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N. Malhotra, Ed.
A. Sajassi
Cisco Systems
J. Rabadan
Nokia
J. Drake
Independent
A. Lingala
ATT
S. Thoria
Cisco Systems
22 September 2025

Weighted Multi-Path Procedures for EVPN Multi-Homing
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Abstract

EVPN enables all-active multi-homing for a CE (Customer Equipment) device connected to two or more PE (Provider Equipment) devices via a LAG (Link Aggregation), such that bridged and routed traffic from remote PEs to hosts attached to the Ethernet Segment can be equally load balanced (it uses Equal Cost Multi Path) across the multi-homing PEs. EVPN also enables multi-homing for IP subnets advertised in IP Prefix routes, so that routed traffic from remote PEs to those IP subnets can be load balanced. This document defines extensions to EVPN procedures to optimally handle unequal access bandwidth distribution across a set of multi-homing PEs in order to:

- * provide greater flexibility, with respect to adding or removing individual multi-homed PE-CE links.
- * handle multi-homed PE-CE link failures that can result in unequal PE-CE access bandwidth across a set of multi-homing PEs.

In order to achieve the above, it specifies signaling extensions and procedures to:

- * Loadbalance bridged and routed traffic across egress PEs in proportion to PE-CE link bandwidth or a generalized weight distribution.

- * Achieve BUM (Broadcast, UnknownUnicast, Multicast) DF (Designated Forwarder) election distribution for a given ES (Ethernet Segment) across the multi-homing PE set in proportion to PE-CE link bandwidth. Section 6 of this document further updates RFC 8584, draft-ietf-bess-evpn-per-mcast-flow-df-election and draft-ietf-bess-evpn-pref-df in order for the DF election extension defined in this document to work across different DF election algorithms.

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1. Introduction

In an EVPN IRB (Integrated Routing and Bridging) overlay network as described in [RFC9135], with a CE multi-homed via a EVPN all-active multi-homing, bridged and routed traffic from ingress PEs can be equally load balanced (ECMPed) across the multi-homing egress PEs:

- * ECMP Load-balancing for bridged unicast traffic is enabled via aliasing and mass-withdraw procedures detailed in [RFC7432].
- * ECMP Load-balancing for routed unicast traffic is enabled via existing L3 ECMP mechanisms.
- * Load-sharing of bridged BUM (Broadcast, UnknownUnicast, Multicast) traffic on local ports is enabled via EVPN DF election procedure detailed in [RFC7432].

All of the above load balancing and DF election procedures implicitly assume equal bandwidth distribution between the CE and the set of egress PEs. Essentially, with this assumption of equal "access" bandwidth distribution across all egress PEs, all remote traffic is equally load balanced across the egress PEs. This assumption of equal access bandwidth distribution can be restrictive with respect to adding / removing links in a multi-homed LAG interface and may also be easily broken on individual link failures. A solution to handle unequal access bandwidth distribution across a set of egress PEs is specified in this document. Primary motivation behind this proposal is to enable greater flexibility with respect to adding / removing member PE-CE links, as needed and to optimally handle PE-CE link failures.

1.1. PE-CE Link Provisioning

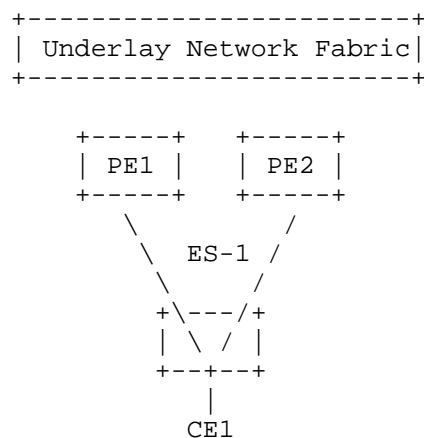


Figure 1

Consider CE1 that is dual-homed to egress PE1 and egress PE2 via EVPN all-active multi-homing with single member links of equal bandwidth to each PE (aka, equal access bandwidth distribution across PE1 and PE2). If the provider wants to increase link bandwidth to CE1, it

must add a link to both PE1 and PE2 in order to maintain equal access bandwidth distribution and inter-work with EVPN ECMP load balancing. In other words, for a dual-homed CE, total number of CE links must be provisioned in multiples of 2 (2, 4, 6, and so on). For a triple-homed CE, number of CE links must be provisioned in multiples of three (3, 6, 9, and so on). To generalize, for a CE that is multi-homed to "n" PEs, number of PE-CE physical links provisioned must be an integral multiple of "n". This is restrictive in case of dual-homing and very quickly becomes prohibitive in case of multi-homing.

