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Layer 2 Virtual Private Network (L2VPN) Operations, Administration, and Maintenance (OAM) Requirements and Framework

Abstract

This document provides framework and requirements for Layer 2 Virtual Private Network (L2VPN) Operations, Administration, and Maintenance (OAM). The OAM framework is intended to provide OAM layering across L2VPN services, pseudowires (PWs), and Packet Switched Network (PSN) tunnels. This document is intended to identify OAM requirements for L2VPN services, i.e., Virtual Private LAN Service (VPLS), Virtual Private Wire Service (VPWS), and IP-only LAN Service (IPLS). Furthermore, if L2VPN service OAM requirements impose specific requirements on PW OAM and/or PSN OAM, those specific PW and/or PSN OAM requirements are also identified.

Status of This Memo

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1. Introduction

This document provides framework and requirements for Layer 2 Virtual Private Network (L2VPN) Operation, Administration, and Maintenance (OAM).

The scope of OAM for any service and/or transport/network infrastructure technologies can be very broad in nature. OSI has defined the following five generic functional areas commonly abbreviated as "FCAPS" [NM-Standards]: a) Fault Management, b) Configuration Management, c) Accounting Management, d) Performance Management, and e) Security Management.

This document focuses on the Fault and Performance Management aspects. Other functional aspects of FCAPS are for further study.

Fault Management can typically be viewed in terms of the following categories:

- Fault Detection
- Fault Verification
- Fault Isolation
- Fault Notification and Alarm Suppression
- Fault Recovery

Fault detection deals with mechanism(s) that can detect both hard failures, such as link and device failures, and soft failures, such as software failure, memory corruption, misconfiguration, etc. Typically, a lightweight protocol is desirable to detect the fault and thus it would be prudent to verify the fault via a fault verification mechanism before taking additional steps in isolating the fault. After verifying that a fault has occurred along the data path, it is important to be able to isolate the fault to the level of a given device or link. Therefore, a fault isolation mechanism is needed in Fault Management. A fault notification mechanism can be used in conjunction with a fault detection mechanism to notify the devices upstream and downstream to the fault detection point. For example, when there is a client/server relationship between two layered networks, fault detection at the server layer may result in the following fault notifications:

- Sending a forward fault notification from the server layer to the client layer network(s) using the fault notification format appropriate to the client layer
- Sending a backward fault notification at the server layer, if applicable, in the reverse direction
- Sending a backward fault notification at the client layer, if applicable, in the reverse direction

Finally, fault recovery deals with recovering from the detected failure by switching to an alternate available data path using alternate devices or links (e.g., device redundancy or link redundancy).

Performance Management deals with mechanism(s) that allow determining and measuring the performance of the network/services under consideration. Performance Management can be used to verify the compliance to both the service-level and network-level metric objectives/specifications. Performance Management typically consists of measurement of performance metrics, e.g., Frame Loss, Frame Delay, Frame Delay Variation (aka Jitter), etc., across managed entities when the managed entities are in available state. Performance Management is suspended across unavailable managed entities.

[L2VPN-FRWK] specifies three different types of Layer 2 VPN services: Virtual Private LAN Service (VPLS), (Virtual Private Wire Service (VPWS), and IP-only LAN Service (IPLS).

This document provides a reference model for OAM as it relates to L2VPN services and their associated pseudowires (PWs) and Public Switched Network (PSN) tunnels. OAM requirements for L2VPN services (e.g., VPLS and VPWS) are also identified. Furthermore, if L2VPN service OAM requirements impose requirements for PW and/or PSN OAM, those specific PW and/or PSN OAM requirements are also identified.

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].

1.2. Relationship with Other OAM Work

This document leverages protocols, mechanisms, and concepts defined as part of other OAM work, specifically the following:

- IEEE Std. 802.1ag-2007 [IEEE802.1ag] specifies the Ethernet Connectivity Fault Management protocol, which defines the concepts of Maintenance Domains, Maintenance End Points, and Maintenance Intermediate Points. This standard also defines mechanisms and procedures for proactive fault detection (Continuity Check), fault notification (Remote Defect Indication (RDI)), fault verification (Loopback), and fault isolation (LinkTrace) in Ethernet networks.

- ITU-T Std. Y.1731 [Y.1731] builds upon and extends IEEE 802.1ag in the following areas: it defines fault notification and alarm suppression functions for Ethernet (via Alarm Indication Signal (AIS)). It also specifies messages and procedures for Ethernet performance management, including loss, delay, jitter, and throughput measurement.

2. Terminology

This document introduces and uses the following terms. This document also uses the terms defined in [L2VPN-FRWK] and [L2VPN-TERM].

AIS	Alarm Indication Signal
IPLS	IP-only LAN Service
ME	Maintenance Entity, which is defined in a given OAM domain and represents an entity requiring management
MEG	Maintenance Entity Group, which represents MEs belonging to the same service instance and is also called Maintenance Association (MA)
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 and respond to certain OAM frames but does not initiate or terminate them.
OAM Domain	OAM Domain represents a region over which OAM frames can operate unobstructed.
QinQ	802.1Q tag inside another 802.1Q tag
RDI	Remote Defect Indication
VPLS	Virtual Private LAN Service
VPWS	Virtual Private Wire Service

3. L2VPN Services and Networks

Figure 1 shows an L2VPN reference model as described in [L2VPN-REQ]. L2VPN A represents a point-to-point service while L2VPN B represents a bridged service.

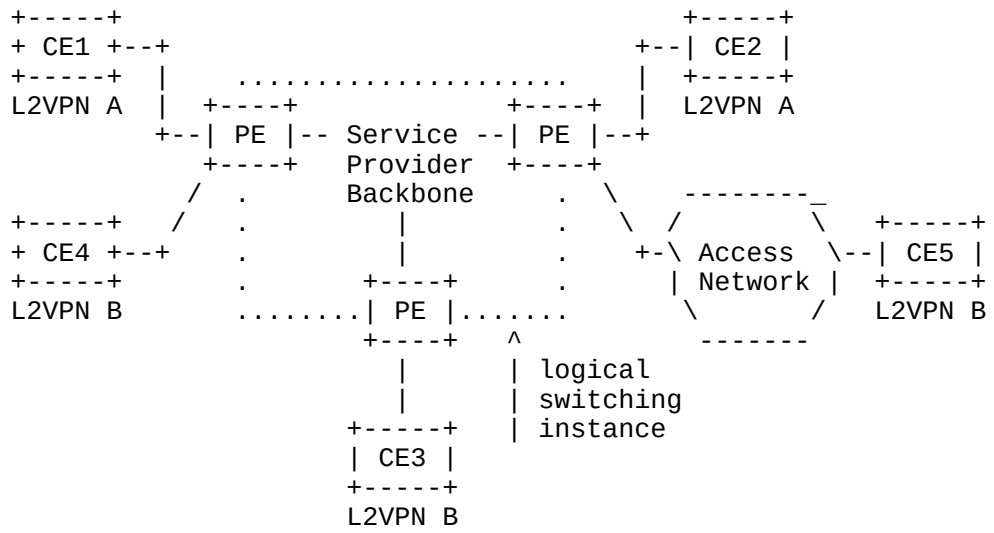


Figure 1: L2VPN Reference Model

[L2VPN-FRWK] specifies VPWS, VPLS, and IPLS. VPWS is a point-to-point service where Customer Edges (CEs) are presented with point-to-point virtual circuits. VPLS is a bridged LAN service provided to a set of CEs that are members of a VPN. CEs that are members of the same service instance communicate with each other as if they were connected via a bridged LAN. IPLS is a special VPLS that is used to carry only IP service packets.

[L2VPN-REQ] assumes the availability of runtime monitoring protocols while defining requirements for management interfaces. This document specifies the requirements and framework for operations, administration, and maintenance (OAM) protocols between network devices.

4. L2VPN OAM Framework

4.1. OAM Layering

The point-to-point or bridged LAN functionality is emulated by a network of Provider Edges (PEs) to which the CEs are connected. This network of PEs can belong to a single network operator or can span across multiple network operators. Furthermore, it can belong to a single service provider or can span across multiple service providers. A service provider is responsible for providing L2VPN services to its customers, whereas a network operator (aka facility provider) provides the necessary facilities to the service provider(s) in support of their services. A network operator and a

service provider can be part of the same administrative organization, or they can belong to different administrative organizations.

The different layers involved in realizing L2VPNs include service layers and network layers. Network layers can be iterative. In the context of L2VPNs, the service layer consists of VPLS, VPWS (e.g., Ethernet, ATM, FR, HDLC, SONET, point-to-point emulation, etc.), and IPLS. Similarly, in the context of L2VPNs, network layers consist of MPLS/IP networks. The MPLS/IP networks can consist of networks links realized by different technologies, e.g., SONET, Ethernet, ATM, etc.

