

DOCSIS[®] Provisioning of GPON Specifications

DPoGv1.0

DPoG Architecture Specification

DPoG-SP-ARCHv1.0-C01-160830

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1 INTRODUCTION

DOCSIS Provisioning of GPON (DPoG) version 1.0 specifications are a joint effort of Cable Television Laboratories (CableLabs), cable operators, vendors, and suppliers to support GPON technology using existing DOCSIS-based back office systems and processes. Gigabit-capable Passive Optical Networks (GPON) as defined in the ITU-T G.984 series defines a standard for the use of passive optical networks for delivery several different bit rates. This architecture is based only on the 2.488 Gigabits per second (Gb/s) of downstream bandwidth, and 1.244 Gb/s of upstream bandwidth. Further, GPON Encapsulation Method (GEM) is required for all user traffic.

Similarly, 10-Gigabit-capable Passive Optical Networks (XG-PON) defines a standard for the use of PON to deliver 9.95328 Gb/s downstream and 2.48832 Gb/s upstream, as per ITU-T G.987. XG-PON encapsulation method (XGEM) is the data frame transport scheme required for all user traffic.

This document will not provide a primer on GPON, XG-PON or the associated ITU standards. It is expected that the reader will refer to those documents as needed.

DPoG specifications are focused on DOCSIS-based provisioning and operations of Internet Protocol (IP) using DOCSIS Internet service (which is typically referred to as High Speed Data (HSD)), or IP(HSD) for short, and Metro Ethernet services as described by Metro Ethernet Forum (MEF) standards. DPoG Networks offer IP(HSD) services, functionally equivalent to DOCSIS networks, where the DPoG System acts like a DOCSIS CMTS and the DPoG System and DPoG Optical Network Unit (D-ONU) together act like a DOCSIS CM.

1.1 DPoG Technology Introduction

Prior standards define the support of DOCSIS provisioning over EPON. This document extends that focus to provide DOCSIS provisioning of GPON. While EPON standardized on 1G/1G (upstream/downstream) and 10G/10G, GPON provides an intermediate rate of 2.5G/1.25G in its current revision with support for 10G/2.5 in XGPON.

As with EPON, GPON is a point-to-multipoint architecture, allowing for efficient multicast and broadcast in the downstream direction. This model was chosen for several reasons and conforms to the current reality of traffic loading, which is significantly higher in the egress (downstream) direction than the ingress.

GPON, as defined in [G.984] and XGPON as defined in [G.987], supports a point-to-multipoint architecture with a centralized controller called an Optical Line Terminal (OLT) and distributed low cost Layer 2 Optical Network Units (ONUs). The basic service mapping architecture in GPON is to map Ethernet (or IP) frame header information (e.g., addresses, IP Differentiated Service Code Points, Ethernet Q tag, S-VLAN/C-VLAN ID, ISID, bridge address, etc.) to a logical circuit called a GEM Port. The service mapping function in DPoG specifications is similar to that used in DOCSIS specifications. Both DOCSIS and DPoG networks rely on a centralized scheduler, although GPON utilizes a GEM port that functions like a SID in DOCSIS to support unicast, broadcast, and multicast.

Standard GPON utilizes 3 layers of control signaling between the OLT and the D-ONU:

- Embedded OAM Channel – The GPON/XG-PON embedded OAM channel is provided by well-defined header fields and embedded structures of the downstream (X)GTC frame and upstream (X)GTC burst. This channel offers a low-latency path for the time-urgent control information, because each information piece is directly mapped into a specific field. The functions that use this channel include: bandwidth allocation, security key switching, and dynamic bandwidth assignment signaling. Use of the Embedded OAM Channel is defined in [G.984.3] and [G.987.3], Section 8.
- Physical Layer OAM (PLOAM) – Used to exchange simple, low level messages. Defined in [G.984.3], Section 9, and [G.987.3], Section 11.
- ONT Management and Control Interface (OMCI) – Defined in [G.984.3] and revised by [G.988] for signaling of control information between the OLT and the D-ONU.

DPoG deviates from this use of the 3 layers by replacing OMCI with Ethernet OAM messages as defined in [DPoG-OAM]. The use of the embedded OAM channel and PLOAM is unchanged from the GPON specifications. The specifics of how PLOAM is used in concert with Ethernet OAM in DPoG are covered in an appendix of [DPoG-OAM].

1.2 Scope

This specification describes the version 1.0 architecture for DPoG Networks.

Existing business services include one or more DOCSIS IP services, baseband and broadband Ethernet services over coaxial cable, IP and Ethernet over fiber with baseband and broadband (Course Wavelength Division Multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM)), Broadband Passive Optical Network (BPON), Ethernet Passive Optical Network (EPON), Gigabit-Capable Passive Optical Network (GPON), and wireless services. The majority of business services (and all residential Internet and voice) customers are supported by the DOCSIS systems and processes. The maturity of both the technology and the back office systems and process allows for a high degree of scaling, as evidenced by the growth of IP(HSD) (residential broadband) and more recently voice service using these existing processes and systems.

This version of the document specifies requirements for IP(HSD) Internet Service as defined by DOCSIS 3.0 only.

An operator can offer IP-based services over the Metro Ethernet service platform by treating IP as an application over the DPoG Network.

Other services can be operated "over-the-top" of the above services, but the provisioning, operations and other requirements for such services are not specified in this version of DPoG specifications.

1.3 DPoG Architecture Specification Goals

The DPoG Architecture specification accomplishes the following objectives:

- Identify and document the common requirements for services for business customers over GPON.
- Define and describe the interfaces and reference points as part of the DPoG reference architecture.
- Define and describe the elements that collectively form a DPoG Network.
- Communicate the architectural foundation on which other DPoG specifications depend.
- Define requirements for services supported using DPoG specifications.

1.4 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST"	This word means that the item is an absolute requirement of this specification.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
"MAY"	This word means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

1.5 DPoG Version 1.0 Specifications

A list of the specifications included in the DPoGv1.0 series is provided in Table 1. For further information please refer to <http://www.cablelabs.com/specs/specification-search/?cat=dpog&scat=dpog-1-0>.

Table 1 - DPoGv1.0 Series of Specifications

Designation	Title
DPoG-SP-ARCHv1.0	DPoG Architecture Specification
DPoG-SP-OAMv1.0	DPoG OAM Extensions Specification
DPoG-SP-PHYv1.0	DPoG Physical Layer Specification
DPoG-SP-SECv1.0	DPoG Security and Certificate Specification
DPoG-SP-MULPIv1.0	DPoG MAC and Upper Layer Protocols Interface Specification
DPoG-SP-OSSIV1.0	DPoG Operations and Support System Interface Specification

1.6 Reference Architecture

The DPoG reference architecture shown in Figure 1 identifies the elements that a DPoG Network minimally requires to illustrate and communicate the physical hardware and logical software interfaces between the functional subsystems of the DPoG architecture. The principal elements in the architecture are the DPoG System with OLT that resides in the head end or hub site, and the ONU (D-ONU) which may be an off-the-shelf GPON ONU, GPON SFP-ONU, or a GPON ONU with additional eDOCSIS subsystems. The remaining elements in the architecture are existing servers and systems in the operator's network. All the server elements have connectivity through an IP (TCP/IP) network. Transport of bearer traffic, and (in some cases) Layer 2 OAM Protocol Data Units (PDUs), are available through either IP or Layer 2 Ethernet-based Network Interfaces.

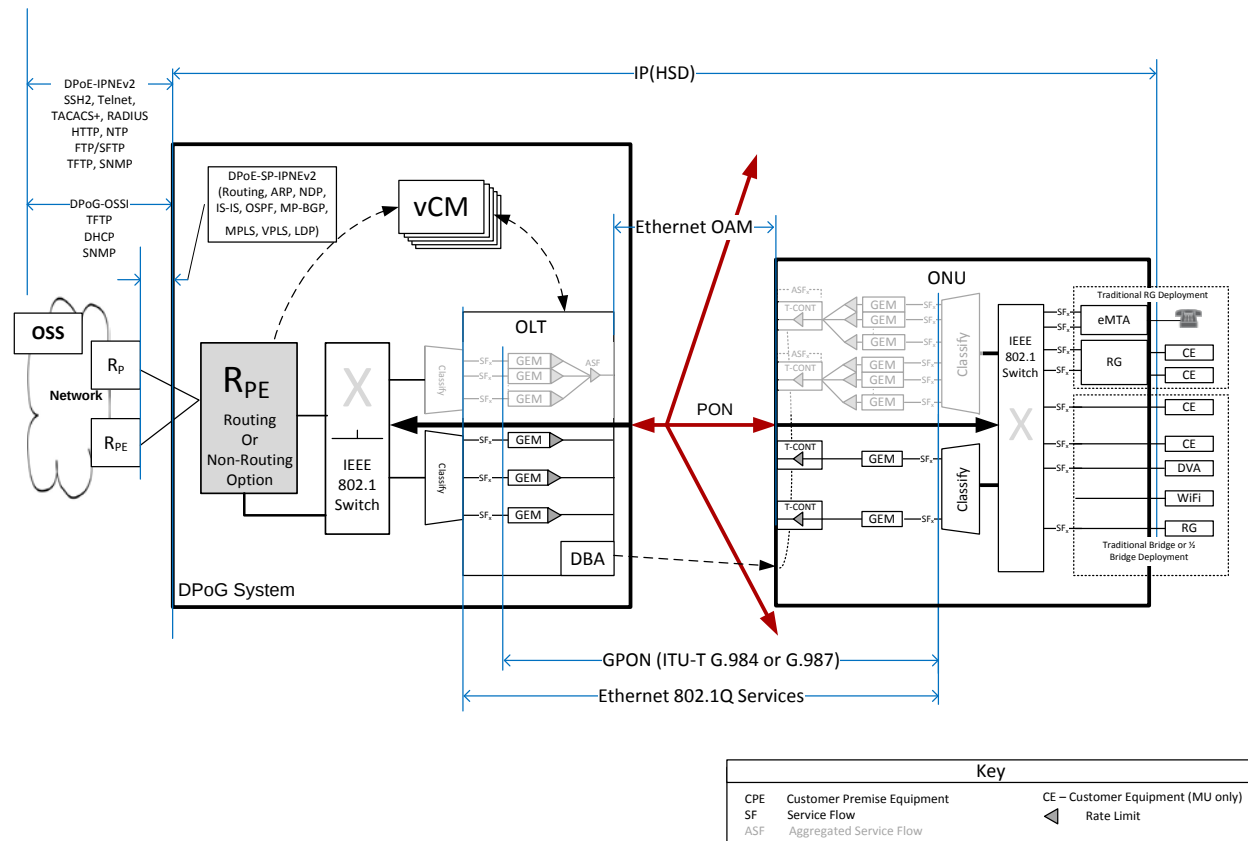


Figure 1 - DPoGv1.0 Reference Architecture

With the DPoG architecture every attempt was made to maintain the architectural aspects of DPoE wherever such were not incompatible with the GPON architecture. In comparison with the DPoE reference architecture, all end to end and provisioning aspects are essentially unchanged. DPoG specification changes are focused on the specific constructs in support of service flows across the PON, operation of the PON (Dynamic Bandwidth Allocation or DBA), and recognition of the need to map the virtual cable modem (vCM) configuration to the OAM-defined objects passed to the D-ONU.

