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                                                  April 16, 2012

                    Extension to VPLS for E-Tree
                    draft-key-l2vpn-vpls-etree-07

Status of this Memo

Abstract

   This document proposes a simple and effective approach to emulate
   E-Tree services over an MPLS network. Section 4 presents a minimal
   extension to the current VPLS architecture defined in [RFC4761] and
   [RFC4762] to fulfil the specific E-Tree requirement: Leaf cannot
   communicate with Leaf. Backward compatibility issues are addressed
   also.

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Conventions used in this document

    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].

1. **Introduction**

   A specific type of multipoint Ethernet services has been defined by
   Metro Ethernet Forum (MEF), called E-Tree [MEF6.1]. At the difference
   of E-LAN where there is no communication restriction between
   endpoints, on E-Tree each endpoint is designated as either a Root or
   a Leaf. Root can communicate with all other endpoints on the E-Tree,
   however Leaf can only communicate with Roots but not Leafs.

   [Draft VPLS ETree Req] provides the functional requirements for MEF
   E-Tree support in VPLS.

   E-LAN services are currently emulated via the use of the VPLS
   architecture.

   This document presents a minimal extension to the current VPLS
   architecture defined in [RFC4761] and [RFC4762], with the objective
   to provide a simple and effective approach to fulfil the additional
   requirements of E-Tree compared to E-LAN.

   Backward compatibility issues are also addressed in this document.
   PEs supporting the extension specified in this document and PEs not
   supporting such extension can inter-operate and participate in the
   same VPLS instance.

   This document does not intend to address efficient packet replication
   or bandwidth optimisation, but the approach presented here does not
   prohibit future enhancements on those aspects.

   In this document, "current standard" refers to [RFC4385], [RFC4447],
   [RFC4448], [RFC4761] and [RFC4762].

[2](#). Terminology

   E-Tree

   An Ethernet VPN in which each Root AC can communicate with every
   other AC, whereas Leaf ACs can only communicate with Root ACs. Each
   AC on an E-Tree construct is designated as either a Root AC or a Leaf
   AC. There can be multiple Root ACs and Leaf ACs per E-Tree construct.

   Root AC

   An ingress frame at a Root AC can be delivered to one or more of
   any of the other ACs in the E-Tree. Please note that this AC is
   bidirectional.

   Leaf AC

   Ingress frame at a Leaf AC can only be delivered to one or more Root
   ACs in the E-Tree. Ingress frame at a Leaf AC MUST NOT be delivered
   to any Leaf ACs in the E-Tree. Please note that this AC is
   bidirectional.

3. **Reference Model**

   Figure 1 below describes a generic reference model where PE1, PE2 and
   PE3 need to establish an E-Tree construct between different Ethernet
   endpoints. Each PE has 2 Root ACs and 2 Leaf ACs connected to a VSI.
   These VSIs are then linked together via Ethernet PWs.

