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              A Framework for Ethernet Tree (E-Tree) Service
              over a Multiprotocol Label Switching (MPLS) Network

Abstract

   This document describes an Ethernet-Tree (E-Tree) solution framework
   for supporting the Metro Ethernet Forum (MEF) E-Tree service over a
   Multiprotocol Label Switching (MPLS) network.  The objective is to
   provide a simple and effective approach to emulate E-Tree services in
   addition to Ethernet LAN (E-LAN) services on an existing MPLS
   network.

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1.  Introduction

   This document describes an Ethernet-Tree (E-Tree) solution framework
   for supporting the Metro Ethernet Forum (MEF) E-Tree service over a
   Multiprotocol Label Switching (MPLS) network.  The objective is to
   provide a simple and effective approach to emulate E-Tree services in
   addition to Ethernet LAN (E-LAN) services on an existing MPLS
   network.

   This document extends the existing IETF-specified Layer 2 Virtual
   Private Network (L2VPN) framework [RFC4664] to provide the emulation
   of E-Tree services over an MPLS network.  It specifies the E-Tree
   architecture reference model and describes the corresponding
   functional components.  It also points out the gaps and required
   extension areas in existing L2VPN solutions such as Virtual Private
   LAN Service (VPLS) [RFC4761] [RFC4762] and Ethernet Virtual Private
   Network (EVPN) [EVPN] for supporting E-Tree services.

1.1.  Terminology

   This document adopts all the terminologies defined in RFC 4664
   [RFC4664], RFC 4761 [RFC4761], and RFC 4762 [RFC4762].  It also uses
   the following terms:

   Leaf Attachment Circuit (AC): An AC with Leaf role.  An ingress
      Ethernet frame at a Leaf AC (Ethernet frame arriving over an AC at
      the Provider Edge (PE) of an MPLS network) can only be delivered
      to one or more Root ACs in an E-Tree service instance.  An ingress
      Ethernet frame at a Leaf AC must not be delivered to any Leaf ACs
      in the E-Tree service instance.

   Root AC: An AC with Root role.  An ingress Ethernet frame at a Root
      AC can be delivered to one or more of the other ACs in the
      associated E-Tree service instance.

   E-Tree: An Ethernet VPN service in which each AC is assigned the role
      of a Root or Leaf.  The forwarding rules in an E-Tree are as
      follows:

      o  The Root AC can communicate with other Root ACs and Leaf ACs.

      o  Leaf ACs can only communicate with Root ACs.

2.  Overview

2.1.  Ethernet Bridge Network

   In this document, "Ethernet bridge network" refers to the Ethernet
   bridge/switch network defined in IEEE 802.1Q [IEEE802.1Q].  In a
   bridge network, a data frame is an Ethernet frame; data forwarding is
   based on destination Media Access Control (MAC) address; MAC
   reachability is learned in the data plane based on the source MAC
   address and the port (or tagged port) on which the frame arrives; and
   the MAC aging mechanism is used to remove inactive MAC addresses from
   the MAC forwarding table on an Ethernet switch.

   Data frames arriving at a switch may be destined to known unicast,
   unknown unicast, multicast, or broadcast MAC destinations.  Unknown
   unicast, multicast, and broadcast frames are forwarded in a similar
   way, i.e., to every port except the ingress port on which the frame
   arrives.  Multicast forwarding can be further constrained when using
   multicast control protocol snooping or using multicast MAC
   registration protocols [IEEE802.1Q].

   An Ethernet host receiving an Ethernet frame checks the destination
   address in the frame to decide whether it is the intended
   destination.

2.2.  MEF Multipoint Ethernet Services: E-LAN and E-Tree

   MEF 6.1 [MEF6.1] defines two multipoint Ethernet Service types:

   o  E-LAN (Ethernet LAN), a multipoint-to-multipoint service

   o  E-Tree (Ethernet Tree), a rooted-multipoint service

   The MEF defines User-Network Interface (UNI) in a multipoint service
   as the Ethernet interface between Customer Equipment (CE) and a
   Provider Edge (PE), i.e., the PE can send and receive Ethernet frames
   to/from the CE.  The MEF also defines UNI roles in a multipoint
   service.  One role is Root, and another is Leaf.

   Note that MEF UNI in a service is equivalent to the Attachment
   Circuit (AC) defined in L2VPN [RFC4664].  The Root AC and Leaf AC
   defined in this document are the same as the Root UNI and Leaf UNI as
   defined in MEF 10.3 [MEF10.3].  The terms "Root AC" and "Leaf AC" are
   used in the following MEF service description.