It should be noted that in this architecture, there are references to aggregated service flows (ASFs). In the diagrams they are grayed out to show that they are a future architectural addition. Within the document, references to ASF remain and are appropriately greyed where possible. When ASF become part of the overall architecture, they will be restored to their full appearance.

1.7 DPoG Interfaces and Reference Points

The DPoG interfaces and reference points shown in Figure 2 provide a basis for the description and enumeration of DPoG specifications for the DPoG architecture. Each interface or reference point indicates a point between separate subsystems. The reference points have protocols that run across them, or have a common format of bearer traffic (with no signaling protocol). All the interfaces are bi-directional interfaces that support two-way communications. The protocols in DPoG specifications operate within different layers based on the [802.3], [802.1], IETF, MEF, and CableLabs specifications. The C reference points are uni-directional for upstream (CO) or downstream (CS) classification, respectively.

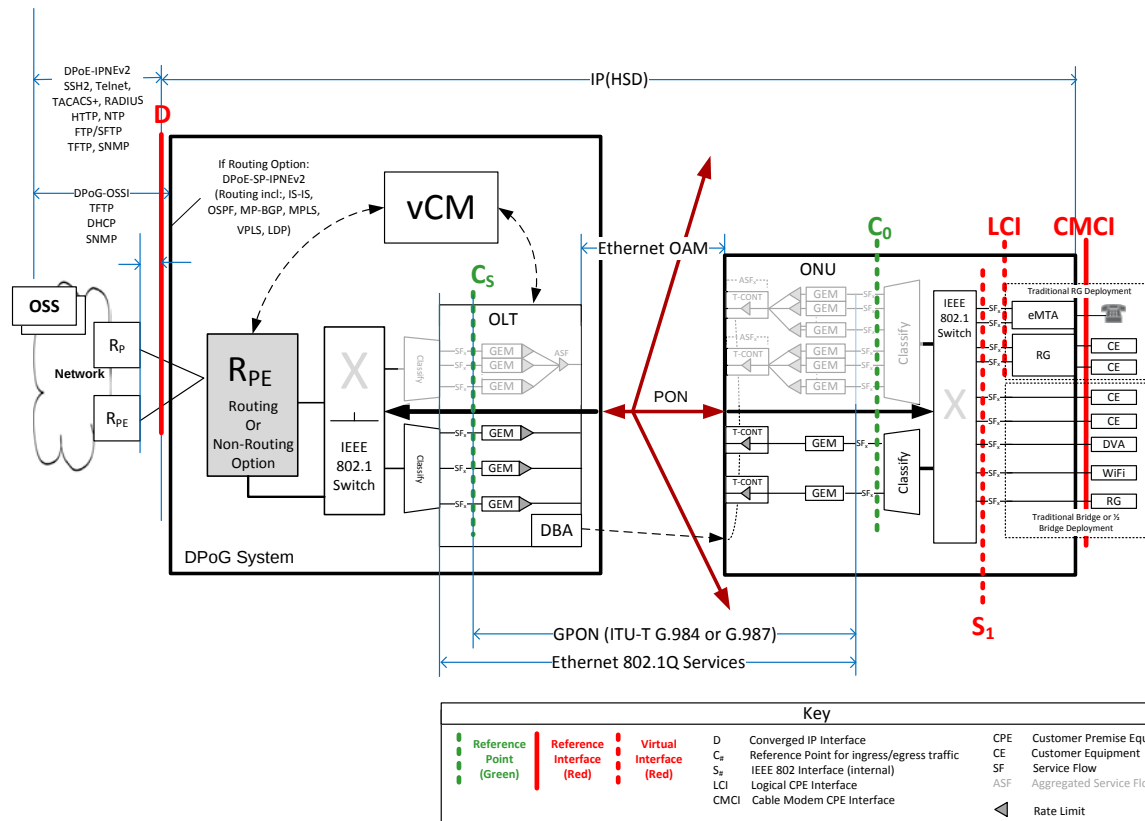


Figure 2 - DPoGv1.0 Interfaces and Reference Points

Table 2 - DPoGv1.0 Interface and Reference Point Descriptions

Interface or Reference Point		Interface or Reference Point Description
D		The D interface is the DOCSIS IP NNI interface. It is an operator network-facing interface, sometimes called a Network Systems Interface (NSI) in DOCSIS specifications. The D interface allows a DPoG System to communicate with an IP network. The D interface carries all IP management traffic including OSS and IP NE traffic. The D interface carries all DOCSIS IP service traffic, IP/MPLS/VPLS traffic, and IP/MPLS/VPWS traffic.
C		The C reference point is used for explanation of traffic ingress to a DPoG classifier.
	C _O	The C _O reference point is used for explanation of traffic ingress to a D-ONU upstream classifier.
	C _S	The C _S reference point is used for explanation of traffic ingress to a DPoG System downstream classifier.
S		The S interface is an IEEE 802 interface. The S interface may be an internal interface, such as [802.3], across a SERDES (GMII or XGMII) interface in a D-ONU (such as an SFP-ONU, SFP+ONU or XFP-ONU), it may be a logic interface between the eRouter, eWifi, or eDVA inside a D-ONU, or it may be an external Ethernet interface in a D-ONU.
	S ₁	The S ₁ interfaces are the general case of any interface on a D-ONU. S ₁ interface may represent a CMCI interfaces.
LCI		The Logical CPE Interface (LCI) interface is an eDOCSIS interface as defined in [eDOCSIS]. eSAFEs are connected to LCI interfaces.
CMCI		CMCI is the DPoG interface equivalent of the DOCSIS Cable Modem CPE Interface as defined in CMCI. This is the service interface for DOCSIS-based IP services. Customer Premise Equipment (CPE) is connected to CMCI interfaces.

1.8 DPoG Packet Flow

With a DPoG solution, the intent is for the overall combination of the DPoG System and one or more D-ONUs to emulate to the DOCSIS OSS a CMTS paired with one or more CMs. To that end, the DPoG architecture is defined. Unfortunately, while this picture is consistent with DPoG emulation of a CMTS/CM solution, it obfuscates the functions which are performed by the various components of a solution and how they interact. This section is intended to provide a bridge between the solution and the specifics of the solution, providing a clearer picture to the reader of where functions are performed in a DPoG System and D-ONU. This is necessary because a clear goal of the DPoG initiative is to be able to utilize as much as possible the standard D-ONU and the behaviors of the OLT as defined by the ITU.

The DPoG solution's functions were shown in Figure 2. In that figure, basic interfaces and reference points were identified. In Figure 3 and Figure 4, additional detail has been added to the data path of the DPoG System and D-ONU to illustrate rate control properties of GPON, as well as where classification and queuing are performed for both upstream and downstream traffic.

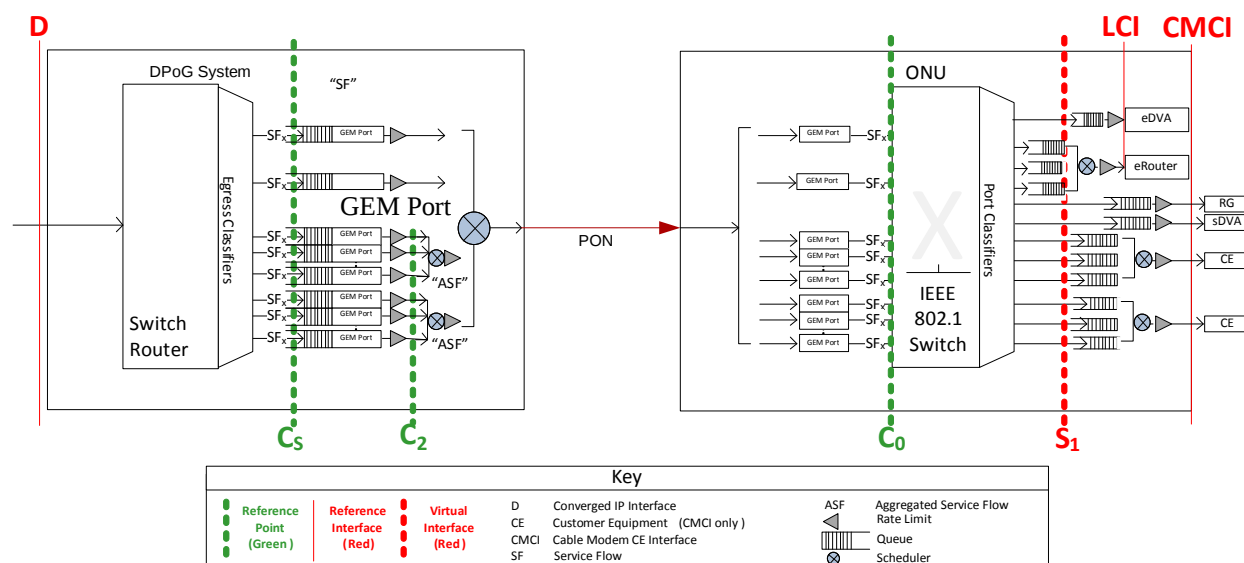


Figure 3 - DS Packet Flow Details

Downstream (left to right in Figure 3 traffic arrives at the DPoG system at reference interface D. It is processed as follows¹:

- Received frames may be tagged or untagged Ethernet frames and may carry DSCP markings applied by upstream devices.²
- The DPoG system forwards the packets via the switch which performs egress classification ([DPoG-MULPI]), assigning the frame to a specific SF. The packet may have been modified by the switch (VLAN header modifications). This is shown as reference point C1. Per-SF accounting is now possible by the DPoG System.
- The SF frame is enqueued on a specific GEM Port. Each SF maps to a single GEM Port.
- As shown, the packet is forwarded from these queues to the PON at up to 2.5Gbps, according to one of two mechanisms:
 - If the SF is not part of an ASF:

The PON scheduler selects which SF queue to forward a frame out of based on a scheduling algorithm which prioritizes/weights the various SF. Each queue has its rate limited (metered or shaped) based on the egress BWP of the SF, preventing the PON scheduler from forwarding SF frames faster than their BWP allows.
 - If the SF is part of an ASF:

The PON scheduler selects which ASF (from an ASF/SF mix) to forward a frame out of based on a scheduling algorithm that prioritizes/weights the various SF and ASF. For ASF there is another scheduler, specific to the ASF, that determines which of the ASF's constituent SF queues the next frame will come from (reference point C2). Note that a given SF may have a BWP, the ASF may have an aggregate BWP, or both. A configuration wherein both the ASF and each of its constituent SF have their own BWP is an example of Hierarchical QoS. Note that support for downstream ASF is optional in the DPoGv1.0 specifications.

