Technical Report

TR-142

Framework for CWMP and USP enabled PON Devices

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Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1	March 2008	March 2008	Christele Bouchat, Alcatel Lucent	Original.
2	February 2010	February 2010	Christele Bouchat, Alcatel Lucent	Further defines the domain of responsibilities of TR-069 and the lower layer management protocol for PON.
3	4 September 2017	25 October 2017	Greg Bathrick, Calix	Added reference for XGS-PON.
4	27 December 2022	27 December 2022	Samuel Chen, Broadcom	Aligned with the current editions of the relevant technical specifications. Deprecated Section 5.

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Executive Summary

This document describes how PON devices having layer 3 capabilities can be remotely configured, troubleshot and managed by an ACS or a Controller using CWMP/USP, leveraging the same management infrastructure and procedures irrespectively of:

- Whether the PON device is an ONU, a Residential Gateway, or a device connected through a home network,
- Whether the services relying on this device are operated by the access network provider, or independently by another service provider
- Whether the access network technology is ITU-T PON (such as G-PON, XG(S)-PON), IEEE PON (such as EPON, 10G-EPON), or another broadband access technology such as xDSL or 5G.

1 Purpose and Scope

1.1 Purpose

The goal of TR-142 is to provide a framework for the remote configuration and management of services for PON (Passive Optical Network) access.

1.2 Scope

This document is intended to define a framework for remote management of CPE over various PON access technologies. CWMP/USP is the protocol of choice used by service providers worldwide for the remote management and configuration of many kinds of broadband CPE. The scope of this document is to detail the applicability to CPE having a PON (G-PON, 1G-EPON, 10G-EPON, XG(S)-PON for example) WAN interface and in particular to clarify the relation between CWMP/USP and OMCI/eOAM. This document specifies the linkage between OMCI/eOAM and CWMP/USP domains, in the context of PON management.

The scope of this document addresses Single Family Units (SFU), Single Business Units (SBU), and Home Gateway Units (HGU). It does not address Multi-Dwelling Units, Multi-Tenant Units, PON-fed DSLAM, PON-fed Distribution Point Unit (DPU), or OLT.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification and RFC 8174 [18]. These words are always capitalized. More information can be found be in RFC 2119 [17].

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [17] [RFC8174] [18] when, and only when, they appear in all capitals, as shown here.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document	Title	Source	Year
[1] TR-069 Amendment 6 Corrigendum 1	CPE WAN Management Protocol	BBF	2020
[2] TR-369 1.1.2	User Services Platform	BBF	2020
[3] TR-106 Issue 1 Amendment 10	Data Model Template for CWMP Endpoints and USP Agents	BBF	2020
[4] TR-104 Issue 2	Provisioning Parameters for VoIP CPE	BBF	2014
[5] TR-181 Issue 2 Amendment 14	Device Data Model for TR-069	BBF	2020
[6] TR-156 Issue 4	Using GPON Access in the context of TR-101	BBF	2017
[7] TR-124 Issue 8	Functional Requirements for Broadband Residential Gateway Devices	BBF	2022
[8] G.984.3 Amd1	Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification	ITU-T	2020
[9] G.9807.1 Amd2	10-Gigabit-capable symmetric passive optical network (XGS-PON)	ITU-T	2020
[10] G.987.3 Amd2	10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification	ITU-T	2021
[11] G.988 Amd4	ONU management and control interface specification	ITU-T	2021
[12] G.989.3	40-Gigabit-capable passive optical networks (NG-PON2): Transmission convergence layer specification	ITU-T	2021

[13] 802.3ah	Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks. Amendment to IEEE 802.3™-2003, now part of IEEE 802.3™	IEEE	2005
[14] 802.3av	Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks. Amendment 1 to IEEE 802.3™-2008, now part of IEEE 802.3™	IEEE	2009
[15] 802.3ca	Physical Layer Specifications and Management Parameters for 25 Gb/s and 50 Gb/s Passive Optical Networks. Amendment 9 to IEEE 802.3™-2018	IEEE	2020
[16] 1904.1	IEEE Standard for Service Interoperability in Ethernet Passive Optical Networks (SIEPON), IEEE 1904.1™-2017	IEEE	2017
[17] RFC 2119	Key words for use in RFCs to Indicate Requirement Levels	IETF	1997
[18] RFC 8174	Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words	IETF	2017

2.3 Definitions

The following terminology is used throughout this Technical Report.

