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Transparent Interconnection of Lots of Links (TRILL):
Clarifications, Corrections, and Updates

Abstract

The IETF Transparent Interconnection of Lots of Links (TRILL) protocol provides least-cost pair-wise data forwarding without configuration in multi-hop networks with arbitrary topology and link technology, safe forwarding even during periods of temporary loops, and support for multipathing of both unicast and multicast traffic. TRILL accomplishes this by using Intermediate System to Intermediate System (IS-IS) link-state routing and by encapsulating traffic using a header that includes a hop count. Since publication of the TRILL base protocol in July 2011, active development of TRILL has revealed errata in RFC 6325 and some cases that could use clarifications or updates.

RFCs 6327 and 6439 provide clarifications and updates with respect to adjacency and Appointed Forwarders. This document provides other known clarifications, corrections, and updates to RFCs 6325, 6327, and 6439.

Status of This Memo

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1. Introduction

The IETF Transparent Interconnection of Lots of Links (TRILL) protocol [RFC6325] provides optimal pair-wise data frame forwarding without configuration in multi-hop networks with arbitrary topology and link technology, safe forwarding even during periods of temporary loops, and support for multipathing of both unicast and multicast traffic. TRILL accomplishes this by using Intermediate System to Intermediate System (IS-IS) [IS-IS] [RFC1195] [RFC7176] link-state routing and encapsulating traffic using a header that includes a hop count. The design supports VLANs (Virtual Local Area Networks) and optimization of the distribution of multi-destination frames based on VLANs and IP derived multicast groups.

In the years since the TRILL base protocol [RFC6325] was published, active development of TRILL has revealed five errors in the specification [RFC6325] and cases that could use clarifications or updates.

[RFC6327] and [RFC6439] provide clarifications with respect to Adjacency and Appointed Forwarders. This document provides other known clarifications, corrections, and updates to [RFC6325], [RFC6327], and [RFC6439].

1.1. Precedence

In case of conflict between this document and any of [RFC6325], [RFC6327], or [RFC6439], this document takes precedence. In addition, Section 1.2 (Normative Content and Precedence) of [RFC6325] is updated to provide a more complete precedence ordering of the sections of [RFC6325] as following, where sections to the left take precedence over sections to their right:

$$4 > 3 > 7 > 5 > 2 > 6 > 1$$

1.2. Changes That Are Not Backward Compatible

The change made by Section 3.4 below is not backward compatible with [RFC6325] but has nevertheless been adopted to reduce distribution tree changes resulting from topology changes.

The several other changes herein that are fixes to errata for [RFC6325] -- [Err3002] [Err3003] [Err3004] [Err3052] [Err3053] [Err3508] -- may not be backward compatible with previous implementations that conformed to errors in the specification.

1.3. Terminology and Acronyms

This document uses the acronyms defined in [RFC6325] and the following acronyms and terms:

CFI - Canonical Format Indicator [802]

DEI - Drop Eligibility Indicator [802.1Q-2011]

EISS - Enhanced Internal Sublayer Service

OOMF - Overload Originated Multi-destination Frame

TRILL Switch - An alternative name for an RBridge

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 [RFC2119].

2. Overloaded and/or Unreachable RBridges

RBridges may be in overload as indicated by the [IS-IS] overload flag in their LSPs (Link State PDUs). This means that either (1) they are incapable of holding the entire link-state database and thus do not have a view of the entire topology or (2) they have been configured to have the overload bit set. Although networks should be engineered to avoid actual link-state overload, it might occur under various circumstances. For example, if a large campus included one or more low-end TRILL Switches.

It is a common operational practice to set the overload bit in an [IS-IS] router (such as an RBridge) when performing maintenance on that router that might affect its ability to correctly forward frames; this will usually leave the router reachable for maintenance traffic, but transit traffic will not be routed through it. (Also, in some cases, TRILL provides for setting the overload bit in the pseudonode of a link to stop TRILL Data traffic on an access link (see Section 4.9.1 of [RFC6325]).)

[IS-IS] and TRILL make a reasonable effort to do what they can even if some RBridges/routers are in overload. They can do reasonably well if a few scattered nodes are in overload. However, actual least-cost paths are no longer assured if any RBridges are in overload.

For the effect of overload on the appointment of forwarders, see Section 10.2.

In this Section 2, the term "neighbor" refers only to actual RBridges and ignores pseudonodes.

2.1. Reachability

Frames are not least-cost routed through an overloaded TRILL Switch, although they may originate or terminate at an overloaded TRILL Switch. In addition, frames will not be least-cost routed over links with cost $2^{24} - 1$ [RFC5305]; such links are reserved for traffic-engineered frames, the handling of which is beyond the scope of this document.

