Internet Engineering Task Force (IETF)   D. Mohan, Ed.
Request for Comments: 7023   Nortel Networks
Category: Standards Track   N. Bitar, Ed.
ISSN: 2070-1721   Verizon
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                                                        October 2013

         MPLS and Ethernet Operations, Administration, and Maintenance (OAM)
                              Interworking

Abstract

   This document specifies the mapping of defect states between Ethernet
   Attachment Circuits (ACs) and associated Ethernet pseudowires (PWs)
   connected in accordance with the Pseudowire Emulation Edge-to-Edge
   (PWE3) architecture to realize an end-to-end emulated Ethernet
   service. It standardizes the behavior of Provider Edges (PEs) with
   respect to Ethernet PW and AC defects.

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1. Introduction

   RFC 6310 [RFC6310] specifies the mapping and notification of defect
   states between a pseudowire (PW) and the Attachment Circuit (AC) of
   the end-to-end emulated service. It standardizes the behavior of
   Provider Edges (PEs) with respect to PW and AC defects for a number
   of technologies (e.g., Asynchronous Transfer Mode (ATM) and Frame
   Relay (FR)) emulated over PWs in MPLS and MPLS/IP Packet Switched
   Networks (PSNs). However, [RFC6310] does not describe this function
   for the Ethernet PW service owing to its unique characteristics.

   This document specifies the mapping of defect states between ACs and
   associated Ethernet PWs connected in accordance with the PWE3
   architecture [RFC3985] to realize an end-to-end emulated Ethernet
   service. This document augments the mapping of defect states between
   a PW and associated AC of the end-to-end emulated service in
   [RFC6310]. Similar to [RFC6310], the intent of this document is to
   standardize the behavior of PEs with respect to failures on Ethernet
   ACs and PWs, so that there is no ambiguity about the alarms generated
   and consequent actions undertaken by PEs in response to specific
   failure conditions.

1.1. Specification of Requirements

   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].

2. Overview

   There are a number of Operations, Administration, and Maintenance
   (OAM) technologies defined for Ethernet, providing various
   functionalities. This document covers the following Ethernet OAM
   mechanisms and their interworking with PW OAM mechanisms:

   - Ethernet Link OAM [802.3]
   - Ethernet Local Management Interface (E-LMI) [MEF16]
   - Ethernet Continuity Check (CC) [CFM] [Y.1731]
   - Ethernet Alarm Indication Signaling (AIS) and Remote Defect
      Indication (RDI) [Y.1731]

   Ethernet Link OAM [802.3] allows some link defect states to be
   detected and communicated across an Ethernet link. When an Ethernet
   AC is an Ethernet physical port, there may be some application of
   Ethernet Link OAM [802.3]. Further, E-LMI [MEF16] also allows for
   some Ethernet Virtual Circuit (EVC) defect states to be communicated
   across an Ethernet User Network Interface (UNI) where Ethernet UNI
   constitutes a single-hop Ethernet link (i.e., without any bridges

compliant with IEEE 802.1Q/.1ad in between). There may be some
application of E-LMI [MEF16] for failure notification across single-
hop Ethernet ACs in certain deployments that specifically do not
support IEEE Connectivity Fault Management [CFM] and/or ITU-T Y.1731
[Y.1731], simply referred to as CFM and Y.1731, respectively, in this
document. Mechanisms based on Y.1731 and CFM are applicable in all
types of Ethernet ACs. Ethernet Link OAM and E-LMI are optional, and
their applicability is called out, where applicable.

Native service (NS) OAM may be transported transparently over the
corresponding PW as user data. This is referred to as the "single
emulated OAM loop mode" per [RFC6310]. For Ethernet, as an example,
CFM continuity check messages (CCMs) between two Maintenance Entity
Group End Points (MEPs) can be transported transparently as user data
over the corresponding PW. At MEP locations, service failure is
detected when CCMs are not received over an interval that is 3.5
times the local CCM transmission interval. This is one of the
failure conditions detected via continuity check. MEP peers can
exist between customer edge (CE) endpoints (MEPs of a given
Maintenance Entity Group (MEG) reside on the CEs), between PE pairs
(the MEPs of a given MEG reside on the PEs), or between the CE and PE
(the MEPs of a given MEG reside on the PE and CE), as long as the MEG
level nesting rules are maintained. It should be noted that Ethernet
allows the definition of up to 8 MEG levels, each comprised of MEPs
(Down MEPs and Up MEPs) and Maintenance Entity Group Intermediate
Points (MIPs). These levels can be nested or touching. MEPs and
MIPs generate and process messages in the same MEG level. Thus, in
this document, when we refer to messages sent by a MEP or a MIP to a
peer MEP or MIP, these MEPs and MIPs are in the same MEG level.