   In most use cases, an E-Tree construct has only a few Root ACs but
   many Leaf ACs. There may be only Root ACs or only Leaf ACs on a PE.

```
                     <------------E-Tree------------>
                     +---------+             +---------+
                     |   PE1   |             |   PE2   |
       +----+        |   +---+ |             |   +---+ |              +----+
       |CE01+----AC1----+   | |             |   |   +--+----AC5----+CE05|
       +----+ (Root AC) |   | V | |             |   | V |   | (Root AC) +----+
       +----+        |   |   | |             |   |   |   |              +----+
       |CE02+----AC2----+   |   |  Ethernet   |   |   +--+----AC6----+CE06|
       +----+ (Root AC) |   | S +--+-----PW-----+--+ S |   | (Root AC) +----+
       +----+        |   |   |   |             |   |   |   |              +----+
       |CE03+----AC3----+   |   |             |   |   +--+----AC7----+CE07|
       +----+ (Leaf AC) |   | I |   |             |   | I |   | (Leaf AC) +----+
       +----+        |   |   |   |             |   |   |   |              +----+
       |CE04+----AC4----+   |   |             |   |   +--+----AC8----+CE08|
       +----+ (Leaf AC) |   +-+-+ |             |   +-+-+   | (Leaf AC) +----+
                     |   |   |             |   |   |
                     +----+----+             +----+----+
                          |                       |
                          |Ethernet               |Ethernet
                          |PW                      |PW
                          |                        |
                          |                    +----+----+
                          |                    |   |   |
                          |                    |  +-+-+ |              +----+
                          |                    |  |   |   +--+----AC9----+CE09|
                          |                    |  | V |   | (Root AC) +----+
                          |                    |  |   |   |              +----+
                          |                    |  |   +--+----AC10---+CE10|
                          +-----------------+--+ S |   | (Root AC) +----+
                                               |  |   |   |              +----+
                                               |  |   +--+----AC11---+CE11|
                                               |  | I |   | (Leaf AC) +----+
                                               |  |   |   |              +----+
                                               |  |   +--+----AC12---+CE12|
                                               |  +---+ | (Leaf AC) +----+
                                               |   PE3   |
                                               +---------+
                     <------------E-Tree------------>
```
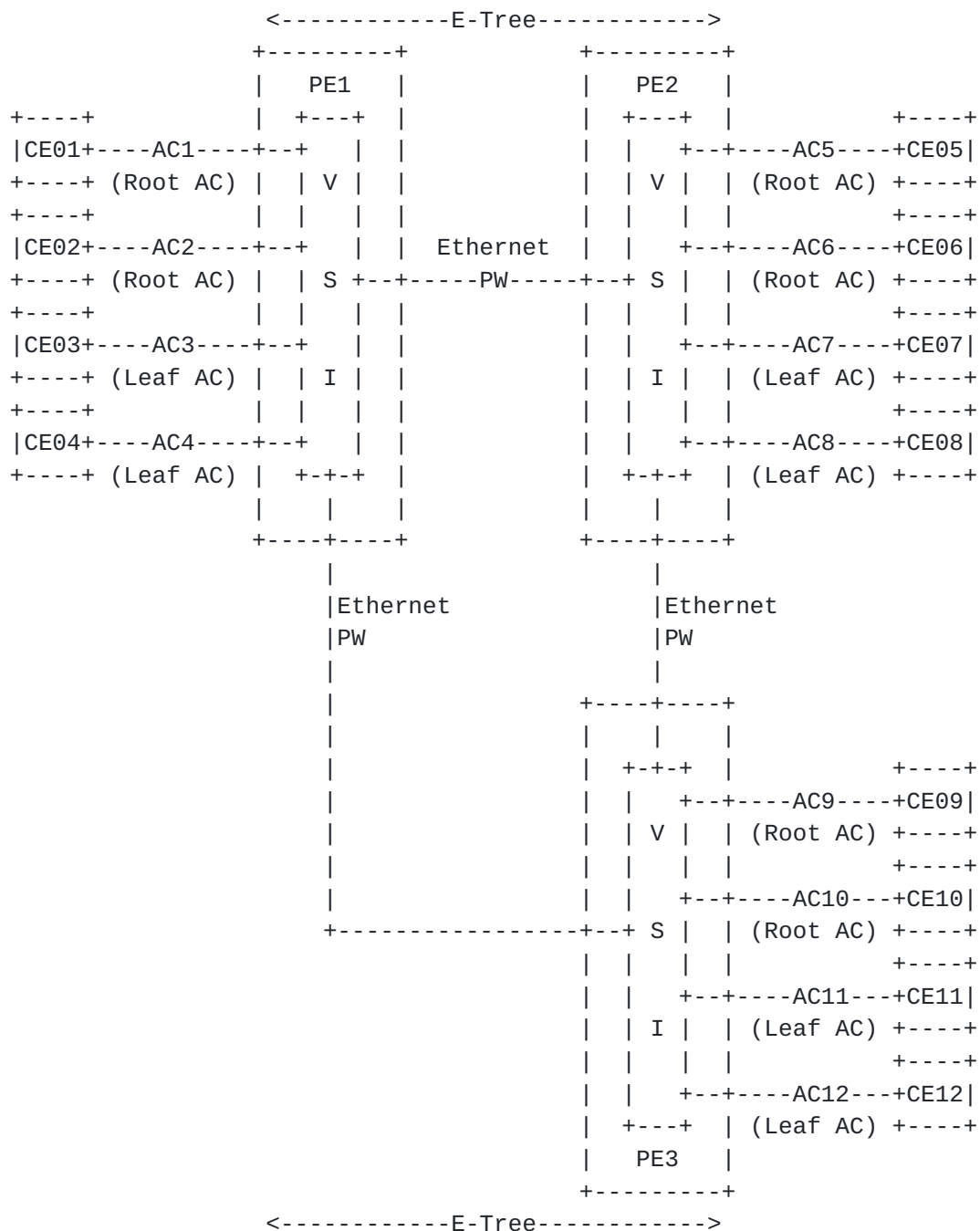
Figure 1: E-Tree Reference Model

   With an E-Tree construct:
     - A Root AC can receive from and transmit to any other ACs.
     - A Leaf AC can receive from and transmit to any Root ACs.
     - A Leaf AC cannot receive from and transmit to any other Leaf ACs.

   This applies to all traffic, including Unicast Known, Unicast
   Unknown, Broadcast and Multicast.

   When an Ethernet Frame is received on PE1 via AC1, the frame can be
   transmitted to any other local ACs on PE1 and via Ethernet PWs to any
   remote ACs on PE2 and PE3.

   However when an Ethernet Frame is received on PE1 via AC3, the frame
   can be transmitted to any other local Root ACs on PE1 and via
   Ethernet PWs to any remote Root ACs on PE2 and PE3, but the frame
   cannot be transmitted to any local Leaf ACs on PE1 nor any remote
   Leaf ACs on PE2 and PE3.

4. Extension to VPLS for E-Tree

4.1 AC Type

   Each AC connected to a specific VPLS instance on a PE MUST have an AC
   Type attribute, either Leaf AC or Root AC. The default value for AC
   Type attribute MUST be Root AC.

   This AC Type is only locally configured on a PE and no signaling is
   required between PEs.

4.2 Control Word

   A PE MUST be capable of sending and receiving the Control Word on
   Ethernet PW. Use of Control Word on Ethernet PW MUST be PREFERRED.

   The procedure for negotiating the use of Control Word as per current
   standard is sufficient and MUST be followed. As a result, Control
   Word will always be used on Ethernet PW between two PEs when both PEs
   support the extension specified in this document.

   Refer to Appendix A for different Control Word scenarios.

4.3 Additional Action in Data Forwarding

   A PE MUST support the Control Word L-bit defined in [Draft CW L-bit].

   A PE MUST perform the additional actions specified in Table 1 below.

The "Set CW L-bit" action and "Forward or Drop" decision are in
addition to and performed after the following
   - MAC-based forwarding decision as per current standard
   - Loop free VPLS "split horizon" rule (MUST NOT forward traffic
     from one PW to another PW in the same VPLS mesh) as per current
     standard

		IF Conditions AND			THEN Actions	
Rule	Forward Frame to	Receive Frame from	CW L-bit	Set CW L-bit	Forward or Drop
1	Root AC	any AC/PW	any	n/a	Forward
2	PW with no CW	any AC	n/a	n/a	Forward
3	PW with CW	Root AC	n/a	Set to 0	Forward
4	PW with CW	Leaf AC	n/a	Set to 1	Forward
5	Leaf AC	Root AC	n/a	n/a	Forward
6	Leaf AC	Leaf AC	n/a	n/a	Drop
7	Leaf AC	PW with no CW	n/a	n/a	Forward
8	Leaf AC	PW with CW	= 0	n/a	Forward
9	Leaf AC	PW with CW	= 1	n/a	Drop

Table 1: Additional Action in Data Forwarding

"Forward Frame to" is the result of MAC-based forwarding decision as
per current standard.