Term	Definition
1G-EPON	An EPON architecture operating at 1 Gb/s in both downstream and upstream directions. Defined in IEEE802.3ah [13], now part of IEEE 802.3.
10G-EPON	An EPON architecture operating at 10 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 10/10G-EPON and 10/1G-EPON architectures. Defined in IEEE802.3av [14], now part of IEEE 802.3.
25G-EPON	An EPON architecture supporting a maximum sustained throughput of 25 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 25/10G-EPON and 25/25G-EPON architectures. Defined in IEEE802.3ca [15].
50G-EPON	An EPON architecture supporting a maximum sustained throughput of 50 Gb/s in either downstream or both downstream and upstream directions. This term collectively refers to 50/10G-EPON, 50/25G-EPON, and 50/50G-EPON architectures. Defined in IEEE802.3ca [15].
ACS	Auto-Configuration Server. This is a component in the broadband network responsible for auto-configuration of the CPE for advanced services.
Agent	A generic term that refers (as appropriate) to either a CWMP Endpoint or to a USP Agent, as defined in TR-106 [3].
Controller	A generic term that refers (as appropriate) to either a CWMP ACS or a USP Controller, as defined in TR-106 [3].
CPE	Customer Premises Equipment, refers (as appropriate) to any CWMP-enabled [1] or USP-enabled [2] device and therefore covers both Internet Gateway devices and LAN-side end devices.

CWMP	CPE WAN Management Protocol. Defined in TR-069 [1], CWMP is a communication protocol between an ACS and CWMP-enabled CPE that defines a mechanism for secure auto-configuration of a CPE and other CPE management functions in a common framework.
eOAM	Extended Operations, Administration, and Maintenance (eOAM) for EPON, as defined in IEEE 1904.1 [16]. The eOAM is based on the IEEE 802.3, Clause 57, and provides mandatory mechanisms for managing link operation, including ONU authentication, ONU configuration, ONU software-image management, event notification, and performance monitoring in IEEE PON.
GEM	G-PON Encapsulation Method: A data frame transport scheme used in G-PON (ITU-T G.984.x [8]) systems that is connection-oriented and that supports fragmentation of the user data frames into variable sized transmission fragments. In this document, the term “GEM” is also used generically to include ITU-T G.987.3, G.989.3 and G.9807.1 “XGEM”.
GEM port	A virtual flow over GEM Encapsulation identified by a series of GEM frames that share a common GEM Port Id. A unique GEM Port is assigned per Ethernet flow (or group of flows), and is used for distinguishing between the flows at the GEM layer.
GEM port id	The GEM Port Id field is part of the GEM header. It is used to identify a GEM port.
G-PON	Gigabit capable Passive Optical Network as defined in ITU-T G.984 series.
IEEE PON	In this document, IEEE PON is used as a generic term to denote any IEEE PON variant such as G-EPON (IEEE802.3ah [13]), 10G-EPON (IEEE802.3av [14]), or 25G-EPON/50G-EPON (IEEE802.3ca [15]).
Integrated PON CPE	An Integrated PON CPE is a device that encompasses both ONU entity and RG entity in a single physical device. In the context of this Technical Report, an Integrated PON CPE has two management domains, for the ONU entity and the RG entity, respectively. The U reference point is the demarcation point between the two management domains. An Integrated PON CPE is also referred to as a multi-managed ONU, for simplicity, it is sometimes referred to as a PON CPE in this Technical Report.
ITU-T PON	In this document, ITU-T PON is used as a generic term to denote any ITU-T PON variant such as G-PON (ITU-T G.984.x [8]), XG-PON (ITU-T G.987.x [10]), XGS-PON (ITU-T G.9807.x [9]), or NG-PON2 (ITU-T G.989.x [12]).
MPCP	Multi-Point Control Protocol as defined in IEEE 802.3.
ODN	Optical Distribution Network. In the PON context, a tree of optical fibers in the access network, supplemented with power or wavelength splitters, filters, or other passive optical devices.
OLT	Optical Line Termination. A device that terminates the common (root) endpoint of an ODN, and implements a PON protocol (either ITU-T PON or IEEE PON). The OLT provides management and maintenance functions for the subtended ODN and ONUs.
OMCI	ONT Management and Control Interface as defined in ITU-T G.988.
ONT	Optical Network Termination. A single subscriber device that terminates any one of the distributed (leaf) endpoints of an ODN, and implements a PON protocol. An ONT is a special case of an ONU.
ONU	Optical Network Unit. A generic term denoting a device that terminates any one of the distributed (leaf) endpoints of an ODN, and implements a PON protocol. In some contexts, an ONU implies a multiple subscriber device. Unless explicitly indicated otherwise, this Technical Report uses ONU as a generic term.