Each layer is responsible for its own OAM. This document provides the OAM framework and requirements for L2VPN services and networks.

4.2. OAM Domains

When discussing OAM tools for L2VPNs, it is important to provide OAM capabilities and functionality over each domain for which a service provider or a network operator is responsible. It is also important that OAM frames not be allowed to enter/exit other domains. We define an OAM domain as a network region over which OAM frames operate unobstructed, as explained below.

At the edge of an OAM domain, filtering constructs should prevent OAM frames from exiting and entering that domain. OAM domains can be nested but not overlapped. In other words, if there is a hierarchy of the OAM domains, the OAM frames of a higher-level domain pass transparently through the lower-level domains, but the OAM frames of a lower-level domain get blocked/filtered at the edge of that domain.

In order to facilitate the processing of OAM frames, each OAM domain can be associated with the level at which it operates. Higher-level OAM domains can contain lower-level OAM domains, but the converse is not true. It may be noted that the higher-level domain does not necessarily mean a higher numerical value of the level encoding in the OAM frame.

A PE can be part of several OAM domains, with each interface belonging to the same or a different OAM domain. A PE, with an interface at the boundary of an OAM domain, shall block outgoing OAM frames, filter out incoming OAM frames whose domain level is lower or the same as the one configured on that interface, and pass through the OAM frames whose domain level is higher than the one configured on that interface.

Generically, L2VPNs can be viewed as consisting of a customer OAM domain, a service provider OAM domain, and network operator OAM domains as depicted in Figure 2.

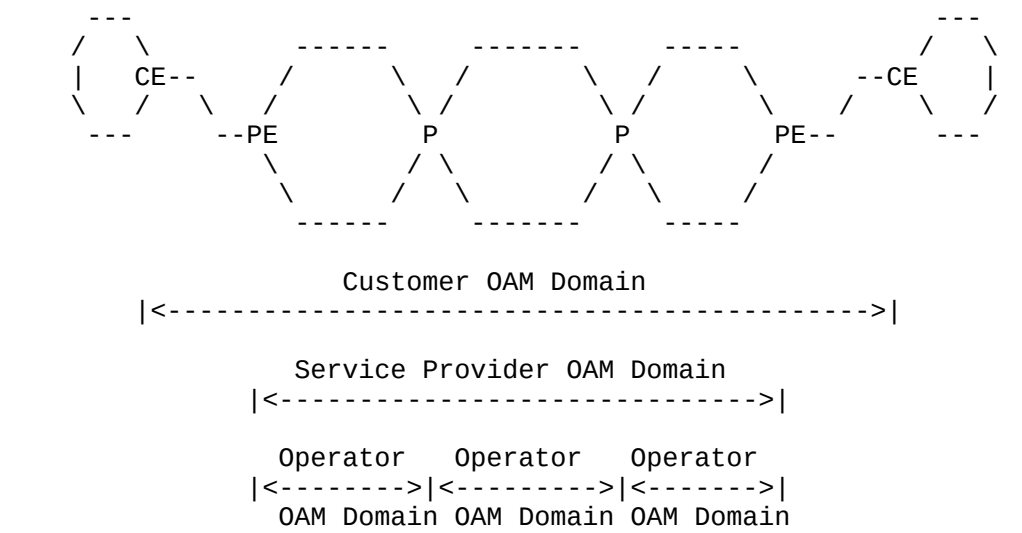


Figure 2: OAM Domains

The OAM Domains can be categorized as follows:

- Hierarchical OAM Domains: Hierarchical OAM Domains result from OAM Layering and imply a contractual agreement among the OAM Domain owning entities. In Figure 2, the customer OAM domain, the service provider OAM domain, and the operator OAM domains are hierarchical.

- Adjacent OAM Domains: Adjacent OAM Domains are typically independent of each other and do not have any relationship among them. In Figure 2, the different operator OAM domains are independent of each other.

4.3. MEPs and MIPs

Maintenance End Points (MEPs) are responsible for origination and termination of OAM frames. MEPs are located at the edge of their corresponding OAM domains. Maintenance Intermediate Points (MIPs) are located within their corresponding OAM domains, and they normally pass OAM frames but never initiate them. Since MEPs are located at the edge of their OAM domains, they are responsible for filtering outbound OAM frames from leaving the OAM domain or inbound OAM frames from entering the OAM domain.

An OAM frame is generally associated with a Maintenance Entity Group (MEG), where a MEG consists of a set of Maintenance Entities (MEs)

associated with the same service instance. An ME is a point-to-point association between a pair of MEPs and represents a monitored entity. For example, in a VPLS that involves n CEs, all the MEs associated with the VPLS in the customer OAM domain (i.e., from CE to CE) can be considered to be part of a VPLS MEG, where the n-point MEG consists of a maximum of n(n-1)/2 MEs. MEPs and MIPs correspond to a PE, or, more specifically, to an interface of a PE. For example, an OAM frame can be said to originate from an ingress PE or more specifically an ingress interface of that PE. A MEP on a PE receives messages from n-1 other MEPs (some of them may reside on the same PE) for a given MEG.

In Hierarchical OAM Domains, a MEP of lower-level OAM domain can correspond to a MIP or a MEP of a higher-level OAM domain. Furthermore, the MIPs of a lower-level OAM domain are always transparent to the higher-level OAM domain (e.g., OAM frames of a higher-level OAM domain are not seen by MIPs of a lower-level OAM domain and get passed through them transparently). Further, the MEs (or MEGs) are hierarchically organized in hierarchical OAM domains. For example, in a VPWS, the VPWS ME in the customer OAM domain can overlap with the Attachment Circuit (AC) ME, PW ME, and another AC ME in service provider OAM domain. Similarly, the PW ME can overlap with different ME in operator OAM domains.

4.4. MEP and MIP Identifiers

As mentioned previously, OAM at each layer should be independent of other layers, e.g., a service layer OAM should be independent of an underlying transport layer. MEPs and MIPs at each layer should be identified with layer-specific identifiers.

5. OAM Framework for VPLS

Virtual Private LAN Service (VPLS) is used in different contexts, such as the following: a) as a bridged LAN service over networks, some of which are MPLS/IP, b) as an MPLS/IP network supporting these bridged LAN services, and c) as (V)LAN emulation.

5.1. VPLS as Service/Network

5.1.1. VPLS as Bridged LAN Service

The most common definition for VPLS is for bridged LAN service over an MPLS/IP network. The service coverage is considered end-to-end from UNI to UNI (or AC to AC) among the CE devices, and it provides a virtual LAN service to the attached CEs belonging to that service instance. The reason it is called bridged LAN service is because the VPLS-capable PE providing this end-to-end virtual LAN service is

performing bridging functions (either full or a subset) as described in [L2VPN-FRWK]. This VPLS definition, as specified in [L2VPN-REQ], includes both bridge module and LAN emulation module (as specified in [L2VPN-FRWK]).

Throughout this document, whenever the term "VPLS" is used by itself, it refers to the service as opposed to network or LAN emulation.

A VPLS instance is also analogous to a VLAN provided by IEEE 802.1Q networks since each VLAN provides a Virtual LAN service to its Media Access Control (MAC) users. Therefore, when a part of the service provider network is Ethernet based (such as H-VPLS with QinQ access network), there is a one-to-one correspondence between a VPLS instance and its corresponding provider VLAN in the service provider Ethernet network. To check the end-to-end service integrity, the OAM mechanism needs to cover the end-to-end VPLS as defined in [L2VPN-REQ], which is from AC to AC, including bridge module, VPLS forwarder, and the associated PWs for this service. This document specifies the framework and requirements for such OAM mechanisms.

5.1.2. VPLS as a Network

Sometimes VPLS is also used to refer to the underlying network that supports bridged LAN services. This network can be an end-to-end MPLS/IP network, as in H-VPLS with MPLS/IP access, or it can be a hybrid network consisting of MPLS/IP core and Ethernet access network, as in H-VPLS with QinQ access. In either case, the network consists of a set of VPLS-capable PE devices capable of performing bridging functions (either full or a subset). These VPLS-capable PE devices can be arranged in a certain topology, such as hierarchical topology, distributed topology, or some other topologies such as multi-tier or star topologies. To check the network integrity regardless of the network topology, network-level OAM mechanisms (such as OAM for MPLS/IP networks) are needed. The discussion of network-level OAM is outside of the scope of this document.

5.1.3. VPLS as (V)LAN Emulation

Sometimes VPLS also refers to (V)LAN emulation. In this context, VPLS only refers to the full mesh of PWs with split horizon that emulates a LAN segment over a MPLS/IP network for a given service instance and its associated VPLS forwarder. Since the emulated LAN segment is presented as a Virtual LAN (VLAN) to the bridge module of a VPLS-capable PE, the emulated segment is also referred to as an emulated VLAN. The OAM mechanisms in this context refer primarily to integrity check of VPLS forwarders and their associated full mesh of

PWs and the ability to detect and notify a partial mesh failure. This document also covers the OAM framework and requirements for such OAM mechanisms.