"CW L-bit" is the bit 4 in the Ethernet PW Control Word as defined in
[Draft CW L-bit] (the 5th bit in Control Word since the first bit is
bit 0). The CW L-bit = 1 if and only if the payload Ethernet frame is
from a Leaf AC.

Refer to Appendix B for different data forwarding scenarios.

5. **Backward Compatibility**

5.1. **AC Type**

   Since there is no restriction on communication between any ACs
   connected to a VPLS instance as per current standard, on a PE not
   supporting the extension specified in this document, an AC is
   functionally equivalent to a Root AC as per the extension specified
   in this document.

5.2. **Control Word**

   For backward compatibility reason, use of Control Word on Ethernet PW
   is not mandatory. If the PE on the other end prefers not to use
   Control Word or does not support Control Word (which implies such PE
   does not support the extension specified in this document), then
   Control Word will not be used on the Ethernet PW.

   Refer to Appendix A for different Control Word scenarios.

5.3. **Additional Action in Data Forwarding**

   For backward compatibility reason, a PE not supporting the extension
   specified in this document can participate in an E-Tree construct,
   but Leaf ACs MUST NOT be connected to such PE.

   Lack of Control Word L-bit per-payload signaling between a PE
   supporting the extension specified in this document and a PE not
   supporting such extension does not result in any problem.

   Refer to Appendix B for different data forwarding scenarios.

5.3.1 **Ingress PE Support the Extension but Egress PE Not**

   If Control Word is used on the Ethernet PW, the ingress PE will set
   CW L-bit to either 0 or 1 (Rule 3 and Rule 4 in Table 1). The egress
   PE will ignore the reserved bits (which include the L-bit position)
   as per current standard [RFC4448] and forward the frame. This is
   correct as only Root ACs exist on a PE not supporting the extension
   specified in this document. A Root AC can receive from any other ACs.

   If Control Word is not used on the Ethernet PW, there will be no CW
   L-bit. The egress PE will forward the frame as per current standard.
   This is correct as only Root ACs exist on a PE not supporting the
   extension specified in this document. A Root AC can receive from any
   other ACs.

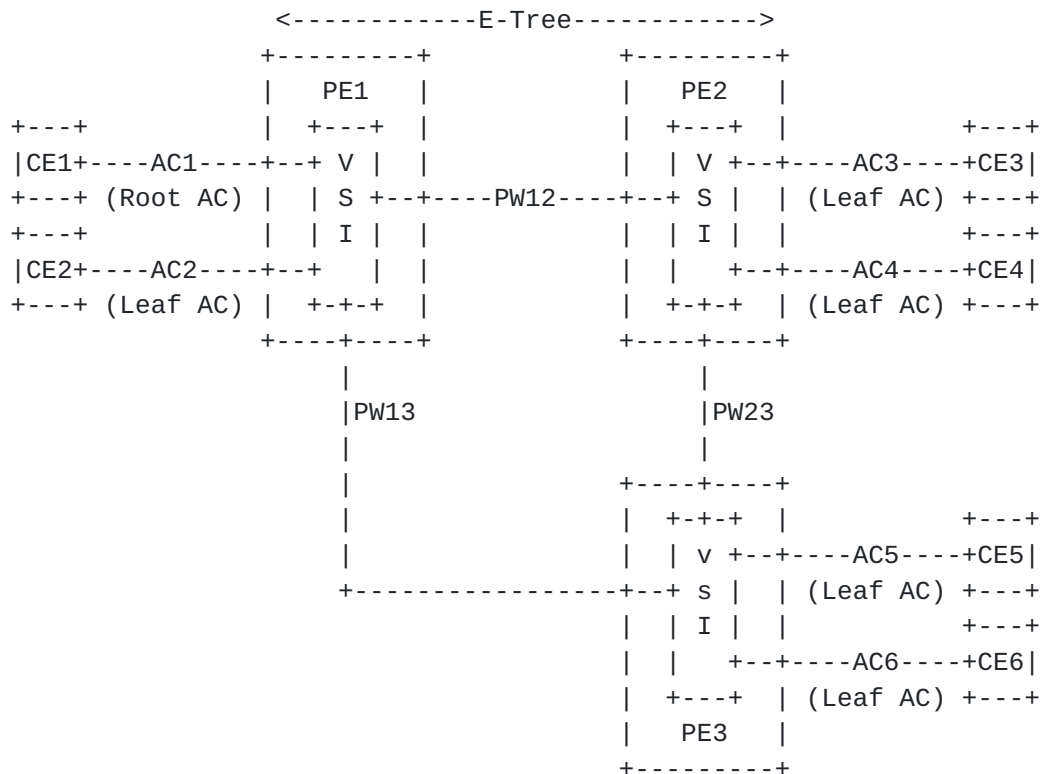**5.3.2** **Egress PE Support the Extension but Ingress PE Not**

If Control Word is used on the Ethernet PW, the ingress PE will set
the reserved bits (which include the L-bit position) to 0 as per
current standard [RFC4448]. The egress PE will process it as CW L-bit
= 0, which means the frame is from a Root AC. This is correct as only
Root ACs exist on a PE not supporting the extension specified in this
document. A Root AC can transmit to any other ACs.

If Control Word is not used on the Ethernet PW, there will be no CW
L-bit. The egress PE will process it in the same way as CW L-bit = 0
(compare Rule 7 and Rule 8 in Table 1), which means the frame is from
a Root AC. This is correct as only Root ACs exist on a PE not
supporting the extension specified in this document. A Root AC can
transmit to any other ACs.

6. **Optional Enhancements for Leaf-only PE**

It is important to note that the enhancements specified in this
section are OPTIONAL for achieving an E-Tree implementation using
VPLS.

