           Coordinated Multicast Trees (CMT)
    for Transparent Interconnection of Lots of Links (TRILL)

Abstract

   TRILL (Transparent Interconnection of Lots of Links) facilitates
   loop-free connectivity to non-TRILL networks via a choice of an
   Appointed Forwarder for a set of VLANs. Appointed Forwarders provide
   VLAN-based load sharing with an active-standby model. High-
   performance applications require an active-active load-sharing model.
   The active-active load-sharing model can be accomplished by
   representing any given non-TRILL network with a single virtual
   RBridge (also referred to as a virtual Routing Bridge or virtual
   TRILL switch). Virtual representation of the non-TRILL network with
   a single RBridge poses serious challenges in multi-destination RPF
   (Reverse Path Forwarding) check calculations. This document
   specifies required enhancements to build Coordinated Multicast Trees
   (CMT) within the TRILL campus to solve related RPF issues. CMT,
   which only requires a software upgrade, provides flexibility to
   RBridges in selecting a desired path of association to a given TRILL
   multi-destination distribution tree. This document updates RFC 6325.

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1. Introduction

   TRILL (Transparent Interconnection of Lots of Links), as presented in
   [RFC6325] and other related documents, provides methods of utilizing
   all available paths for active forwarding, with minimum
   configuration. TRILL utilizes IS-IS (Intermediate System to
   Intermediate System) [IS-IS] as its control plane and uses a TRILL
   Header that includes a Hop Count.

   [RFC6325], [RFC7177], and [RFC6439] provide methods for
   interoperability between TRILL and Ethernet end stations and bridged
   networks. [RFC6439] provides an active-standby solution, where only
   one of the RBridges (aka Routing Bridges or TRILL switches) on a link
   with end stations is in the active forwarding state for end-station
   traffic for any given VLAN. That RBridge is referred to as the
   Appointed Forwarder (AF). All frames ingressed into a TRILL network
   via the AF are encapsulated with the TRILL Header with a nickname
   held by the ingress AF RBridge. Due to failures, reconfigurations,
   and other network dynamics, the AF for any set of VLANs may change.
   RBridges maintain forwarding tables that contain bindings for
   destination Media Access Control (MAC) addresses and Data Labels
   (VLAN or Fine-Grained Labels (FGLs)) to egress RBridges. In the
   event of an AF change, forwarding tables of remote RBridges may
   continue to forward traffic to the previous AF. That traffic may get
   discarded at the egress, causing traffic disruption.

   High-performance applications require resiliency during failover.
   The active-active forwarding model minimizes impact during failures
   and maximizes the available network bandwidth. A typical deployment
   scenario, depicted in Figure 1, may have end stations and/or bridges
   attached to the RBridges. These devices typically are multi-homed to
   several RBridges and treat all of the uplinks independently using a
   Local Active-Active Link Protocol (LAALP) [RFC7379], such as a single
   Multi-Chassis Link Aggregation (MC-LAG) bundle or Distributed
   Resilient Network Interconnect [802.1AX]. The AF designation
   presented in [RFC6439] requires each of the edge RBridges to exchange
   TRILL Hello packets. By design, an LAALP does not forward packets
   received on one of the member ports of the MC-LAG to other member
   ports of the same MC-LAG. As a result, the AF designation methods
   presented in [RFC6439] cannot be applied to the deployment scenario
   depicted in Figure 1.

   An active-active load-sharing model can be implemented by
   representing the edge of the network connected to a specific edge
   group of RBridges by a single virtual RBridge. Each virtual RBridge
   MUST have a nickname unique within its TRILL campus. In addition to
   an active-active forwarding model, there may be other applications
   that may require similar representations.

Sections 4.5.1 and 4.5.2 of [RFC6325], as updated by [RFC7780],
specify distribution tree calculation and RPF (Reverse Path
Forwarding) check calculation algorithms for multi-destination
forwarding. These algorithms strictly depend on link cost and parent
RBridge priority. As a result, based on the network topology, it may
be possible that a given edge RBridge, if it is forwarding on behalf
of the virtual RBridge, may not have a candidate multicast tree on
which it (the edge RBridge) can forward traffic, because there is no
tree for which the virtual RBridge is a leaf node from the edge
RBridge.