5.2. VPLS OAM

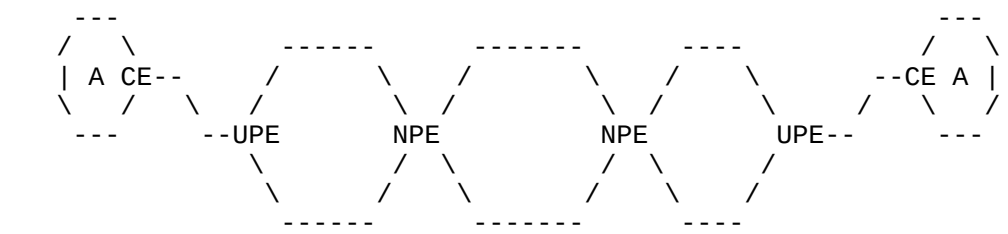
When discussing the OAM mechanisms for VPLS, it is important to consider that the end-to-end service can span across different types of L2VPN networks. For example, the access network on one side can be a bridged network, e.g., [IEEE802.1ad], as described in Section 11 of [VPLS-LDP]. The access network can also be a [IEEE802.1ah]-based bridged network. The access network on the other side can be MPLS-based, as described in Section 10 of [VPLS-LDP], and the core network connecting them can be IP, MPLS, ATM, or SONET. Similarly, the VPLS instance can span across [VPLS-BGP] and distributed VPLS as described in [L2VPN-SIG].

Therefore, it is important that the OAM mechanisms can be applied to all these network types. Each such network may be associated with a separate administrative domain, and multiple such networks may be associated with a single administrative domain. It is important to ensure that the OAM mechanisms are independent of the underlying transport mechanisms and solely rely on VPLS, i.e., the transparency of OAM mechanisms must be ensured over underlying transport technologies such as MPLS, IP, etc.

This proposal is aligned with the discussions in other standard bodies and groups such as ITU-T Q.5/13, IEEE 802.1, and Metro Ethernet Forum (MEF), which address Ethernet network and service OAM.

5.2.1. VPLS OAM Layering

Figure 3 shows an example of a VPLS (with two CEs belonging to customer A) across a service provider network marked by UPE and NPE devices. More CE devices belonging to the same customer A can be connected across different customer sites. The service provider network is segmented into a core network and two types of access networks. In Figure 3, (A) shows the bridged access network represented by its bridge components marked B and the MPLS access and core network represented by MPLS components marked P. In Figure 3, (B) shows the service/network view at the Ethernet MAC layer marked by E.



(A) CE----UPE--B--B--NPE---P--P---NPE---P----UPE----CE

(B) E------E---E--E---E-----------E----------E-----E

Figure 3: VPLS-Specific Device View

As shown in (B) of Figure 3, only the devices with Ethernet functionality are visible to OAM mechanisms operating at the Ethernet MAC layer, and the P devices are invisible. Therefore, the OAM along the path of P devices (e.g., between two PEs) is covered by the transport layer, and it is outside the scope of this document.

However, VPLSs may impose some specific requirements on PSN OAM. This document aims to identify such requirements.

5.2.2. VPLS OAM Domains

As described in the previous section, a VPLS for a given customer can span across one or more service providers and network operators. Figure 4 depicts three OAM domains: (A) customer domain, which is among the CEs of a given customer, (B) service provider domain, which is among the edge PEs of the given service provider, and (C) network operator domain, which is among the PEs of a given operator.

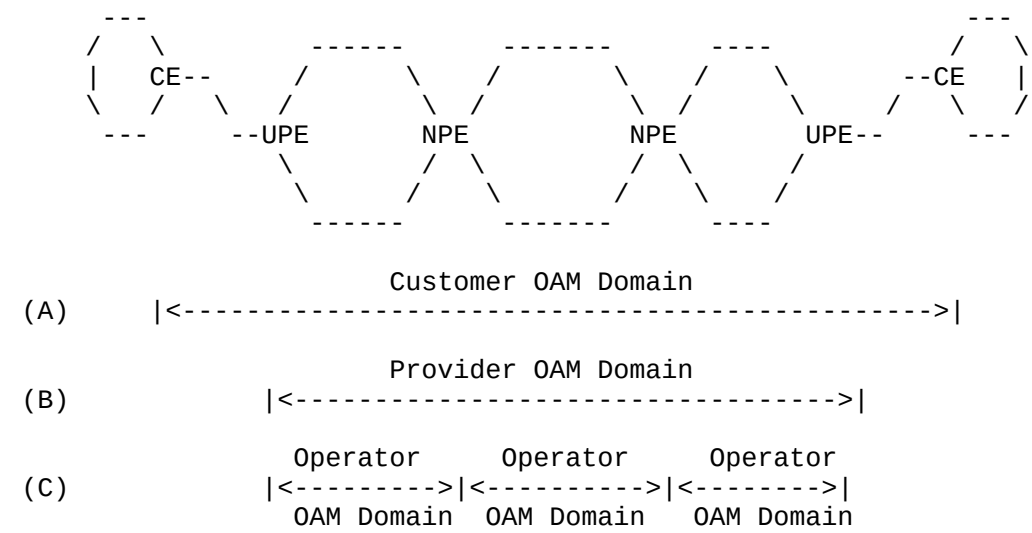
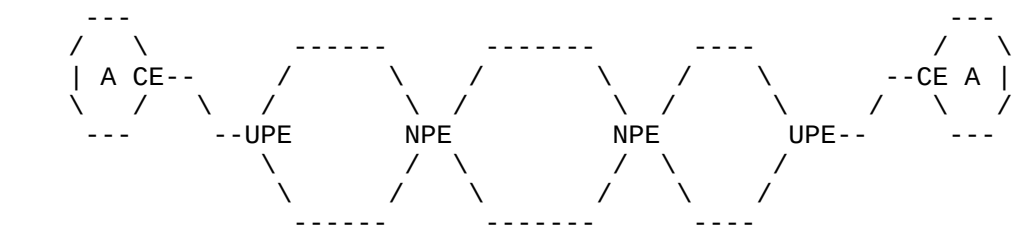


Figure 4: VPLS OAM Domains

5.2.3. VPLS MEPs and MIPs

As shown in Figure 5, (C) represents those MEPs and MIPs that are visible within the customer domain. The MIPs associated with (C) are expected to be implemented in the bridge module/VPLS forwarder of a PE device, as per [L2VPN-FRWK]. (D) represents the MEPs and MIPs visible within the service provider domain. These MEPs and MIPs are expected to be implemented in the bridge module/VPLS forwarder of a PE device, as per [L2VPN-FRWK]. (E) represents the MEPs and MIPs visible within each operator domain, where MIPs only exist in an Ethernet access network (i.e., an MPLS access network does not have MIPs at the operator level). Further, (F) represents the MEPs and MIPs corresponding to the MPLS layer and may apply MPLS-based mechanisms. The MPLS layer shown in Figure 5 is just an example; specific OAM mechanisms are outside the scope of this document.



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(A)    CE----UPE--B-----NPE---P------NPE---P----UPE----CE
(B)    E------E---E------E------------E----------E-----E

                        Customer OAM Domain
(C)    MEP---MIP--------------------------------MIP---MEP

                        Provider OAM Domain
(D)          MEP--------MIP-----------MIP-------MEP

                Operator    Operator     Operator
(E)          MEP-MIP--MEP|MEP-------MEP|MEP-----MEP
               OAM domain   OAM domain   OAM domain

                             MPLS OAM   MPLS OAM
(F)                       MEP--MIP--MEP|MEP-MIP-MEP
                             domain     domain
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Figure 5: VPLS OAM Domains, MEPs, and MIPs

5.2.4. VPLS MEP and MIP Identifiers

In VPLS, for the Ethernet MAC layer, the MEPs and MIPs should be identified with their Ethernet MAC addresses and Maintenance Entity Group Identifier (MEG ID). As described in [VPLS-LDP], a VPLS instance can be identified in an Ethernet domain (e.g., 802.1ad domain) using a VLAN tag (service tag) while in an MPLS/IP network, PW-ids are used. Both PW-ids and VLAN tags for a given VPLS instance are associated with a Service Identifier (e.g., VPN identifier). MEPs and MIPs Identifiers, i.e., MEP Ids and MIP Ids, must be unique within their corresponding Service Identifiers within the OAM domains.

