DOCSIS® Provisioning of GPON Specifications DPoGv1.0

DPoG MAC and Upper Layer Protocols Interface Specification

DPoG-SP-MULPIv1.0-C01-160830

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Work in Progress	An incomplete document, designed to guide discussion and generate feedback that may include several alternative requirements for consideration.
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Trademarks

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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 Scope

The scope of this document is the MAC and upper layer protocols for DPoG Networks. The MAC in DPoG Networks is GPON or XG-PON. This specification does not place any additional requirements on the GPON or XG-PON MAC beyond what is standardized in [G.984] and [G.987]. The first set of requirements is for the support of DOCSIS-based Operations Administration Maintenance and Provisioning (OAMP) for the MAC and upper layer protocols as specified in [MULPIv3.0]. The second set of requirements is in addition to the above functionality traffic classification (as provisioned) and traffic forwarding (as both provisioned and according to the requirements set forth in this specification).

1.2 Goals

The objective of this specification is to document the requirements to support the automated provisioning of IP High Speed Data Services and Metro Ethernet services over GPON networks using DOCSIS provisioning methods and Back Office servers. The intention of this document is to specify requirements and guidelines to assure interoperability between DPoG products. The idea is to establish requirements that are additive and in some cases in replacement to requirements in DOCSIS 3.0.

1.3 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.

1.4 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

1.5 Reference Architecture

The DPoG reference architecture is shown in Figure 1. Refer to [DPoG-ARCH] for a discussion of this architecture.

