TRILL OAM Framework
draft-salam-trill-oam-framework-01

Abstract

   This document specifies a reference framework for Operations,
   Administration and Maintenance (OAM) in TRILL networks. The focus of
   the document is on the fault and performance management aspects of
   TRILL OAM.

Status of this Memo

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1. Introduction

This document specifies a reference framework for Operations, Administration and Maintenance (OAM) in TRILL networks.

TRILL [RFC6325] defines a solution for shortest-path frame routing in multi-hop Ethernet networks with arbitrary topologies, using the IS-IS routing protocol. TRILL capable devices are referred to as Routing Bridges or RBridges. RBridges provide an optimized and transparent Layer 2 delivery service for Ethernet unicast and multicast traffic. The characteristics of a TRILL network are such that it differs from Ethernet in the following aspects:

- TRILL networks do not enforce congruency of unicast and multicast paths between a given pair of RBridges.

- TRILL networks do not impose symmetry of the forward and reverse paths between a given pair of RBridges.

- TRILL supports multipathing of unicast as well as multicast traffic.

In this document, we refer to the term OAM as defined in [RFC6291]. The Operations aspect involves finding problems that prevent proper functioning of the network. It also includes monitoring of the network to identify potential problems before they occur. Administration involves keeping track of network resources. Maintenance activities are focused on facilitating repairs and upgrades as well as corrective and preventive measures. [ISO/IEC 7498-4] defines 5 functional areas in the OSI model for network management, commonly referred to as FCAPS:

-Fault Management
-Configuration Management
-Accounting Management
-Performance Management
-Security Management

The focus of this document is on the first two functional aspects, namely: Fault Management and Performance Management in the context of TRILL networks. These primarily map to the "Operations" and "Maintenance" part of OAM.

The draft provides a generic framework for a comprehensive solution that meets the requirements outlined in [TRILL-OAM-REQ]. However, specific mechanisms to address these requirements are considered to be outside the scope of this document.

1.1 Terminology

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 RFC 2119 [RFC2119].

1.2 Relationship to Other OAM Work

OAM is a technology area where a wealth of prior art exists. This
document leverages concepts and draws upon elements defined and/or
used in the following documents:

[TRILL-OAM-REQ] defines the requirements for TRILL OAM which serve as
the basis for this framework.

[802.1ag] specifies the Connectivity Fault Management protocol, which
defines the concepts of Maintenance Domains, Maintenance End Points,
and Maintenance Intermediate Points.

[Y.1731] extends IEEE 802.1ag in the following areas: it defines
fault notification and alarm suppression functions for Ethernet. It
also specifies mechanisms for Ethernet performance management,
including loss, delay, jitter, and throughput measurement.

[RFC6136] specifies a reference model for OAM as it relates to L2VPN
services, pseudowires and associated Public Switched Network (PSN)
tunnels. The document also specifies OAM requirements for L2VPN
services.

[RFC6371] describes a framework to support a comprehensive set of OAM
procedures that fulfill the MPLS-TP OAM requirements for fault,
performance, and protection-switching management and that do not rely
on the presence of a control plane.

[TRILL-BFD] defines a TRILL encapsulation for BFD that enables the
use of the latter for network fast convergence.

2. TRILL OAM Model

2.1 OAM Layering

In the RBridge architecture, the TRILL layer is independent of the
underlying Link Layer technology. Therefore, it is possible to run
TRILL over any transport layer capable of carrying Layer 2 frames
such as Ethernet, PPP, or MPLS. Furthermore, TRILL provides a virtual
Ethernet connectivity service that is transparent to higher layer
entities (e.g. Layer 3 and above). This strict layering is observed
by TRILL OAM.

Of particular interest is the layering of TRILL OAM with respect to:
- BFD, which is typically used for fast convergence
- Ethernet CFM [802.1ag], especially that TRILL switches are likely
to be deployed alongside existing 802.1 bridges in a network.

- Link OAM, which is media specific.