For Ethernet services, e.g., VPLS, Ethernet frames are used for OAM frames, and the source MAC address of the OAM frames represent the source MEP in that domain for a specific MEG. For unicast Ethernet OAM frames, the destination MAC address represents the destination MEP in that domain for a specific MEG. For multicast Ethernet OAM frames, the destination MAC addresses correspond to all MEPs in that domain for a specific MEG.

6. OAM Framework for VPWS

Figure 6 shows the VPWS reference model. VPWS is a point-to-point service where CEs are presented with point-to-point virtual circuits. VPWS is realized by combining a pair of Attachment Circuits (ACs) and a single PW between two PEs.

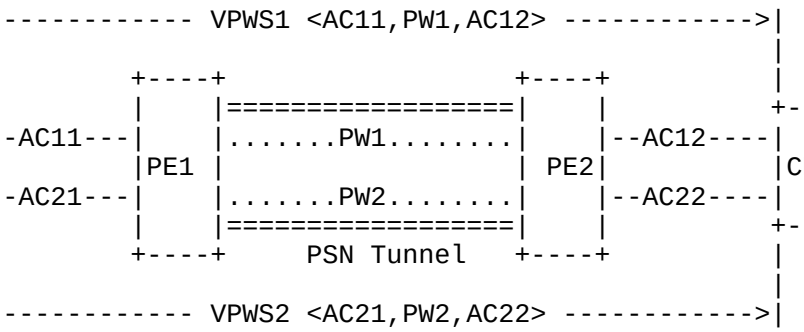

Figure 6: VPWS Reference Model

6.1. VPWS as Service

VPWS can be categorized as follows:

- VPWS with homogeneous ACs (where both ACs are same type)
- VPWS with heterogeneous ACs (where the ACs are of different Layer-2 encapsulation)

Further, the VPWS can itself be classified as follows:

- Homogeneous VPWS (when two ACs and PW are of the same type)
- Heterogeneous VPWS (when at least one AC or PW is a different type than the others)

Based on the above classifications, the heterogeneous VPWS may have either homogeneous or heterogeneous ACs. On the other hand, homogeneous VPWS can have only homogeneous ACs.

Throughout this document, whenever the term "VPWS" is used by itself, it refers to the service.

6.2. VPWS OAM

When discussing the OAM mechanisms for VPWS, it is important to consider that the end-to-end service can span across different types of networks. As an example, the access network between the CE and PE on one side can be an Ethernet-bridged network, an ATM network, etc. In common scenarios, it could simply be a point-to-point interface such as Ethernet Physical Layer (PHY). The core network connecting PEs can be IP, MPLS, etc.

Therefore, it is important that the OAM mechanisms can be applied to different network types, some of which are mentioned above. Each such network may be associated with a separate administrative domain, and multiple such networks may be associated with a single administrative domain.

6.2.1. VPWS OAM Layering

Figure 7 shows an example of a VPWS (with two CE devices belonging to customer A) across a service provider network marked by PE devices. The service provider network can be considered to be segmented into a core network and two types of access networks.

In the most general case, a PE can be client service aware when it processes client service PDUs and is responsible for encapsulating and de-encapsulating client service PDUs onto PWs and ACs. This is particularly relevant for homogeneous VPWS. The service-specific device view for such a deployment is highlighted by (A) in Figure 7, for these are the devices that are expected to be involved in end-to-end VPWS OAM.

In other instances, a PE can be client service unaware when it does not process native service PDUs but instead encapsulates access technology PDUs over PWs. This may be relevant for VPWS with heterogeneous ACs, such as Ethernet VPWS, which is offered across an ATM AC, ATM PW, and Ethernet AC. In this case, the PE that is attached to ATM AC and ATM PW may be transparent to the client Ethernet service PDUs. On the other hand, the PE that is attached to ATM PW and Ethernet AC is expected to be client Ethernet service aware. The service-specific device view for such a deployment is highlighted by (B) in Figure 7, for these are the devices that are expected to be involved in end-to-end VPWS OAM, where PE1 is expected to be client service unaware.

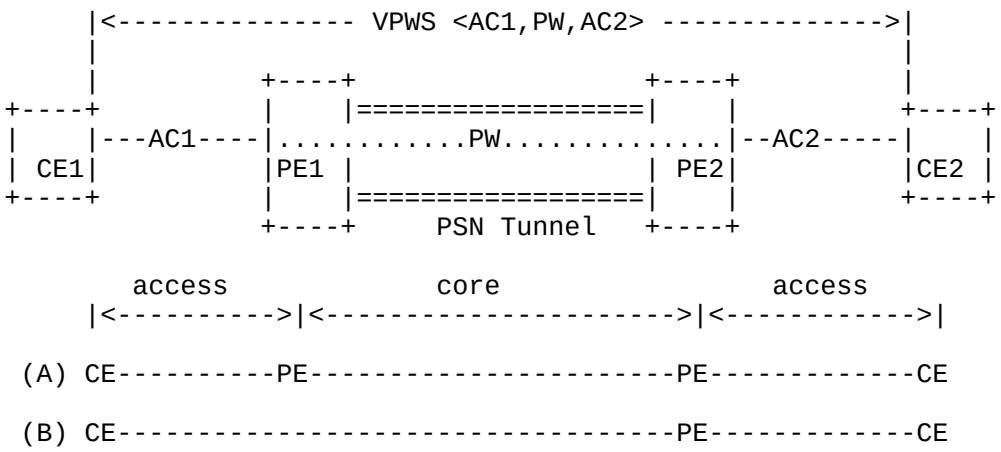

Figure 7: VPWS-Specific Device View

6.2.2. VPWS OAM Domains

As described in the previous section, a VPWS for a given customer can span across one or more network operators.

Figures 8a and 8b depict three OAM domains: (A) customer domain, which is among the CEs of a given customer, (B) service provider domain, which depends on the management model, and (C) network operator domain, which is among the PEs of a given operator and could also be present in the access network if the ACs are provided by a different network operator. The core network operator may be responsible for managing the PSN Tunnel in these examples.

For the first management model, shown in Figure 8a, the CEs are expected to be managed by the customer, and the customer is responsible for running end-to-end service OAM if needed. The service provider is responsible for monitoring the PW ME, and the monitoring of the AC is the shared responsibility of the customer and the service provider. In most simple cases, when the AC is realized across a physical interface that connects the CE to PE, the monitoring requirements across the AC ME are minimal.

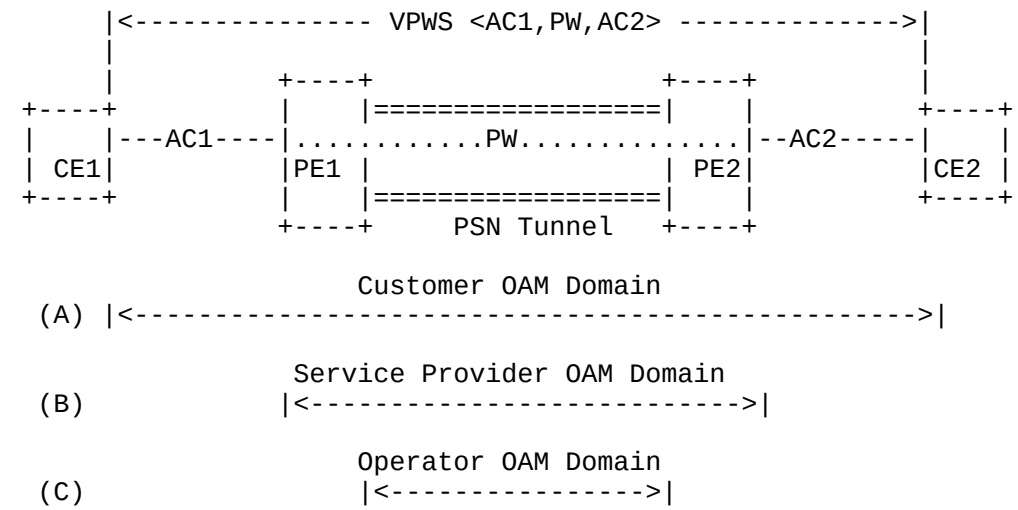

Figure 8a: VPWS OAM Domains - Management Model 1

Figure 8b highlights another management model, where the CEs are managed by the service provider and where CEs and PEs are connected via an access network. The access network between the CEs and PEs may or may not be provided by a distinct network operator. In this model, the VPWS ME spans between the CEs in the service provider OAM domain, as shown by (B) in Figure 8b. The service provider OAM domain may additionally monitor the AC MEs and PW MEs individually, as shown by (C) in Figure 8b. The network operators may be responsible for managing the access service MEs (e.g., access tunnels) and core PSN Tunnel MEs, as shown by (D) in Figure 8b. The distinction between (C) and (D) in Figure 8b is that in (C), MEs have MEPs at CEs and at PEs and have no MIPs. While in (D), MEs have MEPs at CEs and at PEs; furthermore, MIPs may be present in between the MEPs, thereby providing visibility of the network to the operator.