As a result, a portion of the campus may be unreachable for least-cost routed TRILL Data because all paths to it would be through a link with cost $2^{24} - 1$ or through an overloaded RBridge. For example, an RBridge RB1 is not reachable by TRILL Data if all of its neighbors are connected to RB1 by links with cost $2^{24} - 1$. Such RBridges are called "data unreachable".

The link-state database at an RBridge RB1 can also contain information on TRILL Switches that are unreachable by IS-IS link-state flooding due to link or RBridge failures. When such failures partition the campus, the TRILL Switches adjacent to the failure and on the same side of the failure as RB1 will update their LSPs to show the lack of connectivity, and RB1 will receive those updates. As a result, RB1 will be aware of the partition. Nodes on the far side of the partition are both IS-IS unreachable and data unreachable. However, LSPs held by RB1 for TRILL Switches on the far side of the failure will not be updated and may stay around until they time out, which could be tens of minutes or longer. (The default in [IS-IS] is twenty minutes.)

2.2. Distribution Trees

An RBridge in overload cannot be trusted to correctly calculate distribution trees or correctly perform the RPF (Reverse-Path Forwarding Check). Therefore, it cannot be trusted to forward multi-destination TRILL Data frames. It can only appear as a leaf node in a TRILL multi-destination distribution tree. Furthermore, if all the immediate neighbors of an RBridge are overloaded, then it is omitted from all trees in the campus and is unreachable by multi-destination frames.

When an RBridge determines what nicknames to use as the roots of the distribution trees it calculates, it MUST ignore all nicknames held by TRILL Switches that are in overload or are data unreachable. When calculating RPFs for multi-destination frames, an RBridge RB1 MAY, to avoid calculating unnecessary RPF check state, ignore any trees

that cannot reach to RB1 even if other RBridges list those trees as trees that other TRILL Switches might use. (But see Section 3.)

2.3. Overloaded Receipt of TRILL Data Frames

The receipt of TRILL Data frames by overloaded RBridge RB2 is discussed in the subsections below. In all cases, the normal Hop Count decrement is performed, and the TRILL Data frame is discarded if the result is less than one or if the egress nickname is illegal.

2.3.1. Known Unicast Receipt

RB2 will not usually receive unicast TRILL Data frames unless it is the egress, in which case it decapsulates and delivers the frames normally. If RB2 receives a unicast TRILL Data frame for which it is not the egress, perhaps because a neighbor does not yet know it is in overload, RB2 MUST NOT discard the frame because the egress is an unknown nickname as it might not know about all nicknames due to its overloaded condition. If any neighbor, other than the neighbor from which it received the frame, is not overloaded, it MUST attempt to forward the frame to one of those neighbors. If there is no such neighbor, the frame is discarded.

2.3.2. Multi-Destination Receipt

If RB2 in overload receives a multi-destination TRILL Data frame, RB2 MUST NOT apply an RPF check since, due to overload, it might not do so correctly. RB2 decapsulates and delivers the frame locally where it is Appointed Forwarder for the frame's VLAN, subject to any multicast pruning. But since, as stated above, RB2 can only be the leaf of a distribution tree, it MUST NOT forward a multi-destination TRILL Data frame (except as an egressed native frame where RB2 is Appointed Forwarder).

2.4. Overloaded Origination of TRILL Data Frames

Overloaded origination of unicast frames with known egress and of multi-destination frames are discussed in the subsections below.

2.4.1. Known Unicast Origination

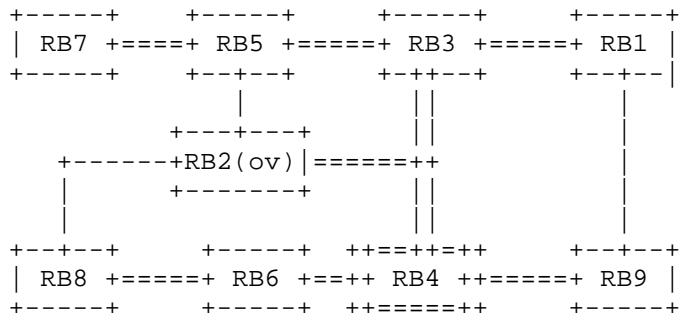
When an overloaded RBridge RB2 ingresses or creates a known destination unicast TRILL Data frame, it delivers it locally if the destination Media Access Control (MAC) is local. Otherwise, RB2 unicasts it to any neighbor TRILL Switch that is not overloaded. It MAY use what routing information it has to help select the neighbor.

2.4.2. Multi-Destination Origination

Overloaded RBridge RB2 ingressing or creating a multi-destination TRILL Data frame is more complex than for a known unicast frame.