Instead, a provider may wish to increase PE-CE bandwidth or number of links in any link increments. As an example, for CE1 dual-homed to egress PE1 and egress PE2 in all-active mode, provider may wish to add a third link to only PE1 to increase total bandwidth for this CE by 50%, rather than being required to increase access bandwidth by 100% by adding a link to each of the two PEs. While existing EVPN based all-active load balancing procedures do not necessarily preclude such asymmetric access bandwidth distribution among the PEs providing redundancy, it may result in unexpected traffic loss due to congestion in the access interface towards CE. This traffic loss is due to the fact that PE1 and PE2 will continue to be treated as equal cost paths at remote PEs, and as a result may attract approximately equal amount of CE1 destined traffic, even when PE2 only has half the bandwidth to CE1 as PE1. This may lead to congestion and traffic loss on the PE2-CE1 link. If bandwidth distribution to CE1 across PE1 and PE2 is 2:1, traffic from remote hosts must also be load balanced across PE1 and PE2 in 2:1 manner.

1.2. PE-CE Link Failures

More importantly, unequal PE-CE bandwidth distribution described above may occur during regular operation following a link failure, even when PE-CE links were provisioned to provide equal bandwidth distribution across multi-homing PEs.

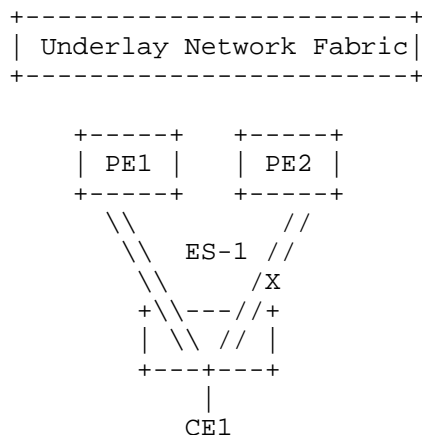


Figure 2

Consider a CE1 that is multi-homed to egress PE1 and egress PE2 via a LAG with two member links to each PE. On a PE2-CE1 physical link failure, LAG represented by an Ethernet Segment ES-1 on PE2 stays up, however, its bandwidth is cut in half. With existing ECMP procedures, both PE1 and PE2 may continue to attract equal amount of traffic from remote PEs, even when PE1 has double the bandwidth to CE1. If bandwidth distribution to CE1 across PE1 and PE2 is 2:1, traffic from remote hosts must also be load balanced across PE1 and PE2 in 2:1 manner to avoid unexpected congestion and traffic loss on PE2-CE1 links within the LAG. As an alternative, min-link on LAGs is sometimes used to bring down the LAG interface on member link failures. This however results in loss of available bandwidth in the network, and is not ideal.

1.3. Design Requirement

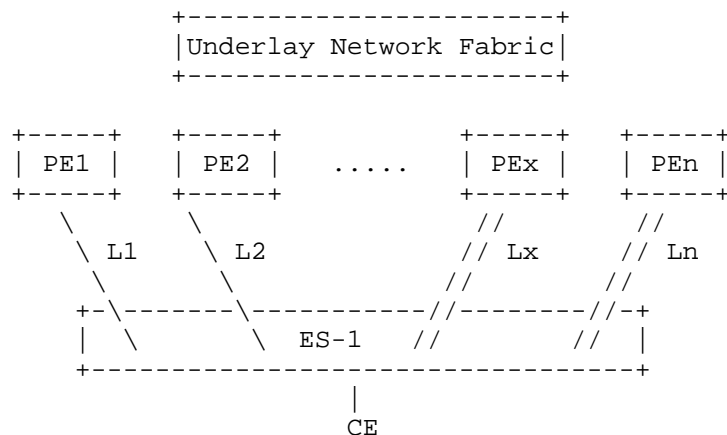


Figure 3

To generalize, if total link bandwidth to a CE is distributed across "n" egress PEs, with L_x being the total bandwidth to PE_x across all links, traffic from ingress PEs to this CE must be load balanced unequally across egress PE set $[PE_1, PE_2, \dots, PE_n]$ such that, fraction of total unicast and BUM flows destined for CE that are serviced by egress PE_x is:

$$L_x / [L_1 + L_2 + \dots + L_n]$$

Figure 3 illustrates a scenario where egress $PE_1..PE_n$ are attached to a multi-homed Ethernet Segment, however this document generalizes this requirement so that the unequal load balancing can be applied to PEs attached to a vES or to a multi-homed subnet advertised by EVPN IP Prefix routes.

The solution specified below includes extensions to EVPN procedures to achieve the above. Following assumption apply to procedure described in this document:

- * For procedures related to bridged unicast and BUM traffic, EVPN all active multi-homing is assumed.
- * Procedures related to bridged unicast and BUM traffic are applicable to both aliasing and non-aliasing mode as defined in [RFC7432].