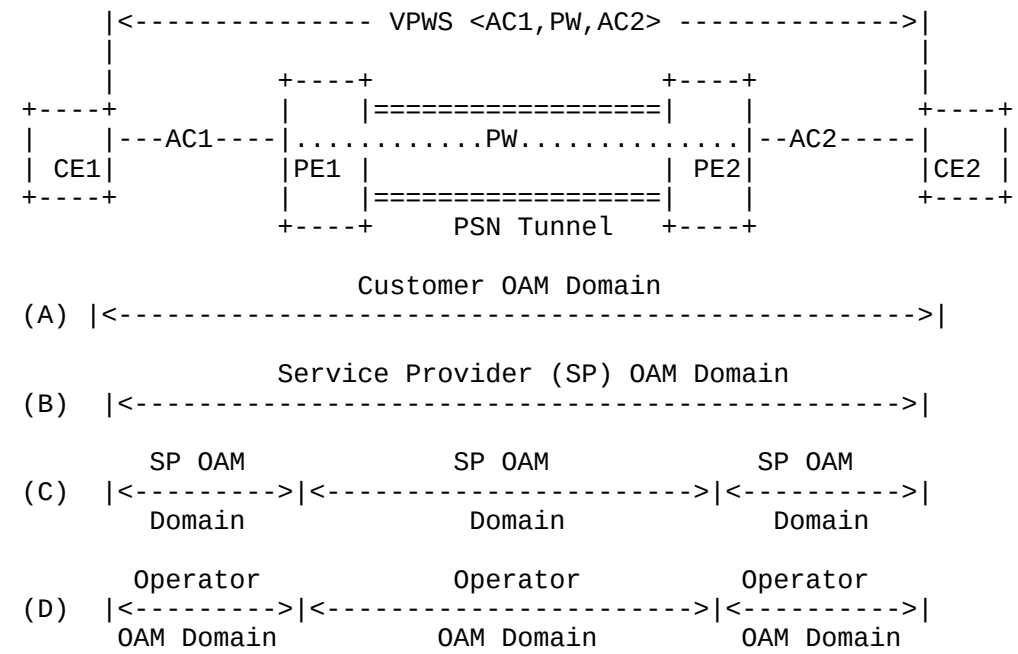

Figure 8b: VPWS OAM Domains - Management Model 2

Note: It may be noted that unlike VPLS OAM Domain in Figure 4, where multiple operator domains may occur between the User-facing PE (U-PE) devices, VPWS OAM domain in Figures 8a and 8b highlights a single operator domain between PE devices. This is since, unlike the distributed VPLS PE case (D-VPLS), where VPLS-aware U-PEs and Network-facing PEs (N-PEs) may be used to realize a distributed PE, the VPWS has no such distributed PE model. If the PSN involves multiple operator domains, resulting in a Multi-segment PW [MS-PW-Arch], VPWS OAM Domains remain unchanged since switched PEs are typically not aware of native service.

6.2.3. VPWS MEPs and MIPs

The location of MEPs and MIPs can be based upon the management model used in the VPWS scenarios. The interest remains in being able to monitor end-to-end service and also support segment monitoring in the network to allow isolation of faults to specific areas within the network.

The end-to-end service monitoring is provided by an end-to-end ME, and additional segment OAM monitoring is provided by segment MEs, all in the service provider OAM domain. The end-to-end MEs and segment MEs are hierarchically organized as mentioned in Section 4.2 for hierarchical OAM domains. This is shown in (B) and (C) in Figure 8b.

The CE interfaces support MEPs at the end-to-end service provider OAM level for VPWS as an end-to-end service as shown in (B1) and (B2) in Figure 9. In addition, PE interfaces may support MIPs at the end-to-end service provider OAM level when PEs are client service aware, as shown in (B2) in Figure 9. As an example, if one considers an end-to-end Ethernet line service offered using ATM transport (ATM over MPLS PW), then the PEs are considered to be Ethernet service unaware and therefore cannot support any Ethernet MIPs. (B1) in Figure 9 represents this particular situation. Of course, another view of the end-to-end service can be ATM, in which case PE1 and PE2 can be considered to be service aware and therefore support ATM MIPs. (B2) in Figure 9 represents this particular situation.

In addition, CEs and PE interfaces support MEPs at a segment (lower level) service provider OAM level for AC and PW MEs, and no MIPs are involved at this segment service provider OAM level, as shown in (C) in Figure 9. Operators may also run segment OAM by having MEPs at network operator OAM level, as shown in (D) in Figure 9.

The advantage of having layered OAM is that end-to-end and segment OAM can be carried out in an independent manner. It is also possible to carry out some optimizations, e.g., when proactive segment OAM monitoring is performed, proactive end-to-end monitoring may not be needed since client layer end-to-end ME could simply use fault notifications from the server layer segment MEs.

Although many different OAM layers are possible, as shown in Figure 9, not all may be realized. For example, (B2) and (D) in Figure 9 may be adequate in some cases.

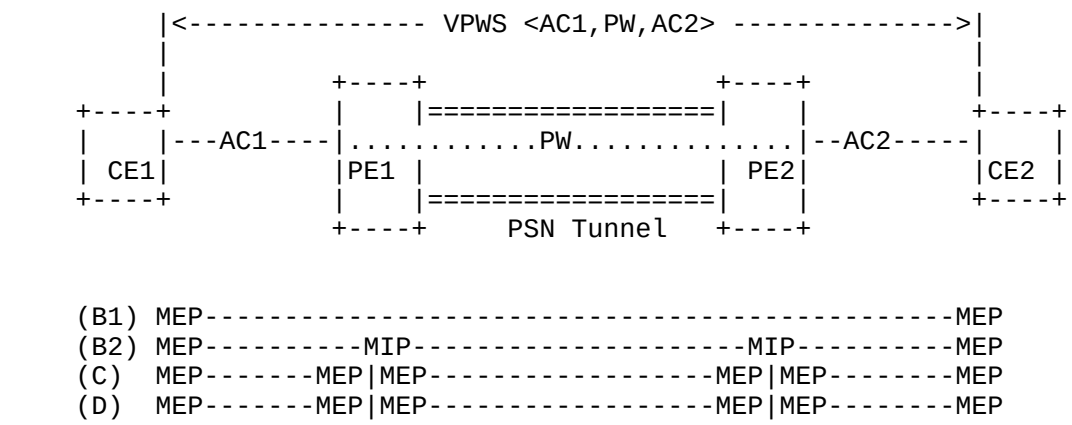

Figure 9: VPWS MEPs and MIPs

6.2.4. VPWS MEP and MIP Identifiers

In VPWS, the MEPs and MIPs should be identified with their native addressing schemes. MEPs and MIPs Identifiers, i.e., MEP Ids and MIP Ids, must be unique to the VPWS instance and in the context of their corresponding OAM domains.

7. VPLS OAM Requirements

These requirements are applicable to VPLS PE offering VPLS as an Ethernet Bridged LAN service, as described in Section 5.1.1. Further, the performance metrics used in requirements are based on [MEF10.1] and [RFC2544].

It is noted that OAM solutions that meet the following requirements may make use of existing OAM mechanisms, e.g., Ethernet OAM, VCCV, etc.; however, they must not break these existing OAM mechanisms. If extensions are required to existing OAM mechanisms, these should be coordinated with relevant groups responsible for these OAM mechanisms.

7.1. Discovery

Discovery allows a VPLS-aware device to learn about other devices that support the same VPLS instance within a given domain.

Discovery also allows a VPLS-aware device to learn sufficient information (e.g., IP addresses, MAC addresses, etc.) from other VPLS-aware devices such that VPLS OAM frames can be exchanged among the service-aware devices.

(R1) VPLS OAM MUST allow a VPLS-aware device to discover other devices that share the same VPLS instance(s) within a given OAM domain.

7.2. Connectivity Fault Management

VPLS is realized by exchanging service frames/packets between devices that support the same VPLS instance. To allow the exchange of service frames, connectivity between these service-aware devices is required.

7.2.1. Connectivity Fault Detection

To ensure service, proactive connectivity monitoring is required. Connectivity monitoring facilitates connectivity fault detection.

(R2a) VPLS OAM MUST allow proactive connectivity monitoring between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

7.2.2. Connectivity Fault Verification

Once a connectivity fault is detected, connectivity fault verification may be performed.

(R2b) VPLS OAM MUST allow connectivity fault verification between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

7.2.3. Connectivity Fault Localization

Further, localization of connectivity fault may be carried out.

(R2c) VPLS OAM MUST allow connectivity fault localization between two VPLS-aware devices that support the same instance within a given OAM domain.