When interworking two networking domains, such as native Ethernet and
PWs to provide an end-to-end emulated service, there is a need to
identify the failure domain and location even when a PE supports both
the NS OAM mechanisms and the PW OAM mechanisms. In addition,
scalability constraints may not allow running proactive monitoring,
such as CCMs with transmission enabled, at a PE to detect the failure
of an EVC across the PW domain. Thus, network-driven alarms
generated upon failure detection in the NS or PW domain and their
mappings to the other domain are needed. There are also cases where
a PE MAY not be able to process NS OAM messages received on the PW
even when such messages are defined, as in the case of Ethernet,
necessitating the need for fault notification message mapping between
the PW domain and the NS domain.

   For Multi-Segment PWs (MS-PWs) [RFC5659], Switching PEs (S-PEs) are
   not aware of the NS. Thus, failure detection and notification at
   S-PEs will be based on PW OAM mechanisms. Mapping between PW OAM and
   NS OAM will be required at the Terminating PEs (T-PEs) to propagate
   the failure notification to the EVC end points.

2.1. Reference Model and Defect Locations

   Figure 1 was used in [RFC6310]; it is reproduced in this document as
   a reference to highlight defect locations.

```
            ACs                 PSN tunnel            ACs
                         +----+                +----+
        +----+           | PE1|================| PE2|        +----+
        |    |---(a)---(b)..(c)......PW1..(d)..(e)..(f)---(g)---|    |
        | CE1|   (N1)    |    |                |    |   (N2)  |CE2 |
        |    |----------|...........PW2.............|----------|    |
        +----+          |    |================|    |          +----+
              ^         +----+                +----+         ^
              |       Provider Edge 1     Provider Edge 2    |
              |                                              |
              |<-------------- Emulated Service --------------->|


         Customer                                    Customer
         Edge 1                                      Edge 2
```
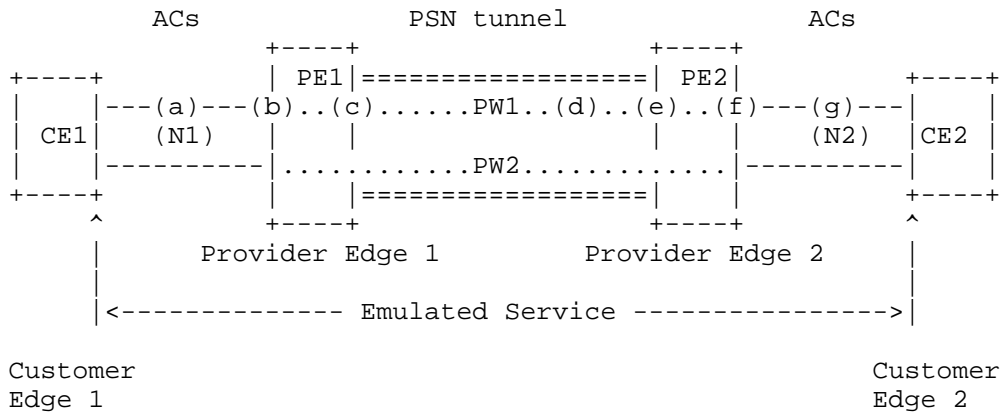
                Figure 1: PWE3 Network Defect Locations

2.2. Abstract Defect States

   Abstract defect states are also introduced in [RFC6310]. As shown in
   Figure 2, this document uses the same conventions as [RFC6310]. It
   may be noted, however, that CE devices, shown in Figure 2, do not
   necessarily have to be end customer devices. These are essentially
   devices in client network segments that are connecting to the Packet
   Switched Network (PSN) for the emulated services.
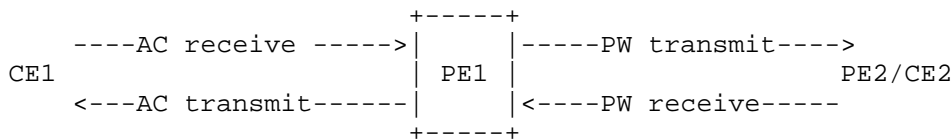
```
                            +-----+
           ----AC receive ----->|     |-----PW transmit---->
         CE1                 | PE1 |                    PE2/CE2
           <---AC transmit------|     |<----PW receive-----
                            +-----+
    (arrows indicate direction of user traffic impacted by a defect)
```