2.4.2.1. An Example Network

For example, consider the network below in which, for simplicity, end stations and any bridges are not shown. There is one distribution tree of which RB4 is the root; it is represented by double lines. Only RBridge RB2 is overloaded.



Since RB2 is overloaded, it does not know what the distribution tree or trees are for the network. Thus, there is no way it can provide normal TRILL Data encapsulation for multi-destination native frames. So RB2 tunnels the frame to a neighbor that is not overloaded if it has such a neighbor that has signaled that it is willing to offer this service. RBridges indicate this in their Hellos as described below. This service is called OOMF (Overload Originated Multi-destination Frame) service.

- The multi-destination frame MUST NOT be locally distributed in native form at RB2 before tunneling to a neighbor because this would cause the frame to be delivered twice. For example, if RB2 locally distributed a multicast native frame and then tunneled it to RB5, RB2 would get a copy of the frame when RB3 transmitted it as a TRILL Data frame on the multi-access RB2-RB3-RB4 link. Since RB2 would, in general, not be able to tell that this was a frame it had tunneled for distribution, RB2 would decapsulate it and locally distribute it a second time.
- On the other hand, if there is no neighbor of RB2 offering RB2 the OOMF service, RB2 cannot tunnel the frame to a neighbor. In this case, RB2 MUST locally distribute the frame where it is Appointed Forwarder for the frame's VLAN and optionally subject to multicast pruning.

2.4.2.2. Indicating OOMF Support

An RBridge RB3 indicates its willingness to offer the OOMF service to RB2 in the TRILL Neighbor TLV in RB3's TRILL Hellos by setting a bit associated with the SNPA (Subnetwork Point of Attachment, also known as MAC address) of RB2 on the link. (See Section 11.) Overloaded RBridge RB2 can only distribute multi-destination TRILL Data frames to the campus if a neighbor of RB2 not in overload offers RB2 the OOMF service. If RB2 does not have OOMF service available to it, RB2 can still receive multi-destination frames from non-overloaded neighbors and, if RB2 should originate or ingress such a frame, it distributes it locally in native form.

2.4.2.3. Using OOMF Service

If RB2 sees this OOMF (Overload Originated Multi-destination Frame) service advertised for it by any of its neighbors on any link to which RB2 connects, it selects one such neighbor by a means beyond the scope of this document. Assuming RB2 selects RB3 to handle multi-destination frames it originates, RB2 MUST advertise in its LSP that it might use any of the distribution trees that RB3 advertises so that the RPFC will work in the rest of the campus. Thus, notwithstanding its overloaded state, RB2 MUST retain this information from RB3 LSPs, which it will receive as it is directly connected to RB3.

RB2 then encapsulates such frames as TRILL Data frames to RB3 as follows: M bit = 0, Hop Count = 2, ingress nickname = a nickname held by RB2, and, since RB2 cannot tell what distribution tree RB3 will use, egress nickname = a special nickname indicating an OOMF frame (see Section 11). RB2 then unicasts this TRILL Data frame to RB3. (Implementation of Item 4 in Section 4 below provides reasonable assurance that, notwithstanding its overloaded state, the ingress nickname used by RB2 will be unique within at least the portion of the campus that is IS-IS reachable from RB2.)

On receipt of such a frame, RB3 does the following:

- changes the Egress Nickname field to designate a distribution tree that RB3 normally uses,
- sets the M bit to one,
- changes the Hop Count to the value it would normally use if it were the ingress, and
- forwards the frame on that tree.

RB3 MAY rate limit the number of frames for which it is providing this service by discarding some such frames from RB2. The provision of even limited bandwidth for OOMFs by RB3, perhaps via the slow

path, may be important to the bootstrapping of services at RB2 or at end stations connected to RB2, such as supporting DHCP and ARP/ND (Address Resolution Protocol / Neighbor Discovery). (Everyone sometimes needs a little OOMF (pronounced "oomph") to get off the ground.)

3. Distribution Trees

Two corrections, a clarification, and two updates related to distribution trees appear in the subsections below. See also Section 2.2.

3.1. Number of Distribution Trees

In [RFC6325], Section 4.5.2, page 56, Point 2, 4th paragraph, the parenthetical "(up to the maximum of {j,k})" is incorrect [Err3052]. It should read "(up to k if j is zero or the minimum of (j, k) if j is non-zero)".

3.2. Clarification of Distribution Tree Updates

When a link-state database change causes a change in the distribution tree(s), there are several possibilities. If a tree root remains a tree root but the tree changes, then local forwarding and RPF entries for that tree should be updated as soon as practical. Similarly, if a new nickname becomes a tree root, forwarding and RPF entries for the new tree should be installed as soon as practical. However, if a nickname ceases to be a tree root and there is sufficient room in local tables, the forwarding and RPF entries for the former tree MAY be retained so that any multi-destination TRILL Data frames already in flight on that tree have a higher probability of being delivered.