¹ It should be noted that specific implementations may rearrange the order that functions are performed, or move which components in the DPoG system perform the function. All implementations will contain all the functions in some order.

² Some services, such as IP(HSD) mandate that the frames on interface D be untagged.

- When the frame is transmitted on the PON, it is marked with the GEM Port ID associated with its SF queue. There is no indication in the frame on the PON as to which ASF this frame was associated with (if any).
- The ONU listening for the GEM Port ID will receive the frame and forward it to the switch performing any SF accounting.
- The switch will perform Port Classification to determine which physical port or eSafe device the frame is destined for and which queue on that port or virtual port the frame is to be placed in (reference point S1). Note that Port Classification can be based on one or more of the following:
 - The received GEM Port ID
 - Destination MAC
 - Provisioned L2 Header fields (PCP, VLAN (S-TAG and/or C-TAG), SA, DA)
 - Provisioned L3/L4 Header Fields (5-Tuple fields, DSCP, etc.)
- The port scheduler will forward from the next available queue on that port or virtual port. Note that there is generally no need for a per-queue rate limit since each SF has already been rate limited, although such can be defined.

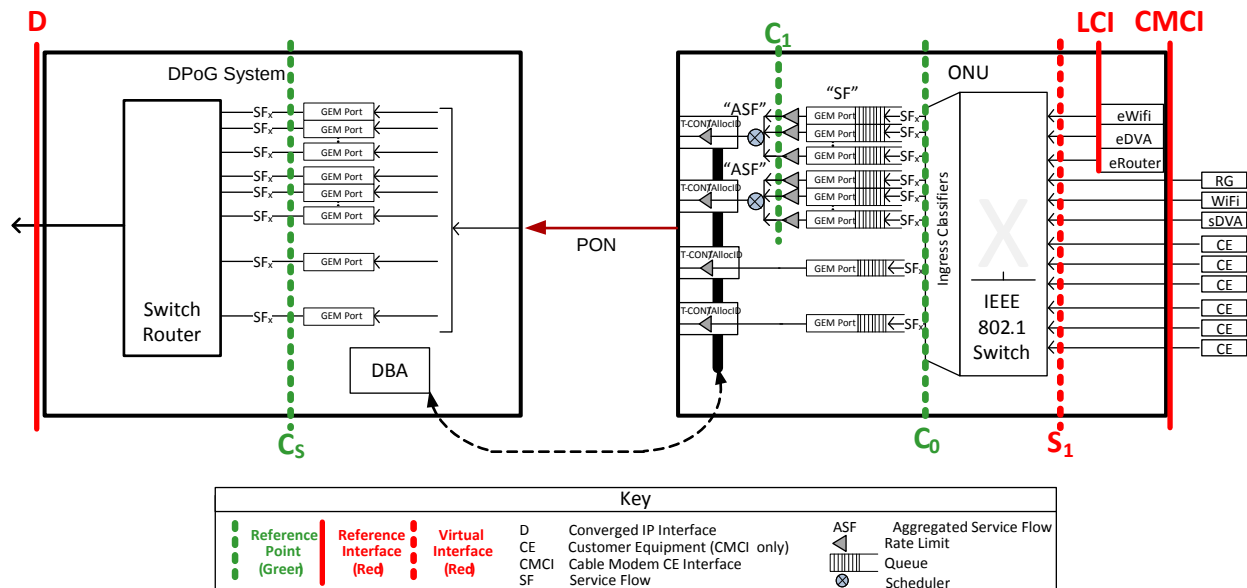


Figure 4 - US Packet Flow Details

With upstream traffic (right to left as shown in Figure 4), the tagged or untagged Ethernet frames arrive at either the CMCI reference interface if the source is on a physical port or at the LCI virtual interface if it is an eSAFE device. Either way, the upstream frames can be perceived to originate at the S₁ reference point.

- These S₁ Ethernet frames are passed to the local bridge which will forward the frame either to another port on the same ONU (optionally if a single family unit), or will forward the frames to the ingress classification function.
- The ingress classification function will perform any packet modifications (S-TAG and/or C-TAG VLAN header modifications), accounting, and then forward the packet to the appropriate SF queue.
- Each SF Queue has an associated GEM Port ID.

- The packet is forwarded toward the PON according to one of two mechanisms:
 1. If the SF is not part of an ASF:

The T-CONT scheduler de-queues and sends frames on the PON based on availability on the SF queue (GEM Port). Availability is rate limited (metered or shaped) based on the egress BWP of the SF, preventing the T-CONT from forwarding SF frames faster than their BWP allows.
 2. If the SF is part of an ASF:

The T-CONT scheduler selects which SF queue (GEM port) to forward a frame out of based on a scheduling algorithm that prioritizes/weights the various constituent SF. Each queue is rate limited (metered or shaped) based on the ingress BWP of the SF, preventing the T-CONT from forwarding SF frames faster than their BWP allows. A configuration wherein each T-CONT constituent SF (GEM port) has their own BWP is an example of Hierarchical QoS.
- When the packet arrives at the OLT, the frame is forwarded to the switch that will forward it upstream out the D reference interface. Egress frames may be tagged or untagged³. If the aggregate egress rate at the D interface is less than the aggregate ingress rate from all the PON ports, then some level of queuing will be employed in order to guarantee low priority traffic is discarded first. This is not shown in the figures.

1.9 Multicast Control and Packet Flow (IPTV)

Multicast for DPoG is primarily for two purposes:

- Support of IPv6 services such as NDP and DHCPv6
- Support of IPTV

Support for IPv6 services other than IPTV is not in scope for this overview. In support of IPTV, the control protocols are IGMPv2/v3 and MLDv2 (for IPTV service control only). For IPTV support, DOCSIS 3.0 switched the control for IPTV from utilization of IGMPv2 snoop on the CM to a centralized control on the CMTS with signaling to the CM to control IPTV switching. This model was carried forward to DPoE with OAM enhanced to include IPTV control, although support for snooping was allowed as an option.

The definition of DPoG IPTV support is essentially the same as for DPoE, with a multicast GEM port replacing the Multicast Logical Link. The DPoG architecture supports flexibility with regard to mapping of multicast sessions (IPTV channels) to multicast GEM ports, but most implementations will have limited numbers of multicast GEM ports, which will restrict the possible multicast session mappings.

The setup of the multicast GEM ports is based on the configuration of the Group Service Flows (GSF) and Group Classifier Rules (GCR) resulting from provisioning of the Group Configuration (GC) and Group QoS Configuration (GQC) tables. The vCM configuration includes the set of IPTV group address (with source IP, if SSM) that a D-ONU is to deliver on demand. This set of group addresses is known to the OLT, allowing it to filter IGMP/MLD requests as well as to map the group addresses defined in the vCM configuration to the GSF.

Using the defined group address to GSF mappings on the OLT, basic operation of IPTV switching is as follows:

- The D-ONU receives IGMP/MLD “joins” on one of its S₁ interfaces and passes it transparently up the PON to the OLT
- The OLT identifies the originating device requesting the multicast content (its source MAC), validates the requested group address (and source, if SSM) and passes down an OAM message to the D-ONU identifying the multicast GEM port (GSF), source IP address (if SSM), destination group IP address, and destination MAC to where the D-ONU is to forward the content
- The D-ONU configures the multicast filter function to accept that multicast session (source IP/destination group IP) and the multicast forwarder delivers it to the S₁ interface associated with the destination MAC.

³ Note that IP(HSD) frames are always untagged.

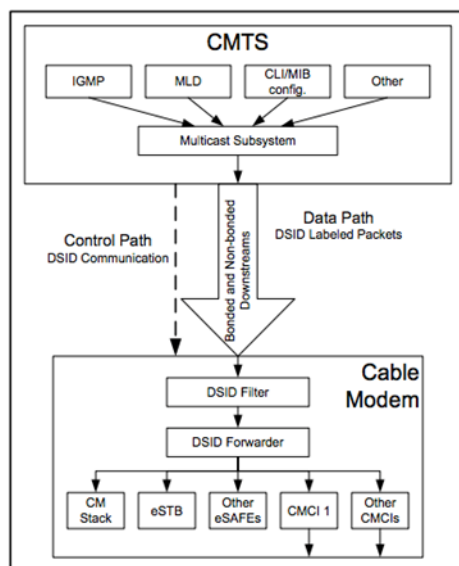


Figure 5 - DOCSIS IPTV Data Flow

The basic architecture of downstream video services is shown in Figure 5, taken from [MULPIv3.0]. This diagram is functionally identical to that used by DPoG, but with CMTS replaced with OLT, DSID with Multicast GEM Port, and Cable Modem with D-ONU.

For support of broadcast IPv4 protocols such as ARP, a single broadcast GEM port is used for all D-ONUs.

2 REFERENCES

2.1 Normative References

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references. At the time of publication, the editions indicated were valid. All references are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below. References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific. For a non-specific reference, the latest version applies.