      Figure 2: Transmit and Receive Defect States and Notifications

The procedures outlined in this document define the entry and exit
criteria for each of the four defect states with respect to Ethernet
ACs and corresponding PWs; this document also defines the consequent
actions that PE1 MUST support to properly interwork these defect
states and corresponding notification messages between the PW domain
and the native service (NS) domain. Receive defect state SHOULD have
precedence over transmit defect state in terms of handling, when both
transmit and receive defect states are identified simultaneously.

Following is a summary of the defect states from the viewpoint of PE1
in Figure 2:

- A PW receive defect at PE1 impacts PE1's ability to receive
   traffic on the PW. Entry and exit criteria for the PW receive
   defect state are described in Section 4.4.1.

- A PW transmit defect at PE1 impacts PE1's ability to send user
   traffic toward CE2. PE1 MAY be notified of a PW transmit defect
   via a Reverse Defect Indication from PE2, which could point to
   problems associated with PE2's inability to receive traffic on the
   PW or PE2's inability to transmit traffic on its local AC. Entry
   and exit criteria for the PW transmit defect state are described
   in Section 4.4.2.

- An AC receive defect at PE1 impacts PE1's ability to receive user
   traffic from the client domain attached to PE1 via that AC. Entry
   and exit criteria for the AC receive defect state are described in
   Section 5.1.

- An AC transmit defect at PE1 impacts PE1's ability to send user
   traffic on the local AC. Entry and exit criteria for the AC
   transmit defect state are described in Section 5.2.

3. Abbreviations and Terminology

3.1. Abbreviations

     AC   Attachment Circuit
     AIS   Alarm Indication Signal
     BFD   Bidirectional Forwarding Detection
     CC   Continuity Check
     CCM   Continuity Check Message
     CE   Customer Edge
     CV   Connectivity Verification
     E-LMI Ethernet Local Management Interface
     EVC   Ethernet Virtual Circuit
     LDP   Label Distribution Protocol
     LoS   Loss of Signal
     MA   Maintenance Association
     MD   Maintenance Domain
     ME   Maintenance Entity
     MEG   Maintenance Entity Group
     MEP   MEG End Point
     MIP   MEG Intermediate Point
     MPLS Multiprotocol Label Switching
     MS-PW Multi-Segment Pseudowire
     NS   Native Service
     OAM   Operations, Administration, and Maintenance
     PE   Provider Edge
     PSN   Packet Switched Network
     PW   Pseudowire
     RDI   Remote Defect Indication when used in the context of CCM
     RDI   Reverse Defect Indication when used to semantically refer to
           defect indication in the reverse direction
     S-PE Switching Provider Edge
     T-PE Terminating Provider Edge
     TLV   Type-Length Value
     VCCV Virtual Circuit Connectivity Verification

3.2. Terminology

     This document uses the following terms with corresponding
     definitions:

     - MEG Level: identifies a value in the range of 0-7 associated with
        an Ethernet OAM frame. MEG level identifies the span of the
        Ethernet OAM frame.

     - MEG End Point (MEP): is responsible for origination and
        termination of OAM frames for a given MEG.

- MEG Intermediate Point (MIP): is located between peer MEPs and can
     process OAM frames but does not initiate them.

- MPLS PSN: a PSN that makes use of MPLS Label-Switched Paths
     [RFC3031] as the tunneling technology to forward PW packets.

- MPLS/IP PSN: a PSN that makes use of MPLS-in-IP tunneling
     [RFC4023] to tunnel MPLS-labeled PW packets over IP tunnels.

   Further, this document also uses the terminology and conventions used
   in [RFC6310].

4. PW Status and Defects

   [RFC6310] introduces a range of defects that impact PW status. All
   these defect conditions are applicable for Ethernet PWs.