Consider the example network depicted in Figure 1 below, where a
TRILL network is interconnected via Ethernet links:
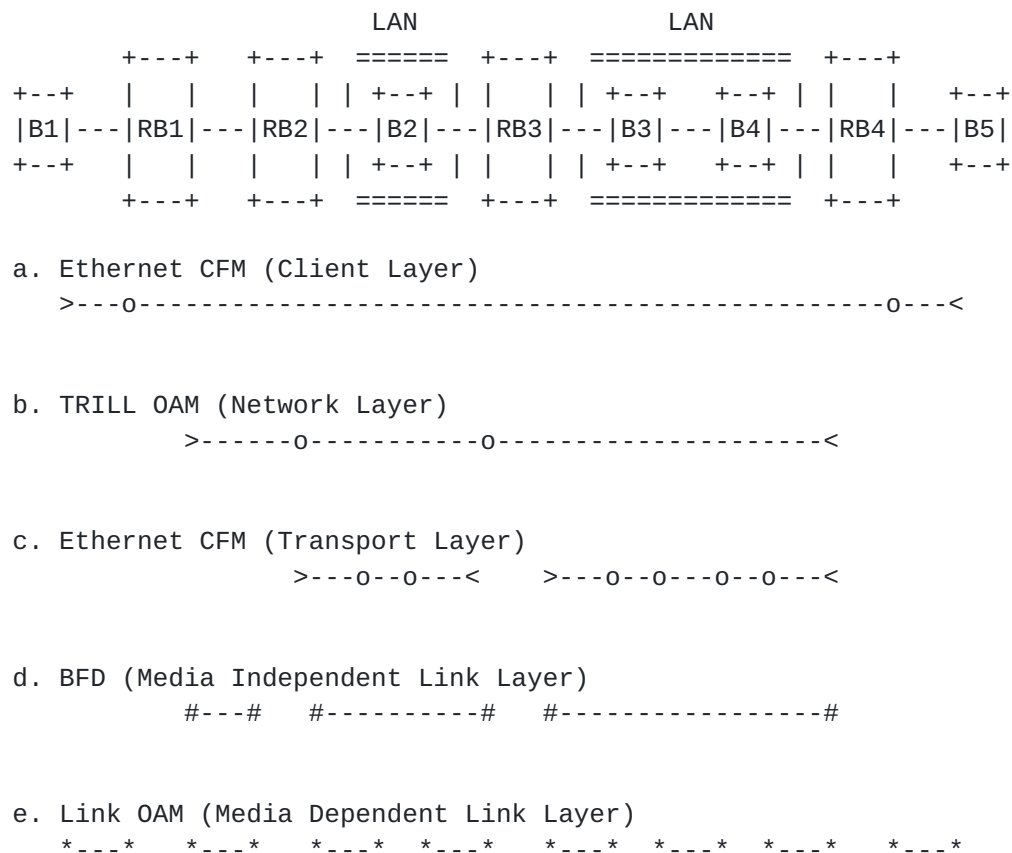
```
                         LAN                LAN
          +---+    +---+  ======  +---+  ============  +---+
 +--+     |   |    |   |  | +--+ | |   |  | | +--+   +--+ | |    |     +--+
 |B1|---|RB1|---|RB2|---|B2|---|RB3|---|B3|---|B4|---|RB4|---|B5|
 +--+     |   |    |   |  | +--+ | |   |  | | +--+   +--+ | |    |     +--+
          +---+    +---+  ======  +---+  ============  +---+


  a. Ethernet CFM (Client Layer)
     >---o-------------------------------------------------o---<



  b. TRILL OAM (Network Layer)
             >------o-----------o---------------------<



  c. Ethernet CFM (Transport Layer)
                   >---o--o---<     >---o--o---o--o---<



  d. BFD (Media Independent Link Layer)
             #---#   #----------#   #-----------------#



  e. Link OAM (Media Dependent Link Layer)
     *---*    *---*    *---*  *---*   *---*  *---*  *---*   *---*


   Legend:  > MEP    o MIP     # BFD Endpoint    * Link OAM Endpoint
```

Figure 1: OAM Layering in TRILL

Where Bn and RBn (n= 1,2,3,4) denote IEEE 802.1 bridges and TRILL
RBridges, respectively.

2.1.1 Relationship to CFM

In the context of a TRILL network, CFM can be used as either a client
layer OAM or a transport layer OAM mechanism.

When acting as a client layer OAM (see Figure 1a), CFM provides fault management capabilities for the user VLAN (or fine-grain label), on an end-to-end basis over the TRILL network. Edge ports of the TRILL network may be visible to CFM operations through the presence of a CFM Maintenance Intermediate Point (MIP).

When acting as a transport layer OAM (see Figure 1c), CFM provides fault management functions for the IEEE 802.1 Ethernet bridged networks that may interconnect RBridges. RBridges directly connected to the intervening 802.1 bridges may host CFM Down Maintenance End Points (MEPs).

2.1.2 Relationship to BFD and Link OAM

One-hop BFD (see Figure 1d) runs between adjacent RBridges and provides fast link as well as node failure detection capability. Note that BFD sits a layer above Link OAM, which is media specific. BFD provides fast convergence characteristics to TRILL networks.

Link OAM (see Figure 1e) depends on the nature of the physical medium used in the links interconnecting RBridges. For e.g., for Ethernet links, [802.3] Clause 57 OAM may be used.

2.2 TRILL OAM in RBridge Port Model

TRILL OAM processing can be modeled as shim situated between the Extended Internal Sublayer Service (EISS) in [802.1Q] and the RBridge Forwarding Engine function, on a virtual port with no physical layer (Null PHY). TRILL OAM requires services of the RBridge forwarding engine and utilizes information from the IS-IS control plane. Figure 2 below depicts TRILL OAM processing in the context of the RBridge port model defined in [RFC6325]. In this figure, double lines represent flow of both frames and information whereas single lines represent flow of information only.