In the context of a specific VPLS instance, a Leaf-only PE means that
the PE only has Leaf ACs connected to it. In Figure 2 below, PE2 and
PE3 are Leaf-only PEs.

```
                        <------------E-Tree------------>
                        +---------+         +---------+
                        |   PE1   |         |   PE2   |
     +---+              |  +---+  |         |  +---+  |           +---+
    |CE1+----AC1----+--+ V |  |         |  | V +--+----AC3----+CE3|
     +---+ (Root AC) |  | S +--+----PW12----+--+ S |  | (Leaf AC) +---+
     +---+           |  | I |  |         |  | I |  |           +---+
    |CE2+----AC2----+--+   |  |         |  |   +--+----AC4----+CE4|
     +---+ (Leaf AC) |  +-+-+  |         |  +-+-+  | (Leaf AC) +---+
                     +----+----+         +----+----+
                          |                   |
                          |PW13               |PW23
                          |                   |
                          |              +----+----+
                          |              |  +-+-+  |           +---+
                          |              |  | v +--+----AC5----+CE5|
                     +----------------+--+ s |  | (Leaf AC) +---+
                          |              |  | I |  |           +---+
                          |              |  |   +--+----AC6----+CE6|
                          |              |  +---+  | (Leaf AC) +---+
                          |              |   PE3   |
                          +---------+
```

```
                   <------------E-Tree------------>

              Figure 2: Reference Model for Leaf-only PE
```

6.1. No PW between Leaf-only PEs

   With an E-Tree construct, a Leaf AC cannot receive from and transmit
   to any other Leaf ACs. Pseudowire PW23 is between two Leaf-only PEs,
   and is therefore not supposed to carry any traffic. If removal of
   such pseudowire can bring significant benefits, enhancement in this
   aspect may be desirable.

6.2. Not Forward Frame from Leaf AC to Leaf-only PE

   When PE1 receives a Broadcast frame via AC2, PE1 will set CW L-bit to
   1 and forward the frame to pseudowires PW12 and PW13. PE2 receives
   the frame via PW12 but does not forward it to any ACs. A similar
   situation occurs for PE3. Network bandwidth is consumed and then the
   egress PE decides to drop the frame. This applies to any frames
   (Broadcast, Multicast, Unicast Known, Unicast Unknown) from a Leaf AC
   towards a Leaf-only egress PE. If such traffic pattern is significant
   in volume, enhancement in this aspect may be desirable.

   Each PW on a PE MUST have an Leaf-only attribute, either Yes or NO,
   indicating whether the peer PE at the other end of the PW is a
   Leaf-only PE or not. The default value for Leaf-only attribute MUST
   be No.

   A PE MUST NOT forward a data frame on a PW with Leaf-only = Yes if
   any of the following conditions is true
      - The frame is from a Leaf AC
      - The frame is from PW and the CW L-bit = 1

   The Leaf-only attribute for each PW can be locally configured on a
   PE for each PW, or MAY be decided through signaling between PEs.

   For LDP VPLS, Interface Parameter Sub-TLV can be used for such
   signaling, refer to section 5.5 in [RFC4447].

   For BGP VPLS, Signaling PE Capability can be used for such signaling,
   refer to section 3.2.4 in [RFC4761].

   Further details will be added in later version of this document.

7. Hierarchical VPLS

7.1. Hierarchical LDP VPLS

7.1.1. Spoke Connectivity for Bridging-Capable Devices

   This refers to section 10.1.1 in [RFC4762].

   MTU-s MUST support the extension specified in section 4 of this

document.

PE-rs MUST support the extension specified in section 4 of this
document.

PE-rs MUST perform the additional actions specified in Table 2 below
when forwarding a data frame from one PW to another PW.

The "Set CW L-bit" action and "Forward or Drop" decision are in
addition to and performed after the following
   - MAC-based forwarding decision as per current standard
   - Loop free VPLS "split horizon" rule (MUST NOT forward traffic
     from one PW to another PW in the same VPLS mesh) as per current
     standard

```
+-----+---------------------------------------+--------------------+
|     |            IF Conditions AND          |    THEN Actions    |
|Rule +---------------+---------------+-------+-----------+--------+
|     | Forward       | Receive       | CW    | Set CW    | Forward |
|     | Frame to PW   | Frame from PW | L-bit | L-bit     | or Drop |
+-----+---------------+---------------+-------+-----------+--------+
| H1  | PW with CW    | PW with CW    | any   | Copy L-bit| Forward |
+-----+---------------+---------------+-------+-----------+--------+
| H2  | PW with CW    | PW with no CW | n/a   | Set to 0  | Forward |
+-----+---------------+---------------+-------+-----------+--------+
| H3  | PW with no CW | any PW        | any   | n/a       | Forward |
+-----+---------------+---------------+-------+-----------+--------+
```

         Table 2: Additional Action in Data Forwarding - H-VPLS

7.1.2. Multi-domain VPLS Service

   This refers to section 10.3 in [RFC4762].

   Border PE MUST support the extension specified in section 4 of this
   document.

   Border PE MUST perform the additional actions same as those specified
   for PE-rs in section 7.1.1 when forwarding a data frame from one PW
   to another PW.

7.1.3. Spoke Connectivity for Non-Bridging Devices

   This refers to section 10.1.3 in [RFC4762].

   No change is required for PE-r.

   Control Word is not required for the spoke PW between PE-rs and PE-r.

PE-rs MUST treat each spoke PW to PE-r equivalent to an AC of the VPLS instance (consider it as an AC extended by a P2P PW), and MUST support the extension specified in section 4.1 (AC Type) and section 4.3 (Additional Action in Data Forwarding) for such spoke PWs in the same way as ACs.

7.1.4. Hierarchical VPLS Model using Ethernet Access Network

This refers to section 11 in [RFC4762].