   Similarly, there are different mechanisms described in [RFC6310] to
   detect PW defects, depending on the PSN type (e.g., MPLS PSN or
   MPLS/IP PSN). Any of these mechanisms can be used when monitoring
   the state of Ethernet PWs. [RFC6310] also discusses the
   applicability of these failure detection mechanisms.

4.1. Use of Native Service (NS) Notification

   When two PEs terminate an Ethernet PW with associated MEPs, each PE
   can use native service (NS) OAM capabilities for failure
   notifications by transmitting appropriate NS OAM messages over the
   corresponding PW to the remote PE. Options include:

- Sending of AIS frames from the local MEP to the MEP on the remote
     PE when the MEP needs to convey PE receive defects and when CCM
     transmission is disabled.

- Suspending transmission of CCM frames from the local MEP to the
     peer MEP on the remote PE to convey PE receive defects when CCM
     transmission is enabled.

- Setting the RDI bit in transmitted CCM frames when loss of CCMs
     from the peer MEP is detected or when the PE needs to convey PW
     reverse defects.

   Similarly, when the defect conditions are cleared, a PE can take one
   of the following actions, depending on the mechanism that was used
   for failure notification, to clear the defect state on the peer PE:

- Stopping AIS frame transmission from the local MEP to the MEP on
     the remote PE to clear PW receive defects.

-   Resuming transmission of CCM frames from the local MEP to the peer
    MEP on the remote PE to clear PW forward defect notification when
    CCM transmission is enabled.

-   Clearing the RDI bit in transmitted CCM frames to clear PW
    transmit defect notification when CCM transmission is enabled.

4.2. Use of PW Status Notification for MPLS PSNs

   RFC 4447 [RFC4447] specifies that for PWs that have been set up using
   the Label Distribution Protocol (LDP), the default mechanism to
   signal status and defects for ACs and PWs is the LDP status
   notification message. For PWs established over an MPLS or MPLS/IP
   PSN using other mechanisms (e.g., static configuration), in-band
   signaling using VCCV-BFD [RFC5885] SHOULD be used to convey AC and PW
   status and defects. Alternatively, the mechanisms defined in
   [RFC6478] MAY be used.

   [RFC6310] identifies the following PW defect status code points:

-   Forward defect: corresponds to a logical OR of Local Attachment
    Circuit (ingress) Receive Fault, Local PSN-facing PW (egress)
    Transmit Fault, and Pseudowire Not Forwarding fault.

-   Reverse defect: corresponds to a logical OR of Local Attachment
    Circuit (egress) Transmit Fault and Local PSN-facing PW (ingress)
    Receive Fault.

   There are also scenarios where a PE carries out PW label withdrawal
   instead of PW status notification. These include administrative
   disablement of the PW or loss of the Target LDP session with the peer
   PE.

4.3. Use of BFD Diagnostic Codes

   When using VCCV, the control channel type and Connectivity
   Verification (CV) type are agreed on between the peer PEs using the
   VCCV parameter field signaled as a sub-TLV of the interface
   parameters TLV when using FEC 129 and the interface parameter sub-TLV
   when using FEC 128 [RFC5085].

   As defined in [RFC6310], when a CV type of 0x04 or 0x10 is used to
   indicate that BFD is used for PW fault detection only, PW defect is
   detected via the BFD session while other defects, such as AC defect
   or PE internal defects preventing it from forwarding traffic, are
   communicated via an LDP status notification message in MPLS and
   MPLS/IP PSNs or other mechanisms in L2TP/IP PSNs.

Similarly, when a CV type of 0x08 or 0x20 is used to indicate that
BFD is used for both PW fault detection and AC/PW fault notification,
all defects are signaled via BFD.

4.4. PW Defect States Entry and Exit Criteria

4.4.1. PW Receive Defect State Entry and Exit

As described in Section 6.2.1 of [RFC6310], PE1 will enter the PW
receive defect state if one or more of the following occur:

- It receives a Forward Defect Indication (FDI) from PE2 either
   indicating a receive defect on the remote AC or indicating that
   PE2 detected or was notified of a downstream PW fault.

- It detects loss of connectivity on the PSN tunnel upstream of PE1,
   which affects the traffic it receives from PE2.

- It detects a loss of PW connectivity through VCCV-BFD, VCCV-Ping,
   or NS OAM mechanisms (i.e., CC) when enabled, which affects the
   traffic it receives from PE2.