In this document, we present a method that allows RBridges to specify
the path of association for real or virtual child nodes to
distribution trees. Remote RBridges calculate their forwarding
tables and derive the RPF for distribution trees based on the
distribution tree association advertisements. In the absence of
distribution tree association advertisements, remote RBridges derive
the SPF (Shortest Path First) based on the algorithm specified in
Section 4.5.1 of [RFC6325], as updated by [RFC7780]. This document
updates [RFC6325] by changing, when Coordinated Multicast Trees (CMT)
sub-TLVs are present, [RFC6325] mandatory provisions as to how
distribution trees are constructed.

In addition to the above-mentioned active-active forwarding model,
other applications may utilize the distribution tree association
framework presented in this document to associate to distribution
trees through a preferred path.

This proposal requires (1) the presence of multiple multi-destination
trees within the TRILL campus and (2) that all the RBridges in the
network be updated to support the new Affinity sub-TLV (Section 3).
It is expected that both of these requirements will be met, as they
are control-plane changes and will be common deployment scenarios.
In case either of the above two conditions is not met, RBridges MUST
support a fallback option for interoperability. Since the fallback
is expected to be a temporary phenomenon until all RBridges are
upgraded, this proposal gives guidelines for such fallbacks and does
not mandate or specify any specific set of fallback options.

1.1. Scope and Applicability

This document specifies an Affinity sub-TLV to solve RPF issues at
the active-active edge. Specific methods in this document for making
use of the Affinity sub-TLV are applicable where a virtual RBridge is
used to represent multiple RBridges connected to an edge Customer
Equipment (CE) device through an LAALP, such as MC-LAG or some
similar arrangement where the RBridges cannot see each other's
Hellos.

This document does not provide other required operational elements to
implement an active-active edge solution, such as MC-LAG methods.
Solution-specific operational elements are outside the scope of this
document and will be covered in other documents. (See, for example,
[RFC7781].)

Examples provided in this document are for illustration purposes
only.

2. 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].

In this document, these words will appear with that interpretation
only when in ALL CAPS. Lowercase uses of these words are not to be
interpreted as carrying [RFC2119] significance.

2.1. Acronyms and Phrases

The following acronyms and phrases are used in this document:

AF: Appointed Forwarder [RFC6439].

CE: Customer Equipment device, that is, a device that performs
    forwarding based on 802.1Q bridging. This also can be an
    end station or a server.

Data Label: VLAN or FGL.

FGL: Fine-Grained Label [RFC7172].

LAALP: Local Active-Active Link Protocol [RFC7379].

MC-LAG: Multi-Chassis Link Aggregation. A proprietary extension to
    [802.1AX] that facilitates connecting a group of links from an
    originating device (A) to a group of discrete devices (B).
    Device (A) treats all of the links in a given MC-LAG bundle as a
    single logical interface and treats all devices in Group (B) as a
    single logical device for all forwarding purposes. Device (A)
    does not forward packets received on the multi-chassis link bundle
    out of the same multi-chassis link bundle. Figure 1 depicts a
    specific use case example.

   RPF: Reverse Path Forwarding. See Section 4.5.2 of [RFC6325].

   Virtual RBridge: A purely conceptual RBridge that represents an
      active-active edge group and is in turn represented by a nickname.
      For example, see [RFC7781].

3. The Affinity Sub-TLV

   Association of an RBridge to a multi-destination distribution tree
   through a specific path is accomplished by using a new IS-IS sub-TLV,
   the Affinity sub-TLV.

   The Affinity sub-TLV appears in Router Capability TLVs or
   MT Capability TLVs that are within Link State PDUs (LSPs), as
   described in [RFC7176]. [RFC7176] specifies the code point and data
   structure for the Affinity sub-TLV.

4. Multicast Tree Construction and Use of Affinity Sub-TLV

   Figures 1 and 2 below show the reference topology and a logical
   topology using CMT to provide active-active service.

```
                      --------------------
                     /                     \
                     |                     |
                     |     TRILL Campus    |
                     |                     |
                     \                     /
                      --------------------
                        |      |     |
                      -----    |    --------
                     |         |            |
                 +------+   +------+    +------+
                 |      |   |      |    |      |
                 |(RB1) |   |(RB2) |    | (RBk)|
                 +------+   +------+    +------+
                  |..|       |..|        |..|
                  |  +----+  |  |        |  |
                  |   +---|-----|--|----------+  |
                  | +-|---|-----+  +----------+  |
                  | | |   +----------------+  | |
                 (| | |)  <-- MC-LAG        (| | |) <-- MC-LAG
                 +------+    .   .   .     +------+
                 | CE1  |                  | CEn  |
                 |      |                  |      |
                 +------+                  +------+
```

