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Domain Path (D-PATH) for Ethernet VPN (EVPN) Interconnect Networks

Abstract

The BGP Domain PATH (D-PATH) attribute is defined for Inter-Subnet Forwarding (ISF) BGP Sub-Address Families that advertise IP prefixes. When used along with EVPN IP Prefix routes or IP-VPN routes, it identifies the domain(s) through which the routes have passed and that information can be used by the receiver BGP speakers to detect routing loops or influence the BGP best path selection. This document extends the use of D-PATH so that it can also be used along with other EVPN route types.

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1. Introduction

The BGP Domain PATH (D-PATH) attribute [[I-D.ietf-bess-evpn-ipvpn-interworking](#)] is defined for Inter-Subnet Forwarding (ISF) BGP Sub-Address Families that advertise IP prefixes. When used along with EVPN IP Prefix routes or IP-VPN routes, it identifies the domain(s) through which the routes have passed and that information can be used by the receiver BGP speakers to detect routing loops or influence the BGP best path selection. This document extends the use of D-PATH so that it can also be used along with other EVPN route types.

The D-PATH attribute can be used to prevent control plane loops for EVPN routes, or to provide full path visibility of all the EVPN Interconnect Gateways through which a route has gone and modify the best path selection based on it. Some use cases in which D-PATH can

be used along with (non-IP Prefix) EVPN routes follow, but the use cases are not limited to the ones described in this section.

1.1. D-PATH to Prevent Loops for EVPN Routes

[Figure 1](#) illustrates an EVPN Interconnect case where EVPN MAC/IP Advertisement routes can be looped indefinitely. The three Gateways (GW1, GW2 and GW3) and PE1 in the diagram are attached to the same EVPN Broadcast Domain (BD1). However, BD1 is extended throughout three different domains that are interconnected by the Gateways, which follow [\[RFC9014\]](#) procedures. Suppose a host with MAC address M1 is learned on GW1 and GW1 advertises an EVPN MAC/IP Advertisement route for M1 into Domain-1 and Domain-2. When the route gets imported by GW2 and GW3 and later exported into Domain-3, GW2 and GW3 may redistribute each other's route for M1 back into Domain-1 and Domain-2, respectively, creating a loop. D-PATH can be used by the Gateways when redistributing the route between Domains, to identify the Domains through which the route for M1 has gone. When GW1 receives an EVPN MAC/IP Advertisement route for M1 that contains a D-PATH with a domain-id locally assigned, GW1 identifies the route as "looped".

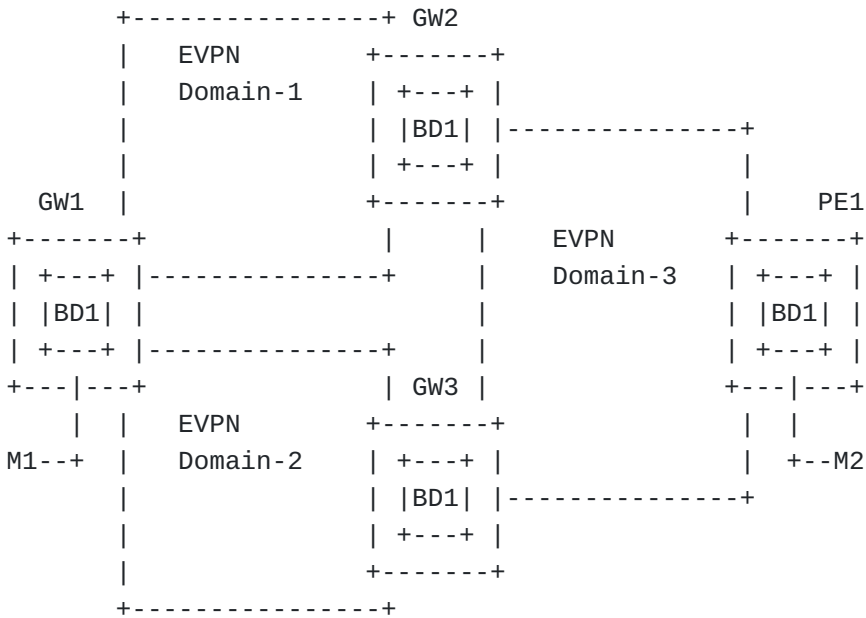


Figure 1: Loops for EVPN routes

Similar examples are possible with EVPN VPWS services on the Gateways and PEs, where loop prevention for the redistributed A-D per EVI routes is needed. D-PATH provides the end to end path visibility that is required to prevent the loop.