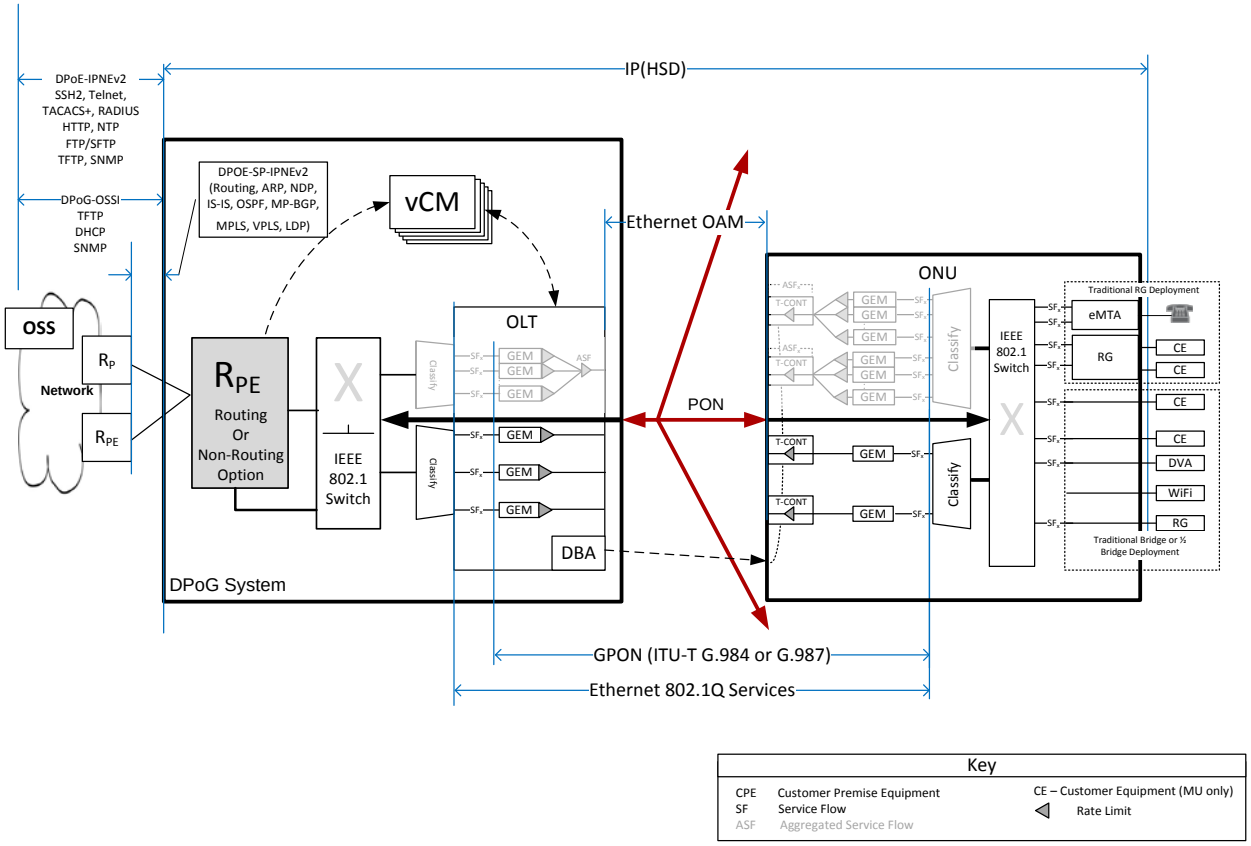

Figure 1 - DPoGv1.0 Reference Architecture

1.6 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. Refer to [DPoG-ARCH] for a discussion of these interfaces and reference points.

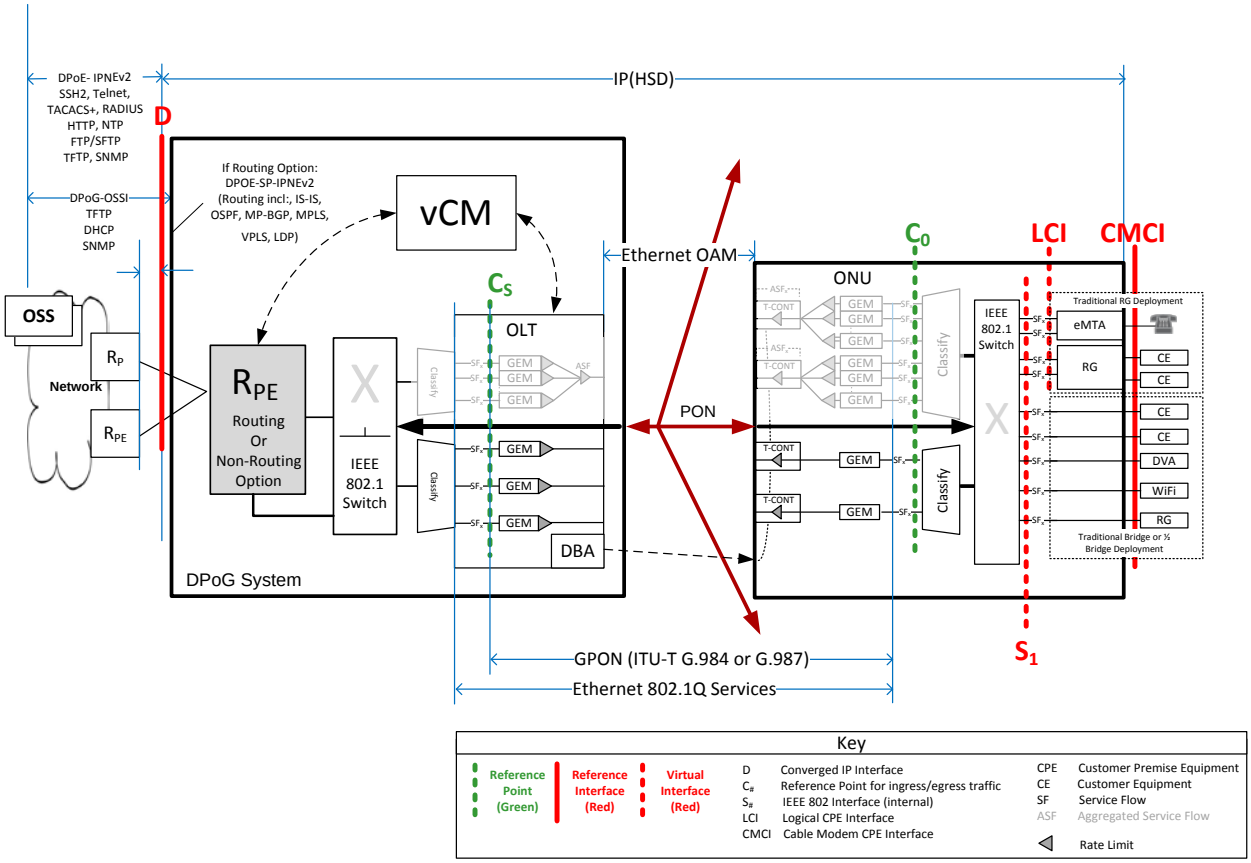

Figure 2 - DPoGv1.0 Interfaces and Reference Points

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.