This will be added in later version of this document.

7.2. Hierarchical BGP VPLS

This refers to section 3.6 in [RFC4761].

No change is required.

8. Compliance with Requirements

This refers to [Draft VPLS ETree Req] Section 5. Requirements.

The solution prohibits communication between any two Leaf ACs in a VPLS instance.

The solution allows multiple Root ACs in a VPLS instance.

The solution allows Root AC and Leaf AC of a VPLS instance co-exist on any PE.

The solution is applicable to both BGP-VPLS [RFC4761] and LDP-VPLS [RFC4762].

The solution is applicable to Case 1: Single technology "VPLS Only".

The solution has minimal impact on existing VPLS solution.

The solution is backward compatible with the existing VPLS solution.

9. Security Considerations

This will be added in later version of this document.

10. IANA Considerations

This document does not require IANA assignment.

11. Acknowledgements

The authors would like to thank Chen Ran, Weilian Jiang and Yuji

Kamite for their valuable comments.

12. References

12.1. Normative References

   [RFC2119]   Bradner, S., Key words for use in RFCs to Indicate
                Requirement Levels, BCP 14, RFC 2119, March 1997.

   [RFC4385]   Bryant,S., Swallow, G., and Al, Pseudowire Emulation
                Edge-to-Edge (PWE3) Control Word for Use over an MPLS
                PSN, February 2006.

   [RFC4447]   Martini, L., and al, Pseudowire Setup and Maintenance
                Using the Label Distribution Protocol (LDP), April 2006

   [RFC4448]   Martini, L., and al, Encapsulation Methods for
                Transport of Ethernet over MPLS Networks, April 2006

   [RFC4761]   Kompella & Rekhter, Virtual Private LAN Service (VPLS)
                Using BGP for Auto-Discovery and Signaling, January 2007

   [RFC4762]   Lasserre & Kompella, Virtual Private LAN Service (VPLS)
                Using Label Distribution Protocol (LDP) Signaling,
                January 2007

   [MEF6.1]   Metro Ethernet Forum, Ethernet Services Definitions -
                Phase 2, April 2008

12.2. Informative References

   [Draft VPLS ETree Req]
                Key, et al., Requirements for MEF E-Tree Support in
                VPLS, draft-ietf-l2vpn-etree-reqt-00 (work in progress),
                October 2011

   [Draft CW L-bit]
                Delord, et al., Control Word Reserved bit for use in
                E-Tree, draft-delord-pwe3-cw-bit-etree-07 (work in
                progress), April 2012

Appendix A.   Control Word Scenarios

   As per current standard [RFC4447]: If both endpoints prefer the use
   of the control word, this procedure will cause it to be used. If
   either endpoint prefers not to use the control word or does not
   support the control word, this procedure will cause it not to be
   used. If one endpoint prefers to use the control word but the other
   does not, the one that prefers not to use it is has no extra protocol
   to execute; it just waits for a Label Mapping message that has c=0.

   There are three possible scenarios.

```
+----------+--------------+-------------------------+--------------+
|          |     PE1      |           PE2           | Control Word |
| Scenario +--------------+-----------+-------------+  used on PW  |
|          | Support this |Support this|  Support   | between PE1  |
|          |  Extension?  | Extension? |Control Word?|  and PE2?   |
+----------+--------------+-----------+-------------+--------------+
|    1     |     Yes      |    Yes    |     Yes     |     Yes      |
+----------+--------------+-----------+-------------+--------------+
|    2     |     Yes      |    No     |     Yes     |     Yes      |
+----------+--------------+-----------+-------------+--------------+
|    3     |     Yes      |    No     |     No      |     No       |
+----------+--------------+-----------+-------------+--------------+
```

                   Table 2: Control Word Scenarios

   For Scenario 2, although Control Word is used on the Ethernet PW, the
   two PEs process the Control Word L-bit differently:
       - PE1 will always set and interpret the CW L-bit as specified in
         [Draft CW L-bit], i.e. 0 = from Root AC; 1 = from Leaf AC.
       - PE2 will always set the CW L-bit to 0 when sending a frame on
         the PW and ignore the CW L-bit when receiving a frame from the
         PW. Actually PE2 has no concept of CW L-bit but just treat it
         as bit 4, one of the reserved bits for future use.