For an E-LAN service, all ACs have the Root role, which means that
any AC can communicate with other ACs in the service.  The E-LAN
service defined by the MEF may be implemented by IETF L2VPN solutions
such as VPLS and EVPN [EVPN].

An E-Tree service has one or more Root ACs and at least two Leaf ACs.
An E-Tree service supports communication among the roots and between
a root and a leaf but prohibits communication among the leaves.
Existing IETF L2VPN solutions can't support the E-Tree service.  This
document specifies the E-Tree architecture reference model that
supports the E-Tree service defined by the MEF [MEF6.1].  Section 4
will discuss different E-Tree use cases.

2.3.  IETF L2VPN

2.3.1.  Virtual Private LAN Service (VPLS)

VPLS [RFC4761] [RFC4762] is an L2VPN solution that provides
multipoint-to-multipoint Ethernet connectivity across IP/MPLS
networks.  VPLS emulates traditional Ethernet Virtual LAN (VLAN)
services in MPLS networks and may support MEF E-LAN services.

A data frame in VPLS is an Ethernet frame.  Data forwarding in a VPLS
instance is based on the destination MAC address and the VLAN on
which the frame arrives.  MAC reachability learning is performed in
the data plane based on the source address and the AC or pseudowire
(PW) on which the frame arrives.  MAC aging is the mechanism used to
remove inactive MAC addresses from a VPLS switching instance (VSI) on
a PE.  VPLS supports forwarding for known unicast frames, as well as
unknown unicast, broadcast, and multicast Ethernet frames.

Many service providers have deployed VPLS in their networks to
provide L2VPN services to customers.

2.3.2.  Ethernet VPN (EVPN)

Ethernet VPN [EVPN] is an enhanced L2VPN solution that emulates an
Ethernet LAN or virtual LAN(s) across MPLS networks.

EVPN supports active-active multihoming of CEs and uses the
Multiprotocol Border Gateway Protocol (MP-BGP) control plane to
advertise MAC address reachability from an ingress PE to egress PEs.
Thus, a PE learns MAC addresses that are reachable over local ACs in
the data plane and other MAC addresses reachable across the MPLS
network over remote ACs via the EVPN MP-BGP control plane.  As a
result, EVPN aims to support large-scale L2VPN with better resiliency
compared to VPLS.

EVPN is a relatively new technique and is still under development in
the IETF L2VPN WG.

2.3.3.  Virtual Private Multicast Service (VPMS)

VPMS [VPMS] is an L2VPN solution that provides point-to-multipoint
connectivity across MPLS networks and supports various attachment
circuit (AC) types, including Frame Relay, ATM, Ethernet, PPP, etc.

In the case of Ethernet ACs, VPMS provides single coverage of
receiver membership, i.e., there is no differentiation among
multicast groups in one VPN.  The destination address in the Ethernet
frame is not used in data forwarding.

VPMS supports unidirectional point-to-multipoint transport from a
sender to multiple receivers and may support reverse transport in a
point-to-point manner.

3.  E-Tree Architecture Reference Model

Figure 1 illustrates the E-Tree architecture reference model.  Three
Provider Edges -- PE1, PE2, and PE3 -- are shown in the figure.  Each
PE has a Virtual Service Instance (VSI) associated with an E-Tree
service instance.  A CE attaches to the VSI on a PE via an AC.  Each
AC must be configured with a Root or Leaf role.  In Figure 1, AC1,
AC2, AC5, AC6, AC9, and AC10 are Root ACs; AC3, AC4, AC7, AC8, AC11,
and AC12 are Leaf ACs.  This implies that a PE (local or remote)
processes the Ethernet frames from CE01, CE02, etc., as if they
originated from a Root AC, and it processes the Ethernet frames from
CE03, CE04, etc., as if they originated from a Leaf AC.

Under this architecture model, the forwarding rules among the ACs,
regardless of whether the sending AC and receiving AC are on the same
PE or on different PEs, are described as follows:

o  An egress frame (the frame to be transmitted over an AC) at an AC
   with Root role must be the result of an ingress frame at an AC
   (the frame received at an AC) that has Root or Leaf role and is
   attached to the same E-Tree service instance.

o  An egress frame at the AC with Leaf role must be the result of an
   ingress frame at an AC that has Root role and is attached to the
   same E-Tree service instance.