[802.1ad] 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.

[CANN-DHCP-Reg] CableLabs' DHCP Options Registry, CL-SP-CANN-DHCP-Reg, Cable Television Laboratories, Inc.

[DPoG-OAM] DOCSIS Provisioning of GPON Specifications, DPoG OAM Extensions Specification, DPoG-SP-OAMv1.0, Cable Television Laboratories, Inc.

[DPoG-OSSI] DOCSIS Provisioning of GPON Specifications, DPoG Operations Support System Interface Specification, DPoG-SP-OSSIv1.0, Cable Television Laboratories, Inc.

[DPoG-PHY] DOCSIS Provisioning of GPON Specifications, DPoG Physical Layer Specification, DPoG-SP-PHYv1.0, Cable Television Laboratories, Inc.

[DPoE-IPNEv2.0] DOCSIS Provisioning of EPON, IP Network Element Requirements, DPoE-SP-IPNEv2.0, Cable Television Laboratories, Inc.

[DPoE-MULPIv2.0] DOCSIS Provisioning of EPON, MAC and Upper Layer Interface Specification, DPoE-SP-MULPIv2.0, Cable Television Laboratories, Inc.

[DPoE-OSSIv2.0] DOCSIS Provisioning of EPON, Operations and Support System Interface Specification, DPoE-SP-OSSIv2.0, Cable Television Laboratories, Inc.

[eDOCSIS] Data-Over-Cable Service Interface Specifications, eDOCSIS Specification, CM-SP-eDOCSIS, Cable Television Laboratories, Inc.

[G.984] ITU-T Recommendation G.984, refers to the entire suite of ITU-T Gigabit Capable Passive Optical Networks (G-PON) standards, unless otherwise specified

[G.984.3] ITU-T Recommendation G.984.3, Gigabit Capable Passive Optical Networks (G-PON): Transmission Convergence (TC) Layer Specification.

[G.987] ITU-T Recommendation G.987, refers to the entire suite of ITU-T 10 Gigabit Capable Passive Optical Networks (XG-PON) standards, unless otherwise specified

[G.987.3] ITU-T Recommendation G.987.3, 10 Gigabit Capable Passive Optical Networks (XG-PON): Transmission Convergence (TC) Layer Specification.

[L2VPN] Data-Over-Cable Service Interface Specifications, Layer 2 Virtual Private Networks, CM-SP-L2VPN, Cable Television Laboratories, Inc.

[MULPIv3.0] Data-Over-Cable Service Interface Specifications, MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.0, Cable Television Laboratories, Inc.

[RFC 2131] IETF RFC 2131, Dynamic Host Configuration Protocol, R. Droms, March 1997.

[RFC 2132] IETF RFC 2132, DHCP Options and BOOTP Vendor Extensions, S. Alexander, R. Droms, March 1997.

[RFC 3046] IETF RFC 3046, DHCP Relay Agent Information Option, January 2001.

[RFC 3315] IETF RFC 3315, R. Droms, Ed., J. Bound, B. Volz, T. Lemon, C. Perkins, M. Car, Dynamic Host Configuration Protocol for IPv6 (DHCPv6), July 2003.

[RFC 3376] IETF RFC 3376, B. Cain, S. Deering, I. Kouvelas, B. Fenner, A.Thyagarajan, Internet Group Management Protocol, Version 3, October 2002.

[RFC 3513] IETF RFC 3513, R. Hinden, S. Deering, Internet Protocol Version 6 (IPv6) Addressing Architecture, April 2003.

[RFC 3810] IETF RFC 3810, R. Vida, Ed., L. Costa, Ed. Multicast Listener Discovery Version 2 (MLDv2) for IPv6, June 2004.

[RFC 4361] IETF RFC 4361 Node-specific Client Identifiers for Dynamic Host Configuration, February 2006.

[RFC 4649] IETF RFC 4649, B. Volz, "Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Relay Agent Remote-ID Option" August 2006.

[RFC 4862] IETF RFC 4862, S. Thomson, T. Narten, T. Jinmei, IPv6 Stateless Address Autoconfiguration, September 2007.

