MPLS and Ethernet OAM Interworking
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Abstract

This document specifies the mapping of defect states between Ethernet Attachment Circuits (ACs) and associated Ethernet Pseudowires (PWs) connected in accordance to 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 [PW-OAM-MSG-MAP]. In [PW-OAM-MSG-MAP], Ethernet OAM was not covered due to lack of Ethernet OAM maturity. However, since then, [Y.1731] and

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[802.1ag] have been completed, and this document specifies the mapping of defect states between Ethernet ACs and corresponding Ethernet PWs.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

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1. Introduction

This document specifies the mapping of defect states between Ethernet Attachment Circuits (ACs) and associated Ethernet Pseudowires (PWs) connected in accordance to 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 [PW-OAM-MSG-MAP]. In [PW-OAM-MSG-MAP], Ethernet OAM was not covered due to lack of Ethernet OAM maturity. However, since then, [Y.1731] and [802.1ag] have been completed, and this document specifies the mapping of defect states between Ethernet ACs and corresponding Ethernet PWs.

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 PHY, there may be some application of Ethernet Link OAM [802.3]. Further, E-LMI [MEF16] also allows for some EVC defect states to be communicated across an Ethernet UNI where Ethernet UNI constitutes a single hop Ethernet Link (i.e. without any 802.1Q/.1ad compliant bridges in between). There may be some application of E-LMI [MEF16] for failure notification across single hop Ethernet AC in certain deployments that specifically do not support [802.1ag] and/or [Y.1731]. [Y.1731] and [802.1ag] based mechanisms are applicable in all types of Ethernet ACs. Ethernet Link OAM [802.3] and E-LMI [MEF16] 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. For Ethernet, as an example, 802.1ag continuity check messages (CCMs) between two Maintenance End Points (MEPs) can be transported transparently as user data over the corresponding PW. At MEP locations, service failure is detected when a number of consecutive CCMs are missed. MEP locations can be the PE, the CE or both with different Maintenance Domain Levels. However, when interworking two networking domains, such as native Ethernet and PWs to provide an end-to-end emulated service, there is 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 on, at a PE to detect the failure of an Ethernet Virtual circuit (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 Ethernet case, necessitating the need for fault notification message mapping between the PW domain and the Client domain.

For Multi-Segment PWs (MS-PWs) [MS-PW-ARCH], 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...
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NS OAM will be required at the Terminating PEs (T-PEs) to propagate
the failure notification to the EVC endpoints.

Similar to [PW-OAM-MSG-MAP], 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.          Reference Model and Defect Locations

Figure 1 is the same as used in [PW-OAM-MSG-MAP] and is reproduced
in this document as a reference to highlight defect locations.

---(a)---(b)..(c).......PW1...(d)..(c)---(f)---(e)---
|     |                  |    |
---(N1) |                  |    |

Figure 1: PWE3 Network Defect Locations

1.2.          Abstract Defect States

Abstract Defect States are also introduced in [PW-OAM-MSG-MAP]. This
document uses the same conventions, as shown in Figure 2 from [PW-
OAM-MSG-MAP]. 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 PSN network for the emulated services.

(arrow indicate direction of user traffic impacted by a defect)

Figure 2: Forward and Reverse Defect States and Notifications
PE1 may detect a forward defect in local Ethernet AC via one of the following mechanisms:
- An AIS alarm generated at an upstream node in the client domain (CE1 in Figure 2) and received by a local MEP associated with the local AC.
- Failure of the local link on which the AC is configured. Link failure may be detected via physical failures e.g. 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.
- Failure to receive CCMs on the AC if a local MEP is configured for the AC.

AC forward defect impacts the ability of PE1 to receive user traffic from the Client domain.

Similarly, PE1 may detect a forward defect in the PW via one of the following mechanisms:
- Forward Defect indication received from PE2. This defect indication could point to problems associated with PE2’s inability to transmit traffic on the PW or PE2’s inability to receive traffic on its local AC.
- Unavailability of a PSN path in the PW domain to PE2.

PW forward defect received on PE1 impacts the ability of PE1 to receive traffic on the PW.

PE1 may be notified of an AC reverse defect via one of the following mechanisms:
- CCMs with RDI (Remote Defect Indication) bit set.
- In case when the AC is associated with a physical port, failure of the local link on which the AC is configured (e.g. via Ethernet Link OAM [802.3] critical link event notifications generated at an upstream node CE1 with "Link Fault" indication).

AC reverse defect impacts the ability of PE1 to send user traffic on the local AC.

Similarly, PE1 may be notified of a PW reverse defect via 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. PW reverse defect impacts PE1 ability to send user traffic to CE2.

