set to ingress replication and downstream assigned inclusive multicast MPLS label 17002.

Given CE1 is dual-homed to PE1 and PE2, assume that PE1 is the DF for ISID 10 for the port corresponding to the ESI 11aa.22bb.33cc.44dd.5500.

When an operator at PE3 initiates a connectivity check for the inclusive multicast on PE1, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN Inclusive Multicast Sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {Transport Label(s) to reach PE1, EVPN Incl. Multicast Label = 17001, GAL} MPLS label stack and IP ACH Channel header. Once the Echo Request packet reaches PE1, PE1 will use the GAL and the IP ACH Channel header to determine that the packet is IPv4 OAM Packet. The packet will have EVPN Inclusive multicast label. PE1 will process the packet and perform checks for the EVPN Inclusive Multicast Sub-TLV present in the Target FEC Stack TLV as described in [Section 4.4 in \[RFC8029\]](#) and respond according to [\[RFC8029\]](#) processing rules. For the success case, PE1 will reply with with Return Code 3 - "Replying router is an egress for the FEC at stack-depth".

Similarly, an operator at PE3, may initiate an LSP Ping to PE2 with the target FEC stack TLV containing EVPN Inclusive Multicast sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {transport Label(s) to reach PE2, EVPN Incl. Multicast Label = 17002, GAL} MPLS label stack and IP ACH Channel header. Once the Echo Request packet reaches PE2, PE2 will use the GAL and the IP ACH Channel header to determine that the packet is IPv4 OAM Packet. The processing on PE2 will be similar to the that on PE1 as described

above and for the success case, PE2 will reply with Return Code 3 - "Replying router is an egress for the FEC at stack-depth" as per [\[RFC8029\]](#).

In case of EVPN, in the Echo Request packet, an EVPN Ethernet AD Sub-TLV and the associated MPLS Split Horizon Label above the GAL in the MPLS label stack, may be added to emulate traffic coming from a multi-homed site. The Split Horizon label is used by leaf PE(s) attached to the same multi-homed site to not forward packets back to the multi-homed site. If the behavior on a leaf PE is to not forward the packet to the multi-homed site on the ESI identified by EVPN Ethernet AD Sub-TLV because of Split Horizon filtering, the PE will reply with a Return Code indicating that "Replying router is egress for the FEC at the stack depth. In addition, the BUM packets are dropped on the ES corresponding to the ESI received in EVPN Ethernet AD Sub-TLV because of the Split Horizon Group filtering" as described in [Section 8](#).

[6.2.2](#). Using P2MP P-tree

Both inclusive P-Tree and aggregate inclusive P-tree can be used in EVPN or PBB-EVPN networks.

When using an inclusive P-tree arrangement, p2mp p-tree transport label itself is used to identify the L2 service associated with the Inclusive Multicast Route, this L2 service could be a customer Bridge, or a Provider Backbone Bridge.

For an Inclusive P-tree arrangement, when an operator performs a connectivity check for the multicast L2 service, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN Inclusive Multicast Sub-TLV in the Echo Request packet. The Echo Request packet is sent over P2MP LSP with the {P2MP P-tree label, GAL} MPLS label stack and IP ACH Channel header.

When using Aggregate Inclusive P-tree, a PE announces an upstream assigned MPLS label along with the P-tree ID, so both the p2mp p-tree MPLS transport label and the upstream MPLS label can be used to identify the L2 service.

For an Aggregate Inclusive P-tree arrangement, when an operator performs a connectivity check for the multicast L2 service, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN Inclusive Multicast Sub-TLV in the Echo Request packet. The Echo Request packet is sent over P2MP LSP using the IP-ACH Control channel with the {P2MP P-tree label, EVPN Upstream assigned Multicast Label, GAL} MPLS label stack and IP ACH Channel header.

The Leaf PE(s) of the p2mp tree will process the packet and perform checks for the EVPN Inclusive Multicast Sub-TLV present in the Target FEC Stack TLV as described in [Section 4.4 in \[RFC8029\]](#) and respond according to [\[RFC8029\]](#) processing rules. For the success case, the Leaf PE will reply with with Return Code 3 - "Replying router is an egress for the FEC at stack-depth".