2.2 Informative References

This specification uses the following informative references.

[802.1] Refers to entire suite of IEEE 802.1 standards unless otherwise specified.

[DPoG-ARCH] DOCSIS Provisioning of GPON Specifications, DPoG Architecture Specification, DPoG-SP-ARCHv1.0, Cable Television Laboratories, Inc.

[DPoG-SEC] DOCSIS Provisioning of GPON Specifications, DPoG Security Specification, DPoG-SP-SECv1.0, Cable Television Laboratories, Inc.

[DOCSIS] Refers to entire suite of DOCSIS 3.0 specifications unless otherwise specified.

[DPoE-MEFv2.0]	DOCSIS Provisioning of EPON, Metro Ethernet Forum Specification, DPoE-SP-MEFv2.0, Cable Television Laboratories, Inc.
[DPoE-OAMv2.0]	DOCSIS Provisioning of EPON, OAM Extensions Specification, DPoE-SP-OAMv2.0, Cable Television Laboratories, Inc.
[DPoE-SOAMv2.0]	DOCSIS Provisioning of EPON, DPoE Service OAM Specification, DPoE-SP-SOAMv2.0, Cable Television Laboratories, Inc.
[G.988]	ITU-T Recommendation G.988, Optical Network Unit Management and Control Interface Specification.
[OSSIv3.0]	Data-Over-Cable Service Interface Specifications, Operations Support System Interface Specification, CM-SP-OSSIv3.0, Cable Television Laboratories, Inc.

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. A D-ONU may optionally have one or more eSAFEs.
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).

3.2 Other Terms and Definitions

GPON	A GPON (2.4 Gb/s downstream, 1.2 Gb/s upstream) as defined by G.984
XG-PON	An XG-PON (10 Gb/s downstream, 2.4 Gb/s upstream) as defined by G.987
Address Resolution Protocol	A protocol of the IETF for converting network addresses to 48-bit Ethernet addresses.
Byte	A contiguous sequence of eight bits. An octet.
Burst	A single, continuous transmission in the upstream direction originating from a single ONU, where queued customer data is transmitted towards the DPoG System at the full data rate supported by the transmission channel. Between bursts, ONUs do not transmit any data.
Cable Modem CPE Interface	CMCI as defined in [MULPIv3.0].
Classifier	A set of criteria used for packet matching according to TCP, UDP, IP, LLC, [802.1Q] packet fields. A classifier maps each packet to a Service Flow. A Downstream classifier is used by the DPoG System to assign packets to downstream service flows. An Upstream classifier is used by The D-ONU to assign packets to upstream service flows.
Codeword	An element of an error-correcting code used to detect and correct transmission errors.
Customer Premise Equipment (CPE)	Customer Premise Equipment as defined in [DOCSIS].
Data Link Layer	Layer 2 in the Open System Interconnection (OSI) architecture; the layer that provides services to transfer data over the transmission link between open systems (here, equal to GPON).
Data Rate	Rate Throughput, data transmitted in units of time usually in bits per second (bps). Various multipliers are used in this document, ranging from kbit/s (thousand bits per second) to Gbps (billion bits per second).
DPoG Operations and Maintenance Messaging (OAM)	DPoG OAM messaging as defined in [DPoG-OAM] and [DPoE-OAMv2.0].

Frame	Basic data organizational unit. Here, equal to GEM frame per [G.984.3] or XGEM frames per [G.987.3].
Logical CPE Interface	LCI as defined in [eDOCSIS].
Network Interface Device (NID)	A DEMARC device in DPoG specifications.
Upstream	The direction of transmission from the customer to the head-end.