1.2. Add Path Visibility and Influence Best Path Selection for EVPN Routes

[Figure 2](#) illustrates another [\[RFC9014\]](#) EVPN Interconnect case where, in addition to using D-PATH to prevent EVPN MAC/IP Advertisement route loops when redistributing routes between domains, the D-PATH attribute can also influence the best path selection for the routes. For example, if all the Gateways in the diagram are attached to the same BD1, an EVPN MAC/IP Advertisement route for MAC address M1 advertised by GW1 is advertised into Domain-1 and Domain-4. Two routes for M1 will arrive at GW3 with different Route Distinguishers and BGP Next Hops. If D-PATH is used by all the Gateways, the two routes arriving at GW3 will have a different sequence of domain-ids in the D-PATH attribute. GW3 can use the length of the D-PATH as a way of influencing the selection (i.e., the shortest D-PATH route is selected). D-PATH improves the path visibility of the route since it provides information about all the Domains through which the route has passed.

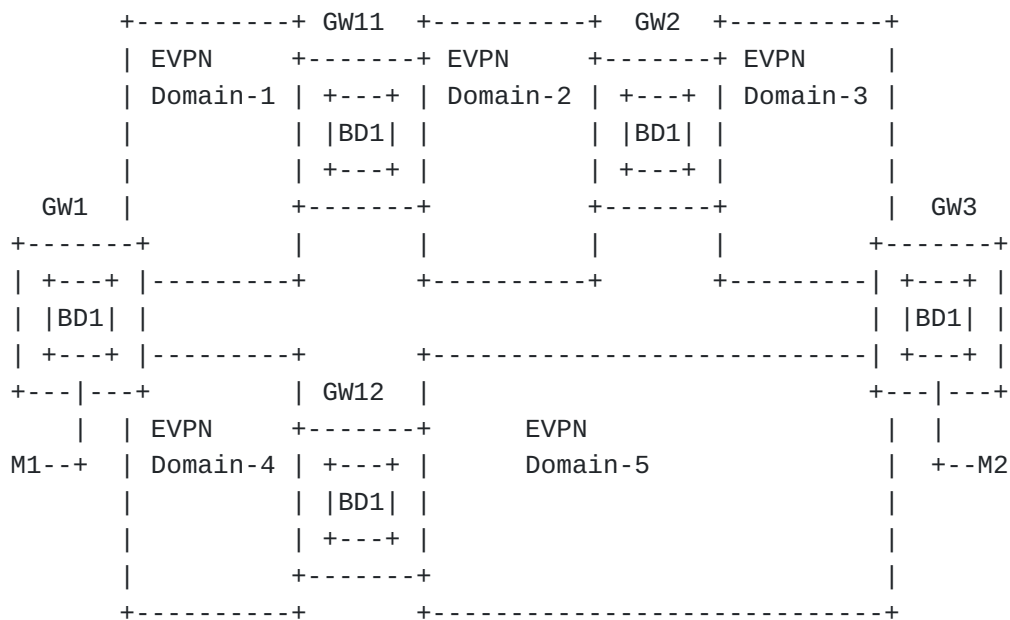


Figure 2: Influence Best Path Selection for EVPN routes

2. Conventions used in this document

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

3. Terminology

This section summarizes the terminology that is used throughout the rest of the document.

*AC: Attachment Circuit or logical interface associated to a given BT. To determine the AC on which a packet arrived, the PE examines the combination of a physical port and VLAN tags (where the VLAN tags can be individual c-tags, s-tags or ranges of both).