3.3. Multicast Pruning Based on IP Address

The TRILL base protocol specification [RFC6325] provides for and recommends the pruning of multi-destination frame distribution trees based on the location of IP multicast routers and listeners; however, multicast listening is identified by derived MAC addresses as communicated in the Group MAC Address sub-TLV [RFC7176].

TRILL Switches MAY communicate multicast listeners and prune distribution trees based on the actual IPv4 or IPv6 multicast addresses involved. Additional Group Address sub-TLVs are provided in [RFC7176] to carry this information. A TRILL Switch that is only capable of pruning based on derived MAC address SHOULD calculate and use such derived MAC addresses from multicast listener IPv4/IPv6 address information it receives.

3.4. Numbering of Distribution Trees

Section 4.5.1 of [RFC6325] specifies that, when building distribution tree number j , node (RBridge) N that has multiple possible parents in the tree is attached to possible parent number $j \bmod p$. Trees are numbered starting with 1, but possible parents are numbered starting with 0. As a result, if there are two trees and two possible parents, in tree 1, parent 1 will be selected, and in tree 2, parent 0 will be selected.

This is changed so that the selected parent MUST be $(j-1) \bmod p$. As a result, in the case above, tree 1 will select parent 0, and tree 2 will select parent 1. This change is not backward compatible with [RFC6325]. If all RBridges in a campus do not determine distribution trees in the same way, then for most topologies, the RPFC will drop many multi-destination frames before they have been properly delivered.

3.5. Link Cost Directionality

Distribution tree construction, like other least-cost aspects of TRILL, works even if link costs are asymmetric, so the cost of the hop from RB1 to RB2 is different from the cost of the hop from RB2 to RB1. However, it is essential that all RBridges calculate the same distribution trees, and thus, all must either use the cost away from the tree root or the cost towards the tree root. As corrected in [Err3508], the text in Section 4.5.1 of [RFC6325] is incorrect. It says:

In other words, the set of potential parents for N , for the tree rooted at R , consists of those that give equally minimal cost paths from N to R and ...

but the text should say "from R to N ":

In other words, the set of potential parents for N , for the tree rooted at R , consists of those that give equally minimal cost paths from R to N and ...

4. Nickname Selection

Nickname selection is covered by Section 3.7.3 of [RFC6325]. However, the following should be noted:

1. The second sentence in the second bullet item in Section 3.7.3 of [RFC6325] on page 25 is erroneous [Err3002] and is corrected as follows:

- o The occurrence of "IS-IS ID (LAN ID)" is replaced with "priority".
- o The occurrence of "IS-IS System ID" is replaced with "seven-byte IS-IS ID (LAN ID)".

The resulting corrected sentence in [RFC6325] reads as follows:

If RB1 chooses nickname x, and RB1 discovers, through receipt of an LSP for RB2 at any later time, that RB2 has also chosen x, then the RBridge or pseudonode with the numerically higher priority keeps the nickname, or if there is a tie in priority, the RBridge with the numerically higher seven-byte IS-IS ID (LAN ID) keeps the nickname, and the other RBridge MUST select a new nickname.

2. In examining the link-state database for nickname conflicts, nicknames held by IS-IS unreachable TRILL Switches MUST be ignored, but nicknames held by IS-IS reachable TRILL Switches MUST NOT be ignored even if they are data unreachable.
3. An RBridge may need to select a new nickname, either initially because it has none or because of a conflict. When doing so, the RBridge MUST consider as available all nicknames that do not appear in its link-state database or that appear to be held by IS-IS unreachable TRILL Switches; however, it SHOULD give preference to selecting new nicknames that do not appear to be held by any TRILL Switch in the campus, reachable or unreachable, so as to minimize conflicts if IS-IS unreachable TRILL Switches later become reachable.
4. An RBridge, even after it has acquired a nickname for which there appears to be no conflicting claimant, MUST continue to monitor for conflicts with the nickname or nicknames it holds. It does so by checking in LSP PDUs it receives that should update its link-state database for the following: any occurrence of any of its nicknames held with higher priority by some other TRILL Switch that is IS-IS reachable from it. If it finds such a conflict, it MUST select a new nickname, even when in overloaded state. (It is possible to receive an LSP that should update the link-state database but does not due to overload.)
5. In the very unlikely case that an RBridge is unable to obtain a nickname because all valid RBridge nicknames (0x0001 through 0xFFBF inclusive) are in use with higher priority by IS-IS reachable TRILL Switches, it will be unable to act as an ingress, egress, or tree root but will still be able to function as a transit TRILL Switch. Although it cannot be a tree root, such an

RBridge is included in distribution trees computed for the campus unless all its neighbors are overloaded. It would not be possible to send a unicast RBridge Channel message specifically to such a TRILL Switch [RFC7178]; however, it will receive unicast Channel messages sent by a neighbor to the Any-RBridge egress nickname and will receive appropriate multi-destination Channel messages.