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, and 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. Forward defect state should have precedence over reverse defect state in terms of handling, when both forward and reverse defect states are identified simultaneously.
2. Terminology

This document uses the following terms.

AIS       Alarm Indication Signal
MD Level  Maintenance Domain (MD) Level which identifies a value
in the range of 0-7 associated with Ethernet OAM frame.
MD Level identifies the span of the Ethernet OAM frame.
MEP       Maintenance End Point is responsible for origination
and termination of OAM frames for a given MEG
MIP       Maintenance Intermediate Point is located between peer
MEPs and can process OAM frames but does not initiate
or terminate them
RDI       Remote Defect Indication

Further, this document also uses the terminology and conventions
used in [PW-OAM-MSG-MAP].

3. PW Status and Defects

[PW-OAM-MSG-MAP] 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 [PW-OAM-MSG-
MAP] to detect PW defects, depending on the PSN type (e.g. MPLS PSN,
MPLS-IP PSN). Any of these mechanisms can be used when monitoring
the state of Ethernet PWs. [PW-OAM-MSG-MAP] also discusses the
applicability of these failure detection mechanisms.

3.1 Use of Native Service notification

There is no NS fault notification capability currently specified for
Ethernet PWs. However, with the completion of Ethernet OAM work,
this capability should be added. This includes the ability to create
a MEP associated with the Ethernet PW on the PE. The native service
notification options include:

- AIS Frames sent by the local MEP to the MEP on the remote PE when
the MEP needs to convey PE forward defects, and when CCM
transmission is configured not to be turned ON.
- Suspension of CCM frames transmission from the MEP to the peer MEP
on the other PE to convey PE forward defects, when CCM
transmission is configured to be turned ON.
- RDI in transmitted CCM frames, when loss of CCMs from the peer MEP
is detected or PE needs to convey PW reverse defects.

These NS OAM notifications are inserted into the corresponding PW.

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:
- Stop AIS Frame transmission from the local MEP to the MEP on the remote PE to clear PW forward defects;
- Resuming CCM frames transmission from the MEP to the peer MEP to clear PW forward defects notification, when CCM transmission is configured to be turned ON.
- Clearing RDI indication in transmitted CCM frames, to clear PW reverse defects notification.

3.2 Use of PW Status notification for MPLS PSNs

When PWs are established using LDP, LDP status notification signaling SHOULD be used as the default mechanism to signal AC and PW status and defects [RFC4447]. For PWs established over an MPLS or MPLS-IP PSN using other mechanisms (e.g. static configuration), inband signaling using VCCV-BFD [VCCV] SHOULD be used to convey AC and PW status and defects.

[PW-OAM-MSG-MAP] identifies the following PW defect status codepoints:
- Forward defect: corresponds to a logical OR of local AC (ingress) Receive fault AND local PSN-facing PW (egress) transmit fault.
- Reverse defect: corresponds to a logical OR of local AC (egress) transmit fault and local PW PSN-facing (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 Target LDP session with the peer PE.

3.3 Use of BFD Diagnostic Codes

When using VCCV, the control channel (CC) type and Connectivity Verification (CV) Type are agreed on between the peer PEs using the OAM capability sub-TLV signaled as part of the interface parameter TLV when using FEC 129 and the interface parameter sub-TLV when using FEC 128.

As defined in [PW-OAM-MSG-MAP], when CV type of 0x04 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 defects or PE internal defects preventing it from forwarding traffic, are communicated via LDP Status notification message in MPLS and MPLS-IP PSN or other mechanisms in L2TP-IP PSN.

Similarly, when CV type of 0x08 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. Ethernet AC Defect States Entry or Exit Criteria

4.1 AC Forward Defect State Entry or Exit

PE1 enters the AC forward defect state if any of the following conditions are 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.
- A MEP associated with the local AC receives an Ethernet AIS frame.
- A MEP associated with the local AC does not receive CCM frames from the peer MEP in the client domain (e.g. CE1) within a configurable interval equal to a multiple (e.g. 3.5) of the CCM transmission period configured for the MEP. This is the case when CCM transmission is configured to be turned ON.

PE1 exits the AC forward 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 notified previously, is removed (e.g. via loss of signal (LoS), or Ethernet Link OAM [802.3] critical link event notifications with "Dying Gasp" or "Critical Event" indication 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 was resulted in entering the defect state.
- A MEP associated with the local AC and configured with CCM transmission on 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 (e.g. 3.5) of the CCM transmission period configured for the MEP.