In this specification, terms "802.1ad" and "802.1ah" are used to indicate compliance with the [802.1ad] and [802.1ah] standards, respectively, now incorporated as part of [802.1Q]. For all intents and purposes, claiming compliance to [802.1Q], [802.1ad] or [802.1ah] in the scope of this specification will be treated as claiming compliance to IEEE Std 802.1Q-2011. Unless otherwise stated, claiming compliance to 802.1Q-2005 requires a specific date reference.

[802.1]	Refers to entire suite of IEEE 802.1 standards unless otherwise specified.
[802.1ad]	IEEE Std 802.1ad-2005™, IEEE Standard for Local and Metropolitan Area Networks – Virtual Bridged Local Area Networks Amendment 4: Provider Bridges, May 2006. Former amendment to 802.1Q, now part of 802.1Q-2011.
[802.1ah]	IEEE Std 802.1ah-2008, IEEE Standard for Local and Metropolitan Area Networks – Virtual Bridged Local Area Networks – Amendment 6: Provider Backbone Bridges, January 2008. Former amendment to 802.1Q, now part of 802.1Q-2011.
[802.1d]	IEEE Std 802.1d™-2004, IEEE Standard for Local and Metropolitan Area Networks – Media Access Control (MAC) Bridges.
[802.1Q]	IEEE Std. 802.1Q-2011, IEEE Standard for Local and Metropolitan Area Networks – Media Access Control (MAC) Bridges and Virtual Bridge Local Area Networks, August 2011.
[802.3]	IEEE Std 802.3-2012, IEEE Standard for Ethernet, December 2012.
[802.3ah]	IEEE Std 802.3ah™-2004, IEEE Standard for Information technology-Telecommunications and information systems-Local and metropolitan area networks-Specific requirements, Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, Amendment: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks, now part of [802.3].
[G.984]	ITU-T Recommendation G.984, Series G: Transmission Systems and Media, Digital Systems and Networks, Gigabit-capable Passive Optical Networks (GPON) – This is a series of specifications
[G.984.3]	ITU-T Recommendation G.983, Gigabit Capable Passive Optical Networks (G-PON): Transmission Convergence (TC) Layer Specification
[G.984.4]	ITU-T Recommendation G.984.4, Gigabit-capable passive optical networks (G-PON): ONT management and control interface specification
[G.987]	ITU-T Recommendation G.987, Series G: Transmission Systems and Media, Digital Systems and Networks, 10-Gigabit-capable passive optical networks (XG-PON) – This is a series of specifications
[G.987.3]	ITU-T Recommendation G.987.3, 10 Gigabit Capable Passive Optical Networks (XG-PON): Transmission Convergence (TC) Layer Specification
[G.988]	ITU-T Recommendation G.988, Digital sections and digital line system – Optical line systems for local and access networks Series G: Transmission Systems and Media, Digital Systems and Networks, Digital sections and digital line system – Optical line systems for local and access networks ONU management and control interface (OMCI) – ITU-T-G.988

[DPoE-IPNE]	DOCSIS Provisioning of EPON, IP Network Element Requirements, DPoE-SP-IPNE, Cable Television Laboratories, Inc.
[DPoG-MULPI]	DOCSIS Provisioning of GPON, MAC and Upper Layer Protocols Interface Specification, DPoG-SP-MULPIv1.0, Cable Television Laboratories, Inc.
[DPoG-OAM]	DOCSIS Provisioning of GPON, OAM Extensions Specification, DPoG-SP-OAMV1.0, Cable Television Laboratories, Inc.
[DPoG-OSSI]	DOCSIS Provisioning of GPON, Operations and Support System Interface Specification, DPoG-SP-OSSIV1.0, Cable Television Laboratories, Inc.
[eDOCSIS]	Data-Over-Cable Service Interface Specifications, eDOCSIS Specification, CM-SP-eDOCSIS, Cable Television Laboratories, Inc.

2.2 Informative References

This specification uses the following informative references.

[DOCSIS]	Refers to DOCSIS 3.0 unless otherwise specified.
[CMCI]	Cable Modem to Customer Premise Equipment Interface Specification, CM-SP-CMCI, Cable Television Laboratories, Inc.
[eRouter]	Data-Over-Cable Service Interface Specifications, eRouter Specification, CM-SP-eRouter, Cable Television Laboratories, Inc.
[G.805]	ITU-T Recommendation G.805, (03/2000), Generic functional architecture of transport networks.
[MULPIv3.0]	Data-Over-Cable Service Interface Specifications, MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.0, Cable Television Laboratories, Inc.
[RFC 1918]	IETF RFC 1918, Address Allocation for Private Internets, February 1996.

2.3 Reference Acquisition

- Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027; Phone +1-303-661-9100; Fax +1-303-661-9199; <http://www.cablelabs.com>
- Internet Engineering Task Force (IETF) Secretariat, 48377 Fremont Blvd., Suite 117, Fremont, California 94538, USA, Phone: +1-510-492-4080, Fax: +1-510-492-4001, <http://www.ietf.org>
- Institute of Electrical and Electronics Engineers (IEEE), +1 800 422 4633 (USA and Canada); <http://www.ieee.org>
- ITU: International Telecommunications Union (ITU), <http://www.itu.int/home/contact/index.html>
- ITU-T Recommendations: <http://www.itu.int/ITU-T/publications/recs.html>

3 TERMS AND DEFINITIONS

This specification uses the following elements, terms and definitions.

3.1 DPoG Network Elements

DPoG Network	This term means all the elements of a DPoG implementation, including at least one DPoG System, one or more D-ONUs connected to that DPoG System, and possibly one or more DEMARCs
DPoG System	This term refers to the set of subsystems within the hub site that provides the functions necessary to meet DPoG specification requirements.
DPoG ONU (D-ONU)	This term means a DPoG-capable ONU that complies with all the DPoG specifications.
DEMARC	Short form of "Demarcation Device." This term means the device, owned and operated by the operator that provides the demarcation (sometimes called the UNI interface) to the customer. Some architectures describe this device as the CPE (as in DOCSIS) or the NID (as in the MEF model).

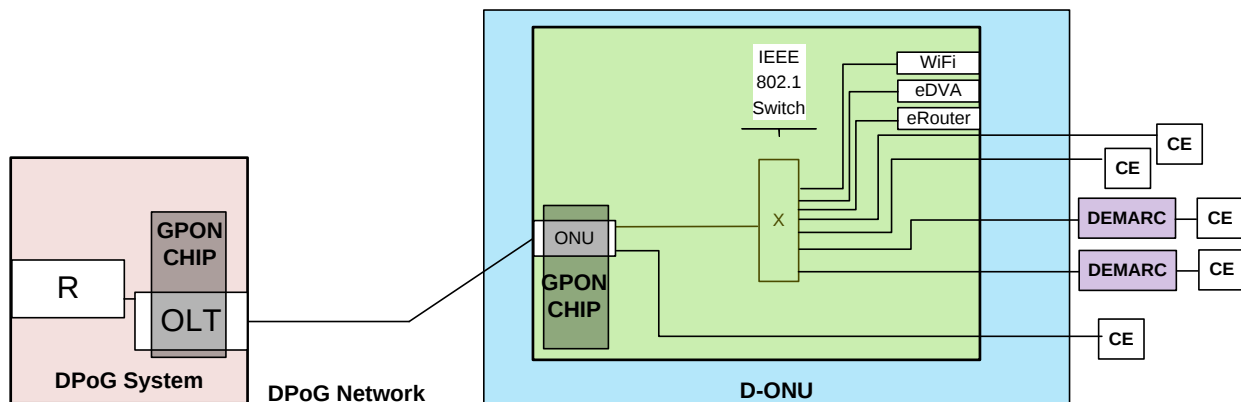


Figure 6 - DPoG Network Elements

3.2 Other Terms

2.5G-GPON	GPON as defined in [G.984]
10G-GPON	GPON as defined in [G.987]
Cable Modem CPE Interface	CMCI as defined in [MULPIv3.0]
Customer Premise Equipment (CPE)	Customer Premise Equipment as defined in [DOCSIS]
GPON Interface Adapter (GIA)	SFP based GPON ONU allowing for adaptation of devices supporting SFP GE uplinks to utilize GPON as the uplink
Multi-Layer Switching (MLS)	A switch that can switch based on Layer 2, Layer 3, Layer 4, etc.
Logical CPE Interface	LCI as defined in [eDOCSIS]
Network Interface Device (NID)	A DEMARC device in DPoG specifications
Service Flow	A unidirectional flow of packets from the upper layer service entity to the RF with pre-defined QoS traffic parameters.
Service Provider	The organization providing Ethernet services.
Subscriber	The organization purchasing and/or using Ethernet services.
TRAN-Trail	A TRAN-trail (see ITU-T Recommendation [G.805]) is a "transport entity" responsible for the transfer of information from the input of a trail termination source to the output of a trail termination sink.