.   Data Forwarding Scenarios

. Reference Model

```
                       <------------E-Tree------------>
                       +---------+          +---------+
                       |  PE1    |          |  PE2    |
   +----+              |  +---+  |          |  +---+  |              +----+
   |CE01+----R11----+--+   |  |  |          |  |   +--+----R21----+CE05|
   +----+ (Root AC) |  | V |  |  |          |  | V |  | (Root AC) +----+
   +----+           |  |  |  |  |          |  |  |  |  |              +----+
   |CE02+----R12----+--+   |  |  |          |  |   +--+----R22----+CE06|
   +----+ (Root AC) |  | S +--+----PW12----+--+ S |  | (Root AC) +----+
   +----+           |  |  |  |Control Word|  |  |  |  |              +----+
   |CE03+----L11----+--+   |  |  |          |  |   +--+----L21----+CE07|
   +----+ (Leaf AC) |  | I |  |  |          |  | I |  | (Leaf AC) +----+
   +----+           |  |  |  |  |          |  |  |  |  |              +----+
   |CE04+----L12----+--+   |  |  |          |  |   +--+----L22----+CE08|
   +----+ (Leaf AC) |  +-+-+  |  |          |  +-+-+  | (Leaf AC) +----+
                    |  |   |  |          |  |   |  |
                    +----+----+          +----+----+
                       |                    |
                       |PW13                |PW23
                       |Control Word        |No Control Word
                       |                    |
                       |                 +----+----+
                       |                 |    |    |
                       |                 |  +-+-+  |
                       |                 |  | V |  |              +----+
                       |                 |  |   +--+----R31----+CE09|
                       +-----------------+--+ S |  | (Root AC) +----+
                       |                 |  |  |  |  |              +----+
                       |                 |  | I +--+----R32----+CE10|
                       |                 |  |   |  | (Root AC) +----+
                       |                 |  +---+  |
                       |                 |   PE3   |
                       |                 +---------+
                       <-----------E-Tree----------->
```
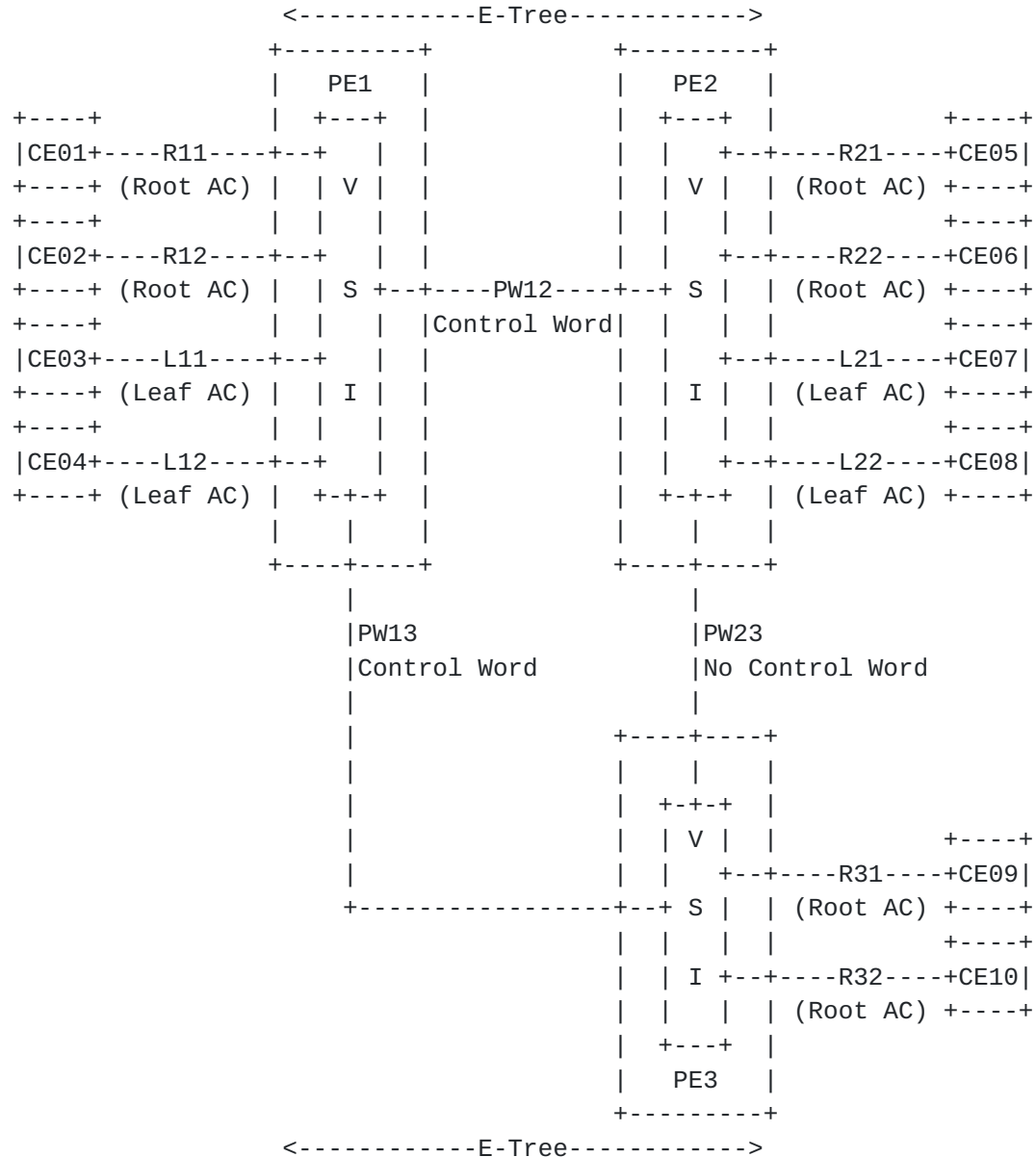
                Figure 3: Reference Model for Data Forwarding Scenarios

   PE1 and PE2 both support the extension specified in this document.

   PE3 does not support the extension specified in this document.

   In this appendix
      - "this extension" means the extension to VPLS specified in this

document.
       - "Rule" refers to Rules in Table 1 in Section 4.3.

B.2. **Unicast Known**

B.2.1. **From Root AC to Root AC**

   9 scenarios, per source and destination matching in table below.

```
   +-----------+----------------------+
   |           |     Destination      |
   |  Source   +-------+-------+-------+
   |           | PE1   | PE2   | PE3   |
   +-----+-----+-------+-------+-------+
   | PE1 | R11 | R12   | R21   | R31   |
   +-----+-----+-------+-------+-------+
   | PE2 | R21 | R11   | R22   | R31   |
   +-----+-----+-------+-------+-------+
   | PE3 | R31 | R11   | R21   | R32   |
   +-----+-----+-------+-------+-------+
```

B.2.1.1. **From R11 to R12 (same PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to R12.
   (2) PE1: Forward as per this extension. (Rule 1)

B.2.1.2. **From R11 to R21 (different PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to PW12.
   (2) PE1: As per this extension, set L-bit to 0. (Rule 3)
   (3) PE2: MAC-based forwarding decision as per current standard,
           forward frame to R21.
   (4) PE2: Forward as per this extension. (Rule 1)

B.2.1.3. **From R11 to R31 (different PE, egress PE not support this**
         extension, control word on PW)

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to PW13.
   (2) PE1: As per this extension, set L-bit to 0. (Rule 3)
   (3) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R31.
   (4) PE3: PE3 not support this extension, L-bit ignored and forward
           frame.