7.2.4. Connectivity Fault Notification and Alarm Suppression

Typically, when a connectivity fault is detected and optionally verified, the VPLS device may notify the NMS (Network Management System) via alarms.

However, a single transport/network fault may cause multiple services to fail simultaneously, thereby causing multiple service alarms. Therefore, VPLS OAM must allow service-level fault notification to be triggered at the client layer as a result of transport/network faults in the service layer. This fault notification should be used for the suppression of service-level alarms at the client layer.

(R2d) VPLS OAM MUST support fault notification to be triggered as a result of transport/network faults. This fault notification SHOULD be used for the suppression of redundant service-level alarms.

7.3. Frame Loss

A VPLS may be considered degraded if service-layer frames/packets are lost during transit between the VPLS-aware devices. To determine if a VPLS is degraded due to frame/packet loss, measurement of frame/packet loss is required.

(R3) VPLS OAM MUST support measurement of per-service frame/packet loss between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

7.4. Frame Delay

A VPLS may be sensitive to delay experienced by the VPLS frames/packets during transit between the VPLS-aware devices. To determine if a VPLS is degraded due to frame/packet delay, measurement of frame/packet delay is required.

VPLS frame/packet delay measurement can be of two types:

1) One-way delay is used to characterize certain applications like multicast and broadcast applications. The measurement for one-way delay usually requires clock synchronization between the two devices in question.

2) Two-way delay or round-trip delay does not require clock synchronization between the two devices involved in measurement and is usually sufficient to determine the frame/packet delay being experienced.

(R4a) VPLS OAM MUST support measurement of per-service two-way frame/packet delay between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

(R4b) VPLS OAM SHOULD support measurement of per-service one-way frame/packet delay between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

7.5. Frame Delay Variation

A VPLS may be sensitive to delay variation experienced by the VPLS frames/packets during transit between the VPLS-aware devices. To determine if a VPLS is degraded due to frame/packet delay variation, measurement of frame/packet delay variation is required. For frame/packet delay variation measurements, one-way mechanisms are considered to be sufficient.

(R5) VPLS OAM MUST support measurement of per-service frame/packet delay variation between two VPLS-aware devices that support the same VPLS instance within a given OAM domain.

7.6. Availability

A service may be considered unavailable if the service frames/packets do not reach their intended destination (e.g., connectivity is down or frame/packet loss is occurring) or the service is degraded (e.g., frame/packet delay and/or delay variation threshold is exceeded).

Entry and exit conditions may be defined for unavailable state. Availability itself may be defined in context of service type.

Since availability measurement may be associated with connectivity, frame/packet loss, frame/packet delay, and frame/packet delay variation measurements, no additional requirements are specified currently.

7.7. Data Path Forwarding

If the VPLS OAM frames flow across a different path than the one used by VPLS frames/packets, accurate measurement and/or determination of service state may not be made. Therefore, data path, i.e., the one being taken by VPLS frames/packets, must be used for the VPLS OAM.

(R6) VPLS OAM frames MUST be forwarded along the same path (i.e., links and nodes) as the VPLS frames.

7.8. Scalability

Mechanisms developed for VPLS OAM need to be such that per-service OAM can be supported even though the OAM may only be used for limited VPLS instances, e.g., premium VPLS instances, and may not be used for best-effort VPLSs.

(R7) VPLS OAM MUST be scalable such that a service-aware device can support OAM for each VPLS that is supported by the device.

7.9. Extensibility

Extensibility is intended to allow introduction of additional OAM functionality in the future such that backward compatibility can be maintained when interoperating with older version devices. In such a case, VPLS OAM with reduced functionality should still be possible. Further, VPLS OAM should be defined such that OAM incapable devices in the middle of the OAM domain should be able to forward the VPLS OAM frames similar to the regular VPLS data frames/packets.

(R8a) VPLS OAM MUST be extensible such that new functionality and information elements related to this functionality can be introduced in the future.

(R8b) VPLS OAM MUST be defined such that devices not supporting the OAM are able to forward the OAM frames in a similar fashion as the regular VPLS data frames/packets.

7.10. Security

VPLS OAM frames belonging to an OAM domain originate and terminate within that OAM domain. Security implies that an OAM domain must be capable of filtering OAM frames. The filtering is such that the OAM frames are prevented from leaking outside their domain. Also, OAM frames from outside the OAM domains should be either discarded (when such OAM frames belong to the same level or to a lower-level OAM domain) or transparently passed (when such OAM frames belong to a higher-level OAM domain).

(R9a) VPLS OAM frames MUST be prevented from leaking outside their OAM domain.

(R9b) VPLS OAM frames from outside an OAM domain MUST be prevented from entering the OAM domain when such OAM frames belong to the same level or to a lower-level OAM domain.

(R9c) VPLS OAM frames from outside an OAM domain MUST be transported transparently inside the OAM domain when such OAM frames belong to a higher-level OAM domain.

7.11. Transport Independence

VPLS frame/packets delivery is carried out across transport infrastructure, also called network infrastructure. Though specific transport/network technologies may provide their own OAM capabilities, VPLS OAM must be independently supported as many different transport/network technologies can be used to carry service frame/packets.

(R10a) VPLS OAM MUST be independent of the underlying transport/network technologies and specific transport/network OAM capabilities.

(R10b) VPLS OAM MAY allow adaptation/interworking with specific transport/network OAM functions. For example, this would be useful to allow fault notifications from transport/network layer(s) to be sent to the VPLS layer.

7.12. Application Independence

VPLS itself may be used to carry application frame/packets. The application may use its own OAM; service OAM must not be dependent on application OAM. As an example, a VPLS may be used to carry IP traffic; however, VPLS OAM should not assume IP or rely on the use of IP-level OAM functions.

(R11a) VPLS OAM MUST be independent of the application technologies and specific application OAM capabilities.

8. VPWS OAM Requirements

These requirements are applicable to VPWS PE. The performance metrics used in requirements are based on [MEF10.1] and [RFC2544], which are applicable to Ethernet services.

It is noted that OAM solutions that meet the following requirements may make use of existing OAM mechanisms, e.g., Ethernet OAM, VCCV, etc.; however, they must not break these existing OAM mechanisms. If extensions are required to existing OAM mechanisms, these should be coordinated with relevant groups responsible for these OAM mechanisms.

8.1. Discovery

Discovery allows a VPWS-aware device to learn about other devices that support the same VPWS instance within a given domain. Discovery also allows a VPWS-aware device to learn sufficient information (e.g., IP addresses, MAC addresses, etc.) from other VPWS-aware devices such that OAM frames can be exchanged among the VPWS-aware devices.

(R12) VPWS OAM MUST allow a VPWS-aware device to discover other devices that share the same VPWS instance(s) within a given OAM domain.

8.2. Connectivity Fault Management

VPWS is realized by exchanging service frames/packets between devices that support the same VPWS instance. To allow the exchange of service frames, connectivity between these service-aware devices is required.

8.2.1. Connectivity Fault Detection

To ensure service, proactive connectivity monitoring is required. Connectivity monitoring facilitates connectivity fault detection.

(R13a) VPWS OAM MUST allow proactive connectivity monitoring between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

(R13b) VPWS OAM mechanism SHOULD allow detection of mis-branching or mis-connections.

8.2.2. Connectivity Fault Verification

Once a connectivity fault is detected, connectivity fault verification may be performed.

(R13c) VPWS OAM MUST allow connectivity fault verification between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

8.2.3. Connectivity Fault Localization

Further, localization of connectivity fault may be carried out. This may amount to identifying the specific AC and/or PW that is resulting in the VPWS connectivity fault.

(R13d) VPWS OAM MUST allow connectivity fault localization between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

8.2.4. Connectivity Fault Notification and Alarm Suppression

Typically, when a connectivity fault is detected and optionally verified, the service device may notify the NMS (Network Management System) via alarms.

However, a single transport/network fault may cause multiple services to fail simultaneously causing multiple service alarms. Therefore, OAM must allow service-level fault notification to be triggered at the client layer as a result of transport/network faults in the service layer. This fault notification should be used for the suppression of service-level alarms at the client layer.

For example, if an AC fails, both the local CE and the local PE, which are connected via the AC, may detect the connectivity failure. The local CE must notify the remote CE about the failure while the local PE must notify the remote PE about the failure.

(R13e) VPWS OAM MUST support fault notification to be triggered as a result of transport/network faults. This fault notification SHOULD be used for the suppression of redundant service-level alarms.

(R13f) VPWS OAM SHOULD support fault notification in backward direction, to be triggered as a result of transport/network faults. This fault notification SHOULD be used for the suppression of redundant service-level alarms.