4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

ATA	Analog Terminal Adapter
BGP	Border Gateway Protocol
BWP	Bandwidth Profile
CBP	Customer Bridge Port
CE	Customer Edge
C-VID	Customer VLAN Identifier
CMCI	Cable Modem CPE Interface
CMIM	Cable Modem Interface Mask
CO	Classifier-ONU
CPE	Customer Premise Equipment
CoS	Class of Service
CS	Classifier-System
CTBH	Cell Tower Backhaul
CWDM	Coarse Wavelength Division Multiplexing
D-ONU	DPoG ONU
DA	Destination Address
DAC	DEMARC Automatic Configuration
DIA	Dedicated Internet Access
DPoG	DOCSIS Provisioning of GPON
DR	Default Router
DSx	Digital Signal (DS1 or DS3)
DVA	Digital Voice Adapter
DWDM	Dense Wavelength Division Multiplexing
eCM	embedded Cable Modem
eDVA	embedded Digital Voice Adapter
ENNI	External Network to Network Interface
EPL	Ethernet Private Line
EP-LAN	Ethernet Private LAN
EP-Tree	Ethernet Virtual Private Tree
eSAFE	embedded Service/Application Functional Entity
ESP	Ethernet Service Path
EVC	Ethernet Virtual Connection
E-VPL	Ethernet Virtual Private Line
EVP-LAN	Ethernet Virtual Private LAN
GIA	GPON Interface Adapter
Gbps	Gigabits per second (as used in the industry)
GBd	Gigabaud
HSD	High Speed Data

IGP	Interior Gateway Protocol
INNI	Internal Network to Network Interface
IP	Internet Protocol
IP(HSD)	High Speed Data (Broadband Internet Access using DOCSIS)
IP-SG	IP Serving Group
IP-VPN	Private IP
iSCSI	Internet Small computer System Interface
I-SID	[802.1ah] I-Component Service Identifier
LCI	Logical CPE Interface
LLDP	Link Layer Discovery Protocol
MAC	Media Access Control
MEF	Metro Ethernet Forum
MEN	Metro Ethernet Network
MI	MEF INNI Interface at a customer premise
MI-SI	MI Service Interface
MLS	Multi-Layer Switching
MN	MEF INNI Interface to operators MEN
MPCP	Multi-Point Control Protocol
MPCPDU	MPCP Data Unit
MPLS	Multiprotocol Label Switching
MSC	Mobile Switching Center
MU	MEF UNI Interface
MU-SI	MU Service Interface
NID	Network Interface Device
NNI	Network to Network Interface
NSI	Network Systems Interface
OAM	GPON Operations Administration and Maintenance
OAMP	Operations Administration Maintenance and Provisioning
ODN	Optical Distribution Network
OLT	Optical Line Termination
ONU	Optical Network Unit
OSC	Optical Splitter Combiner
PB	Provider Bridging [802.1ad]
PBB	Provider Backbone Bridging [802.1ah]
P2P	Point-to-Point
P2PE	Point-to-Point Emulation
P2MP	Point-to-Multi-Point
PCP	Priority Control Point
PCS	Physical Coding Sublayer
PDU	Protocol Data Unit
PE	VPLS Capable Provider Edge

PHY	Physical Layer
PMA	Physical Medium Attachment
PMD	Physical Media Dependent (Sublayer)
PON	Passive Optical Network
PSTN	Public Switched Telephone Network
PW	Pseudowire
QoS	Quality of Service
R	IP Router
RD	Route Distinguisher
RIP	Routing Information Protocol
ROADM	Reconfigurable Optical Add-Drop Multiplexer
RS	Reconciliation Sublayer
S-VID	Service VLAN Identifier
SA	Source Address
SCB	Single Copy Broadcast
SD	Service Delimiter
sDVA	Standalone Digital Voice Adapter
SF	Service Flow
SFP	Small Form-factor Pluggable
SFP+	Small Form-factor Pluggable Plus (+)
SI	Service Interface
SID	Service Identifier
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TPID	Tag Protocol Identifier
UNI	User Network Interface
V-UNI	Virtual UNI
vCM	Virtual Cable Modem
VE	VPLS Edge
VID	VLAN Identifier
VLAN	Virtual Local Area Network
VOIP	Voice Over IP
VPLS	Virtual Private LAN Service
VPWS	Virtual Private Wire Service
VSI	Virtual Switch Instance
VSI-ID	VSI Identifier
WDM	Wavelength Division Multiplexing
WSC	Wireless Switching Center
X	IEEE Ethernet Switch (Generic)
XFP	X Form-factor Pluggable
XG-PON	10-Gigabit-capable Passive Optical Networks

5 DPOG SERVICE REQUIREMENTS

The purpose of this section is to document service requirements in sufficient detail to justify specific technical requirements for DPoG specifications. The DPoG specifications do not attempt to identify the size of the markets, explain the business interests, nor promote one or more services above any others.

This document does not explain the variations of product feature sets required for a specific customer. Again, the focus is on technical requirements. For example, one operator might desire to have a single box ONU solution that fulfills all Ethernet business service customers. Another operator might prefer one ONU product for Ethernet customers below 1Gbps and another for customers above 1Gbps. Other variations might include combinations with other service sets (e.g., IP services, voice, video, etc.), variations in data rate capabilities, variations in packaging and environmental requirements (wall mount, indoor versus outdoor, etc.). None of these variations is explored here. The services requirements described here are those that have an impact on the Operations, Administration, Maintenance, and Provisioning, and data collection for a multi-vendor GPON environment with DOCSIS, IP, and Ethernet controls.

Most of these services require core functionality that is shared across multiple services. Some require additional service-specific functionality.

5.1 Business Services Overview

The majority of business services can be delivered using Ethernet. In the access network, Ethernet can be used to deliver native Ethernet services (Metro Ethernet as defined by the MEF), or IP services transported over Ethernet. IP can, in turn, be used to deliver private IP (IP-VPN) services or public IP (Internet) services.

As used in this document, a service is a set of functions that the operator delivers to a customer that are integrated and managed in such a way that the customer can use the service without the customer having to manage the service. In this specification an application is a use of a service that is not only determined by the customer, but which is managed or operated by the customer.

Metro Ethernet services, as described by the Metro Ethernet Forum (MEF), are services an operator provides to a customer to transport Ethernet frames associated with that customer's applications. The operation of IP by such a customer, for example, is an application running on that service.

IP(HSD) is a service that an operator provides to a customer which delivers Internet access for that customer's applications. Operations such as file transfer, web browsing, or streaming video by such a customer are applications running on that service.

In this context, these DPoG specifications can be used to provide two basic services:

- Metro Ethernet service (as described by the MEF)⁴
- IP(HSD) (also known as Internet Access)

In addition to these services, both Metro Ethernet services and IP (HSD) services can be used as Ethernet and IP transports, respectively, to transport IP packets or frames from either the DPoG System itself or other network elements and systems within the operator's network, to provide additional services. Because IP can always be transported over a Metro Ethernet service, operators have the option of implementing transport for IP services with IP(HSD) transport or IP over Metro Ethernet services.

DPoG Networks can be used to provide nearly all IP, Ethernet, or IP/Ethernet services, either as the service delivery platforms, or as a transports between the service delivery platform and a demarcation device or D-ONU that provides some portion of the service delivery or at least demarcation of the service delivery.

⁴ Note that support for MEF services is not targeted for DPoGv1.0 specifications, but is provided here for consistency.

5.2 Service Requirements

5.2.1 Introduction

Each group of services described here can be further broken down into more detailed services that are closer to the product descriptions of individual services that operators offer to their customers.

5.2.2 Private Data Services

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.2.3 IP (Public IP/Internet)

- IP(HSD) Fixed IP/Internet Service (CMTS IP Routing)
 - Single fixed IPv4 or IPv6 address/MAC
 - Multiple IPv4 or IPv6 addresses/MAC
- Internet Address Learning Service
 - RIP-based address learning
 - Border Gateway Protocol (BGP)-based address learning

5.2.4 Voice Services

This section is retained only to maintain section numbers.

5.2.5 Vertical Markets

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.3 Single Tenant Businesses

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.4 Multiple Tenant Businesses

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.5 DPoG Fully Automated and Partially Automated Services

5.5.1 Private Data Services

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.5.2 Internet Access Service

Internet access service can be offered by two different methods.

1. DPoG specifications describe IP(HSD) service functionally equivalent to that described in DOCSIS, but with higher data rates.
2. The second method is to use Metro Ethernet service, provisioned using DPoG specifications, as transport and operation of IP routing functions for the service on separate operator-managed platforms. This is what operators have historically called Dedicated Internet Access (DIA). Although this can be made functionally

equivalent for customers, there remains a significant operational difference between IP over Metro Ethernet transport and IP(HSD). It requires additional (beyond DOCSIS) provisioning systems and process.

The goal of the DPoG specification is to, as much as possible, demonstrate savings in engineering and operations.

5.5.2.1 Static Address Service

5.5.2.1.1 DPoG IP (HSD) Service

Static address-based services can be implemented in exactly the same manner as with DOCSIS 3.0 services, utilizing either a bridged service to the CMCI interface or the S₁ interface with an eRouter as illustrated in Figure 1 and Figure 2.

5.5.2.1.2 DPoG Ethernet Transport for DIA Service

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.5.2.2 Dynamic Address for Internet Access Service

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.5.3 Internet Transit Service

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.5.4 Internet Peering Function

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

5.6 Recommendations for DPoG as a Metro Ethernet or IP Transport

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

6 ARCHITECTURAL FOUNDATION

6.1 Forwarding

The foundation for all DPoG services is an Ethernet service model as described by MEF. The Metro Ethernet services, IP services, and IP management for DEMARC are based on a common Metro Ethernet service architecture.

6.1.1 Ethernet Virtual Connections

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

6.1.2 Metro Ethernet Services

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

6.1.3 Internet Services

The IP(HSD) service is implemented using DPoG specifications in one of the following ways.

1. The first implementation method is equivalent to a "bridged" service from the customer premise through a D-ONU interface configured as a CMCI, to a default router (DR) operating on the DPoG System.
2. The second implementation is [eRouter], which operates an IP router within the D-ONU. In this implementation, the bridged service is from the router in the DPoG System to an S₁ interface on an eRouter (a type of eSAFE) in a D-ONU that is operating as an eDOCSIS device.

6.2 Service Integration

In DOCSIS the service provisioning and services are tied closely together. This remains the case with DPoG specifications. DPoG specifications use the GPON GEM port (with T-CONT) as the primary mechanism for mapping services in order to provide consistent quality of service (QoS) based on the TDM capabilities of GPON. In DPoG, a GEM port (with T-CONT) may carry more than one service as described in [DPoG-MULPI].

6.3 Multipoint Architecture

One fundamental difference between GPON, DOCSIS, and Ethernet is derived from the multi-access architecture of GPON. GPON is fundamentally a multi-access optical fiber network. Although it can be used to provide broadcast and unicast services just like DOCSIS, the multi-access function in GPON does not operate as it does in DOCSIS. Broadcast services in GPON are natively supported at the physical layer due to the properties of the underlying optical distribution network. GPON supports forward broadcast, multicast, and unicast when using the MAC. Upstream transmissions in GPON are not broadcast to all D-ONUs. In the upstream direction, optical signals from individual D-ONUs are passively combined into a single return path and optical combiners are highly unidirectional. The GPON implementation features a master scheduler in the OLT called Dynamic Bandwidth Allocation (DBA) which assigns transmit grants to the D-ONUs. The portion of fiber in the ODN from the splitter to the customer premise is a dedicated access medium that is a non-broadcast transmission path in the reverse direction. GPON's DBA handles the management of the shared return path. Thus, the D-ONUs are slaves to the OLT.