4.2 AC Reverse Defect State Entry or Exit

PE1 enters the AC reverse defect state if any of the following condition is met:

- It detects or is notified of a physical layer fault on the Ethernet interface (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 turned ON and associated with the local AC receives a CCM frame, with its RDI bit set, from peer MEP in the client domain (e.g. CE1).
PE1 exits the AC reverse 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 notified previously, is removed (e.g. via 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 turned ON and associated with the local AC does not receive a CCM frame with RDI bit set, having received a previous CCM frame with RDI bit set from the peer MEP in the client domain (e.g. CE1).

5. Ethernet AC and PW Defect States Interworking

5.1 PW Forward Defect Entry Procedures

When the PW status on PE1 transitions from working to PW forward 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 Forward Defect State, the following must be done:

- If PE1 is configured with a MEP associated with the local AC and CCM transmission is not configured to be turned ON, the MEP associated with the AC must transmit AIS frames periodically to the MEP in the client domain (e.g. on CE1) based on configured AIS transmission period.
- If PE1 is configured with a MEP associated with the local AC and CCM transmission is configured to be turned ON, and the MEP associated with the AC is configured to support Interface Status TLV in CCM messages, the MEP associated with the AC must transmit CCM frames with Interface Status TLV as being down to the peer MEP in the client domain (e.g. on CE1).
- If PE1 is configured with a MEP associated with the local AC and CCM transmission is configured to be turned ON, and the MEP associated with the AC is configured to not support Interface Status TLV in CCM messages, 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 [MEF 16] with CE1 and if E-LMI is used for failure notification, PE1 must transmit E-LMI asynchronous STATUS message with report type Single EVC Asynchronous Status indicating that PW is Not Active.

Further, when PE1 enters the forward defect state, it must assume that PE2 has no knowledge of the defect and must send reverse defect
failure notification to PE2. For MPLS PSN or MPLS-IP PSN, this is
done via either a PW Status notification message indicating a
reverse defect; or via VCCV-BFD diagnostic code of reverse defect if
VCCV CV type of 0x08 had been negotiated. When Native Service OAM
mechanism is supported on PE, it can also use the NS OAM
notification as specified in Section 3.1.

If PW forward defect 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.

Note: The location of the MEP associated with the local AC within a
PE can be a down MEP on the port associated with the AC or an Up MEP
associated with an emulated LAN interface within the PE, as defined
in L2VPN framework for a VPLS PE. Though for the purposes of VPWS
service, VPLS PE architecture is not mandatory, the VPLS PE
architecture serves as a generic case where the PE can support both
VPWS and VPLS services.

5.2 PW Forward Defect Exit Procedures

When the PW status transitions from PW forward 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 a MEP associated with the local AC and
  CCM transmission is not configured to be turned ON, 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 MEP associated with the local AC and
  CCM transmission is configured to be turned ON, and the MEP
  associated with the AC is configured to support Interface Status TLV
  in CCM messages, the MEP associated with the AC must transmit CCM
  frames with Interface Status TLV as being Up to the peer MEP in the
  client domain (e.g. on CE1).

- If PE1 is configured with a MEP associated with the local AC and
  CCM transmission is configured to be turned ON, and the MEP
  associated with the AC is configured to not support Interface Status
  TLV in CCM messages, 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 [MEF 16] with CE1 and E-LMI is
  used for fault notification, PE1 must transmit E-LMI asynchronous
  STATUS message with report type Single EVC Asynchronous Status
  indicating that PW is Active.
Further, if the PW forward defect was explicitly detected by PE1, it must now notify PE2 about clearing of forward defect state by clearing reverse defect notification. For PWs over MPLS PSN or MPLS-IP PSN, this is either done via PW Status message indicating working; or via VCCV-BFD diagnostic code if VCCV CV type of 0x08 had been negotiated. When Native Service OAM mechanism is supported on PE, it can also clear the NS OAM notification specified in Section 3.1.

If PW forward 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.

### 5.3 PW Reverse Defect Entry Procedures

When the PW status transitions from working to PW reverse defect state, PE1’s ability to transmit user traffic to CE2 is impacted. As a result, PE needs to notify CE1 about this problem which has been detected by PE1.

Upon entry to the PW Reverse Defect State, the following must be done:

- If PE1 is configured with a MEP associated with the local AC and CCM transmission is configured to be turned ON, the MEP associated with the AC must set the RDI bit in transmitted CCM frames sent to the peer MEP in the client domain (e.g. on CE1).

- If PE1 is configured to run E-LMI [MEF 16] with CE1 and E-LMI is used for fault notification, PE1 must transmit E-LMI asynchronous STATUS message with report type Single EVC Asynchronous Status indicating that PW is Not Active.