2. Requirements Language and Terminology

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.

- * BW: BandWidth
- * LAG: Link Aggregation Group
- * ES: Ethernet Segment
- * ESI: Ethernet Segment ID
- * vES: Virtual Ethernet Segment
- * EVI: Ethernet virtual Instance, this is a mac-vrf
- * RT-1: EVPN Route Type 1 as defined in [RFC7432]
- * RT-2: EVPN Route Type 2 as defined in [RFC7432]
- * RT-5: EVPN Route Type 5 as defined in [RFC7432]
- * Path-List: A forwarding object used to load-balance routed or bridged traffic across multiple forwarding paths.
- * Access Bandwidth: Bandwidth of PE-CE links in an Ethernet Segment
- * Egress PE: In the context of an Ethernet Segment or a route, this is the PE that advertises a locally attached Ethernet Segment RT-1, or a locally attached host or prefix route (RT-2, RT-5)
- * Ingress PE: In the context of an Ethernet Segment or a route, this is the receiving PE that learns remote Ethernet Segment RT-1 and/or host and prefix routes (RT-2, RT-5) from the Egress PE
- * IMET: Inclusive Multicast Route
- * DF: Designated Forwarder
- * BDF: Backup Designated Forwarder
- * DCI: Data Center Interconnect Router

3. Solution Overview

In order to achieve weighted load balancing to an ES or vES for overlay unicast traffic, Ethernet A-D per ES route (EVPN Route Type 1) is leveraged to signal the Ethernet Segment weight to ingress PEs. Using Ethernet A-D per ES route to signal the Ethernet Segment weight provides a mechanism that reacts to changes in access bandwidth or number of access links in a service and host independent manner. Ingress PEs computing the MAC path-lists based on global and aliasing Ethernet A-D routes now have the ability to setup weighted load balancing path-lists based on the ES access bandwidth or number of links received from each egress PE that the ES is multi-homed to.

In order to achieve weighted load balancing of overlay BUM traffic, EVPN ES route (Route Type 4) is leveraged to signal the ES weight to egress PEs within an ES's redundancy group to influence per-service DF election. Egress PEs in an ES redundancy group now have the ability to do service carving in proportion to each egress PE's relative ES weight.

Unequal load balancing to multi-homed subnets is achieved by signaling the weight along with the IP Prefix routes advertised for the subnet.

Procedures to accomplish this are described in greater detail next.

4. EVPN Link Bandwidth Extended Community

A new EVPN Link Bandwidth extended community is defined for the solution specified in this document:

- * This extended community is defined of type 0x06 (EVPN Extended Community Sub-Types).
- * IANA has assigned sub-type value of 0x10 for the EVPN Link bandwidth extended community, of type 0x06 (EVPN Extended Community Sub-Types).
- * EVPN Link Bandwidth extended community is defined as transitive.

4.1. Encoding and Usage of EVPN Link Bandwidth Extended Community

EVPN Link Bandwidth Extended Community value field is used to carry total bandwidth of egress PE's all physical links in an ethernet segment, expressed in Mbits/sec (MegabitsPerSecond) represented as an unsigned integer. Note however that the load balancing algorithm defined in this document uses ratio of Link Bandwidths. Hence, the operator may choose a different unit or use the community as a

generalized weight that may be set to link count, locally configured weight, or a value computed based on something other than link bandwidth. In such case, the operator **MUST** ensure consistent usage of the unit across all egress PEs in an ethernet segment. This may involve multiple routing domains/Autonomous Systems.

In order to facilitate this, as well as avoid interop issues because of provisioning error, one octet in the extended community's six octet 'value' field is used to explicitly signal if the weight encoded in the remaining five octets is link bandwidth expressed in Mbps or a generalized weight value. This results in the following encoding for EVPN link bandwidth extended community:

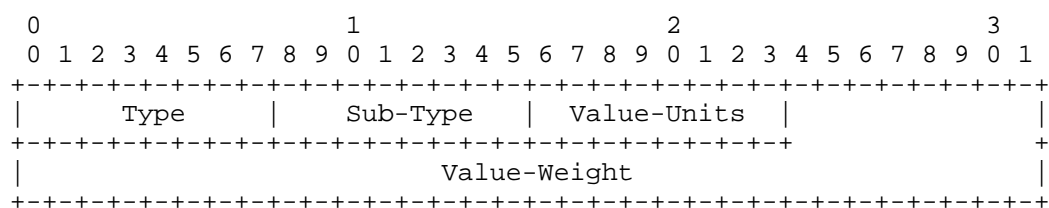


Figure 4

Value-Weight is encoded as an unsigned integer, 5 octets in length, in network byte order in the range of $0..2^{40}-1$.