In case of EVPN, in the Echo Request packet, an EVPN Ethernet AD Sub-TLV and the associated MPLS Split Horizon Label above the GAL in MPLS label stack, may be added to emulate traffic coming from a multi-homed site. In case of p2mp p-tree, the Split Horizon Label is upstream assigned and is received by all the leaf PEs of the p2mp-ptree. The Split Horizon label is used by leaf PE(s) attached to the same multi-homed site not to forward packets back to the multi-homed site. If the behavior on a leaf PE is to not forward the packet to the multi-homed site on the ESI in EVPN Ethernet AD Sub-TLV because of Split Horizon filtering, the PE will reply with a Return Code indicating that "Replying router is egress for the FEC at the stack depth. In addition, the BUM packets are dropped on the ES corresponding to the ESI received in EVPN Ethernet AD Sub-TLV because of the Split Horizon Group filtering" as described in [Section 8](#). If the leaf PE does not have the ESI identified in the EVPN Ethernet AD Sub-TLV, the PE can reply with a Return Code indicating that "Replying router is egress for the FEC at the stack depth. In addition, the BUM packets are forwarded because there is no ES corresponding to the ESI received in EVPN Ethernet AD Sub-TLV".

6.2.3. Controlling Echo Responses when using P2MP P-tree

The procedures described in [\[RFC6425\]](#) for preventing congestion of Echo Responses (Echo Jitter TLV) and limiting the Echo Reply to a single egress node (Node Address P2MP Responder Identifier TLV) can be applied to LSP Ping in PBB EVPN and EVPN when using P2MP P-trees for broadcast, multicast, and unknown unicast traffic.

6.3. EVPN Aliasing Data-plane connectivity check

Assume PE1 announced an Ethernet Auto discovery Route with the ESI set to CE1 system ID and MPLS label 19001, and PE2 an Ethernet Auto discovery Route with the ESI set to CE1 system ID and MPLS label 19002.

When an operator performs at PE3 a connectivity check for the aliasing aspect of the EVPN Ethernet AD route to PE1, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN Ethernet AD Sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {Transport label(s) to reach

PE1, EVPN Ethernet AD Label 19001, GAL} MPLS label stack and IP ACH Channel header.

When PE1 receives the packet it will process the packet and perform checks for the EVPN Ethernet AD Sub-TLV present in the Target FEC Stack TLV as described in [Section 4.4 in \[RFC8029\]](#) and respond according to [\[RFC8029\]](#) processing rules.

6.4. EVPN IP Prefix (RT-5) Data-plane connectivity check

Assume PE1 in Figure 5, announced an IP Prefix Route (RT-5) with an IP prefix reachable behind CE1 and MPLS label 20001. When an operator on PE3 performs a connectivity check for the IP prefix on PE1, the operator initiates an LSP Ping request with the target FEC stack TLV containing EVPN IP Prefix Sub-TLV in the Echo Request packet. The Echo Request packet is sent with the {Transport label(s) to reach PE1, EVPN IP Prefix Label 20001 } MPLS label stack.

When PE1 receives the packet it will process the packet and perform checks for the EVPN IP Prefix Sub-TLV present in the Target FEC Stack TLV as described in [Section 4.4 in \[RFC8029\]](#) and respond according to [\[RFC8029\]](#) processing rules.

7. Security Considerations

The proposal introduced in this document does not introduce any new security considerations beyond that already apply to [\[RFC7432\]](#), [\[RFC7623\]](#) and [\[RFC6425\]](#).

8. IANA Considerations

8.1. Sub-TLV Type

This document defines four new Sub-TLV type to be included in Target FEC Stack TLV (TLV Type 1, 16 and 21) [\[RFC8029\]](#) in Echo Request and Echo Reply messages in EVPN and PBB-EVPN network.

IANA is requested to assign lowest 4 free values for the four Sub-TLVs listed below from the Standards Track" (0-16383) range, in the "Sub-TLVs for TLV Types 1, 16, and 21" sub-registry, in the "TLVs" registry in the "Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" name space:

- o EVPN MAC route Sub-TLV
- o EVPN Inclusive Multicast route Sub-TLV
- o EVPN Auto-Discovery Route Sub-TLV

- o EVPN IP Prefix Route Sub-TLV

8.2. Proposed new Return Codes

[RFC8029] defines values for the Return Code field of Echo Reply. This document proposes two new Return Codes, which SHOULD be included in the Echo Reply message by a PE in response to Echo Request message in EVPN and PBB-EVPN network.

IANA is requested to assign 2 lowest free values for the 2 Return Codes listed below from the Return Codes" registry in the "Multiprotocol Label Switching (MPLS) Label Switched Paths (LSPs) Ping Parameters" name space:

- o Replying router is egress for the FEC at the stack depth. In addition, the BUM packets are dropped on the ES corresponding to the ESI received in EVPN Ethernet AD Sub-TLV because of the Split Horizon Group filtering.
- o Replying router is egress for the FEC at the stack depth. In addition, the BUM packets are forwarded because there is no ES corresponding to the ESI received in EVPN Ethernet AD Sub-TLV.

9. Acknowledgments

The authors would like to thank Loa Andersson, Alexander Vainshtein, Patrice Brissette and Weiguo Hao for their valuable comments.

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