While this figure shows a conceptual model, it is to be understood that implementations need not mirror this exact model as long as the intended OAM requirements and functionality are preserved.

```
       +-------------------------------------------------+----
       |            RBridge              (Flow of OAM Messages)
       |                            +-------------+
       |    Forwarding Engine,       |            |
       |     IS-IS, Etc.             |            |
       |     Processing of native    |            |
       |      and TRILL frames       V            V
       +-----------------------------|-------------+-----
                                     ||         other ports...
                         +-----------+
                         | TRILL OAM |
                         | Processing |
                         |           |
                         +-----------+    <- EISS
                         |           |
                         |   802.1Q  |
                         | Port VLAN |
                         | Processing |
                         |           |
       +---------------------------+-----------+--+ <-- ISS
       |                                          |
       |    802.1/802.3 Low Level Control Frame   |
       |    Processing, Port/Link Control Logic   |
       |                                          |
       +----------++------------------------------+
              ||
              ||        +------------+
              ||        | NULL PHY   |
              |+--------+ (Virtual   |
              +---------+ Interface) |
                        |           |
                        +------------+
```
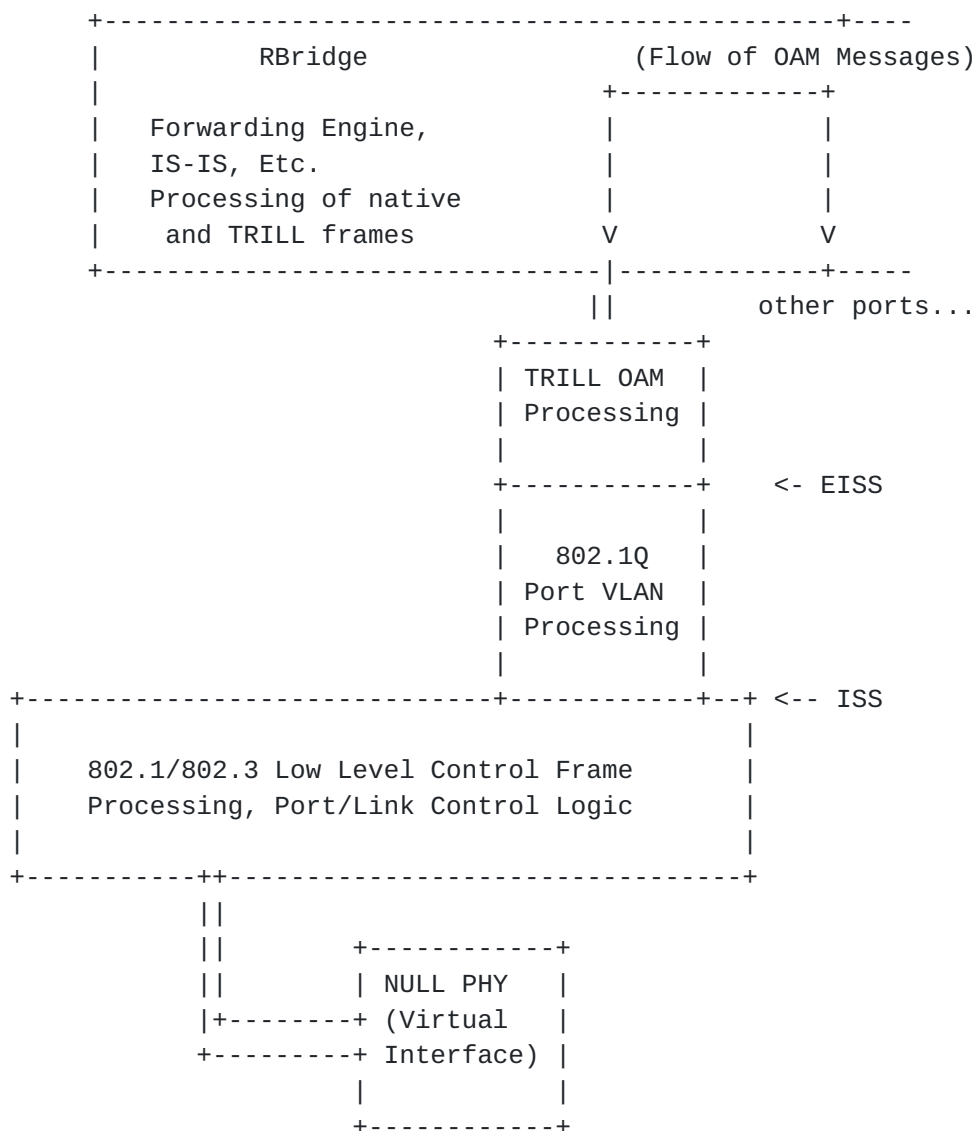
Figure 2: TRILL OAM in RBridge Port Model

   Note that there is a single virtual interface which hosts the TRILL
   OAM shim per RBridge. The rationale for this model is discussed in
   section 2.6 "MEPs and MIPs".