5. MTU (Maximum Transmission Unit)

MTU values in TRILL key off the `originatingL1LSPBufferSize` value communicated in the IS-IS `originatingLSPBufferSize` TLV [IS-IS]. The campus-wide value `Sz`, as described in Section 4.3.1 of [RFC6325], is the minimum value of `originatingL1LSPBufferSize` for the RBridges in a campus, but not less than 1470. The MTU testing mechanism and limiting LSPs to `Sz` assures that the LSPs can be flooded by IS-IS and thus that IS-IS can operate properly.

If nothing is known about the MTU of the links or the `originatingL1LSPBufferSize` of other RBridges in a campus, the `originatingL1LSPBufferSize` for an RBridge should default to the minimum of the LSP size that its TRILL IS-IS software can handle and the minimum MTU of the ports that it might use to receive or transmit LSPs. If an RBridge does have knowledge of link MTUs or other RBridge `originatingL1LSPBufferSize`, then, to avoid the necessity to regenerate the local LSPs using a different maximum size, the RBridge's `originatingL1LSPBufferSize` SHOULD be configured to the minimum of (1) the smallest value that other RBridges are or will be announcing as their `originatingL1LSPBufferSize` and (2) a value small enough that the campus will not partition due to a significant number of links with limited MTU. However, as provided in [RFC6325], in no case can `originatingL1LSPBufferSize` be less than 1470. In a well-configured campus, to minimize any LSP regeneration due to re-sizing, it is desirable for all RBridges to be configured with the same `originatingL1LSPBufferSize`.

Section 5.1 below corrects errata in [RFC6325], and Section 5.2 clarifies the meaning of various MTU limits for TRILL Ethernet links.

5.1. MTU-Related Errata in RFC 6325

Three MTU-related errata in [RFC6325] are corrected in the subsections below.

5.1.1. MTU PDU Addressing

Section 4.3.2 of [RFC6325] incorrectly states that multi-destination MTU-probe and MTU-ack TRILL IS-IS PDUs are sent on Ethernet links with the All-RBridges multicast address as the Outer.MacDA [Err3004]. As TRILL IS-IS PDUs, when multicast on an Ethernet link, they MUST be sent to the All-IS-IS-RBridges multicast address.

5.1.2. MTU PDU Processing

As discussed in [RFC6325] and, in more detail, in [RFC6327], MTU-probe and MTU-ack PDUs MAY be unicast; however, Section 4.6 of [RFC6325] erroneously does not allow for this possibility [Err3003]. It is corrected by replacing Item numbered "1" in Section 4.6.2 of [RFC6325] with the following quoted text to which TRILL Switches MUST conform:

- "1. If the Ethertype is L2-IS-IS and the Outer.MacDA is either All-IS-IS-RBridges or the unicast MAC address of the receiving RBridge port, the frame is handled as described in Section 4.6.2.1"

The reference to "Section 4.6.2.1" in the above quoted text is to that section in [RFC6325].

5.1.3. MTU Testing

The last two sentences of Section 4.3.2 of [RFC6325] have errors [Err3053]. They currently read:

If X is not greater than Sz, then RB1 sets the "failed minimum MTU test" flag for RB2 in RB1's Hello. If size X succeeds, and X > Sz, then RB1 advertises the largest tested X for each adjacency in the TRILL Hellos RB1 sends on that link, and RB1 MAY advertise X as an attribute of the link to RB2 in RB1's LSP.

They should read:

If X is not greater than or equal to Sz, then RB1 sets the "failed minimum MTU test" flag for RB2 in RB1's Hello. If size X succeeds, and X >= Sz, then RB1 advertises the largest tested X for each adjacency in the TRILL Hellos RB1 sends on that link, and RB1 MAY advertise X as an attribute of the link to RB2 in RB1's LSP.

5.2. Ethernet MTU Values

originatingLlLSPBufferSize is the maximum permitted size of LSPs starting with the 0x83 Intradomain Routing Protocol Discriminator byte. In Layer 3 IS-IS, originatingLlLSPBufferSize defaults to 1492 bytes. (This is because, in its previous life as DECnet Phase V, IS-IS was encoded using the SNAP SAP (Subnetwork Access Protocol Service Access Point) [RFC7042] format, which takes 8 bytes of overhead and $1492 + 8 = 1500$, the classic Ethernet maximum. When standardized by ISO/IEC [IS-IS] to use Logical Link Control (LLC) encoding, this default could have been increased by a few bytes but was not.)