ONU entity	The ONU functionality that may be contained in a physically distinct device, or integrated with the RG entity in an Integrated PON CPE.
PLOAM	Physical Layer Operations, Administration and Maintenance.
PON	Passive Optical Network.
RG	A residential gateway (RG) is a CWMP/USP-enabled device that interfaces between the WAN and LAN IP environment for a consumer broadband customer. It may route or bridge traffic, depending on its configuration and specifications. The term RG is retained for historical continuity, even though some features may be directed at business applications. It should be noted that Residential Gateways are not limited to use in consumer applications, and may also be suitable for use by small-medium business customers.
RG entity	The RG functionality that may be contained in a physically distinct device, or integrated with the ONU entity in an Integrated PON CPE.
UNI	User-Network Interface, equivalent of the U reference point in TR-156. It is the subscriber-facing interface of the ONU, and the WAN interface of the residential gateway.
USP	User Services Platform. Defined in TR-369 [2], USP is an evolution of CWMP that allows applications to manipulate Service Elements in a network of Controllers and Agents.
vUNI	Virtual UNI: it is the logical construct of a UNI internal of a PON CPE, representing the boundary between CWMP/USP and OMCI/ eOAM management domains.
T-CONT	T-CONTs are used for controlling the upstream bandwidth allocation in the PON. A T-CONT can carry multiple GEM ports. All the ONU traffic in the upstream direction are mapped into the T-CONTs, which carry the GEM frames, based on bandwidth allocations from the OLT.
WAN	Wide Area Network.

3 Technical Report Impact

3.1 Energy Efficiency

By enabling multi-managed PON devices, TR-142 is expected to facilitate the integration of multiple home network platforms into a single platform. For example, a residential gateway, an Analog Terminal Adapter and an ONU can be integrated into a single device, therefore improving significantly the energy efficiency of the broadband home.

3.2 IPv6

By defining the concept of a Virtual-UNI, enabling a clean separation between the management domains of CWMP/USP and OMCI/1904.1 eOAM within a PON CPE, TR-142 allows independency between the management of IPv6 related functions and the management of PON-specific functions, therefore facilitating the deployment of IPv6 services over these devices.

3.3 Security

TR-142 has no impact on security.

3.4 Privacy

TR-142 has no impact on privacy.

4 Applying CWMP/USP to PON CPE

TR-069 [1] describes the CPE WAN Management Protocol (CWMP), intended for communication between a CWMP-enabled CPE and an Auto-Configuration Server (ACS). The CPE WAN Management Protocol defines a mechanism that encompasses secure auto-configuration of a CPE, and also incorporates other CPE management functions into a common framework.

Defined in TR-369 [2], User Services Platform (USP) is an evolution of CWMP that allows applications to manipulate Service Elements in a network of Controllers and Agents. USP uses an expanded version of the CWMP data models to represent device operations, network interfaces, and service functions.

Both CWMP and USP are targeted at management of CPE devices. Both are transparent to the physical layer and link layer. The only assumption made is that the device must be IP addressable. In broad terms, layer 3 auto-configuration is the same for a PON CPE as for a DSL WAN or an Ethernet WAN CPE. A PON CPE can be assigned an IP address via DHCP, IPCP, or static IP addressing[1]. Once the IP address is assigned to the CPE, a CWMP/USP session can take place in between this CPE and a Controller.