                   Figure 1: Reference Topology

```
         --------------------        Sample Multicast Tree (T1)
        /                    \
        |          |          |                  |
        |     TRILL Campus    |                o RBn
        |          |          |               / | \
        \                    /              /   |  ---\
         --------------------        RB1 o  o       o
         |        |       |              |   RB2    RBk
         |        |     -------------    |
         |        |     |           |    o RBv
      +------+ +------+      +------+
      |      | |      |      |      |
      |(RB1) | |(RB2) |      | (RBk)|
      +------+ +------+      +------+
       |..|       |..|         |..|
       |  +----+  |  |         |  |
       |  +---|--|--|------------+  |
       | +-|---|--+  +-------------+  |
       | | | |   +----------------+ | |
 MC-LAG -->(| | |)              (| | |)<-- MC-LAG
      +-------+    .  .  .   +-------+
      | CE1   |              | CEn   |
      |       |              |       |
      +-------+              +-------+
```

       RBv: virtual RBridge
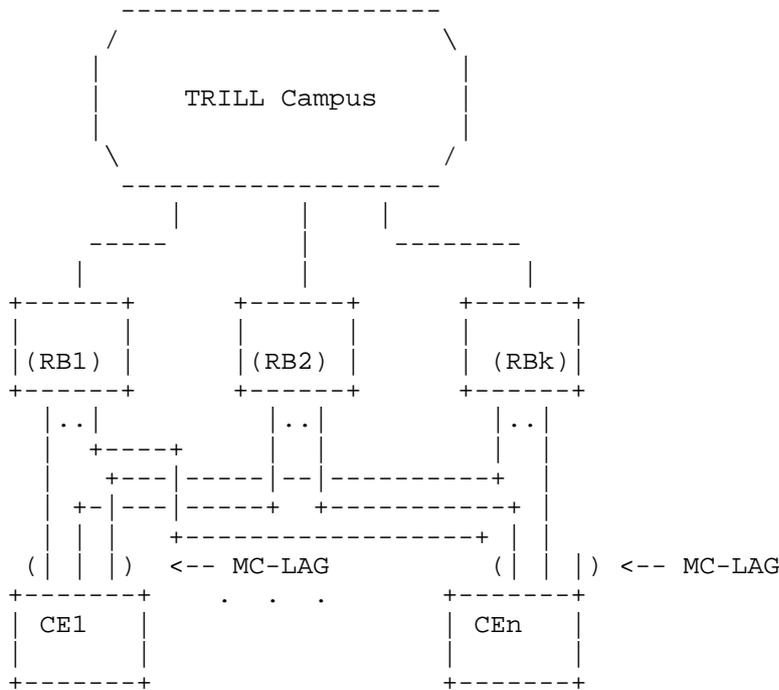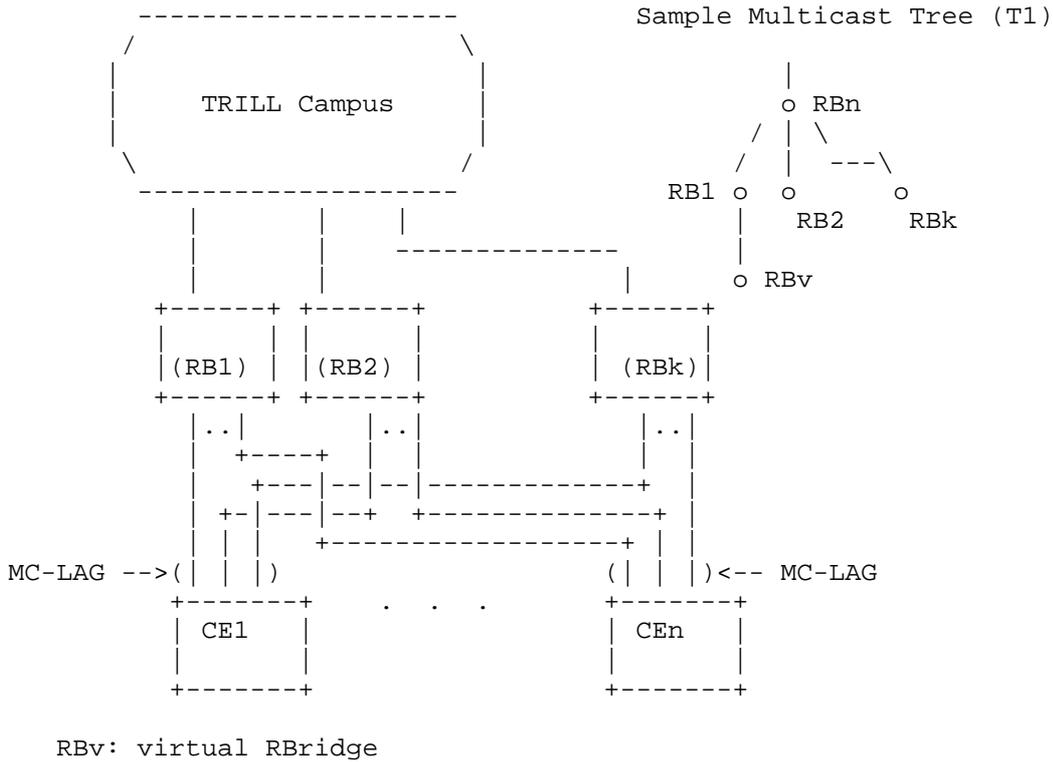
                  Figure 2: Example Logical Topology