B.2.1.4. **From R21 to R11 (different PE)**

   Similar to B.2.1.2.

B.2.1.5. From R21 to R22 (same PE)

   Similar to B.2.1.1.

B.2.1.6. From R21 to R31 (different PE, egress PE not support this
        extension, no control word on PW)

   (1) PE2: MAC-based forwarding decision as per current standard,
           forward frame to PW23.
   (2) PE2: No additional L-bit action as per this extension. (Rule 2)
   (3) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R31.
   (4) PE3: PE3 not support this extension, forward frame.

B.2.1.7. From R31 to R11 (different PE, ingress PE not support this
        extension, control word on PW)

   (1) PE3: MAC-based forwarding decision as per current standard,
           forward frame to PW13.
   (2) PE3: PE3 not support this extension, no L-bit action.
   (3) PE1: MAC-based forwarding decision as per current standard,
           forward frame to R11.
   (4) PE1: Forward as per this extension. (Rule 1)

B.2.1.8. From R31 to R21 (different PE, ingress PE not support this
        extension, no control word on PW)

   (1) PE3: MAC-based forwarding decision as per current standard,
           forward frame to PW23.
   (2) PE3: PE3 not support this extension, no L-bit action.
   (3) PE2: MAC-based forwarding decision as per current standard,
           forward frame to R21.
   (4) PE2: Forward as per this extension. (Rule 1)

B.2.1.9. From R31 to R32 (same PE, PE not support this extension)

   (1) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R32.
   (2) PE3: PE3 not support this extension, forward frame.

B.2.2. **From Root AC to Leaf AC**

6 scenarios, per source and destination matching in table below.

```
+-----------+-----------------------+
|           |      Destination      |
|  Source   +-------+-------+-------+
|           | PE1   | PE2   | PE3   |
+-----+-----+-------+-------+-------+
| PE1 | R11 | L11   | L21   | ---   |
+-----+-----+-------+-------+-------+
| PE2 | R21 | L11   | L21   | ---   |
+-----+-----+-------+-------+-------+
| PE3 | R31 | L11   | L21   | ---   |
+-----+-----+-------+-------+-------+
```

B.2.2.1. **From R11 to L11 (same PE)**

    (1) PE1: MAC-based forwarding decision as per current standard,
            forward frame to L11.
    (2) PE1: Forward as per this extension. (rule 5)

B.2.2.2. **From R11 to L21 (different PE)**

    (1) PE1: MAC-based forwarding decision as per current standard,
            forward frame to PW12.
    (2) PE1: As per this extension, set L-bit to 0. (Rule 3)
    (3) PE2: MAC-based forwarding decision as per current standard,
            forward frame to L21.
    (4) PE2: Forward as per this extension. (Rule 8)

B.2.2.3. **From R21 to L11 (different PE)**

    Similar to B.2.2.2.

B.2.2.4. **From R21 to L21 (same PE)**

    Similar to B.2.2.1.

B.2.2.5. From R31 to L11 (different PE, ingress PE not support this
           extension, control word on PW)

   (1) PE3: MAC-based forwarding decision as per current standard,
            forward frame to PW13.
   (2) PE3: PE3 not support this extension, no L-bit action. As per
            current standard, the corresponding bit position must be
            set to 0.
   (3) PE1: MAC-based forwarding decision as per current standard,
            forward frame to L11.
   (4) PE1: Forward as per this extension. (Rule 8)

B.2.2.6. From R31 to L21 (different PE, ingress PE not support this
           extension, no control word on PW)

   (1) PE3: MAC-based forwarding decision as per current standard,
            forward frame to PW23.
   (2) PE3: PE3 not support this extension, no L-bit action.
   (3) PE2: MAC-based forwarding decision as per current standard,
            forward frame to L21.
   (4) PE2: Forward as per this extension. (Rule 7)

[B.2.3](#). **From Leaf AC to Root AC**

   6 scenarios, per source and destination matching in table below.

```
       +-----------+-----------------------+
       |           |      Destination      |
       |  Source   +-------+-------+-------+
       |           | PE1   | PE2   | PE3   |
       +-----+-----+-------+-------+-------+
       | PE1 | L11 | R11   | R21   | R31   |
       +-----+-----+-------+-------+-------+
       | PE2 | L21 | R11   | R21   | R31   |
       +-----+-----+-------+-------+-------+
       | PE3 | --- | ---   | ---   | ---   |
       +-----+-----+-------+-------+-------+
```

[B.2.3.1](#). **From L11 to R11 (same PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
          forward frame to R11.
   (2) PE1: Forward as per this extension. (Rule 1)

[B.2.3.2](#). **From L11 to R21 (different PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
          forward frame to PW12.
   (2) PE1: As per this extension, set L-bit to 1. (Rule 4)
   (3) PE2: MAC-based forwarding decision as per current standard,
          forward frame to R21.
   (4) PE2: Forward as per this extension. (Rule 1)

[B.2.3.3](#). **From L11 to R31 (different PE, egress PE not support this**
          extension, control word on PW)

   (1) PE1: MAC-based forwarding decision as per current standard,
          forward frame to PW13.
   (2) PE1: As per this extension, set L-bit to 1. (Rule 4)
   (3) PE3: MAC-based forwarding decision as per current standard,
          forward frame to R31.
   (4) PE3: PE3 not support this extension, as per current standard
          L-bit ignored and forward frame.

B.2.3.4. From L21 to R11 (different PE)

   Similar to B.2.3.2.

B.2.3.5. From L21 to R21 (same PE)

   Similar to B.2.3.1.

B.2.3.6. From L21 to R31 (different PE, egress PE not support this
          extension, no control word on PW)

   (1) PE2: MAC-based forwarding decision as per current standard,
           forward frame to PW23.
   (2) PE2: No L-bit action as per this extension. (Rule 2)
   (3) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R31.
   (4) PE3: PE3 not support this extension, forward frame.