Value-Units is encoded as:

- * 0x00: weight expressed using default units of Mbps
- * 0x01: generalized weight expressed in something other than Mbps

Generalized weight units are intentionally left arbitrary to allow for flexibility in its usage for different applications without having to define new encoding for each non-default application. Implementations **MUST** support the default units of Mbps, while support of non-default generalized weight is considered optional. "Value-Units" code-points other than the ones defined in this document are considered to be out of scope.

4.1.1. BGP Error Handling

- * **Value-Units Consistency:** In case of EVPN Link Bandwidth extended community received with a route, a PE **MUST** check that consistent 'Value-Units' are received for all paths associated with the route. In case of RT-1 and RT-4, if the receiving PE is also part of the Ethernet Segment, it **MUST** also ensure that the received 'Value-Units' are consistent with its local 'Value-Units' for that

ES. In case an inconsistency in 'Value-Units' is detected across the paths, the extended community is ignored for all paths.

- * Count: A PE MUST ensure that each path is received with a single instance of this extended community sub-type. In case of more than one instance, the EVPN Link Bandwidth extended community is ignored for all paths associated with the route.
- * Non-Zero 'Value-Weight': Only non-zero 'Value-Weight' received in this extended community is considered as a valid value. In case a zero 'Value-Weight' is received with any path(s), the extended community is considered invalid and ignored for all paths associated with the route.
- * Malformed Extended Community: If a PE detects a malformed EVPN Link Bandwidth Extended Community as defined in [RFC7606], it MUST discard the extended community as specified in [RFC7606]. The extended community is considered invalid and ignored for all paths associated with the route.
- * Unsupported 'Value-Units': If a PE receives "Value-Units" that it does not support, it MUST discard the extended community. The extended community is considered invalid and ignored for all paths associated with the route.
- * If the extended community is not received with any path(s) or is determined to be invalid for any path(s) for any of the above reasons, it is ignored for all paths associated with the route. In case of RT-1, this implies that regular ECMP procedures apply to all routes associated with the ethernet segment. In case of RT-4, this implies that regular DF election procedures apply to the ethernet segment. In case of RT-5, this implies that regular ECMP procedures apply to the prefix route. A syslog SHOULD be generated with a reason when the extended community is ignored because of any of the above reasons.
- * This document specifies procedures for handling this extended community with per-ES RT-1, RT-4, and RT-5. If this extended community is received with any other EVPN route type including per-[ES, EVI] RT-1 or RT-2, it MUST be ignored and a syslog SHOULD be generated with a reason.

5. Weighted Unicast Traffic Load-balancing to an Ethernet Segment

5.1. Egress PE Behavior

A PE that is part of an Ethernet Segment's redundancy group MUST advertise an additional "EVPN link bandwidth" extended community with Ethernet A-D per ES route (EVPN Route Type 1), that carries total bandwidth of PE's physical links in an Ethernet Segment or a generalized weight. New EVPN link bandwidth extended community defined in this document is used for this purpose.

EVPN link bandwidth extended community MUST NOT be attached to per-EVI RT-1 or to EVPN RT-2 as it is a physical ESI property and hence advertised per-ESI.

5.2. Ingress PE Behavior

An ingress PE MUST ensure that the EVPN link bandwidth extended community is received from all the egress PEs in an Ethernet Segment and check for consistent 'Value-Units' received from each egress PE in an Ethernet Segment. In case of missing EVPN Link Bandwidth extended community or inconsistent 'Value-Units' from any of the egress PEs in an Ethernet Segment, this EVPN Link Bandwidth extended community is to be ignored by the ingress PE and ingress PE is to follow regular ECMP forwarding to that Ethernet Segment. Ingress PE SHOULD generate a syslog when the EVPN Link Bandwidth extended community is ignored.

For all paths that are accepted by BGP and installed in Layer 2 RIB as forwarding paths, once consistency of 'Value-Units' is validated, ingress PE SHOULD use the 'Value-Weight' received from each egress PE to compute a relative (normalized) weight for each egress PE, per ES, and then use this relative weight to compute a weighted path-list to be used for load balancing, as opposed to using an ECMP path-list for load balancing across the egress PE paths. Egress PE Weight and resulting weighted path-list computation at ingress PEs is a local matter. An example computation algorithm is shown below to illustrate the idea:

if,

$L(x,y)$: link bandwidth advertised by egress PE-x for ES-y

$W(x,y)$: normalized weight assigned to egress PE-x for ES-y

$H(y)$: Highest Common Factor (HCF) of $[L(1,y), L(2,y), \dots, L(n,y)]$

then, the normalized weight assigned to egress PE-x for ES-y may be computed as follows:

$$W(x,y) = L(x,y) / H(y)$$

For a MAC+IP route (EVPN Route Type 2) received with ES-y, ingress PE may compute MAC and IP forwarding path-list weighted by the above normalized weights.