2.3 Network, Service and Flow OAM

   OAM functions in a TRILL network can be conducted at different levels
   of granularity. This gives rise to 'Network', 'Service' and 'Flow'
   OAM, listed in order of increasing granularity.

   Network OAM mechanisms provide fault and performance management
   functions in the context of a representative 'test' VLAN (or fine
   grain label). The test VLAN can be thought of as a management or

diagnostics VLAN which extends to all RBridges in a TRILL network. In
order to account for multipathing, Network OAM functions also make
use of test flows (both unicast and multicast) to provide coverage of
the various paths in the network.

Service OAM mechanisms provide fault and performance management
functions in the context of the actual VLAN (or fine grain label) set
for which end station service is enabled. Test flows are used here,
as well, to provide coverage in the case of multipathing.

Flow OAM mechanisms provide the most granular fault and performance
management capabilities, where OAM functions are performed in the
context of end station service VLANs (or fine grain labels) and user
flows. While Flow OAM provides the most granular control, it clearly
poses scalability challenges if attempted on large numbers of flows.

2.4 Maintenance Domains

The concept of Maintenance Domains, or OAM Domains, is well known in
the industry. IEEE 802.1ag, RFC6136, RFC5654, etc... all define the
notion of a Maintenance Domain as a collection of devices (e.g.
network elements) that are grouped for administrative and/or
management purposes. Maintenance domains usually delineate trust
relationships, varying addressing schemes, network infrastructure
capabilities, etc...

When mapped to TRILL, a Maintenance Domain is defined as a collection
of RBridges in a network for which faults in connectivity or
performance are to be managed by a single operator. All RBridges in a
given Maintenance Domain are, by definition, owned and operated by a
single entity (e.g. an enterprise or a data center operator, etc...).
RFC6325 defines the operation of TRILL in a single IS-IS area, with
the assumption that the network is managed by a single operator. In
this context, a single (default) Maintenance Domain is sufficient for
TRILL OAM.

However, when considering scenarios where different TRILL networks
need to be interconnected, for e.g. as discussed in [TRILLML], then
the introduction of multiple Maintenance Domains and Maintenance
Domain hierarchies becomes useful to map and contain administrative
boundaries. When considering multi-domain scenarios, the following
rules must be followed: TRILL OAM domains MUST NOT overlap, but MUST
either be disjoint or nest to form a hierarchy (i.e. a higher
Maintenance Domain MAY completely engulf a lower Domain). A
Maintenance Domain is typically identified by a Domain Name and a
Maintenance Level (a numeric identifier). The larger the Domain, the
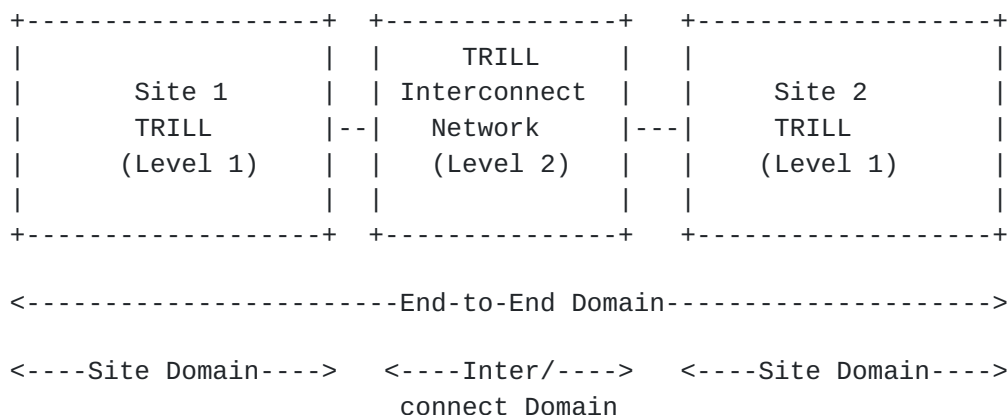higher the Level.

```
      +------------------+  +--------------+  +------------------+
      |                  |  |    TRILL     |  |                  |
      |      Site 1      |  | Interconnect |  |     Site 2       |
      |      TRILL       |--|   Network    |---|     TRILL        |
      |    (Level 1)     |  |   (Level 2)  |  |   (Level 1)      |
      |                  |  |              |  |                  |
      +------------------+  +--------------+  +------------------+

      <----------------------End-to-End Domain-------------------->

      <----Site Domain----->  <----Inter/---->   <----Site Domain---->
                              connect Domain
```

Figure 3: TRILL OAM Maintenance Domains

2.5 Maintenance Entity and Maintenance Entity Group

TRILL OAM functions are performed in the context of logical endpoint
pairs referred to as Maintenance Entities (ME). A Maintenance Entity
defines a relationship between two points in a TRILL network where
OAM functions (e.g. monitoring operations) are applied. The two
points which define a Maintenance Entity are known as Maintenance End
Points (MEPs) - see section 2.6 below. The set of Maintenance
Entities that belong to the same Maintenance Domain are referred to
as a Maintenance Entity Group (MEG). On the network path in between
MEPs, there can be zero or more intermediate points, called
Maintenance Intermediate Points (MIPs). MEPs and MIPs are associated
with the MEG and can be part of more than one ME in a given MEG.