The main difference between the PON CPE and the DSL (or other WAN interface types) CPE configuration and management is in the WAN link layer and the existence of access technology specific protocols managing PON specific functions, such as OMCI and IEEE 802.3 / IEEE 1904.1 eOAM.

For an ITU-T PON ONU, at first, an initial configuration phase takes place on the PON layer, an ONU is assigned its PON ONU-ID using PLOAM (Physical Layer OAM) messaging. The port-ID is given to the ONU on which the OMCI channel is carried. The OMCI (ITU-T G.988 [11]) protocol addresses the ONU configuration management, fault management and performance management for ITU-T PON system operation.

For an IEEE PON ONU, the Multi-Point MAC Control sublayer incorporates the Multi-Point Control Protocol (MPCP), which performs the discovery, registration, and ranging of EPON ONUs. The Multi-Point MAC Control sublayer is specified in IEEE 802.3, in clause 64 for 1G-EPON, Clause 77 for 10G-EPON, and clause 144 for 25G-EPON and 50G-EPON. The Multi-Point MAC Control sublayer for 25G-EPON and 50G-EPON also includes the Channel Control Protocol (CCP) that allows the OLT to query and control the state of individual PHY channels.

The IEEE 802.3 Clause 57 specifies a generic OAM framework, which is optional for Ethernet devices. The IEEE 1904.1 further extends the IEEE 802.3 OAM with additional mechanisms for 1G-EPON and 10G-EPON ONU configuration and service provisioning, status monitoring, and remote failure indication. Support for the extended OAM (eOAM) is mandatory for all compliant IEEE PON devices.

Note that these protocols (PLOAM, OMCI, MPCP, CCP, eOAM) are only used in between the OLT and the ONU, as shown in Figure 1. In contrast, Figure 2 shows that CWMP/USP is transparent for the OLT and going directly from the Controller to the PON CPE and other devices in the home network.

CWMP/USP has access to read-only parameters that are PON-dependent, meaning to parameters that might be managed through PLOAM, OMCI, MPCP, CCP, or eOAM.

[1] For a PON CPE, the OMCI or eOAM data model may optionally configure an IP address for CWMP/USP. The details are beyond the scope of this document.