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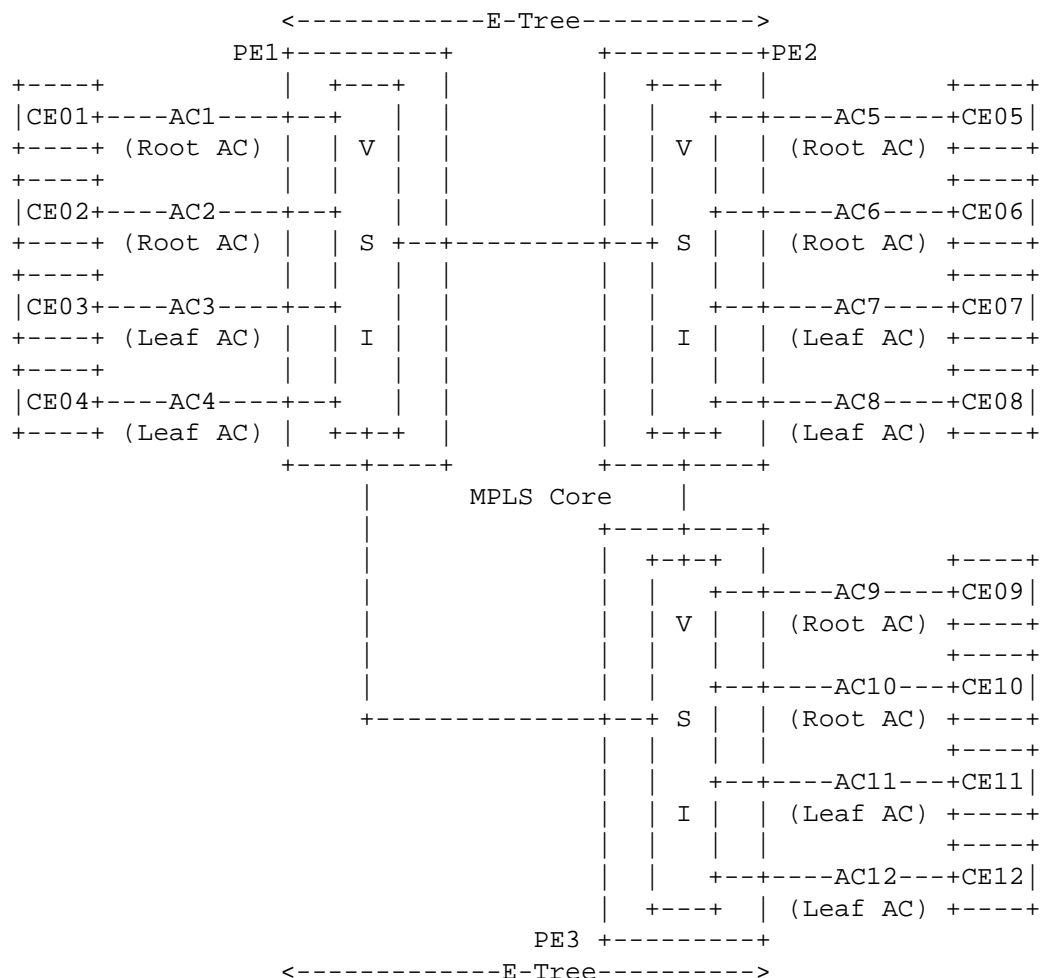
             Figure 1: E-Tree Architecture Reference Model

   These rules apply to all frame types, i.e., known unicast, unknown
   unicast, broadcast, and multicast.  For known unicast frames,
   forwarding in a VSI context is based on the destination MAC address.

   A VSI on a PE corresponds to an E-Tree service instance and maintains
   a MAC forwarding table that is isolated from other VSI tables on the
   PE.  It also keeps track of local AC roles.  The VSI receives a frame
   from an AC or across the MPLS core, and it forwards the frame to
   another AC over which the destination is reachable according to the
   VSI forwarding table and forwarding rules described above.  When the
   target AC is on a remote PE, the VSI forwards the frame to the remote
   PE over the MPLS core.  Forwarding over the MPLS core will be
   dependent on the E-Tree solution.  For instance, a solution may adopt
   PWs to mesh VSIs as in VPLS and to forward frames over VSIs subject

   to the E-Tree forwarding rules.  Alternatively, a solution may adopt
   the EVPN forwarding paradigm constrained by the E-Tree forwarding
   rules.  Thus, solutions that satisfy the E-Tree requirements could be
   extensions to VPLS and EVPN.

   In most use cases, an E-Tree service has only a few Root ACs (root CE
   sites) but many Leaf ACs (leaf CE sites).  Furthermore, a PE may have
   only Root ACs or only Leaf ACs.  Figure 1 provides a general E-Tree
   architecture model.