4.1. Update to RFC 6325

   This document updates Section 4.5.1 of [RFC6325] and changes the
   calculation of distribution trees, as specified below:

   Each RBridge that desires to be the parent RBridge for a child
   RBridge (RBy) in a multi-destination distribution tree (Tree x)
   announces the desired association using an Affinity sub-TLV. The
   child is specified by its nickname. If an RBridge (RB1) advertises
   an Affinity sub-TLV designating one of its own nicknames (N1) as its
   "child" in some distribution tree, the effect is that nickname N1 is
   ignored when constructing other distribution trees. Thus, the
   RPF check will enforce the rule that only RB1 can use nickname N1 to
   do ingress/egress on Tree x. (This has no effect on least-cost path
   calculations for unicast traffic.)

   When such an Affinity sub-TLV is present, the association specified
   by the Affinity sub-TLV MUST be used when constructing the
   multi-destination distribution tree, except in the case of a

conflicting Affinity sub-TLV; such cases are resolved as specified in
Section 5.3. In the absence of such an Affinity sub-TLV, or if there
are any RBridges in the campus that do not support the Affinity
sub-TLV, distribution trees are calculated as specified in
Section 4.5.1 of [RFC6325], as updated by [RFC7780]. Section 4.3
below specifies how to identify RBridges that support the Affinity
sub-TLV.

4.2. Announcing Virtual RBridge Nickname

Each edge RBridge (RB1 to RBk) advertises its LSP virtual RBridge
nickname (RBv) by using the Nickname sub-TLV (6) [RFC7176], along
with their regular nickname or nicknames.

It will be possible for any RBridge to determine that RBv is a
virtual RBridge, because each RBridge (RB1 to RBk) that appears to be
advertising that it is holding RBv is also advertising an Affinity
sub-TLV asking that RBv be its child in one or more trees.

Virtual RBridges are ignored when determining the distribution tree
roots for the campus.

All RBridges outside the edge group assume that multi-destination
packets with their TRILL Header Ingress Nickname field set to RBv
might use any of the distribution trees that any member of the edge
group advertises that it might use.

4.3. Affinity Sub-TLV Capability

RBridges that announce the TRILL Version sub-TLV [RFC7176] and set
the Affinity capability bit (Section 7) support the Affinity sub-TLV,
calculation of multi-destination distribution trees, and RPF checks,
as specified herein.

5. Theory of Operation

5.1. Distribution Tree Assignment

Let's assume that there are n distribution trees and k edge RBridges
in the edge group of interest.

If n >= k

   Let's assume that edge RBridges are sorted in numerically
   ascending order by IS-IS System ID such that RB1 < RB2 < RBk.
   Each RBridge in the numerically sorted list is assigned a
   monotonically increasing number j such that RB1 = 0, RB2 = 1,

        RBi = j, and RBi + 1 = j + 1. (See Section 4.5 of [RFC6325], as
        updated by Section 3.4 of [RFC7780], for how tree numbers are
        determined.)

        Assign each tree to RBi such that tree number
        (((tree_number) % k) + 1) is assigned to edge group RBridge i for
        tree_number from 1 to n, where n is the number of trees, k is the
        number of edge group RBridges considered for tree allocation, and
        "%" is the integer division remainder operation.