*BD and BT: a Broadcast Domain and Bridge Table, as defined in [[I-D.ietf-bess-rfc7432bis](#)]. A BD is a group of PEs attached to the same EVPN layer-2 multipoint service. A BT is the instantiation of a Broadcast Domain in a PE. When there is a single Broadcast Domain in a given EVI, the MAC-VRF in each PE contains a single BT. When there are multiple BTs within the same MAC-VRF, each BT is associated to a different Ethernet Tag. The EVPN routes specific to a BT indicate which Ethernet Tag the route corresponds to.

*ES and ESI: Ethernet Segment and Ethernet Segment Identifier, as defined in [[I-D.ietf-bess-rfc7432bis](#)].

*EVPN Domain: two PEs are in the same EVPN Domain if they are attached to the same service and the packets between them do not require a data path lookup of the inner frame (e.g., in the BT of a MAC-VRF) in any intermediate router. An EVPN Domain Gateway PE is always configured with multiple Domain identifiers (EVPN Domain-ID) in the MAC-VRF or VPWS that connects those EVPN Domains, each EVPN Domain-ID representing an EVPN Domain.

Example: [Figure 3](#) illustrates an example where PE1 and PE2 belong to different EVPN Domains since packets between them (for flows between hosts with MAC addresses M1 and M2) require a MAC lookup in two of the gateways that are connecting the three EVPN Domains. E.g., if frames from M1 to M2 go through PE1, GW1, GW3 and PE2, a MAC lookup is performed at GW1 and GW3.

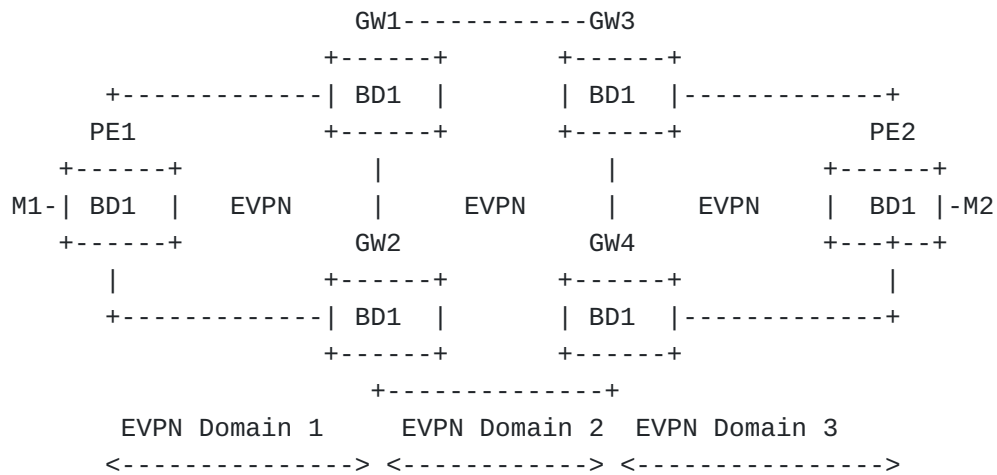


Figure 3: EVPN Domain Interconnect Example

*EVPN Domain Gateway: a PE where a service (BD or VPWS instance) is instantiated and is attached to two or more EVPN Domains. An example of EVPN Domain Gateway is a PE following the procedures in section 4.4 or section 4.6 of [\[RFC9014\]](#). In the example in [Figure 3](#), GW1 and GW2 connect EVPN Domains 1 and 2, whereas GW3 and GW4 connect EVPN Domains 2 and 3. GW1 and GW2 import the MAC/IP Advertisement route for M1 coming from the EVPN Domain 1 into the MAC-VRF for BD1, and redistribute it into EVPN Domain 2. Likewise, GW3 and GW4 import the route into their MAC-VRF and re-advertise it into EVPN Domain 3.

*MAC-VRF: a MAC Virtual Routing and Forwarding table, as defined in [\[I-D.ietf-bess-rfc7432bis\]](#). It is also the instantiation of an EVI (EVPN Instance) in a PE.