As an example, for a CE multi-homed to PE-1, PE-2, PE-3 via 2, 1, and 1 GE physical links respectively, as part of a LAG represented by ES-10:

$$L(1, 10) = 2000 \text{ Mbps}$$

$$L(2, 10) = 1000 \text{ Mbps}$$

$$L(3, 10) = 1000 \text{ Mbps}$$

$$H(10) = 1000$$

Normalized weights assigned to each egress PE for ES-10 are as follows:

$$W(1, 10) = 2000 / 1000 = 2.$$

$$W(2, 10) = 1000 / 1000 = 1.$$

$$W(3, 10) = 1000 / 1000 = 1.$$

For a remote MAC+IP host route received with ES-10, forwarding load balancing path-list may now be computed as: [PE-1, PE-1, PE-2, PE-3] instead of [PE-1, PE-2, PE-3]. This now results in load balancing of all traffic destined for ES-10 across the three egress PEs in proportion to ES-10 bandwidth at each egress PE.

Please note that the pathlist computation algorithm above is for illustration only. Weighted pathlist computation based on the received EVPN link bandwidth extended community is a local implementation choice. As an example, if the received link bandwidth values do not result in a good HCF $H(y)$ in the computation method above to be able to compute reasonable weights that can be programmed in hardware, implementation MAY choose another approximation to arrive at rounded integer weight values that can be programmed in hardware.

Weighted path-list computation must only be done for an ES if EVPN link bandwidth extended community is received from all of the egress PE's advertising reachability to that ES via Ethernet A-D per ES Route Type 1. In an unlikely event that EVPN link bandwidth extended community is not received from one or more egress PEs, forwarding

path-list should be computed using regular ECMP semantics. Note that a default weight cannot be assumed for an egress PE that does not advertise its link bandwidth as the weight to be used in path-list computation is relative.

If per-ES RT-1 is not advertised or withdrawn from any of the egress PE(s), as per [RFC7432], egress PE is removed from the forwarding path-list for that [EVI, ES]. Hence, the weighted path-list MUST be re-computed.

In an unlikely scenario that per-[ES, EVI] RT-1 is not advertised from any of the egress PE(s), as per [RFC7432], egress PE is not included in the forwarding path-list for that [EVI, ES]. Hence, the weighted path-list for the [EVI, ES] MUST be computed based only on the weights received from egress PEs that advertised the per-[ES, EVI] RT-1.

6. Weighted BUM Traffic Load-Sharing across an Ethernet Segment

Optionally, load sharing of per-service DF role, weighted by individual egress PE's link-bandwidth share within a multi-homed ES may also be achieved.

In order to do that, a new DF Election Capability [RFC8584] called "BW" (Bandwidth Weighted DF Election) is defined. BW MAY be used along with some DF Election Types, as described in the following sections.

6.1. The BW Capability in the DF Election Extended Community

[RFC8584] defines a new extended community for PEs within a redundancy group to signal and agree on uniform DF Election Type and Capabilities for each ES. This document requests IANA to allocate a bit in the "DF Election capabilities" registry setup by [RFC8584]:

Bit 4: BW (Bandwidth Weighted DF Election)

ES routes advertised with the BW bit set will indicate the desire of the advertising egress PE to consider the link-bandwidth in the DF Election algorithm defined by the value in the "DF Type".

As per [RFC8584], all the egress PEs in the ES MUST advertise the same Capabilities and DF Type, otherwise the PEs will fall back to Default [RFC7432] DF Election procedure.

The BW Capability MAY be advertised with the following DF Types:

- * Type 0: Default DF Election algorithm, as in [RFC7432]

- * Type 1: HRW (Highest Random Weight) algorithm, as in [RFC8584]
- * Type 2: Preference algorithm, as in [EVPN-DF-PREF]
- * Type 4: HRW per-multicast flow DF Election, as in [EVPN-PER-MCAST-FLOW-DF]

The following sections describe how the DF Election procedures are modified for the above DF Types when the BW Capability is used.

6.2. BW Capability and Default DF Election algorithm

When all the PEs in the Ethernet Segment (ES) agree to use the BW Capability with DF Type 0, the Default DF Election procedure as defined in [RFC7432] is modified as follows:

- * Each PE advertises a "EVPN Link Bandwidth" extended community along with the ES route to signal the PE-CE link bandwidth (LBW) for the ES.
- * A receiving egress PE MUST use the ES link bandwidth extended community received from each egress PE to compute a relative weight for each egress PE in an Ethernet Segment.
- * The DF Election procedure MUST now use this weighted list of egress PEs to compute the per-VLAN Designated Forwarder, such that the DF role is distributed in proportion to this normalized weight. As a result, a single PE may have multiple ordinals in the DF candidate PE list and 'N' used in $(V \bmod N)$ operation as defined in [RFC7432] is modified to be total number of ordinals instead of being total number of egress PEs in an Ethernet Segment.