In TRILL, originatingLlLSPBufferSize defaults to 1470 bytes. This allows 27 bytes of headroom or safety margin to accommodate legacy devices with the classic Ethernet maximum MTU despite headers such as an Outer.VLAN.

Assuming the campus-wide minimum link MTU is Sz, RBridges on Ethernet links MUST limit most TRILL IS-IS PDUs so that PDUz (the length of the PDU starting just after the L2-IS-IS Ethertype and ending just before the Ethernet Frame Check Sequence (FCS)) does not to exceed Sz. The PDU exceptions are TRILL Hello PDUs, which MUST NOT exceed 1470 bytes, and MTU-probe and MTU-ack PDUs that are padded, depending on the size being tested (which may exceed Sz).

Sz does not limit TRILL Data frames. They are only limited by the MTU of the devices and links that they actually pass through; however, links that can accommodate IS-IS PDUs up to Sz would accommodate, with a generous safety margin, TRILL Data frame payloads of (Sz - 24) bytes, starting after the Inner.VLAN and ending just before the FCS. Most modern Ethernet equipment has ample headroom for frames with extensive headers and is sometimes engineered to accommodate 9K byte jumbo frames.

6. Port Modes

Section 4.9.1 of [RFC6325] specifies four mode bits for RBridge ports but may not be completely clear on the effects of various combinations of bits.

The table below explicitly indicates the effect of all possible combinations of the TRILL port mode bits. "*" in one of the first four columns indicates that the bit can be either zero or one. The following columns indicate allowed frame types. The Disable bit normally disables all frames, but, as an implementation choice, some or all low-level Layer 2 control frames (as specified in [RFC6325], Section 1.4) can still be sent or received.

D	A	T			TRILL		
i	c	r			Data		
s	c	r					
a	c	r					
b	P	e	u	native	LSP		
l	2	s	n	ingress	SNP	TRILL	P2P
e	P	s	k	egress	MTU	Hello	Hello
				Layer 2 Control			
0	0	0	0	Yes	Yes	Yes	No
0	0	0	1	Yes	No	Yes	No
0	0	1	0	Yes	Yes	No	No
0	0	1	1	Yes	No	No	No
0	1	0	*	Yes	No	Yes	Yes
0	1	1	*	Yes	No	No	Yes
1	*	*	*	Optional	No	No	No

(The formal name of the "access bit" is the "TRILL traffic disable bit", and the formal name of the "trunk bit" is the "end-station service disable bit" [RFC6325].)

7. The CFI/DEI Bit

In May 2011, the IEEE promulgated [802.1Q-2011], which changes the meaning of the bit between the priority and VLAN ID bits in the payload of C-VLAN tags. Previously, this bit was called the CFI (Canonical Format Indicator) bit [802] and had a special meaning in connection with IEEE 802.5 (Token Ring) frames. Now, under [802.1Q-2011], it is a DEI (Drop Eligibility Indicator) bit, similar to that bit in S-VLAN/B-VLAN tags where this bit has always been a DEI bit.

The TRILL base protocol specification [RFC6325] assumed, in effect, that the link by which end stations are connected to TRILL Switches and the restricted virtual link provided by the TRILL Data frame are IEEE 802.3 Ethernet links on which the CFI bit is always zero. Should an end station be attached by some other type of link, such as a Token Ring link, [RFC6325] implicitly assumed that such frames would be canonicalized to 802.3 frames before being ingressed, and similarly, on egress, such frames would be converted from 802.3 to the appropriate frame type for the link. Thus, [RFC6325] required

that the CFI bit in the Inner.VLAN, which is shown as the "C" bit in Section 4.1.1 of [RFC6325], always be zero.

However, for TRILL Switches with ports conforming to the change incorporated in the IEEE 802.1Q-2011 standard, the bit in the Inner.VLAN, now a DEI bit, MUST be set to the DEI value provided by the EISS (Enhanced Internal Sublayer Service) interface on ingressing a native frame. Similarly, this bit MUST be provided to the EISS when transiting or egressing a TRILL Data frame. As with the 3-bit Priority field, the DEI bit to use in forwarding a transit frame MUST be taken from the Inner.VLAN. The exact effect on the Outer.VLAN DEI and priority bits and whether or not an Outer.VLAN appears at all on the wire for output frames may depend on output port configuration.

TRILL campuses with a mixture of ports, some compliant with [802.1Q-2011] and some compliant with pre-802.1Q-2011 standards, especially if they have actual Token Ring links, may operate incorrectly and may corrupt data, just as a bridged LAN with such mixed ports and links would.