     If n < k

        Distribution trees are assigned to edge group RBridges RB1 to RBn,
        using the same algorithm as the n >= k case. RBridges RBn + 1 to
        RBk do not participate in the active-active forwarding process on
        behalf of RBv.

5.2. Affinity Sub-TLV Advertisement

     Each RBridge in the RB1 through RBk domain advertises an Affinity
     sub-TLV for RBv to be its child.

     As an example, let's assume that RB1 has chosen Trees t1 and tk + 1
     on behalf of RBv.

     RB1 advertises the Affinity sub-TLV;
     {RBv, Num of Trees = 2, t1, tk + 1}.

     Other RBridges in the RB1 through RBk edge group follow the same
     procedure.

5.3. Affinity Sub-TLV Conflict Resolution

     In TRILL, multi-destination distribution trees are built outward from
     the root by each RBridge so that they all derive the same set of
     distribution trees [RFC6325].

     If RBridge RB1 advertises an Affinity sub-TLV with an AFFINITY RECORD
     that asks for RBridge RBroot to be its child in a tree rooted at
     RBroot, that AFFINITY RECORD is in conflict with TRILL distribution
     tree root determination and MUST be ignored.

     If RBridge RB1 advertises an Affinity sub-TLV with an AFFINITY RECORD
     that asks for nickname RBn to be its child in any tree and RB1 is not
     adjacent to RBn nor does nickname RBn identify RB1 itself, that
     AFFINITY RECORD is in conflict with the campus topology and MUST be
     ignored.

If different RBridges advertise Affinity sub-TLVs that try to
associate the same virtual RBridge as their child in the same tree or
trees, those Affinity sub-TLVs are in conflict with each other for
those trees. The nicknames of the conflicting RBridges are compared
to identify which RBridge holds the nickname that is the highest
priority to be a tree root, with the System ID as the tiebreaker.

The RBridge with the highest priority to be a tree root will retain
the Affinity association. Other RBridges with lower priority to be a
tree root MUST stop advertising their conflicting Affinity sub-TLVs,
recalculate the multicast tree affinity allocation, and, if
appropriate, advertise new non-conflicting Affinity sub-TLVs.

Similarly, remote RBridges MUST honor the Affinity sub-TLV from the
RBridge with the highest priority to be a tree root (using System ID
as the tiebreaker in the event of conflicting priorities) and ignore
the conflicting Affinity sub-TLV entries advertised by the RBridges
with lower priorities to be tree roots.

5.4. Ingress Multi-Destination Forwarding

If there is at least one tree on which RBv has affinity via RBk, then
RBk performs the following operations for multi-destination frames
received from a CE node:

1. Flood to locally attached CE nodes subjected to VLAN and multicast
   pruning.

2. Ingress (by encapsulating with a TRILL Header) and set the Ingress
   Nickname field of the TRILL Header to RBv (the nickname of the
   virtual RBridge).

3. Forward to one of the distribution trees, Tree x, in which RBv is
   associated with RBk.

5.4.1. Forwarding when n < k

If there is no tree on which RBv can claim affinity via RBk (probably
because the number of trees (n) built is less than the number of
RBridges (k) announcing the Affinity sub-TLV), then RBk MUST fall
back to one of the following:

1. This RBridge (RBk) should stop forwarding frames from the CE nodes
   and should mark its port towards those CE nodes as disabled. This
   will prevent the CE nodes from forwarding data to this RBridge.
   Thus, the CE nodes will only use those RBridges that have been
   assigned a tree.

     -OR-

   2. This RBridge tunnels multi-destination frames received from
      attached native devices to an RBridge RBy that has an assigned
      tree. The tunnel destination should forward it to the TRILL
      network and also to its local access links. (The mechanism of
      tunneling and handshaking between the tunnel source and
      destination are out of scope for this specification and may be
      addressed in other documents, such as [ChannelTunnel].)

   The above fallback options may be specific to the active-active
   forwarding scenario. However, as stated above, the Affinity sub-TLV
   may be used in other applications. In such an event, the application
   SHOULD specify applicable fallback options.

5.5. Egress Multi-Destination Forwarding

5.5.1. Traffic Arriving on an Assigned Tree to RBk-RBv

   Multi-destination frames arriving at RBk on a Tree x, where RBk has
   announced the affinity of RBv via x, MUST be forwarded to CE members
   of RBv that are in the frame's VLAN. Forwarding to other end nodes
   and RBridges that are not part of the network represented by the
   virtual RBridge nickname (RBv) MUST follow the forwarding rules
   specified in [RFC6325].