4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

ASF	Aggregate Service Flow
ASFID	Aggregate Service Flow Identifier
ASF-REF	Aggregate Service Flow Reference
BE	Best Effort Service
B-DA	Backbone MAC Destination Address
B-SA	Backbone MAC Source Address
B-VID	Backbone VLAN ID
CBS	Committed Burst Size
CID	Classifier IDs
CIR	Committed Information Rate
CMIM	Cable Modem Interface Mask
CoS	Class of Service
CPE	Customer Premise Equipment
DBA	Dynamic Bandwidth Allocation
DCID	Downstream Channel Identifier
DPM	Dual-stack Provisioning Mode
DPoG	DOCSIS Provisioning of GPON
DPoE	DOCSIS Provisioning of EPON
DR	Default Router
DUT	Downstream Unencrypted Traffic
EBS	Excess Burst Size
EIR	Excess Information Rate
ENNI	External Network to Network Interface
eOAM	Extended OAM, as defined by [DPoG-OAM]
EPON	Ethernet Passive Optical Network; refers to both 1G-EPON and 10G-EPON collectively
EToD	EPON Time of Day
eSAFE	embedded Service/Application Functional Entity
EVC	Ethernet Virtual Connection
FEC	Forward error correction
Gbps	Gigabits per second (as used in the industry)
GEM	GPON Encapsulation Method
GPON	Gigabit capable Passive Optical Network
GSF	Group Service Flows
IM	Intensity Modulated
IP	Internet Protocol
IP(HSD)	High Speed Data Broadband Internet Access using DOCSIS
I-NNI	Internal Network to Network Interface
I-SID	[802.1ah] I-Component Service Identifier

IP-SG	IP Serving Group
LCI	Logical CPE Interface as defined in [eDOCSIS]
LTE	Logical Topology Emulation
MAC	Media Access Control
MEF	Metro Ethernet Forum
MEN	Metro Ethernet Network
MESP	Metro Ethernet Service Profile
MESPID	Metro Ethernet Service Profile Identifier
MESP-REF	Metro Ethernet Service Profile Reference
MI	MEF INNI Interface at a customer premise
MN	MEF INNI Interface to operators MEN
MPCP	Multi-Point Control Protocol
MPCPDU	MPCP Data Unit
MSC	Mobile Switching Center
MU	MEF UNI Interface
NID	Network Interface Device
NNI	Network to Network Interface
NSI	Network Systems Interface
OAM	Operations Administration and Maintenance
OAMP	Operations Administration Maintenance and Provisioning
ODN	Optical Distribution Network
OLT	Optical Line Termination
OMCC	ONU Management and Control Channel
OMCI	ONU Management and Control Interface, as defined by [G.988]
ONU	Optical Network Unit
OSC	Optical Splitter Combiner
OSI	Open System Interconnection
P2MP	Point to Multi-Point
P2P	Point-to-Point
P2PE	Point-to-Point Emulation
PB	Provider Bridging [802.1ad]
PBB	Provider Backbone Bridging [802.1ah]
PCS	Physical Coding Sublayer
PDUs	Protocol Data Units
PHY	Physical Layer
PLOAM	Physical Layer OAM
PMA	Physical Medium Attachment
PMD	Physical Media Dependent (Sublayer)
PON	Passive Optical Network
QoS	Quality of Service
R	IP Router

RAIO	Relay Agent Information Option
RS	Reconciliation Sublayer
RTPS	Real Time Polling Service
RTT	Round Trip Time
SAO	DPoG Standalone ONU
SCB	Single Copy Broadcast
sDVA	Standalone Digital Voice Adapter
SF	Service Flow
SFID	Service Flow Identifier
SFP	Small Form-factor Pluggable
SFP+	Small Form-factor Pluggable Plus (+)
SFTP	Secure File Transfer Protocol
SID	Service ID
SNMP	Simple Network Management Protocol
TC	Transmission Convergence layer
T-CONT	Transmission Container
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TFTP	Trivial File Transfer Protocol
ToD	Time of Day
TPID	Tag Protocol Identifier
TQ	Time Quanta
UCID	Upstream Channel Identifier
UGS	Unsolicited Grant Service
UNI	User Network Interface
vCM	Virtual Cable Modem
VFI	Virtual Forwarding Instance
VSI	Virtual Switch Instances
V-UNI	Virtual-UNI
WSC	Wireless Switching Center
X	IEEE Ethernet Switch (Generic)
XGEM	XG-PON Encapsulation Method
(X)GEM	GEM or XGEM, generically
XG-PON	10 Gigabit capable Passive Optical Network
XGTC	XG-PON Transmission Convergence (layer)
XFP	X Form-factor Pluggable

5 OVERVIEW AND THEORY OF OPERATIONS

5.1 MULPI Key Features

The DPoG specifications introduce a number of features that build upon features defined in the DOCSIS 3.0 specifications and the GPON/XG-PON specifications (i.e. [G.984] and [G.987]). This specification includes the following key new features for the MAC and Upper Layer Protocols Interface, as compared to the DOCSIS 3.0 version ([MULPIv3.0]).