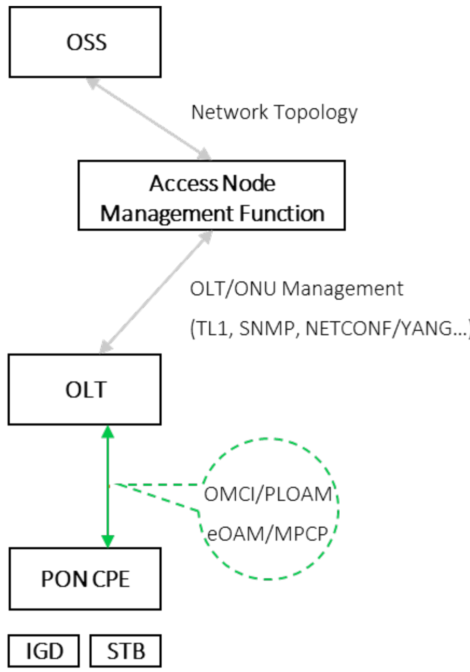

Figure 1: Example of ONU link layer configuration and management

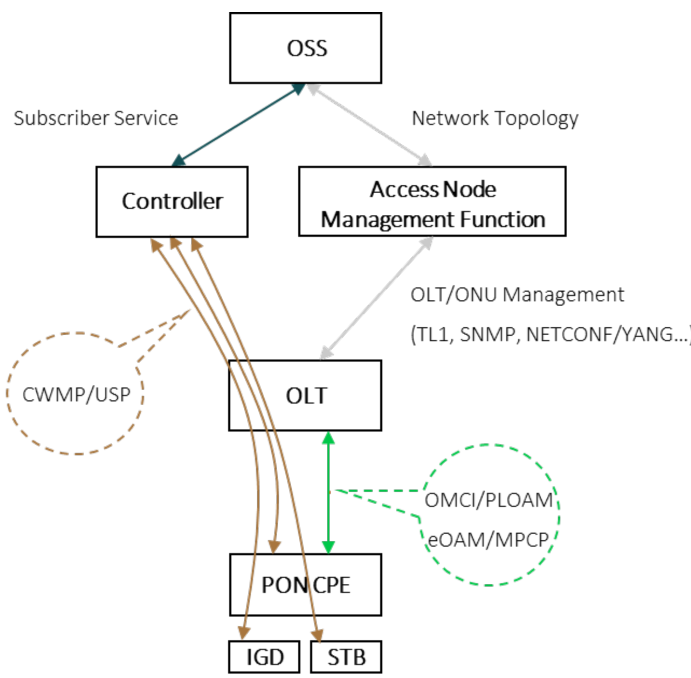

Figure 2: Example of services configuration and management with CWMP/USP for PON access

For the configuration and management of the PON CPE, PLOAM messages, OMCI, MPCP, CCP, and eOAM still play the role for which they were designed. CWMP/USP can complement these protocols for the configuration and management of subscriber services and interfaces. CWMP/USP can also overlap the above protocols in the configuration and management of the PON ONU itself. Section 5 of this document will delineate OMCI/eOAM and CWMP/USP respective management responsibilities for a PON CPE. CWMP/USP is moreover used for the configuration and management of other customer premises devices (STB, VoIP, network storage elements…) as explained in TR-106 [3]. CWMP/USP is transparent to the OLT, since the CWMP/USP connections are established over IP between the Controller and the PON CPE, as shown in Figure 2.