5.5.2. Traffic Arriving on Other Trees

   Multi-destination frames arriving at RBk on a Tree y, where RBk has
   not announced the affinity of RBv via y, MUST NOT be forwarded to CE
   members of RBv. Forwarding to other end nodes and RBridges that are
   not part of the network represented by the virtual RBridge nickname
   (RBv) MUST follow the forwarding rules specified in [RFC6325].

5.6. Failure Scenarios

   The failure recovery algorithm below is presented only as a
   guideline. An active-active edge group MAY use other failure
   recovery algorithms; it is recommended that only one algorithm be
   used in an edge group at a time. Details of such algorithms are
   outside the scope of this document.

5.6.1. Edge RBridge RBk Failure

   Each of the member RBridges of a given virtual RBridge edge group is
   aware of its member RBridges through configuration, LSP
   advertisements, or some other method.

Member RBridges detect nodal failure of a member RBridge through
IS-IS LSP advertisements or lack thereof.

Upon detecting a member failure, each of the member RBridges of the
RBv edge group start recovery timer T_rec for failed RBridge RBi. If
the previously failed RBridge RBi has not recovered after the expiry
of timer T_rec, member RBridges perform the distribution tree
assignment algorithm specified in Section 5.1. Each of the member
RBridges re-advertises the Affinity sub-TLV with the new tree
assignment. This action causes the campus to update the tree
calculation with the new assignment.

RBi, upon startup, advertises its presence through IS-IS LSPs and
starts a timer T_i. Other member RBridges of the edge group,
detecting the presence of RBi, start a timer T_j.

Upon expiry of timer T_j, other member RBridges recalculate the
multi-destination tree assignment and advertise the related trees
using the Affinity sub-TLV. Upon expiry of timer T_i, RBi
recalculates the multi-destination tree assignment and advertises the
related trees using the Affinity sub-TLV.

If the new RBridge in the edge group calculates trees and starts to
use one or more of them before the existing RBridges in the edge
group recalculate, there could be duplication of packets (for
example, more than one edge group RBridge could decapsulate and
forward a multi-destination frame on links into the active-active
group) or loss of packets (for example, due to the Reverse Path
Forwarding check, in the rest of the campus, if two edge group
RBridges are trying to forward on the same tree, those from one will
be discarded). Alternatively, if the new RBridge in the edge group
calculates trees and starts to use one or more of them after the
existing RBridges recalculate, there could be loss of data due to
frames arriving at the new RBridge being black-holed. Timers T_i and
T_j should be initialized to values designed to minimize these
problems, keeping in mind that, in general, duplication of packets is
a more serious problem than dropped packets. It is RECOMMENDED that
T_j be less than T_i, and a reasonable default is 1/2 of T_i.

5.7. Backward Compatibility

Implementations MUST support a backward compatibility modes to
interoperate with "pre-Affinity sub-TLV" RBridges in the network.
Such backward compatibility operations MAY include, but are not
limited to, tunneling and/or active-standby modes of operation. It
should be noted that tunneling would require silicon changes.
However, CMT in itself is a software upgrade.

Example:

Step 1. Stop using the virtual RBridge nickname for traffic
   ingressing from CE nodes.

Step 2. Stop performing active-active forwarding. Fall back to
   active standby forwarding, based on locally defined policies. The
   definition of such policies is outside the scope of this document
   and may be addressed in other documents.

6. Security Considerations

   In general, the RBridges in a campus are trusted routers, and the
   authenticity of their link-state information (LSPs) and link-local
   PDUs (e.g., Hellos) can be enforced using regular IS-IS security
   mechanisms [IS-IS] [RFC5310]. This includes authenticating the
   contents of the PDUs used to transport Affinity sub-TLVs.

   The particular security considerations involved with different
   applications of the Affinity sub-TLV will be covered in the
   document(s) specifying those applications.

   For general TRILL security considerations, see [RFC6325].

7. IANA Considerations

   This document serves as the reference for the registration of
   "Affinity sub-TLV support" (bit 0) in the "TRILL-VER Sub-TLV
   Capability Flags" registry.

   This document mentions the registration of "AFFINITY" (value 17) in
   the "Sub-TLVs for TLV 144" registry, but it is intentionally not
   listed as a reference for that registration; the reference remains
   [RFC7176].

8. References

8.1. Normative References

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