4.  E-Tree Use Cases

   Table 1 below presents some major use cases for E-Tree.

|   | Use Case | Root AC | Leaf AC |
|---|----------|---------|---------|
| 1 | Hub & Spoke VPN | Hub Site | Spoke Site |
| 2 | Wholesale Access | Customer's Interconnect | Customer's Subscriber |
| 3 | Mobile Backhaul | RAN NC | RAN BS |
| 4 | IEEE 1588 PTPv2 [IEEE1588] Clock Synchronization | PTP Server | PTP Client |
| 5 | Internet Access Reference [TR-101] | BNG Router | Subscriber |
| 6 | Broadcast Video (unidirectional only) | Video Source | Subscriber |
| 7 | Broadcast/Multicast Video plus Control Channel | Video Source | Subscriber |
| 8 | Device Management | Management System | Managed Device |

   Where:

      RAN: Radio Access Network     NC: Network Controller
      BS: Base Station              PTP: Precision Time Protocol
      BNG: Broadband Network Gateway

                        Table 1: E-Tree Use Cases

   Common to all use cases, direct Layer 2 leaf-to-leaf communication is
   required to be prohibited.  For mobile backhaul, this may not be
   valid for Long Term Evolution (LTE) X2 interfaces; an LTE X2
   interface [LTE] enables communication between two evolved Node Bs
   (eNBs).  E-Tree service is appropriate for such use cases.

   Also common to the use cases mentioned above, there may be one or
   multiple Root ACs in one E-Tree service.  The need for multiple Root
   ACs may be driven by a redundancy requirement or by having multiple
   serving sites.  Whether a particular E-Tree service needs to support
   one or multiple Root ACs depends on the application.

5.  L2VPN Gaps for Emulating MEF E-Tree Service

   The MEF E-Tree service defines special forwarding rules that prohibit
   forwarding Ethernet frames among leaves.  This poses some challenges
   to IETF L2VPN solutions such as VPLS and EVPN in emulating E-Tree
   service over an MPLS network.  There are two major issues described
   in the following subsections.

5.1.  No Differentiation on AC Role

   IP/MPLS L2VPN architecture has no distinct roles on Attachment
   Circuits (ACs) and supports any-to-any connectivity among all ACs.
   It does not have any mechanism to support forwarding constraints
   based on an AC role.  However, the MEF E-Tree service defines two AC
   roles -- Root and Leaf -- and defines the forwarding rules based on
   the originating and receiving AC roles of a given frame.

5.2.  No AC Role Indication or Advertisement

   In an L2VPN, when a PE, say PE2, receives a frame from another PE,
   say PE1, over the MPLS core, PE2 does not know if the frame from PE1
   is originated from a Root AC or Leaf AC.  This causes the forwarding
   issue on PE2 because the E-Tree forwarding rules require that the
   forwarder must know the role of the frame origin, i.e., from Root AC
   or Leaf AC.  This is specifically important when PE2 has both Root AC
   and Leaf AC attached to the VSI.  E-Tree forwarding rules apply to
   all types of frames (known unicast destination, unknown unicast
   destination, multicast, and broadcast).

5.3.  Other Issues

   Some desirable requirements for IETF E-Tree are specific to an
   IP/MPLS L2VPN implementation such as Leaf-only PE.  A Leaf-only PE is
   a PE that only has Leaf AC(s) in an E-Tree service instance; thus,
   other PEs on the same E-Tree service instance do not necessarily
   forward the frames originated from a Leaf AC to the Leaf-only PE,

which may save some network resources.  It is also desirable for an
E-Tree solution to work with existing PEs that support single-role
ACs, where the role is equivalent to the root in an E-Tree service.
These requirements are described in the E-Tree requirement document
[RFC7152].

6.  Security Considerations

An E-Tree service may be deployed for security reasons to prohibit
communication among sites (leaves).  An E-Tree solution must enforce
E-Tree forwarding constraints.  The solution must also guarantee that
Ethernet frames do not leak outside of the E-Tree service instance to
which they belong.

An E-Tree service prohibits communication among leaf sites but does
not have knowledge of higher-layer security constraints.  Therefore,
in general, higher-layer applications cannot rely on E-Tree to
provide security protection unless all security constraints are fully
implemented by the E-Tree service.

Enhancing L2VPN for E-Tree services inherits the same security issues
described in the L2VPN framework document [RFC4664].  These relate to
both control-plane and data-plane security issues that may arise in
the following areas:

o  issues fully contained in the provider network

o  issues fully contained in the customer network

o  issues in the customer-provider interface network

The framework document has substantial discussions on the security
issues and potential solutions to address them.  An E-Tree solution
must consider these issues and address them properly.  VPLS [RFC4761]
[RFC4762] and/or EVPN [EVPN] will likely be candidate solutions for
an E-Tree service over an MPLS network.  The security capabilities
built into those solutions will be naturally adopted when supporting
E-Tree.  For details, see the Security Considerations sections in
[RFC4761], [RFC4762], and [EVPN].

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Acknowledgments

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