4. Use of Domain Path Attribute (D-PATH) with EVPN routes

This document extends the use of the D-PATH attribute specified in [\[I-D.ietf-bess-evpn-ipvpn-interworking\]](#) so that D-PATH can be advertised and processed along with the following EVPN route types:

*EVPN MAC/IP Advertisement routes that are not used for Inter-Subnet Forwarding (ISF). Note that if the EVPN MAC/IP Advertisement route is used for Inter-Subnet Forwarding as in [\[RFC9135\]](#), the procedures for the D-PATH advertisement and processing are described in [\[I-D.ietf-bess-evpn-ipvpn-interworking\]](#).

*EVPN A-D per EVI routes that are used for EVPN VPWS [\[RFC8214\]](#). Advertised A-D per EVI routes not used for EVPN VPWS SHOULD NOT contain D-PATH.

*EVPN Inclusive Multicast Ethernet Tag routes [\[I-D.ietf-bess-rfc7432bis\]](#).

As discussed, the use of D-PATH with EVPN IP Prefix routes is specified in [[I-D.ietf-bess-evpn-ipvpn-interworking](#)]. When used along with EVPN routes other than IP Prefix routes, the D-PATH attribute is characterized as follows:

1. D-PATH is composed of a sequence of Domain segments following the format specified in [[I-D.ietf-bess-evpn-ipvpn-interworking](#)] where each Domain is represented as <DOMAIN-ID:ISF_SAFI_TYPE>. In this specification, DOMAIN-ID is an EVPN Domain identifier configured in an EVPN Domain Gateway and ISF_SAFI_TYPE is set to either 70 (EVPN) or 0 (local route). To simplify the explanation, this document represents the domains for EVPN routes as <Domain-ID:TYPE>.
2. D-PATH identifies the sequence of EVPN Domains the route has gone through, with the last <Domain-ID:TYPE> entry (rightmost) identifying the first PE or EVPN Domain Gateway that added the D-PATH attribute.
3. For non-ISF MAC/IP Advertisement routes or A-D per EVI routes, D-PATH SHOULD be added/modified by a EVPN Domain Gateway that redistributes the route between EVPN Domains and MAY be added by a PE or EVPN Domain Gateway that originates the route, as follows:
 - a. An EVPN Domain Gateway that connects two EVPN Domains "X" and "Y", and receives a route on a EVPN Domain identified by a Domain-ID "X" SHOULD append a domain <X:EVPN> to the existing (or newly added) D-PATH attribute when redistributing the route to EVPN Domain "Y". The route is redistributed if it is first imported in a MAC-VRF (or VPWS instance), the MAC (or Ethernet Tag) is active, and policy allows the re-export of the route to a BGP neighbor.
 - b. An EVPN Domain Gateway MAY also add the D-PATH attribute for locally learned MACs or MAC/IP pairs. In this case, the domain added would be <A:0>, where "A" is the Domain-ID configured on the Gateway's MAC-VRF that is specific to local routes (MAC/IP learned via local AC), and "0" is the TYPE of the EVPN Domain and indicates that the route is locally originated and not redistributed after receiving it from a BGP-EVPN neighbor. The EVPN Domain-ID for local routes MAY be shared by all the EVPN Domain Gateways of the same redundancy group for local routes, or each EVPN Domain Gateway of the redundancy group can use its own Domain-ID.