B.2.4. **From Leaf AC to Leaf AC (MUST NOT Forward)**

   4 scenarios, per source and destination matching in table below.

```
   +-----------+-----------------------+
   |           |      Destination      |
   |  Source   +-------+-------+-------+
   |           | PE1   | PE2   | PE3   |
   +-----+-----+-------+-------+-------+
   | PE1 | L11 | L12   | L21   | ---   |
   +-----+-----+-------+-------+-------+
   | PE2 | L21 | L11   | L22   | ---   |
   +-----+-----+-------+-------+-------+
   | PE3 | --- | ---   | ---   | ---   |
   +-----+-----+-------+-------+-------+
```

B.2.4.1. **From L11 to L12 (same PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to L12.
   (2) PE1: As per this extension, drop frame. (Rule 6)

B.2.4.2. **From L11 to L21 (different PE)**

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to PW12.
   (2) PE1: As per this extension, set L-bit to 1. (Rule 4)
   (3) PE2: MAC-based forwarding decision as per current standard,
           forward frame to L21.
   (4) PE2: As per this extension, drop frame. (Rule 9)

B.2.4.3. **From L21 to L11 (different PE)**

   Similar to B.2.4.2.

B.2.4.4. **From L21 to L22 (same PE)**

   Similar to B.2.4.1.

[B.3](#). **Unicast Unknown**

[B.3.1](#). **From Root AC**

   Forward to all other AC.

[B.3.1.1](#). **From R11**

   (1) PE1: MAC-based forwarding decision as per current standard,
           forward frame to R12, L11, L12, PW12 and PW13.
   (2) PE1: Forward as per this extension. (Rule 1, 5, 3)
   (3) PE1: For PW12 and PW13, as per this extension, set L-bit to 0.
           (Rule 3)
   (4) PE2: MAC-based forwarding decision as per current standard,
           forward frame to R21, R22, L21 and L22.
   (5) PE2: As per this extension, forward frame. (Rule 1, 8)
   (6) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R31 and R32.
   (7) PE3: PE3 not support this extension, as per current standard
           L-bit ignored and forward frame.

[B.3.1.2](#). **From R21**

   (1) PE2: MAC-based forwarding decision as per current standard,
           forward frame to R22, L21, L22, PW12 and PW23.
   (2) PE2: Forward as per this extension. (Rule 1, 5, 3, 2)
   (3) PE2: For PW12, as per this extension, set L-bit to 0. (Rule 3)
   (4) PE2: For PW23, no L-bit action as per this extension. (Rule 2)
   (5) PE1: MAC-based forwarding decision as per current standard,
           forward frame to R11, R12, L11 and L12.
   (6) PE1: As per this extension, forward frame. (Rule 1, 8)
   (7) PE3: MAC-based forwarding decision as per current standard,
           forward frame to R31 and R32.
   (8) PE3: PE3 not support this extension, forward frame.

B.3.1.3. **From R31**

    (1) PE3: MAC-based forwarding decision as per current standard,
            forward frame to R32, PW13 and PW23.
    (2) PE3: PE3 not support this extension, forward frame.
    (3) PE3: For PW13, PE3 not support this extension, no L-bit action.
            As per current standard, the corresponding bit position
            must be set to 0.
    (4) PE3: For PW23, PE3 not support this extension, no L-bit action.
            No control word on PW23.
    (5) PE1: MAC-based forwarding decision as per current standard,
            forward frame to R11, R12, L11 and L12.
    (6) PE1: As per this extension, forward frame. (Rule 1, 8)
    (7) PE2: MAC-based forwarding decision as per current standard,
            forward frame to R21, R22, L21 and L22.
    (8) PE2: As per this extension, forward frame. (Rule 1, 7)

B.3.2. **From Leaf AC**

    Forward to all Root AC only.

B.3.2.1. **From L11**

    (1) PE1: MAC-based forwarding decision as per current standard,
            forward frame to R11, R12, L12, PW12 and PW13.
    (2) PE1: For R11 and R12, forward as per this extension. (Rule 1)
    (3) PE1: For L12, as per this extension, drop frame. (Rule 6)
    (4) PE1: For PW12 and PW13, as per this extension, set L-bit to 1.
            (Rule 4)
    (5) PE2: MAC-based forwarding decision as per current standard,
            forward frame to R21, R22, L21 and L22.
    (6) PE2: For R21 and R22, forward as per this extension. (Rule 1)
    (7) PE2: For L21 and L22, as per this extension, drop frame. (Rule 9)
    (8) PE3: MAC-based forwarding decision as per current standard,
            forward frame to R31 and R32.
    (9) PE3: PE3 not support this extension, as per current standard
            L-bit ignored and forward frame.

B.3.2.2. **From L21**

    (1) PE2: MAC-based forwarding decision as per current standard,
            forward frame to R21, R22, L22, PW12 and PW23.
    (2) PE2: For R21 and R22, forward as per this extension. (Rule 1)
    (3) PE2: For L22, as per this extension, drop frame. (Rule 6)
    (4) PE2: For PW12, as per this extension, set L-bit to 1. (Rule 4)
    (5) PE2: For PW23, no L-bit action as per this extension. (Rule 2)
    (6) PE1: MAC-based forwarding decision as per current standard,
            forward frame to R11, R12, L11 and L12.
    (7) PE1: For R11 and R12, forward as per this extension. (Rule 1)
    (8) PE1: For L11 and L12, as per this extension, drop frame. (Rule 9)
    (9) PE3: MAC-based forwarding decision as per current standard,
            forward frame to R31 and R32.
    (10) PE3: PE3 not support this extension, forward frame.

B.4. **Broadcast**

    Same as Unicast Unknown in B.3.

B.5. **Multicast**

    Same as Unicast Unknown in B.3.

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