Note that if the PW LDP control session between the PEs fails, the PW
is torn down and needs to be re-established. However, the consequent
actions towards the ACs are the same as if the PW entered the receive
defect state.

PE1 will exit the PW receive defect state when the following
conditions are met. Note that this may result in a transition to the
PW operational state or the PW transmit defect state.

- All previously detected defects have disappeared.
- PE2 cleared the FDI, if applicable.

4.4.2. PW Transmit Defect State Entry and Exit

PE1 will enter the PW transmit defect state if the following
conditions occur:

- It receives a Reverse Defect Indication (RDI) from PE2 either
   indicating a transmit fault on the remote AC or indicating that
   PE2 detected or was notified of an upstream PW fault.

- It is not already in the PW receive defect state.

PE1 will exit the transmit defect state if it receives an OAM message
from PE2 clearing the RDI or if it has entered the PW receive defect
state.

5. Ethernet AC Defect States Entry and Exit Criteria

5.1. AC Receive Defect State Entry and Exit

   PE1 enters the AC receive defect state if any of the following
   conditions is met:

   - It detects or is notified of a physical-layer fault on the
      Ethernet interface. Ethernet link failure can be detected based
      on loss of signal (LoS) or via Ethernet Link OAM [802.3] critical
      link event notifications generated at an upstream node CE1 with
      "Dying Gasp" or "Critical Event" indication or via a client Signal
      Fail message [Y.1731].

   - A MEP associated with the local AC receives an Ethernet AIS frame
      from CE1.

   - A MEP associated with the local AC does not receive CCM frames
      from the peer MEP in the client domain (e.g., CE1) within an
      interval equal to 3.5 times the CCM transmission period configured
      for the MEP. This is the case when CCM transmission is enabled.

   - A CCM has an Interface Status TLV indicating interface down.
      Other CCM Interface Status TLVs will not be used to indicate
      failure or recovery from failure.

   It should be noted that when a MEP at a PE or a CE receives a CCM
   with the wrong MEG ID, MEP ID, or MEP level, the receiving PE or CE
   SHOULD treat such an event as an AC receive defect. In any case, if
   such events persist for 3.5 times the MEP local CCM transmission
   time, loss of continuity will be declared at the receiving end.

   PE1 exits the AC receive defect state if all of the conditions that
   resulted in entering the defect state are cleared. This includes all
   of the following conditions:

   - Any physical-layer fault on the Ethernet interface, if detected or
      where PE1 was notified previously, is removed (e.g., loss of
      signal (LoS) cleared or Ethernet Link OAM [802.3] critical link
      event notifications with "Dying Gasp" or "Critical Event"
      indications cleared at an upstream node CE1).

   - A MEP associated with the local AC does not receive any Ethernet
      AIS frame within a period indicated by previously received AIS if
      AIS resulted in entering the defect state.

-   A MEP associated with the local AC and configured with CCM enabled
    receives a configured number (e.g., 3 or more) of consecutive CCM
    frames from the peer MEP on CE1 within an interval equal to a
    multiple (3.5) of the CCM transmission period configured for the
    MEP.

-   CCM indicates interface status up.

5.2. AC Transmit Defect State Entry and Exit

   PE1 enters the AC transmit defect state if any of the following
   conditions is met:

-   It detects or is notified of a physical-layer fault on the
    Ethernet interface where the AC is configured (e.g., via loss of
    signal (LoS) or Ethernet Link OAM [802.3] critical link event
    notifications generated at an upstream node CE1 with "Link Fault"
    indication).

-   A MEP configured with CCM transmission enabled and associated with
    the local AC receives a CCM frame, with its RDI (Remote Defect
    Indication) bit set, from the peer MEP in the client domain (e.g.,
    CE1).

   PE1 exits the AC transmit defect state if all of the conditions that
   resulted in entering the defect state are cleared. This includes all
   of the following conditions:

-   Any physical-layer fault on the Ethernet interface, if detected or
    where PE1 was notified previously, is removed (e.g., LoS cleared
    or Ethernet Link OAM [802.3] critical link event notifications
    with "Link Fault" indication cleared at an upstream node CE1).

-   A MEP configured with CCM transmission enabled and associated with
    the local AC does not receive a CCM frame with the RDI bit set,
    having received a previous CCM frame with the RDI bit set from the
    peer MEP in the client domain (e.g., CE1).