2.6 MEPs and MIPs

OAM capabilities on RBridges can be defined in terms of logical
groupings of functions that can be categorized into two functional
objects: Maintenance End Points (MEPs) and Maintenance Intermediate
Points (MIPs). The two are collectively referred to as Maintenance
Points (MPs).

MEPs are the active components of TRILL OAM: MEPs source TRILL OAM
messages proactively or on-demand based on operator invocation.
Furthermore, MEPs ensure that TRILL OAM messages do not leak outside
a given Maintenance Domain, e.g. out of the TRILL network and into
end stations. MIPs, on the other hand, are internal to a Maintenance
Domain. They are the passive components of TRILL OAM, primarily
responsible for forwarding TRILL OAM messages and selectively
responding to a subset of these messages.

The following figure shows the MEP and MIP placement for the
Maintenance Domains depicted in Figure 3 above.

```
       TRILL Site 1              Interconnect              TRILL Site 2
     +------------------+  +--------------+   +------------------+
     |                  |  |              |   |                  |
     | +---+     +---+  |  | +---+   +---+ |   | +---+     +---+  |
     | |RB1|-------|RB2| |--|  |RB3|   |RB4| |---| |RB5|-------|RB6| |
     | +---+     +---+  |  | +---+   +---+ |   | +---+     +---+  |
     |                  |  |              |   |                  |
     +------------------+  +--------------+   +------------------+


        <E--------I------------I-----I--------------I--------E>

        <E--------E>            <E-----E>            <E--------E>



        Legend E: MEP      I: MIP
```
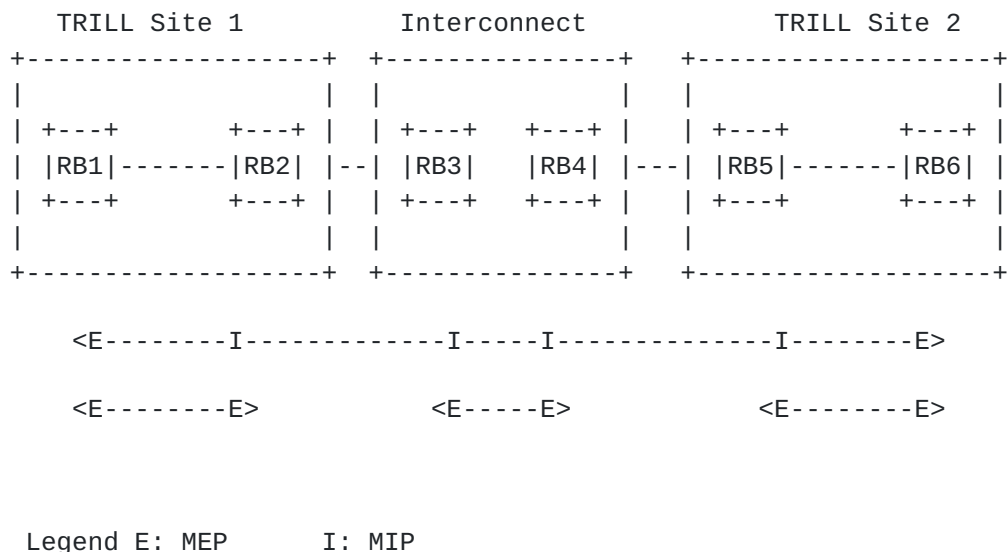
Figure 4: MEPs and MIPs

It is worth noting that a single RBridge port may host multiple MEPs
of different technologies, e.g. TRILL OAM MEP(s) and [802.1ag]
MEP(s). This does not mean that the protocol operation is necessarily
consolidated into a single functional entity on those ports. The
protocol functions for each MEP remain independent and reside in
different shims in the RBridge Port model of figure 2: the TRILL OAM
MEP resides in the "TRILL OAM Processing" block whereas a CFM MEP
resides in the "802.1Q Port VLAN Processing" block.

The model of section 2.2 implies that a single MEP and/or MIP per MEG
can be instantiated per RBridge. This simplifies implementations and
enables TRILL OAM to perform management functions on sections, as
specified in [TRILL-OAM-REQ], while maintaining the simplicity of a
single TRILL OAM Maintenance Domain. Furthermore, [RFC6325] defines
identification of TRILL frames received from the wire only. It does
not define methods to identify frames egress to the wire. Due to this
reason, we do not distinguish between Up MPs and Down MPs (as defined
in [802.1ag]) in this framework. Given that the MPs always reside on
a special virtual port with no PHY layer, MP directionality is
irrelevant.