8. Graceful Restart

TRILL Switches SHOULD support the features specified in [RFC5306], which describes a mechanism for a restarting IS-IS router to signal to its neighbors that it is restarting, allowing them to reestablish their adjacencies without cycling through the down state, while still correctly initiating link-state database synchronization.

9. Updates to RFC 6327

[RFC6327] provides for multiple states of the potential adjacency between two TRILL Switches. It makes clear that only an adjacency in the "Report" state is reported in LSPs. LSP synchronization (LSP and Subnetwork Point (SNP) transmission and receipt), however, is performed if and only if there is at least one adjacency on the link in either the "2-Way" or "Report" state.

To support the PORT-TRILL-VER sub-TLV specified in [RFC7176], the following updates are made to [RFC6327]:

1. The first sentence of the last paragraph in [RFC6327] Section 3.1 is modified from

All TRILL LAN Hellos issued by an RBridge on a particular port MUST have the same source MAC address, priority, desired Designated VLAN, and Port ID, regardless of the VLAN in which the Hello is sent.

to

All TRILL LAN Hellos issued by an RBridge on a particular port MUST have the same source MAC address, priority, desired Designated VLAN, Port ID, and PORT-TRILL-VER sub-TLV [RFC7176] if included, regardless of the VLAN in which the Hello is sent.

2. An additional bullet item is added to the end of Section 3.2 of [RFC6327] as follows:
 - o The five bytes of PORT-TRILL-VER sub-TLV data received in the most recent TRILL Hello from the neighbor RBridge.
 3. In Section 3.3 of [RFC6327], near the bottom of page 12, a bullet item as follows is added:
 - o The five bytes of PORT-TRILL-VER sub-TLV data are set from that sub-TLV in the Hello or set to zero if that sub-TLV does not occur in the Hello.
 4. At the beginning of Section 4 of [RFC6327], a bullet item is added to the list as follows:
 - o The five bytes of PORT-TRILL-VER sub-TLV data used in TRILL Hellos sent on the port.
10. Updates on Appointed Forwarders and Inhibition

An optional method of Hello reduction is specified in Section 10.1 below and a recommendation on forwarder appointments in the face of overload is given in Section 10.2.

10.1. Optional TRILL Hello Reduction

If a network manager has sufficient confidence that it knows the configuration of bridges, ports, and the like, within a link, it may be able to reduce the number of TRILL Hellos sent on that link; for example, if all RBridges on the link will see all Hellos regardless of VLAN constraints, Hellos could be sent on fewer VLANs. However, because adjacencies are established in the Designated VLAN, an RBridge MUST always attempt to send Hellos in the Designated VLAN. Hello reduction makes TRILL less robust in the face of decreased VLAN connectivity in a link such as partitioned VLANs, many VLANs disabled on ports, or disagreement over the Designated VLAN; however, as long as all RBridge ports on the link are configured for the same desired Designated VLAN, can see each other's frames in that VLAN, and utilize the mechanisms specified below to update VLAN inhibition

timers, operations will be safe. (These considerations do not arise on links between RBridges that are configured as point-to-point since, in that case, each RBridge sends point-to-point Hellos, other TRILL IS-IS PDUs, and TRILL Data frames only in what it believes to be the Designated VLAN of the link and no native frame end-station service is provided.)

The provision for a configurable set of "Announcing VLANs", as described in Section 4.4.3 of [RFC6325], provides a mechanism in the TRILL base protocol for a reduction in TRILL Hellos.

To maintain loop safety in the face of occasional lost frames, RBridge failures, link failures, new RBridges coming up on a link, and the like, the inhibition mechanism specified in [RFC6439] is still required. Under Section 3 of [RFC6439], a VLAN inhibition timer can only be set by the receipt of a Hello sent or received in that VLAN. Thus, to safely send a reduced number of TRILL Hellos on a reduced number of VLANs requires additional mechanisms to set the VLAN inhibition timers at an RBridge, thus extending Section 3, Item 4, of [RFC6439]. Two such mechanisms are specified below. Support for both of these mechanisms is indicated by a capability bit in the PORT-TRILL-VER sub-TLV (see Section 9 above and [RFC7176]). It may be unsafe for an RBridge to send TRILL Hellos on fewer VLANs than the set of VLANs recommended in [RFC6325] on a link unless all its adjacencies on that link (excluding those in the Down state [RFC6327]) indicate support of these mechanisms and these mechanisms are in use.