6. Ethernet AC and PW Defect States Interworking

6.1. PW Receive Defect State Entry Procedures

   When the PW status on PE1 transitions from working to PW receive
   defect state, PE1's ability to receive user traffic from CE2 is
   impacted. As a result, PE1 needs to notify CE1 about this problem.

   Upon entry to the PW receive defect state, the following MUST be
   done:

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is not enabled, the MEP associated with the
      AC MUST transmit AIS frames periodically to the peer MEP in the
      client domain (e.g., on CE1) based on the configured AIS
      transmission period.

   - If PE1 is configured with a Down MEP associated with the local AC,
      CCM transmission is enabled, and the MEP associated with the AC is
      configured to support the Interface Status TLV in CCMs, the MEP
      associated with the AC MUST transmit CCM frames with the Interface
      Status TLV as being Down to the peer MEP in the client domain
      (e.g., on CE1).

   - If PE1 is configured with a Down MEP associated with the local AC,
      CCM transmission is enabled, and the MEP associated with the AC is
      configured to not support the Interface Status TLV in CCMs, the
      MEP associated with the AC MUST stop transmitting CCM frames to
      the peer MEP in the client domain (e.g., on CE1).

   - If PE1 is configured to run E-LMI [MEF16] with CE1 and if E-LMI is
      used for failure notification, PE1 MUST transmit an E-LMI
      asynchronous STATUS message with report type Single EVC
      Asynchronous Status indicating that the PW is Not Active.

   Further, when PE1 enters the receive defect state, it MUST assume
   that PE2 has no knowledge of the defect and MUST send a reverse
   defect failure notification to PE2. For MPLS PSN or MPLS/IP PSN,
   this is either done via a PW status notification message indicating a
   reverse defect or done via a VCCV-BFD diagnostic code of reverse
   defect if a VCCV CV type of 0x08 or 0x20 had been negotiated. When a
   native service OAM mechanism is supported on PE1, it can also use the
   NS OAM notification as specified in Section 4.1.

   If PW receive defect state is entered as a result of a forward defect
   notification from PE2 or via loss of control adjacency, no additional
   action is needed since PE2 is expected to be aware of the defect.

6.2. PW Receive Defect State Exit Procedures

   When the PW status transitions from PW receive defect state to
   working, PE1's ability to receive user traffic from CE2 is restored.
   As a result, PE1 needs to cease defect notification to CE1 by
   performing the following:

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is not enabled, the MEP associated with the
      AC MUST stop transmitting AIS frames towards the peer MEP in the
      client domain (e.g., on CE1).

   - If PE1 is configured with a Down MEP associated with the local AC,
      CCM transmission is enabled, and the MEP associated with the AC is
      configured to support the Interface Status TLV in CCMs, the MEP
      associated with the AC MUST transmit CCM frames with the Interface
      Status TLV as being Up to the peer MEP in the client domain (e.g.,
      on CE1).

   - If PE1 is configured with a Down MEP associated with the local AC,
      CCM transmission is enabled, and the MEP associated with the AC is
      configured to not support the Interface Status TLV in CCMs, the
      MEP associated with the AC MUST resume transmitting CCM frames to
      the peer MEP in the client domain (e.g., on CE1).

   - If PE1 is configured to run E-LMI [MEF16] with CE1 and E-LMI is
      used for fault notification, PE1 MUST transmit an E-LMI
      asynchronous STATUS message with report type Single EVC
      Asynchronous Status indicating that the PW is Active.

   Further, if the PW receive defect was explicitly detected by PE1, it
   MUST now notify PE2 about clearing of receive defect state by
   clearing the reverse defect notification. For PW over MPLS PSN or
   MPLS/IP PSN, this is either done via a PW status message indicating a
   working state or done via a VCCV-BFD diagnostic code if a VCCV CV
   type of 0x08 or 0x20 had been negotiated. When a native service OAM
   mechanism is supported on PE, it can also clear the NS OAM
   notification as specified in Section 4.1.

   If PW receive defect was established via notification from PE2 or via
   loss of control adjacency, no additional action is needed since PE2
   is expected to be aware of the defect clearing.

6.3. PW Transmit Defect State Entry Procedures

   When the PW status transitions from working to PW transmit defect
   state, PE1's ability to transmit user traffic to CE2 is impacted. As
   a result, PE1 needs to notify CE1 about this problem.