2.7 Maintenance Point Addressing

TRILL OAM functions must provide the capability to address a specific
Maintenance Point or a set of one or more Maintenance Points in a
MEG. To that end, RBridges need to recognize two sets of addresses:

- Individual MP addresses

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- Group MP Addresses

TRILL OAM must support the Shared MP address model, where all MPs on
an RBridge share the same Individual MP address. In other words,
TRILL OAM messages can be addressed to a specific RBridge but not to
a specific port on an RBridge.

One cannot discern, from observing the external behavior of an
RBridge, whether TRILL OAM messages are actually delivered to a
certain MP or another entity within the RBridge. The Shared MP
address model takes advantage of this fact by allowing MPs in
different RBridge ports to share the same Individual MP address. The
MPs may still reside on different RBridge ports and for the most
part, they have distinct identities.

The Group MP addresses enable the OAM mechanism to reach all the MPs
in a given MEG. Certain OAM functions, e.g. pruned tree verification,
require addressing a subset of the MPs in a MEG. Group MP addresses
are not defined for such subsets. Rather, the OAM function in
question must use the Group MP addresses combined with an indication
of the scope of the MP subset encoded in the OAM Message Channel.
This prevents the unwieldy proliferation of Group MP addresses.

3. OAM Frame Format

3.1 Motivation

In order for TRILL OAM messages to accurately test the data-path, the
OAM message must be indiscernible from a data message to the
transient RBridges. Only the target RBridge, which needs to process
the message, must be able to identify the packet as a control
message. For this reason, the Outer Header and the TRILL Header must
carry no indication that distinguishes an OAM message from user data.