Service segregation and QoS, a fundamental in DOCSIS, is supported by GPON using meters and/or shapers associated with GEM Ports and T-CONTs. To provide service segregation, GEM Port IDs map 1:1 to DOCSIS SF. While GEM Port IDs are generally bi-directional and SF unidirectional, it is agreed that for uni-directional SF, the GEM Port ID will not be used in the reverse direction. Services with SF in both directions will use the same GEM Port ID.

For traffic transmitted by the OLT towards the D-ONU, the OLT applies Traffic Management (TM), usually in the form of either a rate meter or shaper, on a per-GEM port basis, emulating DOCSIS QoS for SF frames. For Aggregated Service Flows (ASF), which are not necessary for HSD services, support is provided via a secondary

,layer of QoS control, akin to Hierarchical QoS (H-QoS), allowing for transmission of groups of SF within an ASF. This secondary layer is not defined in the GPON standard, although some vendors provide such as an added capability.

For traffic from the D-ONU towards the PON, GPON employs both GEM ports with their requisite rate meter or shaper (if supported), as well as a T-CONT. The T-CONT controls transmission towards the PON for all the GEM ports associated with it. There is a N:1 relationship between GEM ports and T-CONT in the ITU standard. The OLT assigns each T-CONT transmit grants that allow the T-CONT to take the most eligible packet on one of its input GEM ports and forward it towards the PON. This allows GPON to emulate what DOCSIS does today for SF or ASF. The N:1 relationship means that when support for ASF is desired, the T-CONT becomes the aggregate rate control for all its constituent GEM ports on traffic from the D-ONU toward the PON.

In the DPoGv1.0 specifications, there is a 1:1 relationship between GEM ports and T-CONT, simplifying the architecture.

6.4 DOCSIS Emulation

A DPoG Network acts like a DOCSIS system with a CMTS and attached CMs to outside systems (CPE and the operator OSS). IP interfaces on the DPoG System act like those on a DOCSIS CMTS. The D-ONU provides the same service capabilities as a CM.

Most ONUs do not have an IP software stack and lack the resources to operate as a CM. The lack of an IP stack is both an additional security advantage and an economic advantage of GPON technology. Operators specifically want to avoid bifurcating the GPON ONU market and specifically want to take advantage of the benefits of scale in manufacturing and support of existing GPON ONU products and technologies.

Since all traffic going to a D-ONU from the OSS passes through the DPoG System, it is possible for the DPoG System to perform the IP layer functions of a CM. DPoG Systems instantiate a vCM for each registered D-ONU. The vCM handles all the OAMP functions for DOCSIS as described in [DPoG-MULPI] and [DPoG-OSSI]. The vCM can proxy requests, signaling, and messages to the D-ONU using Ethernet OAM messages defined in [DPoG-OAM]. The vCM utilizes the MAC address of the D-ONU as its MAC address for all IP address allocations/assignments.

The vCM model applies only to the D-ONU and not to other embedded components that may be present in the D-ONU. eDOCSIS devices (if present) use an IP stack on the D-ONU for all other DOCSIS services beyond CMCI-based services. This includes Embedded Digital Voice Adapter (eDVA), eRouter, or any other eSAFE subsystem within a D-ONU.

Customer-forwarded MEF or IP traffic does not pass through the vCM. The vCM is addressed only by the operator's network. As such, it can be implemented in IETF [RFC 1918] non-globally routed (private) IP address space.

The concept of a DOCSIS SF is maintained in the DPoG architecture. Services transmitted over a DPoG Network are classified and assigned to an SF. SFs are maintained on the OLT for traffic towards the PON to guarantee delivery. For traffic originating on the ONU, a SF maps, as described earlier, to provide the guarantee over the DPoG Network.

Since each service has separate requirements, delivery is to be guaranteed for each individual service. Probabilistic techniques that are not absolutely controlled or controllable are not sufficient to meet this requirement. Therefore, any QoS technologies that use packet or frame marking and queuing only (without a fixed-time algorithm scheduler) are not acceptable. Like the SID scheduler in DOCSIS, the T-CONT scheduler for GPON is a TDMA algorithm, which guarantees service delivery for each properly configured T-CONT. Packet and frame marking technologies are still both useful, and required, for traffic management within an individual service; however, this requirement is distinguished from the need to guarantee individual services.

6.5 eDOCSIS

As shown in Figure 7, an eDOCSIS device defined in [eDOCSIS] consists of an embedded DOCSIS cable modem (eCM) and one or more eSAFEs. An eDOCSIS device may also have one or more physically exposed interfaces. DPoG specifications allow for the optional support of [eDOCSIS]⁵. A D-ONU that includes an eRouter, eDVA, eMTA, or other eSAFE is considered an eDOCSIS device.

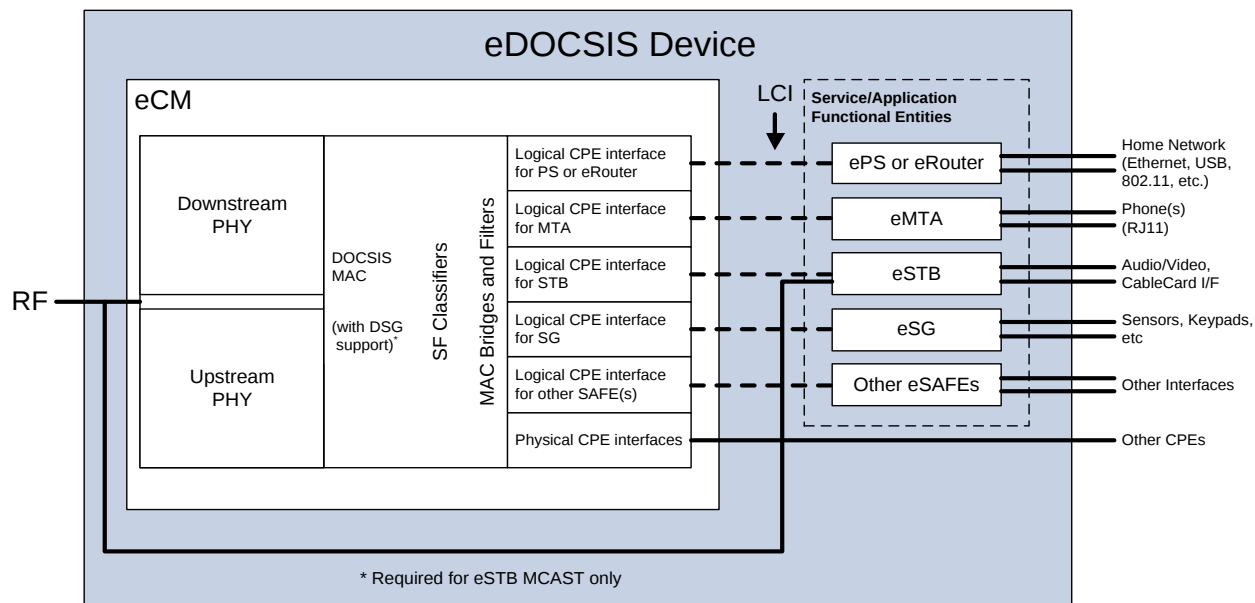


Figure 7 - eDOCSIS Reference Model (from Figure 5-1 of [eDOCSIS])

The DPoG architecture calls for the IP management functionality of a CM to reside in the DPoG System. Thus, similar to a CM without an eSAFE, and notwithstanding the downstream and upstream PHY, the functionality of the eCM in the eDOCSIS device is correspondingly split between the DPoG System and the D-ONU. The eSAFE functionality remains unchanged and is described in [eDOCSIS]. This arrangement is shown conceptually in Figure 8.

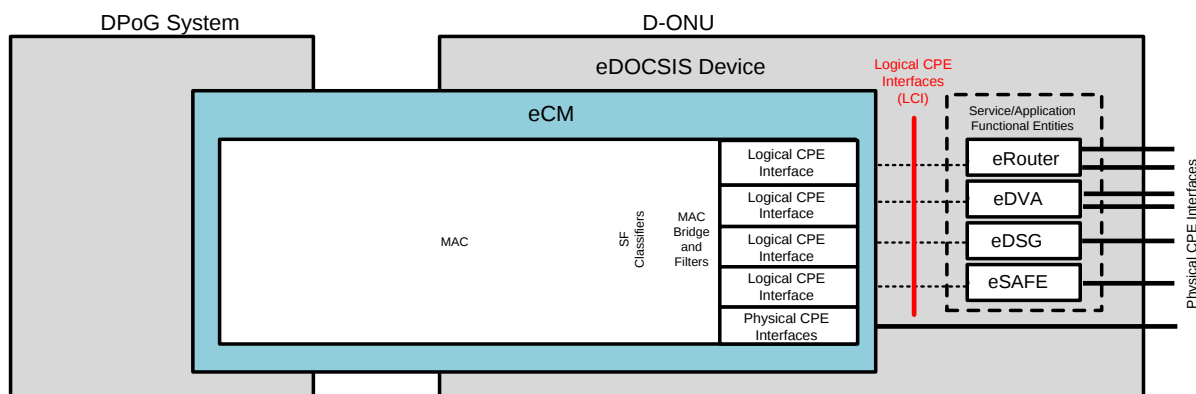


Figure 8 - eCM Functionality in an eDOCSIS Device Split between DPoG System and D-ONU with an LCI

⁵ The SLED functionality defined in [eDOCSIS] is not explicitly supported in DPoG specifications.

Consistent with the DPoG architecture, the portion of the eCM that resides in the DPoG System is identical to the vCM, plus additional requirements levied on the eCM in [eDOCSIS]. The remaining functionality of the eDOCSIS device, which includes classification, forwarding, QoS enforcement, and eSAFE functionality, is implemented in the D-ONU, as shown in Figure 9.

The vCM that is created on behalf of an eDOCSIS D-ONU needs to satisfy the IP management requirements defined in [eDOCSIS], while the eDOCSIS D-ONU needs to satisfy the remaining requirements in [eDOCSIS].