   Upon entry to the PW transmit defect state, the following MUST be
   done:

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is enabled, the MEP associated with the AC
      MUST set the RDI bit in transmitted CCM frames or send a status
      TLV with interface down to the peer MEP in the client domain
      (e.g., on CE1).

   - If PE1 is configured to run E-LMI [MEF16] with CE1 and E-LMI is
      used for fault notification, PE1 MUST transmit an E-LMI
      asynchronous STATUS message with report type Single EVC
      Asynchronous Status indicating that the PW is Not Active.

   - If the PW failure was detected by PE1 without receiving a reverse
      defect notification from PE2, PE1 MUST assume PE2 has no knowledge
      of the defect and MUST notify PE2 by sending an FDI.

6.4. PW Transmit Defect State Exit Procedures

   When the PW status transitions from PW transmit defect state to
   working, PE1's ability to transmit user traffic to CE2 is restored.
   As a result, PE1 needs to cease defect notifications to CE1 and
   perform the following:

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is enabled, the MEP associated with the AC
      MUST clear the RDI bit in the transmitted CCM frames to the peer
      MEP or send a status TLV with interface up to the peer MEP in the
      client domain (e.g., on CE1).

   - If PE1 is configured to run E-LMI [MEF16] with CE1, PE1 MUST
      transmit an E-LMI asynchronous STATUS message with report type
      Single EVC Asynchronous Status indicating that the PW is Active.

   - PE1 MUST clear the FDI to PE2, if applicable.

6.5. AC Receive Defect State Entry Procedures

   When AC status transitions from working to AC receive defect state,
   PE1's ability to receive user traffic from CE1 is impacted. As a
   result, PE1 needs to notify PE2 and CE1 about this problem.

   If the AC receive defect is detected by PE1, it MUST notify PE2 in
   the form of a forward defect notification.

   When NS OAM is not supported on PE1, in PW over MPLS PSN or MPLS/IP
   PSN, a forward defect notification is either done via a PW status
   message indicating a forward defect or done via a VCCV-BFD diagnostic
   code of forward defect if a VCCV CV type of 0x08 or 0x20 had been
   negotiated.

   When a native service OAM mechanism is supported on PE1, it can also
   use the NS OAM notification as specified in Section 4.1.

   In addition to the above actions, PE1 MUST perform the following:

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is enabled, the MEP associated with the AC
      MUST set the RDI bit in transmitted CCM frames.

6.6. AC Receive Defect State Exit Procedures

   When AC status transitions from AC receive defect state to working,
   PE1's ability to receive user traffic from CE1 is restored. As a
   result, PE1 needs to cease defect notifications to PE2 and CE1 and
   perform the following:

   - When NS OAM is not supported on PE1, in PW over MPLS PSN or
      MPLS/IP PSN, the forward defect notification is cleared via a PW
      status message indicating a working state or via a VCCV-BFD
      diagnostic code if a VCCV CV type of 0x08 or 0x20 had been
      negotiated.

   - When a native service OAM mechanism is supported on PE1, PE1
      clears the NS OAM notification as specified in Section 4.1.

   - If PE1 is configured with a Down MEP associated with the local AC
      and CCM transmission is enabled, the MEP associated with the AC
      MUST clear the RDI bit in transmitted CCM frames to the peer MEP
      in the client domain (e.g., on CE1).

6.7. AC Transmit Defect State Entry Procedures

   When AC status transitions from working to AC transmit defect state,
   PE1's ability to transmit user traffic to CE1 is impacted. As a
   result, PE1 needs to notify PE2 about this problem.

   If the AC transmit defect is detected by PE1, it MUST notify PE2 in
   the form of a reverse defect notification.

When NS OAM is not supported on PE1, in PW over MPLS PSN or MPLS/IP
PSN, a reverse defect notification is either done via a PW status
message indicating a reverse defect or done via a VCCV-BFD diagnostic
code of reverse defect if a VCCV CV type of 0x08 or 0x20 had been
negotiated.

When a native service OAM mechanism is supported on PE1, it can also
use the NS OAM notification as specified in Section 4.1.

6.8. AC Transmit Defect State Exit Procedures

When AC status transitions from AC transmit defect state to working,
PE1's ability to transmit user traffic to CE1 is restored. As a
result, PE1 MUST clear the reverse defect notification to PE2.