Downstream channel transmission is performed using time-division multiplexing (TDM) transmission over GPON or XG-PON. Channel Bonding [MULPIv3.0] is not supported in DPoG Networks, and bandwidth is assigned to individual links or circuits on demand via the Dynamic Bandwidth Allocation (DBA) operating in the DPoG System. The downstream channel in DPoG Networks provides broadcast and multicast capabilities inherent for point-to-multipoint passive optical networks.

Upstream channel transmission is performed using time-division multiple access (TDMA) transmission, where several D-ONUs connected to a single DPoG System time-share a single receiver to the upstream medium. Channel Bonding is not supported in DPoG Networks, and bandwidth is assigned to individual D-ONUs / logical entities on demand via the DBA operating in the DPoG System.

5.2 Key GPON Definitions

5.2.1 GEM/XGEM/(X)GEM Ports

GPON networks transport Ethernet (or IP) user service data frames using the GPON Encapsulation Method (GEM) at the Transmission Convergence layer, as defined by [G.984.3]. These frames are referred to as GEM frames.

XG-PON networks transport Ethernet (or IP) services using the XG-PON Encapsulation Method (XGEM) at the transmission convergence (TC) layer, as defined by [G.987.3]. These frames are referred to as XGEM frames.

In this document, the terminology (X)GEM is used to generically refer to GEM ports in GPON and XGEM ports in XG-PON.

In the DPoG specifications, as in [G.984] and [G.987], an (X)GEM port is used to identify a logical connection, or service flow, between the DPoG System and a D-ONU. The (X)GEM port is identified by a Port-ID field transmitted in the header of each (X)GEM frame. [G.984.3] supports a 12-bit field for the GEM Port ID, and [G.987.3] supports a 16–bit field for the XGEM Port ID. Each D-ONU is configured to recognize which (X)GEM Port IDs belong to it, and in the downstream direction only those recognized (X)GEM frames are processed. For DPoG networks, which are based upon DOCSIS unidirectional service flows, (X)GEM ports are configured with differing quality of service (QoS) characteristics and represent independent upstream and downstream service flows.

For each D-ONU, a dedicated (X)GEM port is used for the ONU Management and Control Channel (OMCC) connection. In GPON this GEM port is configured using PLOAM; in XG-PON this XGEM port ID is equal to the ONU-ID. In traditional GPON networks, the OMCC transports ONU Management and Control Interface (OMCI) messages; however, in DPoG Networks the OMCC transports DPoG-OAM messages, as specified in [DPoG-OAM]. All other (X)GEM ports are configured for DPoG Networks by DPoG-OAM messages. The DPoG System MUST use the OMCC for DPoG OAM messages. The D-ONU MUST use the OMCC for DPoG OAM messages.

In the downstream direction, multicast services can be supported by the use of multicast (X)GEM ports that are configured to belong to multiple D-ONUs on the PON. In the downstream direction, broadcast services can be supported by the use of (X)GEM ports that are configured for broadcast and belong to all D-ONUs on the PON.

5.2.2 Time-Division Multiplexing

This is a mode of downstream transmission between the DPoG System and D-ONUs. The data channel is divided into a number of smaller transmission slots, any number of which can be assigned to any of the receiving stations, depending on the data pending transmission at the DPoG System. Downstream data in a DPoG Network is sent in (X)GEM frames.

In the DPoG System downstream channel, there is only one transmitter active at any time, while there can be multiple receivers (D-ONUs); hence, no collision avoidance mechanism is needed.

5.2.3 Time-Division Multiple Access

This is a mode of upstream transmission between the D-ONUs and the DPoG System. Individual D-ONUs take possession of the data channel for a strictly controlled period of time and send data towards the DPoG System using TDM transmission. Upstream data in a DPoG Network is sent in (X)GEM frames.

In the upstream channel, there are multiple D-ONU transmitters that can be active at any time and only one receiver; hence, a collision avoidance mechanism is needed. The DPoG System central medium access controller assigns transmission opportunities to individual D-ONUs in a pre-defined and non-colliding manner. Bandwidth assignment is dynamic and depends on the SLAs, supported services, fairness, etc., subject to definition by the service provider.