- c. A PE that is connected to a single EVPN Domain (therefore the PE is not an EVPN Domain Gateway) MAY add the D-PATH with a domain <B:0>, where "B" is the Domain-ID configured on the PE's MAC-VRF (or VPWS) for locally learned MAC/IPs (or Ethernet Tag IDs for VPWS). "0" is the TYPE that indicates the route is not re-advertised, but originated in the PE.
4. For EVPN Inclusive Multicast Ethernet Tag routes, an EVPN Domain Gateway must not redistribute routes between Domains as specified in [\[RFC9014\]](#). An EVPN Domain Gateway originates an EVPN Inclusive Multicast Ethernet Tag route per Domain to which the Gateway is attached, so that BUM traffic can be attracted from one Domain to the rest. Therefore, only the above point 3.b. applies to EVPN Domain Gateways. That is, an EVPN Domain Gateway MAY add a <A:0> D-PATH attribute for the Inclusive Multicast Ethernet Tag routes generated for the EVPN Domains, where "A" is the configured local Domain-ID, and "0" is the TYPE that indicates the route is locally originated and not redistributed across EVPN Domains. When two EVPN Domain Gateways of the same redundancy group connect two EVPN Domains "X" and "Y" and D-PATH is used for EVPN Inclusive Multicast Ethernet Tag routes, it is RECOMMENDED to add the D-PATH attribute with the same local Domain-ID and only on "X" or "Y" but not on both Domains.
5. On received EVPN routes, D-PATH is processed and used for loop detection ([Section 4.4](#)) as well as to influence the best path selection ([Section 4.1](#), [Section 4.2](#) and [Section 4.3](#)).

4.1. D-PATH and Best Path Selection for MAC/IP Advertisement routes

When two (or more) MAC/IP Advertisement routes with the same route key (and same or different RDs) are received, a best path selection algorithm is used to select and install only one route. This section summarizes the best path selection for MAC/IP Advertisement routes, which extends the rules in [\[I-D.ietf-bess-rfc7432bis\]](#) by including D-PATH in the tie-breaking algorithm. While the algorithm may be implemented in different ways, the selection result SHOULD be the same as the result of the rules that follow.

The tie-breaking algorithm begins by considering all EVPN MAC/IP Advertisement routes equally preferable routes to the same destination, and then selects routes to be removed from consideration. The process terminates as soon as only one route remains in consideration.

1. When the Default Gateway extended community is present in some of the routes, the MAC/IP Advertisement routes without the

Default Gateway indication are removed from consideration, as defined in [[I-D.ietf-bess-rfc7432bis](#)].

2. Then the routes with the Static bit set in the MAC Mobility extended community are preferred, and the routes without the Static bit set are removed from consideration, as defined in [[I-D.ietf-bess-rfc7432bis](#)]. Note that this rule does not apply to routes with the Default Gateway extended community, since these routes SHALL NOT convey the MAC Mobility extended community [[I-D.ietf-bess-rfc7432bis](#)]. Therefore if two or more routes with the Default Gateway extended community remain in consideration, the selection process skips this step.
3. Then the routes with the highest MAC Mobility Sequence number are preferred, hence the routes that are not tied for having the highest Sequence number are removed from consideration, as defined in [[I-D.ietf-bess-rfc7432bis](#)]. If two or more routes with the Default Gateway extended community remain in consideration, the selection process skips this step (for the same reason as in step 2).
4. Then routes with the highest Local Preference are preferred, hence routes that are not tied for having the highest Local Preference are removed from consideration, as defined in [[RFC4271](#)].
5. Then routes with the shortest D-PATH are preferred, hence routes not tied for the shortest D-PATH are removed. Routes without D-PATH are considered zero-length D-PATH.
6. Then routes with the numerically lowest left-most Domain-ID are preferred, hence routes not tied for the numerically lowest left-most Domain-ID are removed from consideration.
7. If the steps above do not produce a single route, the rest of the rules after the highest Local Preference in [[RFC4271](#)] apply after step 6.

The above selection criteria is followed irrespective of the ESI value in the routes. EVPN Multi-Homing procedures for Aliasing or Backup paths in [[I-D.ietf-bess-rfc7432bis](#)] are applied to the selected MAC/IP Advertisement route.

4.2. D-PATH and Best Path Selection for Ethernet A-D per EVI routes

When two (or more) EVPN A-D per EVI routes with the same route key (and same or different RDs) are received for a VPWS, a best path selection algorithm is used. The selection algorithm follows the same steps as in [Section 4.1](#) except for steps 1-3 which do not apply

since the Default Gateway and MAC Mobility extended community are irrelevant to the EVPN A-D per EVI routes.