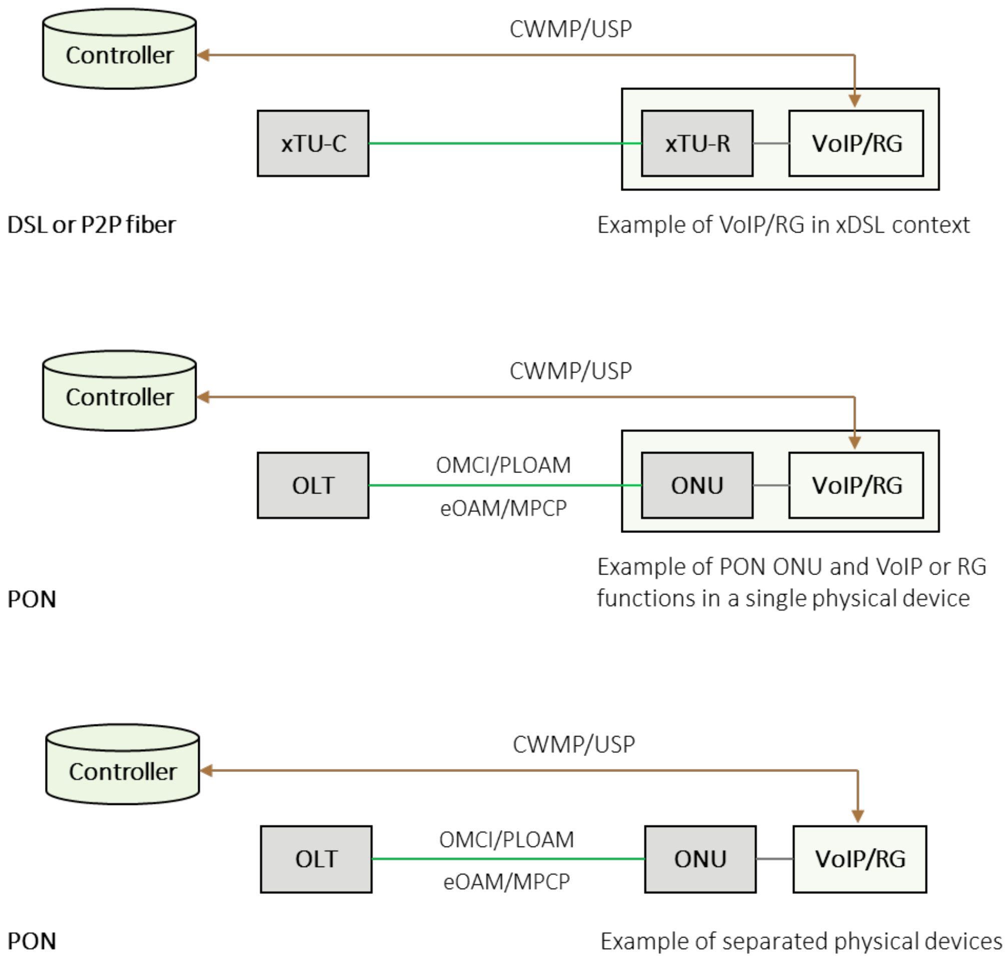

Figure 3: Example of CWMP/USP versus OMCI/eOAM Configuration and Management

Figure 3 shows 3 diagrams. The first one represents the situation where CWMP/USP is used to configure and manage remotely, from the Controller, the parameters of the DSL or P2P fiber CPE, as well as the services incorporated within it, such as the RG and for example a Voice over IP client.

The second and third diagrams of Figure 3 show two possible RG deployment scenarios in a PON network.

The second diagram of Figure 3 shows the situation of an integrated PON CPE embedding PON ONU and RG functions and/or VoIP services in a single physical device. CWMP/USP management of the PON CPE remains the same as for the DSL or P2P fiber CPE. OMCI/eOAM is used to manage the ONU function. In this case, OMCI/eOAM is used for the link layer configuration and management of PON-specific features, while PON-independent features are configured and managed by CWMP/USP. This is also referred to as the integrated ONU/RG scenario in this document.

The third diagram of Figure 3 represents the situation where the PON ONU and VoIP or RG functions are implemented in separate physical devices. CWMP/USP management of the VoIP and the RG functions remains the same as for the integrated PON CPE. OMCI/eOAM management of the PON ONU also remains the same as for the integrated PON CPE. This is also referred to as the separated ONU/RG scenario in this document.

5 Deprecated

The content in this section has been moved to TR-124 Issue 8.

6 Integrated PON CPE

6.1 The Concept

In the separated ONU/RG scenario, physical interfaces between the ONU and the RG are present and externally accessible. The interfaces can be Ethernet, xDSL, or other types of interfaces that provide the Ethernet service. The demarcation point between the two devices is the U reference point.

In the integrated ONU/RG scenario, both the ONU entity and the RG entity are embedded in a single physical device. It may not have an internal physical interface between the two entities. For such a device, we introduce the concept of a “virtual UNI” (User Network Interface) as the “glue” in between the ONU entity and the RG entity. A virtual UNI can be treated as an internal physical interface, but simply not externally accessible. The U reference point remains as the demarcation point between the two entities, but is located inside the device. The ONU functionality and the RG functionality in the integrated ONU/RG scenario are identical to the corresponding functionalities in the separated ONU/RG scenario.

The picture below, Figure 4 , illustrates the split in functionalities in an Integrated PON CPE. There are two management domains that control the same physical device. The ONU functionality is managed by OMCI or eOAM. Any function that could potentially be implemented outside the ONU entity will be managed by CWMP/USP. The virtual UNI denotes the boundary between CWMP/USP and OMCI/eOAM domains of responsibilities.