5.2.4 ONU-ID

Each D-ONU that is ranged on the PON is assigned a unique ONU-ID by the OLT over the PLOAM messaging channel.

In GPON (as defined in [G.984.3]), the ONU-ID field is 8-bits in length and supports values in the range (0–253) for a single PON. Note that in PLOAM, ONU-ID 254 is reserved for broadcast messages, such as ONU autodiscovery by the OLT, and will never be used for carrying user traffic.

In XG-PON (as defined in [G.987.3]), the ONU-ID field is 10-bits in length and supports values in the range (0–1022) for a single PON. Note that ONU-ID 1023 is reserved for broadcast messages, such as ONU autodiscovery by the OLT, and will never be used for carrying user traffic.

5.2.5 Transmission Container: T-CONT

The transmission container (T-CONT) represents a group of logical connections, or service flows, and is managed by the OLT for the purpose of upstream dynamic bandwidth assignment on the PON. It is identified by an allocation ID (Alloc-ID). When the D-ONU is ranged on the PON, the OLT assigns a default Alloc-ID that is equal to the ONU-ID (refer to clause 6.1.2.4 of [G.984.3] and clause 6.4.3 of [G.987.3]). The default Alloc-ID is used for the OMCC. In traditional GPON networks, the OMCC carries OMCI management messages. In contrast, in DPoG Networks the OMCC does not transport OMCI messages and instead transports DPoG OAM frames.

In GPON, the Alloc-ID field is 12 bits in length and supports values of 0–253 for assignment of default Alloc-IDs, and 256-4095 for additional assignment if more than one Alloc-ID is required for the D-ONU. Note that in PLOAM, ONU-ID 254, and therefore Alloc-ID 254, is reserved for broadcast messages and will never be used for carrying user traffic.

In XG-PON, the Alloc-Id field is 14 bits in length and supports values of 0–1022 for assignment of default Alloc-IDs, and 1024–16383 for additional assignment if more than one Alloc-ID is required for the D-ONU. Note that in PLOAM, ONU-ID 1023, and therefore Alloc-ID 1023, is reserved for broadcast messages and will never be used for carrying user traffic.

Per the GPON standards, a D-ONU supports one or more T-CONTs.

5.3 Technical Overview

This specification defines the MAC layer protocols for DPoG Network elements, as well as the requirements for upper layer protocols (IP, DHCP, etc.) operating on top of the GPON MAC. The DPoG specifications introduce the GPON MAC as a substitute for the DOCSIS MAC in the DOCSIS specifications, reusing GPON MAC definitions for transmission of Ethernet encapsulated data over point-to-multipoint passive optical links.

GPON, and therefore DPoG specifications, do not support DOCSIS MAC-specific functions, such as:

- DOCSIS Dynamic Quality of Service (QoS) establishment and two-phase activation process
- DOCSIS-specific load balancing
- DOCSIS Channel Bonding in upstream and downstream channels
- Frame fragmentation at the transport layer

5.3.1 Multicast Operation

The DPoG Specifications support IP multicast for IP(HSD) services by adopting the IP multicast model defined in [MULPIv3.0]. This model supports the delivery of Any-Source Multicast (ASM) and Source-Specific Multicast (SSM) IP multicast streams to D-ONUs. As defined in [MULPIv3.0], the D-ONU is not aware of IP multicast control protocols. In DPoG specifications, the D-ONU does not proxy or snoop to track Layer-3 IP multicast group membership. Instead, all of the processing and management functionality related to multicast group membership is in the DPoG System.

The DPoG Network supports the provisioning and operation of IP multicast for IP(HSD) as defined in [MULPIv3.0], and this includes:

- Support for forwarding SSM traffic for IGMPv3 ([RFC 3376]) and MLDv2 ([RFC 3810]) CPE devices
- Support for forwarding ASM traffic for IGMPv1/v2 and MLDv1 CPE devices
- Support for downstream multicast QoS
- Support for static multicast
- Support for downstream encrypted multicast
- Support for IPv4 and IPv6 multicast traffic
- Explicit tracking by the DPoG System of CPEs joined to a given multicast group

The following exceptions and differences from [MULPIv3.0] for support of IP multicast apply to this version of DPoG specifications:

- Upstream multicast is not defined in this version of the DPoG specification, but the forwarding of upstream multicast traffic is not actively prevented. There is no support defined for functionality such as upstream multicast QoS or upstream multicast encryption.
- Pre-Registration IP multicast is not supported.
- The Downstream Service ID (DSID) defined in [MULPIv3.0] is replaced with a multicast GEM/XGEM port.
- Support for multicast authorization in the DPoG network is performed on a per D-ONU CMIM-interface basis.
- QoS authorization is defined as part of the multicast serving group in [DPoE-IPNEv2.0].