The above selection is followed for A-D per EVI routes with ESI=0. For non-zero ESI routes, the EVPN Multi-Homing procedures in [\[RFC8214\]](#) for Aliasing and Backup path are followed to select the routes (P and B flags are considered for the selection of the routes when sending traffic to a remote Ethernet Segment). If the mentioned Multi-Homing procedures do not produce a single route to each of the remote PEs attached to the same ES, steps 4-7 in [Section 4.1](#) are followed.

4.3. D-PATH and Best Path Selection for Inclusive Multicast Ethernet Tag routes

When two (or more) EVPN Inclusive Multicast Ethernet Tag routes with the same route key (and same or different RDs) are received for a MAC-VRF, a best path selection algorithm is used. The selection algorithm follows the same steps as in [Section 4.1](#) except for steps 1-3 which do not apply.

4.4. Loop Detection

An EVPN route received by a PE with a D-PATH attribute that contains one or more of its locally associated Domain-IDs for the MAC-VRF or VPWS instance is considered to be a looped route. A looped route MUST NOT be redistributed to a different domain and SHOULD be flagged as "looped".

EVPN A-D per EVI looped routes and Inclusive Multicast Ethernet Tag looped routes MUST NOT be installed, where "install" means "create forwarding state" in this document. An EVPN MAC/IP Advertisement looped route MAY be installed if selected as the best route.

For instance, in the example of [Figure 3](#), assuming PE1 advertises M1's MAC/IP and does not add the D-PATH attribute, the EVPN Domain Gateway GW1 receives two MAC/IP Advertisement routes for M1's MAC/IP:

*A MAC/IP Advertisement route with next-hop PE1 and no D-PATH.

*A MAC/IP Advertisement route with next-hop GW2 and D-PATH={length=1,<6500:1:EVPN>}, assuming that the Domain-ID for EVPN Domain 1 is 6500:1.

In this case, EVPN Domain Gateway GW1 flags the MAC/IP Advertisement route with D-PATH as "looped", and does not install the MAC in the BT of the MAC-VRF and does not redistribute the route back to EVPN Domain 1 (since the route includes one of GW1's Domain-IDs). In case the MAC/IP Advertisement route with next-hop PE1 is withdrawn, GW1

may install the route with next-hop GW2 and D-PATH <6500:1:EVPN>; this may help speed up convergence in case of failures.

4.5. Error Handling

The error handling for the D-PATH attribute is described in [[I-D.ietf-bess-evpn-ipvpn-interworking](#)]. This document extends the use of D-PATH to non-ISF EVPN routes.

5. Use-Case Examples

This section illustrates the use of D-PATH in EVPN routes with examples.

[Figure 4](#) and [Figure 5](#) illustrate an integrated interconnect solution for an EVPN BD, as described in section 4.4 and section 4.6 of [[RFC9014](#)]. GW1 and GW2 are EVPN Domain Gateways connecting two EVPN Domains identified by D-PATH domain {1:1:EVPN} and {1:2:EVPN}, respectively. Received Ethernet A-D routes, ES routes, and Inclusive Multicast routes from the routers in one EVPN Domain are consumed and processed by GW1 and GW2, but not redistributed to the other EVPN Domain. However, MAC/IP Advertisement routes received by GW1 and GW2 in one EVPN Domain are processed and, if installed, redistributed into the other EVPN Domain.