1. An RBridge RB2 MAY include in any TRILL Hello an Appointed Forwarders sub-TLV [RFC7176] appointing itself for one or more ranges of VLANs. The Appointee Nickname field(s) in the Appointed Forwarder sub-TLV MUST be the same as the Sender Nickname in the Special VLANs and Flags sub-TLV in the TRILL Hello. This indicates the sending RBridge believes it is Appointed Forwarder for those VLANs. An RBridge receiving such a sub-TLV sets each of its VLAN inhibition timers for every VLAN in the block or blocks listed in the Appointed Forwarders sub-TLV to the maximum of its current value and the Holding Time of the Hello containing the sub-TLV. This is backward compatible because such sub-TLVs will have no effect on any receiving RBridge not implementing this mechanism unless RB2 is the DRB (Designated RBridge) sending Hello on the Designated VLAN, in which case, as specified in [RFC6439], RB2 MUST include in the Hello all forwarder appointments, if any, for RBridges other than itself on the link.

2. An RBridge MAY use the new VLANs Appointed sub-TLV [RFC7176]. When RB1 receives a VLANs Appointed sub-TLV in a TRILL Hello from RB2 on any VLAN, RB1 updates the VLAN inhibition timers for all the VLANs that RB2 lists in that sub-TLV as VLANs for which RB2 is Appointed Forwarder. Each such timer is updated to the maximum of its current value and the Holding Time of the TRILL Hello containing the VLANs Appointed sub-TLV. This sub-TLV will be an unknown sub-TLV to RBridges not implementing it, and such RBridges will ignore it. Even if a TRILL Hello sent by the DRB on the Designated VLAN includes one or more VLANs Appointed sub-TLVs, as long as no Appointed Forwarders sub-TLVs appear, the Hello is not required to indicate all forwarder appointments.

Two different encodings are provided above to optimize the listing of VLANs. Large blocks of contiguous VLANs are more efficiently encoded with the Appointed Forwarders sub-TLV, and scattered VLANs are more efficiently encoded with the VLANs Appointed sub-TLV. These encodings may be mixed in the same Hello. The use of these sub-TLVs does not affect the requirement that the "AF" bit in the Special VLANs and Flags sub-TLV MUST be set if the originating RBridge believes it is Appointed Forwarder for the VLAN in which the Hello is sent. If the above mechanisms are used on a link, then each RBridge on the link MUST send Hellos in one or more VLANs with such VLANs Appointed sub-TLV(s) and/or self-appointment Appointed Forwarders sub-TLV(s), and the "AF" bit MUST be appropriately set such that no VLAN inhibition timer will improperly expire unless three or more Hellos are lost. For example, an RBridge could announce all VLANs for which it believes it is Appointed Forwarder in a Hello sent on the Designated VLAN three times per Holding Time.

10.2. Overload and Appointed Forwarders

An RBridge in overload (see Section 2) will, in general, do a poorer job of ingress and forwarding frames than an RBridge not in overload that has full knowledge of the campus topology. For example, an overloaded RBridge may not be able to distribute multi-destination TRILL Data frames at all.

Therefore, the DRB SHOULD NOT appoint an RBridge in overload as an Appointed Forwarder unless there is no alternative. Furthermore, if an Appointed Forwarder becomes overloaded, the DRB SHOULD re-assign VLANs from the overloaded RBridge to another RBridge on the link that is not overloaded, if one is available. DRB election is not affected by overload.

A counter-example would be if all campus end stations in VLAN-x were on links attached to RB1 via ports where VLAN-x was enabled. In such a case, RB1 SHOULD be made the VLAN-x Appointed Forwarder on all such links even if RB1 is overloaded.

11. IANA Considerations

The following IANA actions have been completed.

1. The nickname 0xFFC1, which was reserved by [RFC6325], is allocated for use in the TRILL Header Egress Nickname field to indicate an OOMF (Overload Originated Multi-destination Frame).
2. Bit 1 from the seven previously reserved (RESV) bits in the per-neighbor "Neighbor RECORD" in the TRILL Neighbor TLV [RFC7176] is allocated to indicate that the RBridge sending the TRILL Hello volunteers to provide the OOMF forwarding service described in Section 2.4.2 to such frames originated by the TRILL Switch whose SNPA (MAC address) appears in that Neighbor RECORD. The description of this bit is "Offering OOMF service".
3. Bit 0 is allocated from the Capability bits in the PORT-TRILL-VER sub-TLV [RFC7176] to indicate support of the VLANs Appointed sub-TLV [RFC7176] and the VLAN inhibition setting mechanisms specified in Section 10.1. The description of this bit is "Hello reduction support".

12. Security Considerations

This memo improves the documentation of the TRILL protocol, corrects five errata in [RFC6325], and updates [RFC6325], [RFC6327], and [RFC6439]. It does not change the security considerations of these RFCs.

13. Acknowledgements

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