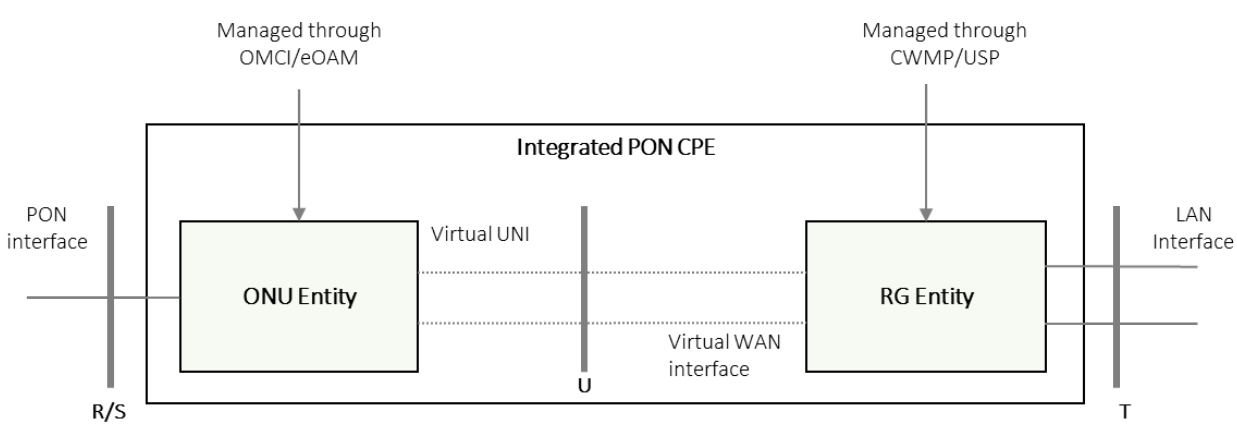

Figure 4: Integrated PON CPE Model

From the perspective of the RG entity, the vUNI represents the egress interface for upstream traffic, and its ingress interface for downstream traffic. The vUNI endpoint in the RG entity corresponds to a (virtual) WAN interface in CWMP/USP terms, represented by an upstream Ethernet link object defined in TR-181i2.

From the perspective of the ONU entity, the vUNI presents the ingress interface for upstream traffic, and its egress interface for downstream traffic. For an ITU-T PON-based ONU Entity, a Virtual UNI endpoint in the OMCI domain is an instance of the Virtual Ethernet Interface Point (VEIP) ME as defined in G.988. In some implementations, the PPTP Ethernet UNI ME is used instead of the VEIP ME. For an IEEE PON-based ONU Entity, a Virtual UNI is an instance of a port at the ONU Client Interface (ONU_CI). The ONU_CI also represents the boundary of the eOAM domain within an integrated PON CPE device.

The value of the Integrated PON CPE model shown in Figure 4 resides in the facts that:

- Provisioning and management will not change when migrating from a separated ONU/RG scenario towards an integrated ONU/RG scenario,
- All business roles and models variations are supported,
- Technologies can change within one management domain without affecting the other management domain, such as migration from IPv4 to IPv6 or from DSL to PON.

6.2 Data Plane Functions in a PON CPE

The picture below, Figure 5, illustrates the data plane functions in a PON CPE by a representation of the upstream traffic, in the case of a multiple-interfaces single-family Integrated PON CPE. A clean separation in between two management domains is created by means of a Virtual UNI interface.