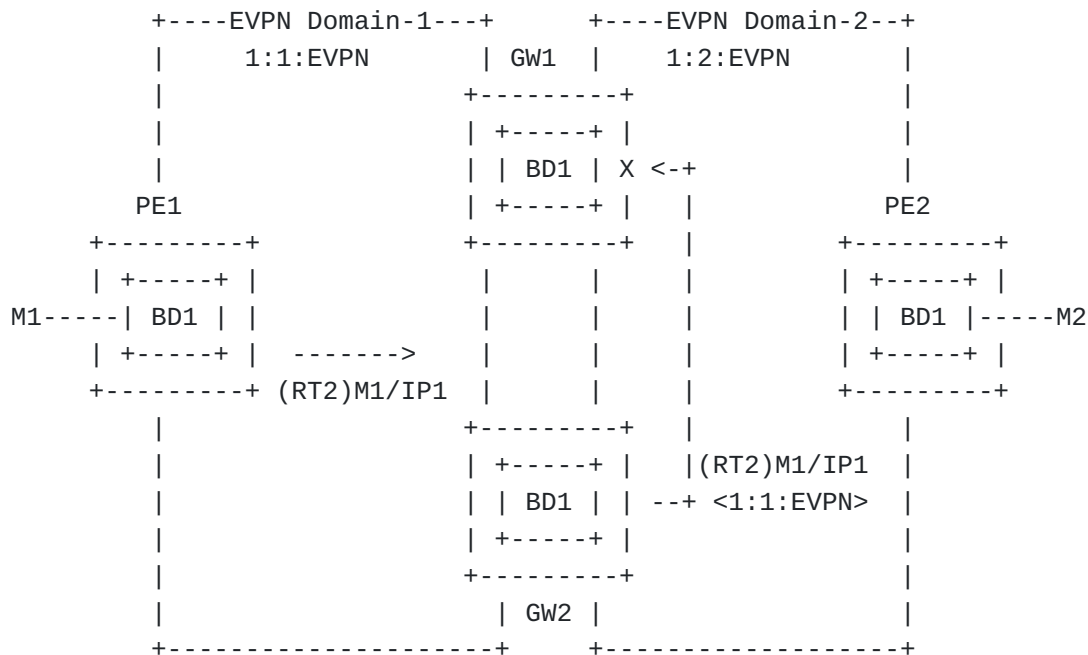
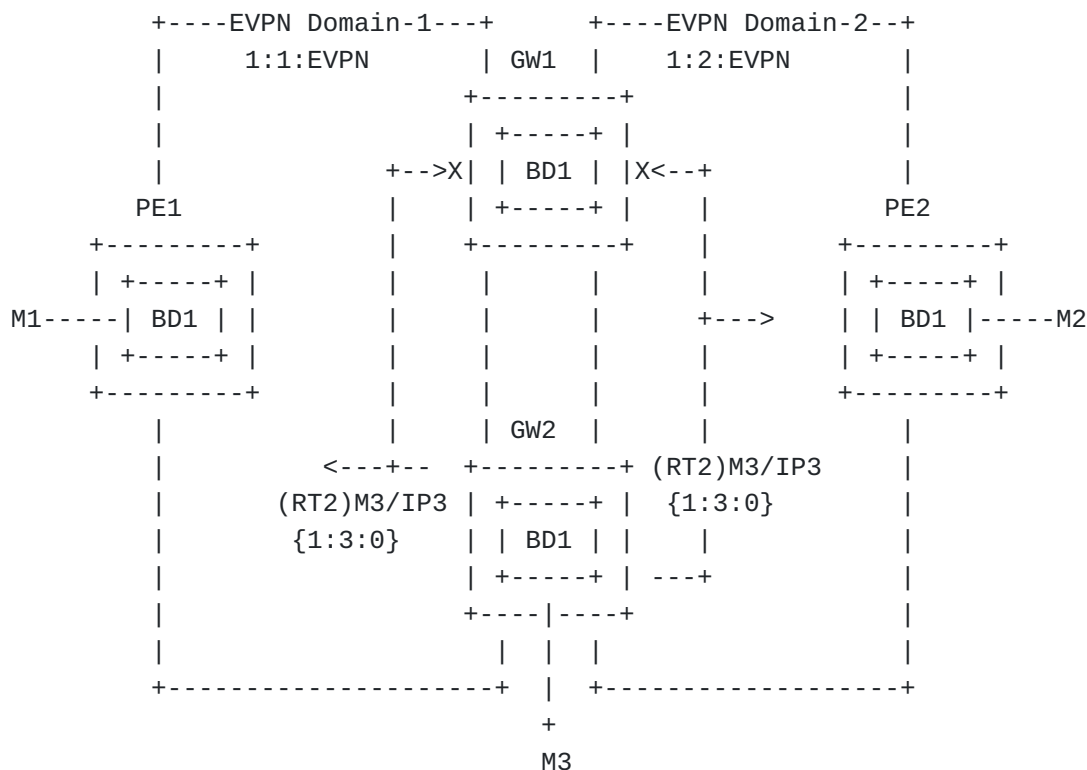