8.3. Frame Loss

A VPWS may be considered degraded if service-layer frames/packets are lost during transit between the VPWS-aware devices. To determine if a VPWS is degraded due to frame/packet loss, measurement of frame/packet loss is required.

(R14) VPWS OAM MUST support measurement of per-service frame/packet loss between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

8.4. Frame Delay

A VPWS may be sensitive to delay experienced by the VPWS frames/packets during transit between the VPWS-aware devices. To determine if a VPWS is degraded due to frame/packet delay, measurement of frame/packet delay is required.

VPWS frame/packet delay measurement can be of two types:

1) One-way delay is used to characterize certain applications like multicast and broadcast applications. The measurement for one-way delay usually requires clock synchronization between the two devices in question.

2) Two-way delay or round-trip delay does not require clock synchronization between the two devices involved in measurement and is usually sufficient to determine the frame/packet delay being experienced.

(R15a) VPWS OAM MUST support measurement of per-service two-way frame/packet delay between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

(R15b) VPWS OAM SHOULD support measurement of per-service one-way frame/packet delay between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

8.5. Frame Delay Variation

A VPWS may be sensitive to delay variation experienced by the VPWS frames/packets during transit between the VPWS-aware devices. To determine if a VPWS is degraded due to frame/packet delay variation, measurement of frame/packet delay variation is required. For frame/packet delay variation measurements, one-way mechanisms are considered to be sufficient.

(R16) VPWS OAM MUST support measurement of per-service frame/packet delay variation between two VPWS-aware devices that support the same VPWS instance within a given OAM domain.

8.6. Availability

A service may be considered unavailable if the service frames/packets do not reach their intended destination (e.g., connectivity is down or frame/packet loss is occurring) or the service is degraded (e.g., frame/packet delay and/or delay variation threshold is exceeded).

Entry and exit conditions may be defined for unavailable state. Availability itself may be defined in context of service type.

Since availability measurement may be associated with connectivity, frame/packet loss, frame/packet delay, and frame/packet delay variation measurements, no additional requirements are specified currently.

8.7. Data Path Forwarding

If the VPWS OAM frames flow across a different path than the one used by VPWS frames/packets, accurate measurement and/or determination of service state may not be made. Therefore data path, i.e., the one being taken by VPWS frames/packets, must be used for the VPWS OAM.

(R17a) VPWS OAM frames MUST be forwarded along the same path as the VPWS data frames.

(R17b) VPWS OAM MUST be forwarded using the transfer plane (data plane) as regular VPWS data frames/packets and must not rely on control plane messages.

8.8. Scalability

Mechanisms developed for VPWS OAM need to be such that per-service OAM can be supported even though the OAM may only be used for limited VPWS instances, e.g., premium VPWS instance, and may not be used for best-effort services.

(R18) VPWS OAM MUST be scalable such that a service-aware device can support OAM for each VPWS that is supported by the device.

8.9. Extensibility

Extensibility is intended to allow introduction of additional OAM functionality in the future such that backward compatibility can be maintained when interoperating with older version devices. In such a case, VPWS OAM with reduced functionality should still be possible. Further, VPWS OAM should be such that OAM incapable devices in the middle of the OAM domain should be able to forward the VPWS OAM frames similar to the regular VPWS data frames/packets.

(R19a) VPWS OAM MUST be extensible such that new functionality and information elements related to this functionality can be introduced in the future.

(R19b) VPWS OAM MUST be defined such that devices not supporting the OAM are able to forward the VPWS OAM frames in a similar fashion as the regular VPWS data frames/packets.

8.10. Security

VPWS OAM frames belonging to an OAM domain originate and terminate within that OAM domain. Security implies that an OAM domain must be capable of filtering OAM frames. The filtering is such that the VPWS OAM frames are prevented from leaking outside their domain. Also,

VPWS OAM frames from outside the OAM domains should be either discarded (when such OAM frames belong to the same level or to a lower-level OAM domain) or transparently passed (when such OAM frames belong to a higher-level OAM domain).

(R20a) VPWS OAM frames MUST be prevented from leaking outside their OAM domain.

(R20b) VPWS OAM frames from outside an OAM domain MUST be prevented from entering the OAM domain when such OAM frames belong to the same level or to a lower-level OAM domain.

(R20c) VPWS OAM frames from outside an OAM domain MUST be transported transparently inside the OAM domain when such OAM frames belong to a higher-level OAM domain.

8.11. Transport Independence

VPWS frame/packets delivery is carried out across transport infrastructure, also called network infrastructure. Though specific transport/network technologies may provide their own OAM capabilities, VPWS OAM must be independently supported as many different transport/network technologies can be used to carry service frame/packets.

(R21a) VPWS OAM MUST be independent of the underlying transport/network technologies and specific transport/network OAM capabilities.

(R21b) VPWS OAM MAY allow adaptation/interworking with specific transport/network OAM functions. For example, this would be useful to allow fault notifications from transport/network layer(s) to be sent to the VPWS layer.

8.12. Application Independence

VPWS itself may be used to carry application frame/packets. The application may use its own OAM; VPWS OAM must not be dependent on application OAM. As an example, a VPWS may be used to carry IP traffic; however, VPWS OAM should not assume IP or rely on the use of IP-level OAM functions.

(R22a) OAM MUST be independent of the application technologies and specific application OAM capabilities.

8.13. Prioritization

VPWS could be composed of several data flows, each related to a given usage/application with specific requirements in terms of connectivity and/or performance. Dedicated VPWS OAM should be applicable to these flows.

(R23) VPWS OAM SHOULD support configurable prioritization for OAM packet/frames to be compatible with associated VPWS packets/frames.

9. VPLS (V)LAN Emulation OAM Requirements

9.1. Partial-Mesh of PWs

As indicated in [BRIDGE-INTEROP], VPLS OAM relies upon bidirectional Ethernet links or (V)LAN segments and failure in one direction or link results in failure of the whole link or (V)LAN segment. Therefore, when partial-mesh failure occurs in (V)LAN emulation, either the entire PW mesh should be shut down when only an entire VPLS is acceptable or a subset of PWs should be shut down such that the remaining PWs have full connectivity among them when partial VPLS is acceptable.

(R13a) PW OAM for PWs related to a (V)LAN emulation MUST allow detection of a partial-mesh failure condition.

(R13b) PW OAM for PWs related to a (V)LAN emulation MUST allow the entire mesh of PWs to be shut down upon detection of a partial-mesh failure condition.

(R13c) PW OAM for PWs related to a (V)LAN emulation MUST allow the subset of PWs to be shut down upon detection of a partial-mesh failure condition in a manner such that full mesh is present across the remaining subset.

Note: Shutdown action in R13b and R13c may not necessarily involve withdrawal of labels, etc.

9.2. PW Fault Recovery

As indicated in [BRIDGE-INTEROP], VPLS OAM fault detection and recovery relies upon (V)LAN emulation recovery such that fault detection and recovery time in (V)LAN emulation should be less than the VPLS fault detection and recovery time to prevent unnecessary switch-over and temporary flooding/loop within the customer OAM domain that is dual-homed to the provider OAM domain.

(R14a) PW OAM for PWs related to a (V)LAN emulation MUST support a fault detection time in the provider OAM domain faster than the VPLS fault detection time in the customer OAM domain.

(R14b) PW OAM for PWs related to a (V)LAN emulation MUST support a fault recovery time in the provider OAM domain faster than the VPLS fault recovery time in the customer OAM domain.

9.3. Connectivity Fault Notification and Alarm Suppression

When a connectivity fault is detected in (V)LAN emulation, PE devices may notify the NMS (Network Management System) via alarms. However, a single (V)LAN emulation fault may result in CE devices or U-PE devices detecting a connectivity fault in VPLS and therefore also notifying the NMS. To prevent multiple alarms for the same fault, (V)LAN emulation OAM must provide alarm suppression capability in the VPLS OAM.

(R15) PW OAM for PWs related to a (V)LAN emulation MUST support interworking with VPLS OAM to trigger fault notification and allow alarm suppression in the VPLS upon fault detection in (V)LAN emulation.

10. OAM Operational Scenarios

This section highlights how the different OAM mechanisms can be applied as per the OAM framework for different L2VPN services.