Considering the same example as in Section 5.2, the candidate PE list for DF election is:

[PE-1, PE-1, PE-2, PE-3].

The DF for a given VLAN-a on ES-10 is now computed as $(VLAN-a \bmod 4)$. This would result in the DF role being distributed across PE1, PE2, and PE3 in portion to each PE's normalized weight for ES-10.

6.3. BW Capability and HRW DF Election algorithm (Type 1 and 4)

[RFC8584] introduces Highest Random Weight (HRW) algorithm (DF Type 1) for DF election in order to solve potential DF election skew depending on Ethernet tag space distribution. [EVPN-PER-MCAST-FLOW-DF] further extends HRW algorithm for per-multicast flow based hash computations (DF Type 4). This section describes extensions to HRW Algorithm for EVPN DF Election specified in [RFC8584] and in [EVPN-PER-MCAST-FLOW-DF] in order to achieve DF election distribution that is weighted by link bandwidth.

6.3.1. BW Increment

A new variable called "bandwidth increment" is computed for each [PE, ES] advertising the ES link bandwidth extended community as follows:

In the context of an ES,

$L(i)$ = Link bandwidth advertised by PE(i) for this ES

L_{min} = lowest link bandwidth advertised across all PEs for this ES

Bandwidth increment, " $b(i)$ " for a given PE(i) advertising a link bandwidth of $L(i)$ is defined as an integer value computed as:

$b(i) = L(i) / L_{min}$

As an example,

with $L(1) = 10$, $L(2) = 10$, $L(3) = 20$

bandwidth increment for each PE would be computed as:

$b(1) = 1$, $b(2) = 1$, $b(3) = 2$

with $L(1) = 10$, $L(2) = 10$, $L(3) = 10$

bandwidth increment for each PE would be computed as:

$b(1) = 1$, $b(2) = 1$, $b(3) = 1$

Note that the bandwidth increment must always be an integer, including, in an unlikely scenario of a PE's link bandwidth not being an exact multiple of L_{min} . If it computes to a non-integer value (including as a result of link failure), it MUST be rounded down to an integer.

6.3.2. HRW Hash Computations with BW Increment

HRW algorithm as described in [RFC8584] and in [EVPN-PER-MCAST-FLOW-DF] computes a random hash value for each PE(i), where, ($0 < i \leq N$), PE(i) is the PE at ordinal i, and Address(i) is the IP address of PE(i).

For 'N' PEs sharing an Ethernet segment, this results in 'N' candidate hash computations. The PE that has the highest hash value is selected as the DF.

We refer to this hash value as "affinity" in this document. Hash or affinity computation for each PE(i) is extended to be computed one per bandwidth increment associated with PE(i) instead of a single affinity computation per PE(i).

PE(i) with $b(i) = j$, results in j affinity computations:

affinity(i, x), where $1 < x \leq j$

This essentially results in number of candidate HRW hash computations for each PE that is directly proportional to that PE's relative bandwidth within an ES and hence gives PE(i) a probability of being DF in proportion to its relative bandwidth within an ES.

As an example, consider an ES that is multi-homed to two PEs, PE1 and PE2, with equal bandwidth distribution across PE1 and PE2. This would result in a total of two candidate hash computations:

affinity(PE1, 1)

affinity(PE2, 1)

Now, consider a scenario with PE1's link bandwidth as 2x that of PE2. This would result in a total of three candidate hash computations to be used for DF election:

affinity(PE1, 1)

affinity(PE1, 2)

affinity(PE2, 1)

which would give PE1 2/3 probability of getting elected as a DF, in proportion to its relative bandwidth in the ES.

Depending on the chosen HRW hash function, affinity function MUST be extended to include bandwidth increment in the computation.

For e.g.,

affinity function specified in [EVPN-PER-MCAST-FLOW-DF] MUST be extended as follows to incorporate bandwidth increment j:

```
affinity(S,G,V, ESI, Address(i,j)) =  
(1103515245.((1103515245.Address(i).j + 12345) XOR  
D(S,G,V,ESI))+12345) (mod 2^31)
```

affinity or random function specified in [RFC8584] MUST be extended as follows to incorporate bandwidth increment j:

```
affinity(v, Es, Address(i,j)) = (1103515245((1103515245.Address(i).j  
+ 12345) XOR D(v,Es))+12345)(mod 2^31)
```