Figure 4: EVPN Interconnect

Consider the example of [Figure 4](#), where PE1 advertises a MAC/IP Advertisement route for M1/IP1. The route is processed and installed by GW1 and GW2 in BD1, and both redistribute the routes into the

EVPN Domain-2. By using D-PATH in GW1 and GW2, when the route is received on PE2, PE2 has the visibility of the EVPN Domains through which the route has gone, and can also use the D-PATH for best path selection. In addition, GW1 and GW2 can compare the D-PATH of the incoming routes with their local list of EVPN Domain-IDs, and detect looped routes if any of the local EVPN Domain-IDs matches a domain in the received D-PATH. This procedure prevents the redistribution of the route back into EVPN Domain-1. For example, when GW1 receives the MAC/IP Advertisement route for M1/IP1 with D-PATH <1:1:EVPN>, GW1 identifies the route as looped and it does not redistribute it back to Domain-1. The M1/IP1 route with Next Hop PE1 is installed. If M1/IP1 with Next Hop PE1 is withdrawn, GW1 MAY install the route M1/IP1 with Next Hop GW2, as specified in [Section 4.4](#).



Assuming GW2 learns M3/IP3 via local AC, GW2 advertises a MAC/IP Advertisement route for M3/IP3 into each of the EVPN Domains that GW2 is connected to. As described in [Section 4](#), GW2 can advertise these two MAC/IP Advertisement routes with a configured EVPN Domain-ID for local MAC/IPs routes that can be shared with GW1. Consider this EVPN Domain-ID is 1:3 and it is configured on both, GW1 and

GW2. When GW2 advertises the route into each EVPN Domain, it adds the D-PATH attribute with a domain {1:3:0}. These routes are flagged by GW1 as "looped" since 1:3 is configured as a local EVPN Domain-ID in GW1. In addition, PE1 and PE2 receive the routes with the D-PATH and they have the visibility of the origin of the routes, in this case local EVPN Domain Gateway routes. This information can be used to influence the best path selection in case of multiple routes for M3/IP3 are received on PE1 or PE2 for BD1.

As an alternative solution to configuring the same EVPN Domain-ID for local routes on both EVPN Domain Gateways, GW2 can be configured with EVPN Domain-ID 1:3 for local routes, and GW1 can use a different EVPN Domain-ID, e.g., 1:4. In this case, GW2 advertises the route for M3/IP3 into each EVPN Domain as before, but now GW1 does not flag the route as "looped" since 1:3 is not on the list of GW1's local EVPN Domain-IDs. GW1 receives the routes from both EVPN Domains, and GW1 selects the route from e.g., EVPN Domain-1. GW1 then installs the route in its BT and redistributes the route into EVPN Domain-2 with D-PATH {1:1:EVPN, 1:3:0}. When PE2 receives two routes for M3/IP3, one from GW2 with D-PATH {1:3:0} and another from GW1 with D-PATH {1:1:EVPN, 1:3:0}, PE2 uses best path selection and choose to send its traffic to GW2. Also GW2 receives the route for M3/IP3 from GW1 and mark it as "looped" since that route conveys its own EVPN Domain-IDs 1:1 and 1:3.

In a nutshell, the use of D-PATH in MAC/IP Advertisement routes helps prevent loops and influences the best path selection so that PEs choose the shortest paths to the destination PEs.

6. Security Considerations

Most of the considerations included in [[I-D.ietf-bess-evpn-ipvpn-interworking](#)] apply to this document.

7. IANA Considerations

None.

8. Acknowledgments

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