10.1. VPLS OAM Operational Scenarios

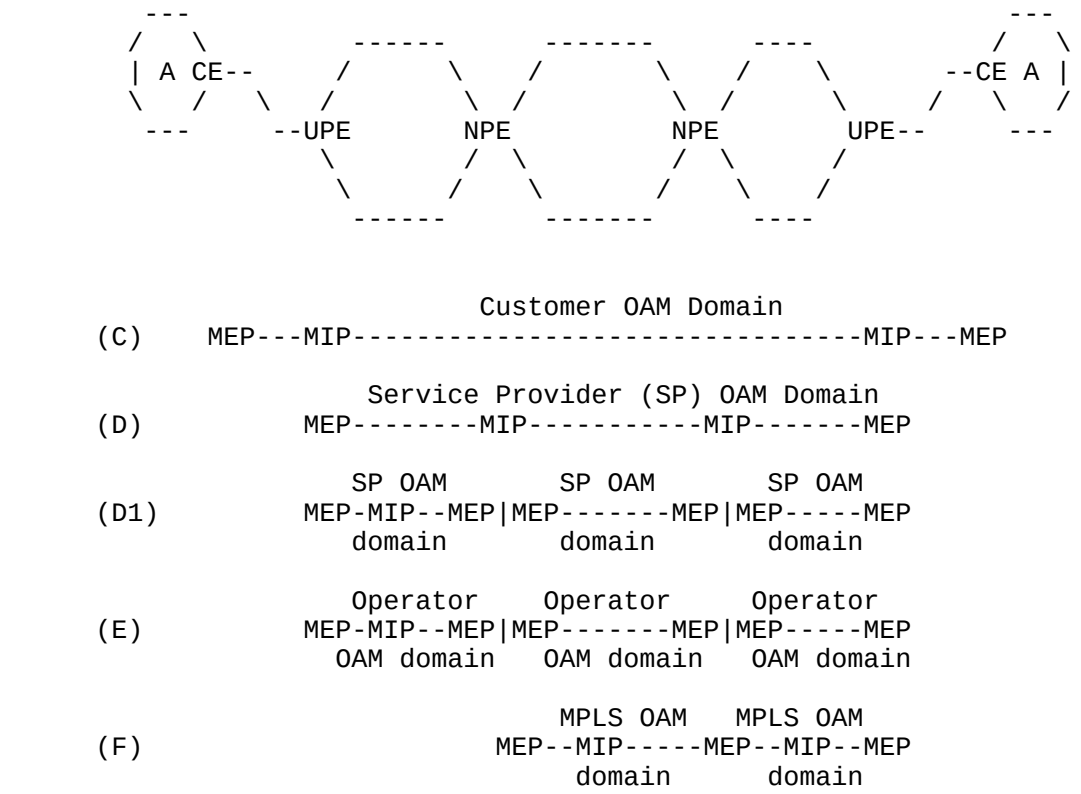

Figure 10: VPLS OAM Domains, MEPs, and MIPs

Among the different MEs identified in Figure 5 for VPLS OAM in the customer OAM domain, [IEEE802.1ag] and [Y.1731] Ethernet OAM mechanisms can be applied to meet the various requirements identified in Section 7. The mechanisms can be applied across (C) in Figure 10 MEs.

Similarly, inside the service provider OAM domain, [IEEE802.1ag] and [Y.1731] Ethernet OAM mechanisms can be applied across (D) MEs in Figure 10 to meet the functional requirements identified in Section 7.

It may be noted that in the interim, when [IEEE802.1ag] and [Y.1731] capabilities are not available across the PE devices, the Fault Management option using segment OAM introduced in Section 6.2.3 can be applied, with the limitations cited below. In this option, the service provider can run segment OAM across the (D1) MEs in Figure

10. The OAM mechanisms across the (D1) MEs in Figure 10 can be non-Ethernet, e.g., Virtual Circuit Connectivity Verification (VCCV), or Bidirectional Forwarding Detection (BFD) when network technology is MPLS. The service provider can monitor each sub-network segment ME using the native technology OAM and, by performing interworking across the segment MEs, attempt to realize end-to-end monitoring between a pair of VPLS endpoints. However, such mechanisms do not fully exercise the data plane forwarding constructs as experienced by native (i.e., Ethernet) service PDUs. As a result, service monitoring ((D1) in Figure 10) is severely limited in the sense that it may lead to an indication that the ME between VPLS endpoints is functional while the customer may be experiencing end-to-end connectivity issues in the data plane.

Inside the network operator OAM domain, [IEEE802.1ag] and [Y.1731] Ethernet OAM mechanisms can also be applied across MEs in (E) in Figure 10 to meet the functional requirements identified in Section 7. In addition, the network operator could decide to use native OAM mechanisms, e.g., VCCV or BFD, across (F) MEs for additional monitoring or as an alternative to monitoring across (E) MEs.

11. Security Considerations

This specification assumes that L2VPN components within the OAM domain are mutually trusted. Based on that assumption, confidentiality issues are fully addressed by filtering to prevent OAM frames from leaking outside their designated OAM domain. Similarly, authentication issues are addressed by preventing OAM frames generated outside a given OAM domain from entering the domain in question. Requirements to prevent OAM messages from leaking outside an OAM domain and for OAM domains to be transparent to OAM frames from higher OAM domains are specified in Sections 7.10 and 8.10.

For additional levels of security, solutions may be required to encrypt and/or authenticate OAM frames inside an OAM domain. However, these solutions are out of the scope of this document.

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Appendix A. Alternate Management Models

In consideration of the management models that can be deployed besides the hierarchical models elaborated in this document, this appendix highlights some alternate models that are not recommended due to their limitations, as pointed out below. These alternatives have been highlighted as potential interim models while the network equipment is upgraded to support full functionality and meet the requirements set forward by this document.

A.1. Alternate Model 1 (Minimal OAM)

In this model, the end-to-end service monitoring is provided by applying CE to CE ME in the service provider OAM domain.

A MEP is located at each CE interface that is part of the VPWS, as shown in (B) in Figure A.1. The network operators can carry out segment (e.g., PSN Tunnel ME, etc.) monitoring independent of the VPWS end-to-end service monitoring, as shown in (D) in Figure A.1.

The advantage of this option is that VPWS monitoring is limited to CEs. The limitation of this option is that the localization of faults is at the VPWS level.

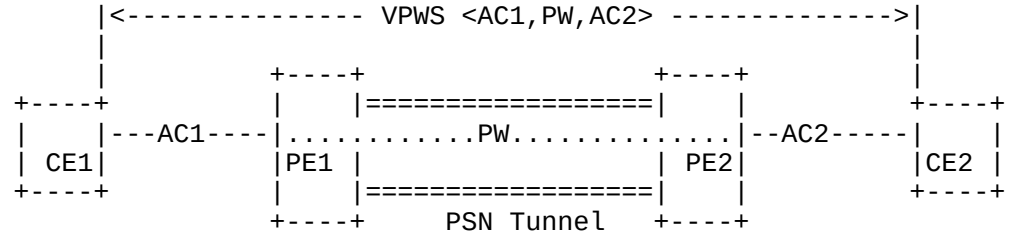


Figure A.1: VPWS MEPs and MIPs (Minimal OAM)

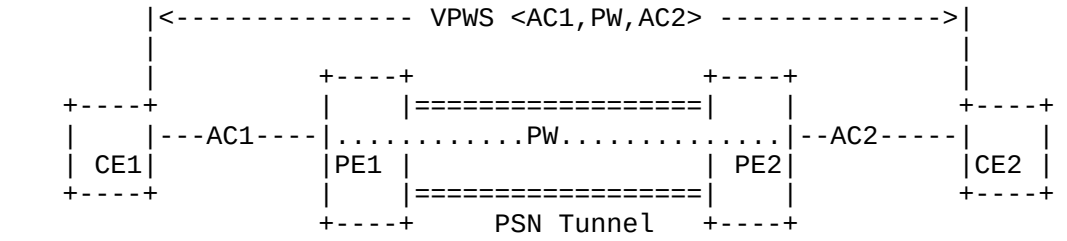
A.2. Alternate Model 2 (Segment OAM Interworking)

In this model, end-to-end service monitoring is provided by interworking OAM across each segment. Typical segments involved in this case include two AC MEs and a PW ME, as shown in (C) in Figure A.2. These segments are expected in the service provider OAM domain. An interworking function is required to transfer the OAM information flows across the OAM segments for the purposes of end-to-end monitoring. Depending on whether homogenous VPWS is deployed or

heterogeneous VPWS is deployed, the interworking function could be straightforward or more involved.

In this option, the CE and PE interfaces support MEPs for AC and PW MEs, and no MIPs are involved at the service provider OAM level, as shown in (C) in Figure A.2. Network operators may run segment OAM by having MEPs at the network operator OAM level, as shown in (D) in Figure A.2.

The limitations of this model are that it requires interworking across the OAM segments and does not conform to the OAM layering principles, where each OAM layer ought to be independent of the others. For end-to-end OAM determinations, the end-to-end service frame path is not necessarily exercised. Further, it requires interworking function implementation for all possible technologies across access and core that may be used to realize end-to-end services.



(C) MEP-------MEP|MEP------------------MEP|MEP--------MEP
(D) MEP-------MEP|MEP------------------MEP|MEP--------MEP

Figure A.2: VPWS MEPs and MIPs (Segment OAM Interworking)

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