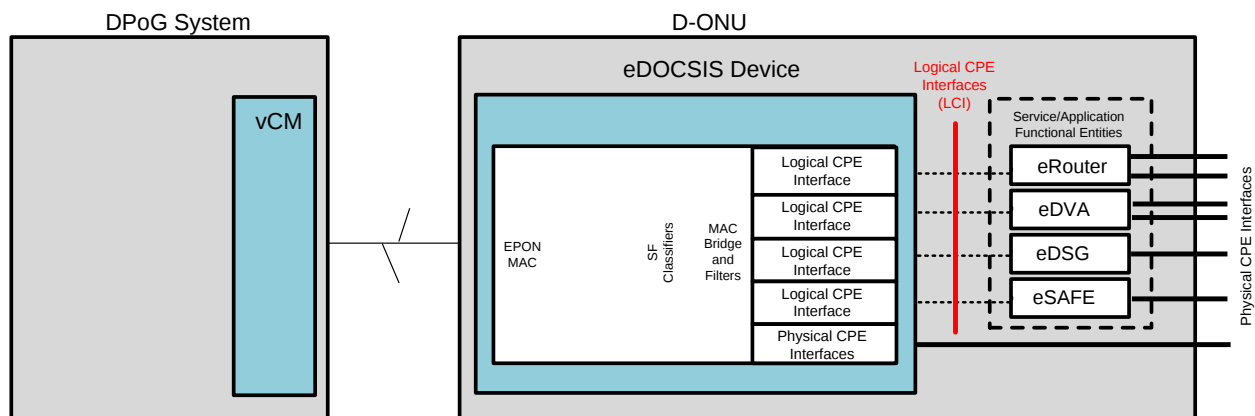


Figure 9 - D-ONU that is an eDOCSIS Device, with vCM in DPoG System

6.6 GPON Ethernet OAM

The traditional control path between a GPON OLT and the D-ONU is accomplished using OMCI messages as defined in [G.988]. With DPoG, this exchange is replaced by the use of Ethernet OAM messages as defined in [DPoG-OAM].

7 REQUIREMENTS

7.1 Introduction

The technical requirements for DPoG Networks are driven by three factors. The first set of requirements is for back-office compatibility with existing DOCSIS infrastructure and DOCSIS-based operations, administration, maintenance, and provisioning. The second set of requirements is for specific services. The third set of requirements is built on support for existing [802.3] and [802.3ah] specifications and products.

One very fundamental difference between DOCSIS and DPoG Networks is that the least common denominator of services in DOCSIS is IP, whereas the least common denominator of services in DPoG Networks is Ethernet. DOCSIS services assume an IP transport and are to emulate Ethernet services. DPoG specifications assume an Ethernet service that can run Ethernet or IP "over-the-top" of Ethernet.

7.2 Architectural Elements

7.2.1 DPoG Network Elements

A DPoG Network element is a device for which DPoG specifications provide requirements. The DPoG Network elements and their corresponding abbreviations are:

Table 3 - DPoG Network Element Abbreviations

DPoG Network Element	Abbreviation
DPoG System	DPoG
DPoG ONU	D-ONU

7.2.2 DPoG Network Definition

The term DPoG Network means the entire network described in Figure 2 from the D interface to the CMCI (or S) interface. This includes one DPoG System, one PON, and all connected D-ONUs. If a DEMARC is present, the DPoG Network is considered to include that portion of the DEMARC defined in the DPoG specifications.

7.2.3 DPoG System Definition

The DPoG System is analogous to the CMTS in DOCSIS Networks. The DPoG System is the control point for the DPoG Network and is responsible for allocating upstream bandwidth to the connected D-ONUs.

The DPoG System refers to of one or more physical devices that are required to mimic the CMTS. It provides the DPoG function within the operator's network facilities. This includes the GPON OLT function, DOCSIS service functions required for the D interface, and IP NE element management, routing, and forwarding functions specified in [DPoE-IPNE]. The DPoG System is depicted in Figure 6.

While the DPoG System may consist of more than a single networked device, it **MUST** appear to the OSS as a single device.

7.2.4 DPoG ONU Definition

This term means a DPoG-capable ONU (D-ONU) that complies with all the DPoG specifications. This term is applied to all ONU as there is no longer a need to bifurcate the naming space between Standalone and Bridged as was done previously.

7.3 Interface and Reference Point Detailed Descriptions

DPoG specifications have both interfaces and reference points. This section describes these references points relative to the DPoG specification.

7.3.1 DPoG Interfaces

Interfaces are the inputs and outputs of the separable subsystems of DPoG Network elements – that is, the inputs and outputs between the OSS and the DPoG System, between the DPoG System and a D-ONU, and between the D-ONU and various types of interfaces to CPE, eDOCSIS devices, and DEMARC devices. Since D-ONUs can contain embedded subsystems (eDOCSIS devices) that are often built by OEMs other than the ONU vendors, the DPoG specifications include a set of interfaces within the D-ONU called the S_1 interfaces.

There are two types of DPoG interfaces: external and internal.

7.3.1.1 External Interfaces

External interfaces (referred to only as "interfaces") are physical interfaces that can be connected to other DPoG Network elements or external devices, and can be tested. Interfaces are accessible for direct testing.

7.3.1.2 Internal Interfaces

Internal interfaces are those that can be described and specified, but cannot be directly tested. An example of an internal interface is the S_1 interface. The function of S_1 can only be indirectly tested by configuring the DPoG System and using it in a DPoG Network that is also connected to an IP network. Although such an internal interface (like a reference point) cannot be directly tested, it is further distinguished from a reference point in that the actions of a DPoG Network element at an internal interface can be indirectly observed. In the example of S_1 , the output at the CMCI interface can be tested to show conformance with specifications for S_1 .

7.3.1.2.1 D Interface

The D interface is the interface from the DPoG System to the operator's IP network for all IP traffic, including:

- Bearer traffic for IP service
- OAMP functionality for IP and Ethernet services

Each D interface on the DPoG System needs to support IP routing and forwarding as described in [DPoE-IPNE]. The D interface is also the interface for interoperability between the operator's OSS and DPoG Systems.

7.3.1.2.2 S Interface

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.1.2.3 S_1 Interface

S_1 interface as presented is slightly different than in the DPoE model. The S_1 interface represents the virtual Ethernet interface between the D-ONU and the eDOCSIS device. The intent is that the S_1 interface operates essentially the same as the CMCI for a physical Ethernet port but without the preamble and CRC.

7.3.1.2.4 LCI Interface

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2 DPoG Reference Interfaces and Reference Points

Reference interfaces are interfaces used on DPoG Network elements for which the requirements are identified by reference to another standard, recommendation, or specification other than the DPoG or DOCSIS specifications.

Reference points are similar to interfaces in that they point to locations where there are inputs and outputs. However, reference points may either not be separable because they are inside of an element, or they may be a reference to an independent industry standard.

7.3.2.1 MN Interface

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2.2 MNE Reference Interface

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2.3 MNI Reference Point

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2.4 S1 Reference Point

S₁ reference points are used to describe either virtual (logical) or real (external) Ethernet ports on D-ONUs. The S₁ reference point is used to provide a logical means for common requirements for all D-ONU interfaces. Requirements for the S₁ reference points are the same as those for the S₁ interface. An S₁ reference point performs the same function as an S₁ interface, but this specification cannot formally specify requirements for that reference point because the element is not fully specified by the DPoG specifications.

7.3.2.5 S2 Reference Point

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2.6 CS Reference Point

The classifier on the DPoG System is identified and described by the Classifier-System (C_S) reference point. This reference point is useful for describing classification, scheduling, and forwarding functions required for interoperability between DPoG Systems and D-ONUs and for interoperability between DPoG Systems and the D interface and reference points.

7.3.2.7 CO Reference Point

The classifier on a D-ONU is identified and described by the Classifier-ONU (C_O) reference point. This reference point is useful for describing classification, scheduling, and forwarding functions required for interoperability between the OSS or DPoG System and D-ONU. It is also useful for describing the same parameters between the C_O reference point and the S interfaces or reference points.

7.3.2.8 MI Reference Point

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.3.2.9 MU Reference Point

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.4 Architectural Requirements

DPoG implementations are organized around an architecture designed for compatibility with:

- DOCSIS Operations and Support Systems (OSS)
- DOCSIS back-office systems
- Layer 2 Ethernet, IP-based Ethernet Transport, or MEF MEN networks
- GPON OLT systems and architecture
- GPON ONUs

All DPoG Network elements require [802.3ah], [802.3], [802.1], and IETF protocol support (as defined in [DPoE-IPNE] and [DPoG-OSSI]). The architecture does not require any interoperability between subsystems that comprise the DPoG System located in the operator's network facility. Each DPoG Network may be implemented in a variety of physical configurations. The DPoG architecture requires only the interfaces to the PON, the OSS, and the IP transport interfaces D.

7.4.1 Ethernet Service Based Architecture

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

7.5 Service Model

DPoG services are based on the operator requirement to deliver a high QoS for each service. The DPoG specifications utilize the T-CONT by associating either multiplexed or individual services with those T-CONTs.

7.5.1 Service Multiplexing Model

In order to provide strict scheduler control for each service, a D-ONU MUST support one T-CONT for each provisioned service.

Specifications for provisioning ports for CMCI service can be found in [DPoG-MULPI]. DPoG Network forwarding and configuration for DOCSIS modes are described in [DPoG-MULPI].

Management traffic for embedded subsystems or external devices may be carried in a separate SF. For example, dedicated management for an eSAFE would be directed to that eSAFE device via proper configuration of the classifiers on the DPoG System and the DPoG ONU. Operators may choose to provision a dedicated T-CONT for such eSAFE management traffic, if Class of Service (CoS) requirements imposed by such traffic justify allocation of a dedicated T-CONT.

An LCI interface is an internal interface that connects only to an eSAFE such as an eRouter, eDVA, or other eSAFE. Each eSAFE uses a single LCI interface. Customer-facing eSAFE ports are not included in any port count for the minimum number of required T-CONT or GEM Ports. For example, an eSAFE with two customer-facing ports is counted as a single LCI interface for minimum per-Port requirements.

Before describing how GEM Port and T-CONT requirements are computed for a D-ONU, a clarified term is needed. For purposes of this discussion, when a service is referenced, the service will be qualified as uni-directional or bi-directional. A uni-directional service has a single SF associated with it (either upstream or downstream). Otherwise, a service always has two SF, one in each direction.

In the DPoG specifications both the number of GEM ports and the number of T-CONT is of significance in understanding the capabilities of a D-ONU. As stated earlier, each service on the PON is assigned a unique GEM port. The DPoG System MUST utilize the same GEM Port ID in both the upstream SF and downstream SF direction on the PON for a service. To understand the number of GEM ports that are needed on a D-ONU, an analysis of the number of services is needed.