The TRILL OAM frame format proposed in [TRILL-OAM-REQ] provides the
necessary flexibility to exercise the data path as close as possible
to actual data packets. This frame format is captured below for quick
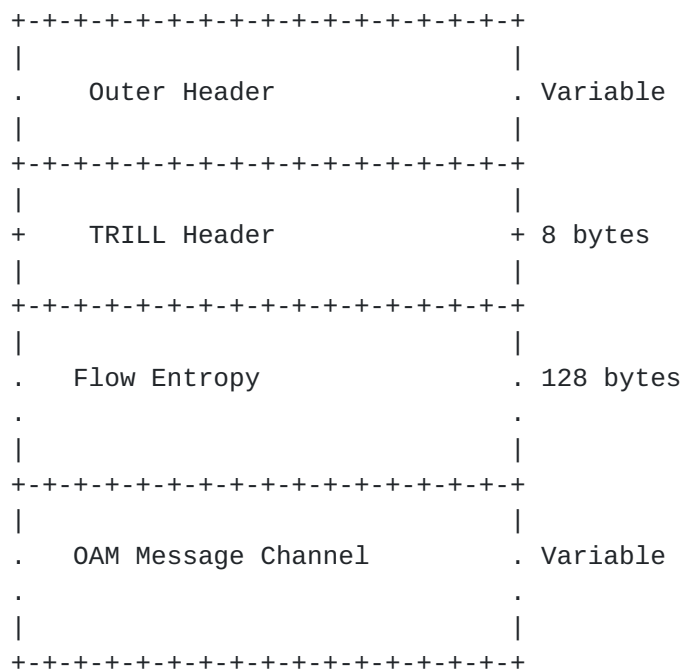reference:

```
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             |
   .     Outer Header           . Variable
   |                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             |
   +     TRILL Header            + 8 bytes
   |                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             |
   .   Flow Entropy             . 128 bytes
   .                             .
   |                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             |
   .   OAM Message Channel      . Variable
   .                             .
   |                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5 Frame format of OAM Messages

The Outer Header and TRILL Header are as specified in [RFC6325] and
need to be as close as possible to the Outer Header and TRILL Header
of the normal data frame corresponding to the traffic that OAM is
testing.

3.2 Determination of Flow Entropy

The Flow Entropy is a fixed 128 byte field that is populated with
either real packet data or synthetic data that mimics the intended
flow.

For a Layer 2 flow (i.e. non-IP) the Flow Entropy must specify the
Ethernet header, including the MAC destination and source addresses
as well as an optional VLAN tag.

For a Layer 3 flow, the Flow Entropy must specify the Ethernet
header, the IP header and UDP or TCP header fields.

Not all fields in the Flow Entropy field need to be identical to the
data flow that the OAM message is mimicking. The only requirement is
for the selected flow entropy to follow the same path as the data
flow that it is mimicking. In other words, the selected flow entropy
must result in the same ECMP selection or multicast pruning behavior
or other applicable forwarding paradigm.

When performing diagnostics on user flows, the OAM mechanisms must
allow the network operator to configure the flow entropy parameters
(L2, L3 and L4) on the RBridge from which the diagnostic operations
are to be triggered.

When running OAM functions over Test Flows, the TRILL OAM should
provide a mechanism for discovering the flow entropy parameters by
querying the RBridges dynamically.

3.2.1 Address Learning and Flow Entropy

TRILL RBridges, like traditional 802.1 bridges, are required to learn
MAC address associations. Learning is accomplished either by snooping
data packets or through other methods. The flow entropy field of
TRILL OAM messages mimics real packets and may impact the address
learning process of the TRILL data plane. TRILL OAM is required to
provide methods to prevent learning addresses associated with the
flow entropy field of OAM messages.

3.3 OAM Message Channel

OAM Message Channel provides methods to communicate OAM specific
details between RBridges. [802.1ag] and [RFC4379] have implemented
OAM message channels. It is important to select the appropriate
technology and re-use it, instead of redesigning yet another OAM
channel. TRILL is a transport layer that carries Ethernet frames, as
such there are close links between TRILL and other 802.1
technologies. The TRILL OAM model specified earlier is based on
the[802.1ag] model. The use of [802.1ag] encoding format for the OAM
Message channel is one possible choice. [TRILL-OAM] presents a
proposal on the use of 802.1ag messaging as the OAM message channel.

3.4 Identification of OAM Messages

RBridges must be able to identify OAM messages that are destined to
them, either individually or as a group, so as to properly process
them. To that end, those target RBridges must discern OAM messages
from normal data traffic and from data traffic experiencing errors
(e.g. Hop Count expiry).

Given that the Outer Header and TRILL Header carry no indication that
distinguishes an OAM message from data messages, the identification
of OAM messages needs to be done based on fields in the OAM Message
Channel, and potentially selective subset of the fields in the Flow
Entropy which do not polarize the hop-by-hop behavior. The latter
will vary depending on the type of flows (L2 vs. L3).

4. Fault Management

4.1 **Proactive Fault Management Functions**

   Proactive fault management functions are configured by the network
   operator to run periodically without a time bound, or are configured
   to trigger certain actions upon the occurrence of specific events.

4.1.1 **Fault Detection (Continuity Check)**

   Proactive fault detection is performed by periodically monitoring the
   reachability between service endpoints, i.e. MEPs in a given MEG,
   through the exchange of Continuity Check messages. The reachability
   between any two arbitrary MEP may be monitored for a specified path,
   all paths or any representative path. The fact that TRILL networks do
   not enforce congruency between unicast and multicast paths means that
   the proactive fault detection mechanism must provide procedures to
   monitor the unicast paths independently of the multicast paths.
   Furthermore, where the network has ECMP, the proactive fault
   detection mechanism must be capable of exercising the equal-cost
   paths individually.

   The set of MEPs exchanging Continuity Check messages in a given
   domain and for a specific monitored entity (flow, network or service)
   must use the same transmission period. As long as the fault detection
   mechanism involves MEPs transmitting periodic heartbeat messages
   independently, then this OAM procedure is not affected by the lack of
   forward/reverse path symmetry in TRILL.

   The proactive fault detection function must detect the following
   types of defects:

   - Loss of continuity (LoC) to one or more remote MEPs- Unexpected
   connectivity between isolated VLANs (mismerge)- Unexpected
   connectivity to one or more remote MEPs- Period mis-configuration

4.1.2 **Defect Indication**

   TRILL OAM MUST support event-driven defect indication upon the
   detection of a connectivity defect. Defect indications can be
   categorized into two types:

4.1.2.1 **Forward Defect Indication**

   This is used to signal a failure that is detected by a lower layer
   OAM mechanism. Forward Defect indication is transmitted away from the
   direction of the failure.

   Forward defect indication may be used for alarm suppression and/or
   for purpose of inter-working with other layer OAM protocols. Alarm

suppression is useful when a transport/network level fault translates
to multiple service or flow level faults. In such a scenario, it is
enough to alert a network management station (NMS) of the single
transport/network level fault in lieu of flooding that NMS with a
multitude of Service or Flow granularity alarms.