When NS OAM is not supported on PE1, in PW over MPLS PSN or MPLS/IP
PSN, the reverse defect notification is cleared via a PW status
message indicating a working state or via a VCCV-BFD diagnostic code
if a VCCV CV type of 0x08 or 0x20 had been negotiated.

When a native service OAM mechanism is supported on PE1, PE1 can
clear NS OAM notification as specified in Section 4.1.

7. Security Considerations

The OAM interworking mechanisms described in this document do not
change the security functions inherent in the actual messages. All
generic security considerations applicable to PW traffic specified in
Section 10 of [RFC3985] are applicable to NS OAM messages transferred
inside the PW.

The security considerations in Section 10 of [RFC5085] for VCCV apply
to the OAM messages thus transferred. Security considerations
applicable to the PWE3 control protocol as described in Section 8.2
of [RFC4447] apply to OAM indications transferred using the LDP
status message.

Since the mechanisms of this document enable propagation of OAM
messages and fault conditions between native service networks and
PSNs, continuity of the end-to-end service depends on a trust
relationship between the operators of these networks. Security
considerations for such scenarios are discussed in Section 7 of
[RFC5254].

8. Acknowledgments

   The authors are thankful to Samer Salam, Matthew Bocci, Yaakov Stein,
   David Black, Lizhong Jin, Greg Mirsky, Huub van Helvoort, and Adrian
   Farrel for their valuable input and comments.

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Appendix A. Ethernet Native Service Management

   This appendix is informative.

   Ethernet OAM mechanisms are broadly classified into two categories:
   Fault Management (FM) and Performance Monitoring (PM). ITU-T Y.1731
   [Y.1731] provides coverage for both FM and PM while IEEE CFM [CFM]
   provides coverage for a subset of FM functions.

   Ethernet OAM also introduces the concept of a Maintenance Entity
   (ME), which is used to identify the entity that needs to be managed.
   An ME is inherently a point-to-point association. However, in the
   case of a multipoint association, a Maintenance Entity Group (MEG)
   consisting of different MEs is used. IEEE 802.1 uses the concept of
   a Maintenance Association (MA), which is used to identify both point-
   to-point and multipoint associations. Each MEG/MA consists of MEG
   End Points (MEPs) that are responsible for originating OAM frames.
   In between the MEPs, there can also be MEG Intermediate Points (MIPs)
   that do not originate OAM frames but do respond to OAM frames from
   MEPs.

   Ethernet OAM allows for hierarchical Maintenance Entities to allow
   for simultaneous end-to-end and segment monitoring. This is achieved
   by having a provision of up to 8 MEG levels (MD levels), where each
   MEP or MIP is associated with a specific MEG level.

   It is important to note that the FM mechanisms common to both IEEE
   CFM [CFM] and ITU-T Y.1731 [Y.1731] are completely compatible.

   The common FM mechanisms include:

   1) Continuity Check Message (CCM)

   2) Loopback Message (LBM) and Loopback Reply (LBR)

   3) Link Trace Message (LTM) and Link Trace Reply (LTR)

   CCMs are used for fault detection, including misconnections and
   misconfigurations. Typically, CCMs are sent as multicast frames or
   unicast frames and also allow RDI notifications. LBM and LBR are
   used to perform fault verification, while also allowing for MTU
   verification and CIR/EIR (Committed Information Rate / Excess
   Information Rate) measurements. LTM and LTR can be used for
   discovering the path traversed between a MEP and another target
   MIP/MEP in the same MEG. LTM and LTR also allow for fault
   localization.

In addition, ITU-T Y.1731 [Y.1731] also specifies the following FM
functions:

4) Alarm Indication Signal (AIS)

AIS allows for fault notification to downstream and upstream nodes.

Further, ITU-T Y.1731 [Y.1731] also specifies the following PM
functions:

5) Loss Measurement Message (LMM) and Loss Measurement Reply (LMR)

6) Delay Measurement Message (DMM) and Delay Measurement Reply (DMR)

7) 1-way Delay Measurement (1DM)

While LMM and LMR are used to measure Frame Loss Ratio (FLR), DMM and
DMR are used to measure single-ended (aka two-way) Frame Delay (FD)
and Frame Delay Variation (FDV, also known as Jitter). 1DM can be
used for dual-ended (aka one-way) FD and FDV measurements.

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