6.4. BW Capability and Preference DF Election algorithm

This section applies to ES'es where all the PEs in the ES agree use the BW Capability with DF Type 2. The BW Capability modifies the Preference DF Election procedure [EVPN-DF-PREF], by adding the LBW value as a tie-breaker as follows:

Section 4.1, bullet (f) in [EVPN-DF-PREF] is updated to now consider the LBW value as below:

f) In case of equal Preference in two or more PEs in the ES, the tie-breakers will be the DP (Don't Preempt me) bit, the LBW value and the lowest IP PE in that order. For instance:

- * If vES1 parameters were [Pref=500,DP=0,LBW=1000] in PE1 and [Pref=500,DP=1, LBW=2000] in PE2, PE2 would be elected due to the DP bit.
- * If vES1 parameters were [Pref=500,DP=0,LBW=1000] in PE1 and [Pref=500,DP=0, LBW=2000] in PE2, PE2 would be elected due to a higher LBW, even if PE1's IP address is lower.
- * The LBW exchanged value has no impact on the Non-Revertive option described in [EVPN-DF-PREF].

6.5. Cost-Benefit Tradeoff on Link Failures

While incorporating link bandwidth into the DF election process provides optimal BUM traffic distribution across the ES links, it also implies that DF elections are re-adjusted on link failures or bandwidth changes. If the operator does not wish to have this level of churn in their DF election, then they should not advertise the BW capability. Not advertising BW capability may result in less than

optimal BUM traffic distribution while still retaining the ability to allow an ingress PE to do weighted ECMP for its unicast traffic to a set of egress PEs.

7. Additional Considerations

7.1. Real-time Available Bandwidth

PE-CE link bandwidth availability may sometimes vary in real-time disproportionately across PE-CE links within a multi-homed ES due to various factors such as flow based hashing combined with fat flows and unbalanced hashing. Reacting to real-time available bandwidth is at this time outside the scope of this document.

7.2. Weighted Load-balancing to Multi-homed Subnets

EVPN Link bandwidth extended community may also be used to achieve unequal load-balancing of prefix routed traffic by including this extended community in EVPN Route Type 5. When included in EVPN RT-5, its value is to be interpreted as egress PE's relative weight for the prefix included in this RT-5. Ingress PE will then compute the forwarding path-list for the prefix route using weighted paths received from each egress PE. EVPN Link bandwidth extended community MUST be encoded with "Value-Units = 0x01" to signal a generalized weight associated with the advertising PE.

7.3. Weighted Load-balancing without EVPN aliasing

[RFC7432] defines per-[ES, EVI] RT-1 based EVPN aliasing procedure as an optional procedure. In an unlikely scenario where an EVPN implementation does not support EVPN aliasing procedures, MAC forwarding path-list at the ingress PE is computed based on per-ES RT-1 and RT-2 routes received from egress PEs instead of per-ES RT-1 and per-[ES, EVI] RT-1 from egress PEs. In such a case, only the weights received via per-ES RT-1 from the egress PEs included in the MAC path-list are to be considered for weighted path-list computation.

7.4. EVPN IRB Multi-homing With Non-EVPN routing

EVPN-LAG based multi-homing on an IRB gateway may also be deployed together with non-EVPN routing, such as global routing or an L3VPN routing control plane. Key property that differentiates this set of use cases from EVPN IRB use cases discussed earlier is that EVPN control plane is used only to enable LAG interface based multi-homing and not as an overlay VPN control plane. Applicability of weighted ECMP procedures specified in this document to these set of use cases is an area of further consideration beyond the scope of this

document.

7.5. EVPN Link Bandwidth Extended Community in Non-EVPN Networks

While this document does not preclude future applicability to non-EVPN networks, it considers usage and handling of EVPN Link Bandwidth Extended Community specified in this document with non-EVPN routes out of scope.

7.6. Preference for EVPN Link Bandwidth in EVPN Networks

It is possible that a non-EVPN Link Bandwidth extended community such as [BGP-LINK-BW] is leaked from an IP or IPVPN route into an EVPN RT-5 towards an EVPN network. If an EVPN PE receives an EVPN route with both the EVPN Link Bandwidth extended community specified in this document and a non-EVPN Link Bandwidth extended community such as the one specified in [BGP-LINK-BW], it MUST as default behavior, prefer the EVPN Link Bandwidth extended community and handle it as per procedures specified in this document. In other words, any non-EVPN Link Bandwidth extended community is to be ignored if an EVPN route is received with the EVPN Link Bandwidth extended community specified in this document.

It is recommended that an implementation SHOULD provide a way to modify the above default local preference order via optional provisioning.