4.1.2.2 Reverse Defect Indication (RDI)

RDI is used to signal that the advertising MEP has detected a loss of
continuity (LoC) defect. RDI is transmitted in the direction of the
failure.

RDI allows single-sided management, where the network operator can
examine the state of a single MEP and deduce the overall health of a
monitored entity (network, flow or service).

4.2 On-Demand Fault Management Functions

On-demand fault management functions are initiated manually by the
network operator and continue for a time bound period. These
functions enable the operator to run diagnostics to investigate a
defect condition.

4.2.1 Connectivity Verification

As specified in [TRILL-OAM-REQ], TRILL OAM must support on-demand
connectivity verification for unicast and multicast. The connectivity
verification mechanism must provide a means for specifying and
carrying in the messages:
- variable length payload/padding to test MTU related connectivity
problems.
- test traffic patterns as defined in [RFC2544].

4.2.1.1 Unicast

Unicast connectivity verification operation must be initiated from a
MEP and may target either a MIP or another MEP. For unicast,
connectivity verification can be performed at either Network or Flow
granularity.

Connectivity verification at the Network granularity tests
connectivity between a MEP on a source RBridge and a MIP or MEP on a
target RBridge over a representative test VLAN and for a test flow.
The user must supply the source and target RBridges for the
operation, and the test VLAN/flow information uses pre-set values or
defaults.

Connectivity verification at the Network granularity tests

connectivity between a MEP on a source RBridge and a MIP or MEP on a
target RBridge over a user specified VLAN and flow parameters.

The above functions must be supported on sections, as defined in
[TRILL-OAM-REQ]. When connectivity verification is triggered over a
section, and the initiating MEP does not coincide with the edge
(ingress) RBridge, the MEP must use the edge RBridge nickname instead
of the local RBridge nickname on the associated connectivity
verification messages. The user must supply the edge RBridge nickname
as part of the operation parameters.

4.2.1.2 Multicast

For multicast, the connectivity verification function tests all
branches and leaf nodes of a multicast distribution tree for
reachability. This function should include mechanisms to prevent
reply storms from overwhelming the initiating RBridge. This may be
done, for e.g., by staggering the replies. To further prevent reply
storms, connectivity verification operation is initiated from a MEP
and must target MEPs only. MIPs are transparent to multicast
connectivity verification.

Per [TRILL-OAM-REQ], multicast connectivity verification must provide
the following granularity of operation:

A. Un-pruned Tree
- Connectivity verification for un-pruned multicast distribution
tree. The user in this case supplies the tree identifier (egress
RBridge nickname).

B. Pruned Tree
- Connectivity verification for a VLAN (or fine-grain label) in a
given multicast distribution tree. The user in this case supplies the
tree identifier and VLAN (or fine-grain label).
- Connectivity verification for an IP multicast group in a given
multicast distribution tree. The user in this case supplies: the tree
identifier, VLAN and IP (S,G) or (*,G).

4.2.2 Fault Isolation

TRILL OAM MUST support an on-demand connectivity fault localization
function. This is the capability to trace the path of a Flow on a
hop-by-hop (i.e. RBridge by RBridge) basis to isolate failures. This
involves the capability to narrow down the locality of a fault to a
particular port, link or node. The characteristic of forward/reverse
path asymmetry, in TRILL, renders fault isolation into a direction-
sensitive operation. That is, given two RBridges A and B,
localization of connectivity faults between them requires running

   fault isolation procedures from RBridge A to RBridge B as well as
   from RBridge B to RBridge A. Generally speaking, single-sided fault
   isolation is not possible in TRILL OAM.

5. Performance Management

   Performance Management functions can be performed both proactively
   and on-demand. Proactive management involves a scheduling function,
   where the performance management probes can be triggered on a
   recurring basis. Since the basic performance management functions
   involved are the same, we make no distinction between proactive and
   on-demand functions in this section.

5.1 Packet Loss

   Given that TRILL provides inherent support for multipoint-to-
   multipoint connectivity, then packet loss cannot be accurately
   measured by means of counting user data packets. This is because user
   packets can be delivered to more RBridges or more ports than are
   necessary (e.g. due to broadcast, un-pruned multicast or unknown
   unicast flooding). As such, a statistical means of approximating
   packet loss rate is required. This can be achieved by sending
   "synthetic" (i.e. TRILL OAM) packets that are counted only by those
   ports (MEPs) that are required to receive them. This provides a
   statistical approximation of the number of data frames lost, even
   with multipoint-to-multipoint connectivity.

   Packet loss probes must be initiated from a MEP and must target a
   MEP. This function must be supported on sections, as defined in
   [TRILL-OAM-REQ]. When packet loss is measured over a section, and the
   initiating MEP does not coincide with the edge (ingress) RBridge, the
   MEP must use the edge RBridge nickname instead of the local RBridge
   nickname on the associated loss measurement messages. The user must
   supply the edge RBridge nickname as part of the operation parameters.

5.2 Packet Delay

   Packet delay is measured by inserting time-stamps in TRILL OAM
   packets. In order to ensure high accuracy of measurement, TRILL OAM
   must specify the time-stamp location at fixed offsets within the OAM
   packet in order to facilitate hardware-based time-stamping. Hardware
   implementation must implement the time-stamping function as close to
   the wire as possible in order to maintain high accuracy.

6. Security Considerations

TRILL OAM must provide mechanisms for:

- Preventing denial of service attacks caused by exploitation of the OAM message channel.- Optionally authenticate communicating endpoints (MEPs and MIPs)- Preventing TRILL OAM packets from leaking outside of the TRILL network or outside their corresponding Maintenance Domain. This can be done by having MEPs implement a filtering function based on the Maintenance Level associated with received OAM packets.

7. IANA Considerations

None.

8. Acknowledgements

We invite feedback and contributors.

9. References

9.1 Normative References

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