### 5.4 PW Reverse Defect Exit Procedures

When the PW status transitions from PW reverse 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 MEP associated with the local AC and CCM transmission is configured to be turned ON, the MEP associated with the AC must clear the RDI bit in the transmitted CCM frames to the peer MEP (e.g. on CE1).

- If PE1 is configured to run E-LMI [MEF 16] with CE1, PE1 must transmit E-LMI asynchronous STATUS message with report type Single EVC Asynchronous Status indicating that PW is Active.
5.5 AC Forward Defect Entry Procedures

When AC status transitions from working to AC Forward 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 Forward 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, and for PW over MPLS PSN or MPLS-IP PSN, forward defect notification is done via either PW Status message indicating a forward defect or via VCCV-BFD diagnostic code of forward defect if VCCV CV type of 0x08 had been negotiated.

When Native Service OAM mechanism is supported on PE1, it can also use the NS OAM notification as specified in Section 3.1.

In addition to above actions, PE1 must perform the following:
- If PE1 is configured with a MEP associated with the local AC and CCM transmission is configured to be turned ON, the MEP associated with AC must set the RDI bit in transmitted CCM frames.

5.6 AC Forward Defect Exit Procedures

When AC status transitions from AC Forward defect 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 and for PW over MPLS PSN or MPLS-IP PSN, forward defect notification is cleared via PW Status message indicating a working state; or via VCCV-BFD diagnostic code if VCCV CV type of 0x08 had been negotiated.
- When Native Service OAM mechanism is supported on PE1, PE1 clears the NS OAM notification as specified in Section 3.1.
- If PE1 is configured with a MEP associated with the local AC and CCM transmission is configured to be turned ON, 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).

5.7 AC Reverse Defect Entry Procedures

When AC status transitions from working to AC Reverse defect, 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 Reverse defect is detected by PE1, it must notify PE2 in the form of a reverse defect notification.

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

When Native Service OAM mechanism is supported on PE, it can also use the NS OAM notification as specified in Section 3.1.

5.8 AC Reverse Defect Exit Procedures

When AC status transitions from AC Reverse defect to working, PE1’s ability to transmit user traffic to CE1 is restored. As a result, PE1 needs to clear notification to PE2.

If the AC Reverse defect is cleared, PE1 must clear reverse defect notification to PE2.

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

When Native Service OAM mechanism is supported on PE1, PE1 can clear NS OAM notification as specified in Section 3.1.

6. Acknowledgments

The authors are thankful to Samer Salam and Ray Qiu for their comments.

7. IANA Considerations

This document has no actions for IANA.

8. Security Considerations

This document does not impose any security concerns since it makes use of existing OAM mechanisms and mapping of these messages does not change inherent security features.

9. References

9.1 Normative References
Ethernet OAM mechanisms are broadly classified into two categories: Fault Management (FM) and Performance Monitoring (PM). ITU-T Y.1731 provides coverage for both FM and PM while IEEE 802.1ag provides coverage for a sub-set of FM functions.

Ethernet OAM also introduces the concept of Maintenance Entity (ME) which is used to identify the entity that needs to be managed. A ME is inherently a point-to-point association. However, in case of a multipoint association, Maintenance Entity Group (MEG) consisting of different MEs is used. IEEE 802.1 uses the concept of Maintenance Association (MA) which is used to identify both point-to-point and multipoint associations. Each MA consists of Maintenance End Points (MEPs) which are responsible for originating OAM frames. In between the MEPs, there can also be Maintenance Intermediate Points (MIPs) which do not originate OAM frames however 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 Maintenance Domain Levels (MD).
It is important to note that the common set of FM mechanisms between IEEE 802.1ag and ITU-T Y.1731 are completely compatible.

The common FM mechanisms include:

1) Continuity Check Messages (CCM)
2) Loopback Message (LBM) and Loopback Reply (LBR)
3) Linktrace Message (LTM) and Linktrace Reply (LTR)

CCM messages are used for fault detection including misconnections and mis-configurations. Typically CCM messages are sent as multicast frames or Unicast frames and also allow RDI notifications. LBM/LBR are used to perform fault verification, while also allow for MTU verification and CIR/EIR measurements. LTM/LTR can be used for discovering the path traversed between a MEP and another target MIP/MEP in the same MA. LTM/LTR also allow for fault localization.

In addition, ITU-T 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 also specifies the following PM functions:

5) Loss Measurement Message (LMM) and Reply (LMR)
6) Delay Measurement Message (DMR) and Reply (DMR)
7) 1-way Delay Message (1DM)

While LMM/LMR is used to measure Frame Loss Ratio (FLR), DMM/DMR is 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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