7.7. Interworking with Non-EVPN networks

In EVPN routing interworking use cases with IPVPN and IPv4/IPv6 routing, it is not beneficial to preserve the the EVPN Link Bandwidth extended community from EVPN routes to non-EVPN routes as the next-hop is rewritten when a prefix learnt via EVPN RT-5 is advertised into IPVPN or IP routing networks. Interworking procedures, including preservation, cummulation or translation of EVPN Link Bandwidth extended community to address current or future use cases are however considered beyond the scope of this document. Readers are encouraged to refer to [EVPN-IPVPN] for interworking specification.

8. Operational Considerations

- * In order for the solution specified in this document to function correctly, implementation SHOULD ensure that EVPN Link Bandwidth Extended Communiuty is being advertised with same "Value-Units" across all PEs.

- * Further, when a generalized weight option is used with "Value-Units = 0x1", implementation SHOULD ensure that the weights are assigned to each PE in a consistent manner.
- * Implementation SHOULD alert the users via syslog when an inconsistency in "Value-Units" is detected across the PE set for a given ESI or prefix.
- * Implementation SHOULD also alert users via syslog if an unreasonable discrepancy is detected across advertised BW or weights from different PEs, such that the implementation is unable to compute a weighted pathlist that can be programmed in hardware. This could likely result from inconsistent units of weight used by different PEs.
- * Operators MAY monitor the traffic flow distribution and DF election distribution across the egress PE set to ensure that the implementation is working as expected.

9. Security Considerations

Security considerations discussed in [RFC7432] and [RFC8584] apply to this document. Methods described in this document further extend signaling of multi-homed devices using ESI LAG. They are hence subject to same considerations if the control plane or data plane was to be compromised. As an example, if control plane is compromised, signaling of heavily skewed Link Bandwidth Attributes could result in all traffic to be directed towards one PE resulting in its host facing links to be overloaded. Exposure to such an attack is limited by suggested syslogs discussed in Operational Consideration section. Considerations for protecting control and data plane described in [RFC7432] are equally applicable to signaling of Link Bandwidth Attribute defined in this document.

10. IANA Considerations

10.1. Bandwidth Weighted DF Election Capability

[RFC8584] defines a new extended community for PEs within a redundancy group to signal and agree on uniform DF Election Type and Capabilities for each ES. This document requests IANA to allocate a bit in the "DF Election capabilities" registry setup by [RFC8584] with the following suggested bit number:

Bit 4: BW (Bandwidth Weighted DF Election)

10.2. EVPN Link Bandwidth Extended Community

A new EVPN Link Bandwidth extended community is defined to signal local ES link bandwidth to ingress PEs. This extended community is defined of type 0x06 (EVPN Extended Community Sub-Types). IANA has assigned a sub-type value of 0x10 for the EVPN Link bandwidth extended community, of type 0x06 (EVPN Extended Community Sub-Types). EVPN Link Bandwidth extended community is defined as transitive.

10.3. Value-Units Registry

IANA is requested to set up a registry called "Value-Units" for the 1-octet field in the EVPN Link Bandwidth Extended Community. New registrations will be made through the "RFC Required" procedure defined in [RFC8126]. The following are suggested initial values in that registry exist:

Value	Name	Reference
----	-----	-----
0	Weight in units of Mbps	This document
1	Generalized Weight	This document
2-255	Unassigned	

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12. Contributors

Satya Ranjan Mohanty
Cisco Systems
US
Email: satyamoh@cisco.com

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Appendix A. BGP-Link-Bandwidth-Extended-Community

Link bandwidth extended community described in [BGP-LINK-BW] for layer 3 VPNs was considered for re-use here. This Link bandwidth extended community is however defined in [BGP-LINK-BW] as optional non-transitive. Since it is not possible to change deployed behavior of extended community defined in [BGP-LINK-BW], it was decided to define a new one. In inter-AS scenarios within an EVPN network, EVPN link-bandwidth needs to be signaled to eBGP neighbors. When signaled across AS boundary, this extended community can be used to achieve optimal load-balancing towards egress PEs in a different AS. This is applicable both when next-hop is changed or unchanged across AS boundaries.

Authors' Addresses

Neeraj Malhotra (editor)
Cisco Systems
170 W. Tasman Drive
San Jose, CA 95134
United States of America
Email: nmalhotr@cisco.com

Ali Sajassi
Cisco Systems
170 W. Tasman Drive
San Jose, CA 95134
United States of America

Email: sajassi@cisco.com

Jorge Rabadan
Nokia
777 E. Middlefield Road
Mountain View, CA 94043
United States of America
Email: jorge.rabadan@nokia.com

John Drake
Independent
Email: je_drake@yahoo.com

Avinash Lingala
ATT
200 S. Laurel Avenue
Middletown, CA 07748
United States of America
Email: ar977m@att.com

Samir Thoria
Cisco Systems
170 W. Tasman Drive
San Jose, CA 95134
United States of America
Email: sthoria@cisco.com