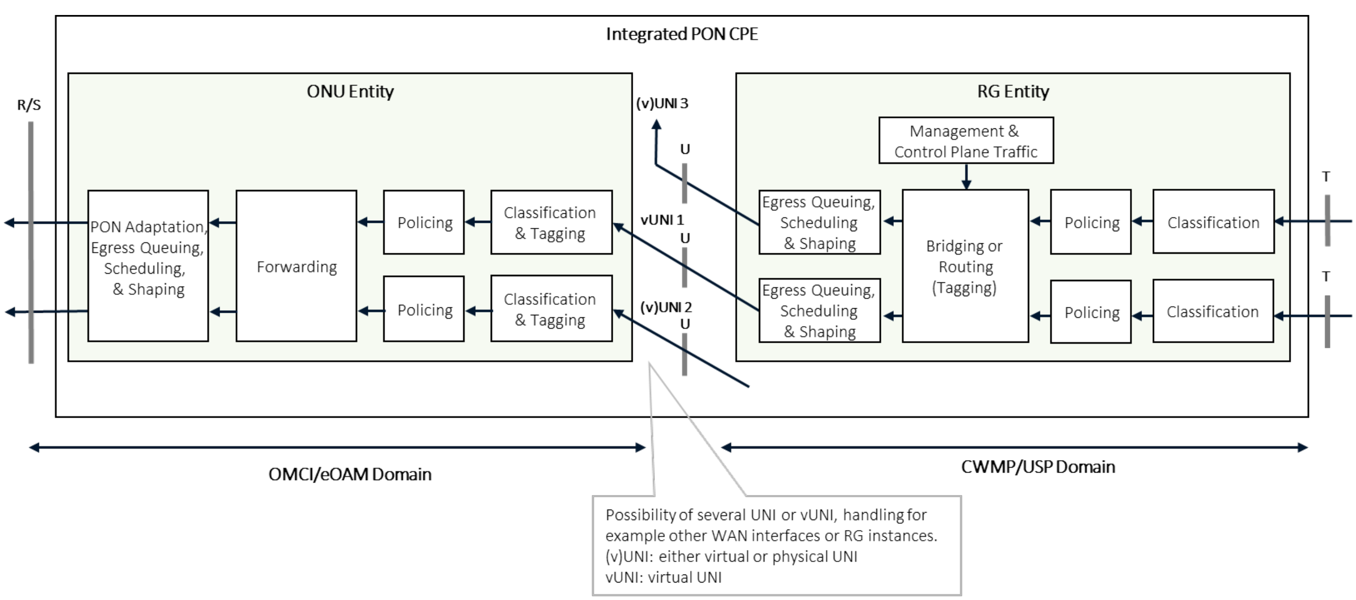

Figure 5: Example Upstream Traffic Processing in a PON CPE

As shown on the Figure 5, there might be several Virtual UNI in a PON CPE: (v)UNI 1 represents the virtual interface between the RG entity and the ONU entity; (v)UNI 2 might connect the ONU entity with another RG instance; and (v)UNI 3 might connect the RG entity with another WAN entity, such as for example a 5G modem.

These (v)UNI might be virtual interfaces, when connecting entities implemented into the same physical device, or they might be physical interfaces, when connecting entities implemented into separate physical devices.

Figure 5 shows the different logical possibilities that can be supported by the management of the PON CPE, it does not intend to represent the internal implementation of a PON CPE.

Several important characteristics of an Integrated PON CPE are listed below.

- In the upstream direction, an Ethernet frame flowing across the demarcation point can be conceptually classified twice, first by the RG entity, based on the classification rules defined in TR-181, then by the ONU entity, based on the classification rules defined in OMCI or eOAM. Similarly, an upstream Ethernet frame can be modified twice. For example, the RG entity may add a VLAN tag to untagged Ethernet frame received on at the T reference point, then pass the packet through the demarcation point; the ONU entity may again add or modify the VLAN tag of the same Ethernet frame, then perform the PON adaptation function to transport the packet over the PON link. The processing in the downstream direction is similar. One implication is for the same traffic flow, the traffic class defined in two management domains needs to be aligned, so that consistent QoS treatment can be applied.
- In some scenarios, the Forwarding/Bridging block in the ONU entity is quite simple. For example, the ONU entity may just forward a downstream Ethernet frame received from the PON interface to the appropriate egress port, using the received GEM port/LLID as the forwarding criteria. In other scenarios, MAC-based bridging is performed to determine the egress port.
- The upstream queues in the RG entity associated with a (v)UNI may not always exist in a physical implementation. The upstream queueing/scheduling functions illustrated in the RG entity is to preserve consistency of the data models from two management domains. Similarly, the downstream queues associated with a (v)UNI in the ONU entity may not always exist.

6.3 Management of Shared Resources

As described in previous sections, an Integrated PON CPE has two management domains to manage its resources. In principle, PON-specific resources are managed by OMCI/eOAM, while PON-independent resources are managed by CWMP/USP. However, there are also cases that a resource may be managed by either of the management domains. For example, an Integrated PON CPE may advertise some of its physical Ethernet interfaces to the OMCI/eOAM domain, and other physical Ethernet interfaces to the CWMP/USP domain. For another example, an Integrated PON CPE may advertise some of its physical Ethernet interfaces to both management domains, one domain with full read-write access, the other domain with read-only access. In both examples, the resource (physical Ethernet interface) is shared between two management domains.

Some examples of the shared resources in an integrated PON CPE are listed below. Note the list is not intended to be exhaustive.

- Subscriber-facing physical interfaces
- Firmware upgrade
- Voice service, etc.

In some deployment scenarios, it may be preferable to use OMCI/eOAM to manage a shared resource, while in other cases CWMP/USP is preferred as it is independent of the access technology. There are advantages in each approach. Best practice suggests that data models in each management domain should give operators the flexibility in choosing how a shared resource is managed. The specifics of data model Is beyond the scope of this Technical Report.

End of Broadband Forum Technical Report TR-142