T-CONTs present another challenge. In the absence of an ASF, each upstream service requires a T-CONT. In the case of an ASF, each ASF requires a single T-CONT for all its constituent services.

To compute the number of GEM ports and T-CONT a given D-ONU requires, the D-ONU capabilities and the number of services it will provide need to be considered. A D-ONU scales based on the number of supported services. Thus, a D-ONU requires a GEM port for each supported service. The number of T-CONT is equal to the number of upstream non-aggregated services plus the number of upstream ASF (if any).

Most ONUs can support 32 T-CONT and all D-ONU support the same or a greater number of GEM ports than T-CONTs. In the absence of ASF, this allows for up to 32 bi-directional services on a single D-ONU. If ASF are used and the D-ONU supports more than 32 GEM Ports but only 32 T-CONT, it is possible to support more than 32 services (upstream) due to the aggregation of services into T-CONT.

It should be noted that there are some older ONU that have limited numbers of T-CONT (as little as 4 or 8). Such units will have severe limitations on the number of SF they can support. This T-CONT limitation results from the TR-156 GPON model, which shared a predefined set of 4 T-CONT between all GEM Ports (SF).

The following examples are illustrative.

A basic residential service on a D-ONU operating full bridge (Voice, IPTV, and HSI) requires the following SF, GEM ports, and T-CONTs:

- Voice: 1 control service (Assured Forwarding) and 1 bearer service (Expedited Forwarding)
- HSI: 1 data service (Best Effort)
- IPTV: 1 unicast data service (Assured Forwarding or High Priority Best Effort), 1 uni-directional service (Downstream-only – MCAST)

Based on these, the following are identified as necessary:

5 GEM Ports (4 service GEM Ports and 1 downstream-only Multicast GEM Port)
4 T-CONT (one for each upstream service)

A hypothetical complex business service on a D-ONU: Supports 10 voice lines, shared IPTV and HSI as well as an 8-priority TLAN service:

- Voice: 1 control service (Assured Forwarding) and 10 bearer services (Expedited Forwarding)
- IPTV: 1 unicast data service (Assured Forwarding or High Priority Best Effort), 1 uni-directional service (Downstream-only MCAST)
- HSI: 1 data service (Best Effort)
- TLAN: 8 priority services and one ASF for the entire TLAN

Based on these, the following are identified as necessary:

22 GEM Ports (21 bi-directional GEM Ports and 1 downstream Multicast GEM Port)
14 T-CONT (11 for Voice, 1 for IPTV, 1 for HSI, and 1 for TLAN ASF)

7.5.2 Classification Reference Points

Classification and scheduling in a DPoG Network is defined by the DPoG System classification reference point C_s and the D-ONU classification reference point C_o .

7.5.2.1 Upstream Classification Reference Point

D-ONUs MUST perform all upstream traffic encapsulation, tagging, marking, and transcoding of frames at or before the C_s reference point. Upstream traffic encapsulation and forwarding are described in [DPoG-MULPI] for IP(HSD). Classification and scheduling for all services are described in [DPoG-MULPI]. By definition, all upstream classification is performed at or before the C_o reference point. Some traffic encapsulation, tagging, marking, and transcoding of frames or packets is performed on the DPoG System, but always prior to the D interface.

7.5.2.2 Downstream Classification Reference Point

DPoG Systems MUST perform all traffic encapsulation, tagging, marking, and transcoding at or before the C₀ reference point. Downstream traffic encapsulation and forwarding are described in [DPoG-MULPI] for IP(HSD). Classification and scheduling for all services are described in [DPoG-MULPI]. By definition, all downstream classification is performed before the C_S reference point.

7.6 IP(HSD) Forwarding Model

The IP(HSD) forwarding model is described in this specification and also in [DPoG-MULPI]. The DPoG System MUST include a fully functional IP router to meet all the requirements in [DPoE-IPNE]. These are the same requirements that operators have for DOCSIS-based CMTS systems.

IP(HSD) frame forwarding on the D-ONU can be either of 2 methodologies: bridge or ½ bridged.

Bridged operation: IP(HSD) frame forwarding is based on [802.1d] bridging. The D-ONU and the DPoG System (in combination) implement the MAC learning function, where the source MAC address of the UNI received frame is recorded in a local MAC address table, creating an association with the given UNI port and the specific CPE MAC address. This allows for traffic to be forwarded between UNI by the D-ONU in support of subscriber local services (i.e. whole home DVR).

In the downstream direction, data forwarding through the DPoG System is a combination of transparent bridging and network layer forwarding. After network layer processing completes, the DPoG System uses the aforementioned MAC address table to map the destination MAC address of a frame to the appropriate GEM port for transmission over the ODN. Once the frame is received by the D-ONU, the D-ONU may consult its MAC address table to forward the frame out the appropriate interface.

½ Bridged Operation: Any frame received on a physical port or from an eSAFE device is always forwarded towards the PON. The D-ONU and the DPoG System (in combination) implement a MAC learning function, where the source MAC address of the UNI received frame is recorded in a local MAC address table, creating an association with the given UNI port and the specific CPE MAC address. Unlike the bridged operation, these learned mappings are only used to direct traffic received from the PON. UNI ingress frames are always forwarded towards the PON, classified into their appropriate GEM port, any tag operations required by the service are performed, and the frame is then queued to the T-CONT associated to the GEM port. This is done regardless of whether the destination is local or not.

Specific requirements for DPoG Systems and D-ONU are provided in [DPoG-MULPI].

7.7 eDOCSIS

DOCSIS supports a bridged as well as a routed option utilizing an eRouter with embedded IP routing on the CM. IP services that operate on the DOCSIS model do so across the eDOCSIS S₁. The D-ONU, via OAM, reports the port configuration of the device to the OLT. For D-ONUs that support eSAFE devices, such devices are reported to the OLT as virtual ports, one to one mapping to each eSAFE device. Such ports report capabilities that allow the OLT to identify the supported eSAFE device. Services are configured on these devices just as they would on physical Ethernet ports. Configuration of the connected eSAFE device is defined in the appropriate eDOCSIS standards.

7.8 eDOCSIS on D-ONU

Any D-ONU that implements a DOCSIS eSAFE such as eRouter, eSTB, or eDVA is an eDOCSIS device and MUST support [eDOCSIS]. An D-ONU that is an eDOCSIS device MUST have an IP stack on the D-ONU for each eSAFE. This includes eDVA, eRouter, or any other eSAFE subsystem within an D-ONU. External CPE devices such as a DVA uses IP stacks on each respective device. The vCM model is only used for DOCSIS CM management functions.

An D-ONU that is an eDOCSIS device MUST implement the "SF Classifier" and "MAC Bridge and Filter" functions of the eCM.

7.8.1 eSAFE Discovery

A vCM MUST support Ethernet OAM ([DPoG-OAM]) to discover the presence of any eDOCSIS devices on the D-ONU. The indicated embedded components are then used to populate subsequent DHCP messages sent by the vCM to the OSS, as described in the following sections.

7.8.2 vCM and eCM

DPoG Systems MUST implement part of the eDOCSIS eCM within the DPoG System as illustrated in Figure 10. The vCM in the DPoG System MUST operate as the eDOCSIS eCM for management purposes. The vCM MUST use DHCP Option 43, detailed in [eDOCSIS], to report eSAFEs present in an D-ONU. When a vCM receives and proxies a software image for an D-ONU that is an eDOCSIS device, the D-ONU software image MUST be a monolithic software image for the eDOCSIS device, as described in [eDOCSIS].

DPoG Systems MUST use OAM for all required eCM functions described in [eDOCSIS]. D-ONUs MUST use OAM for all required eCM functions described in [eDOCSIS].

7.8.3 eDOCSIS Applicability

An eDOCSIS device consists of an embedded DOCSIS cable modem (eCM) and one or more eSAFEs. The eCM is connected to an eSAFE via the S_1 interface. An eDOCSIS device may also have one or more physically exposed interfaces (CMCI ports). The eDOCSIS model defines a set of eSAFEs (e.g., eMTA, eSTB, eRouter,) and also allows for "other eSAFEs" with "other interfaces" (as described in [eDOCSIS]). The DPoG specifications continue to use the eDOCSIS model and allow for the support of "other eSAFEs" within an eDOCSIS device. An example might be an embedded MoCA or WiFi device which acts as a PHY bridge. eDOCSIS also specifically includes interfaces from the internal MAC bridge directly to Physical CPE interfaces.

With each S_1 connection in an D-ONU (as shown in Figure 10), there is a uniform model for provisioning eSAFEs. For external devices connected to a CMCI port (and not an S_1), the OSS is not aware of the QoS that may be necessary for that external device. Nevertheless, if a particular D-ONU provides dedicated ports for specific external devices, operators may provision specific QoS for the interface connected to the external device.

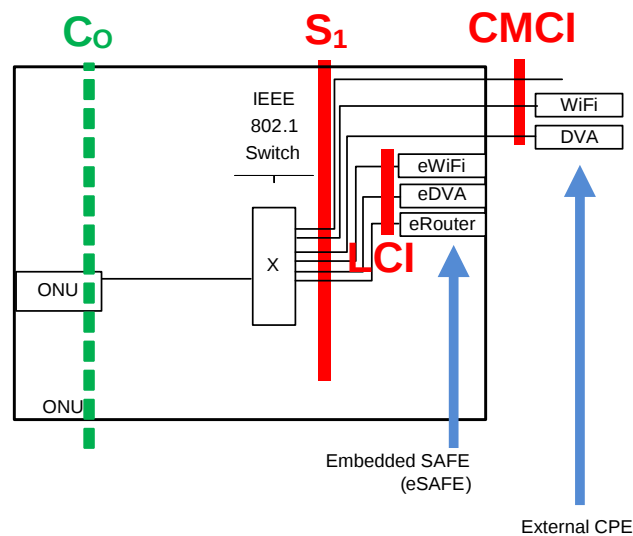


Figure 10 - DPoG Specifications Support Both Embedded SAFEs and External CPE

7.9 DEMARC Management EVC

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

8 EVPL, E-LAN, AND E-TREE SERVICES

Not supported by DPoGv1.0 specifications. This section is retained only to maintain section numbers.

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