5.3.2 Network and Higher Layer Protocols

The DPoG System MUST perform (Ethernet) MAC Layer bridging and Network Layer routing of data traffic. The D-ONU MUST perform only MAC layer bridging of data traffic. However, both the DPoG System and D-ONU are network-layer and transport-layer aware. Specifically, the DPoG System and D-ONU support classifying user traffic based on an operator-configured set of criteria for the purposes of providing QoS and packet filtering. This classification can be based on network layer and transport layer criteria, among others.

Additionally, the DPoG System MUST support the following protocols for operation and management:

- SNMP, used by the DPoG System for operational reporting
- TFTP, used by the DPoG System for downloading operational software and configuration information
- SFTP, used by the DPoG System as a file transfer method for DEMARC Automatic Configuration
- DHCPv4 and DHCPv6, used by the DPoG System to obtain IP addresses and other configuration for D-ONU for virtual cable modem (vCM) and DEMARC provisioning and management

5.3.3 vCM, D-ONU, and CPE Provisioning and Management

5.3.3.1 Initialization, Provisioning and Management of CMs

During initialization, the D-ONU goes through a number of steps before becoming fully operational in the DPoG Network. The full initialization comprises the same four fundamental stages specified for a DOCSIS CM:

1. Topology resolution and physical layer initialization
2. Authentication and encryption initialization
3. IP initialization
4. Registration (MAC layer initialization)

The D-ONU initialization is shown in Figure 3.

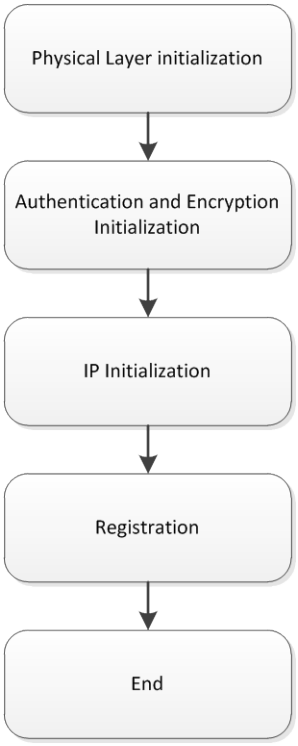

Figure 3 - D-ONU Initialization

The first stage, topology resolution and physical layer initialization, is specified in [DPoG-PHY] and describes the DPoG Network relationship to GPON ([G.984]) and XG-PON ([G.987]) system specifications.

The second stage, authentication and encryption, is specified in [DPoG-SEC] and describes how security is implemented in a DPoG Network. In GPON, downstream unicast encryption is negotiated using PLOAM messages. In XG-PON, downstream AND upstream unicast encryption is negotiated using PLOAM messages. XG-PON also optionally supports downstream multicast encryption via the use of eOAM. Authentication is performed as specified in [DPoG-SEC].

The third stage, IP initialization, requires the assignment of an IPv4, IPv6, or both IPv4 and IPv6 addresses to a vCM. This enables management of the D-ONU through the vCM, in accordance with the capabilities of the OSSI system. Since the D-ONU does not contain an IP stack (i.e., not directly addressable using IP), the vCM MUST obtain an IP address and CM configuration file from the OSS provisioning systems on behalf of the D-ONU as part of the registration process.

As described in [DPoG-OSSI], the DPoG System MUST provide management capabilities on behalf of the D-ONU for all IP-based management functions when the OSS management systems send management requests to a given D-ONU. The concept of a vCM is used in this specification to represent the IP-addressable management entity maintained and controlled within the DPoG System; one vCM is maintained per D-ONU, as shown in Figure 4. The vCM is used to map requirements that were previously required of the DOCSIS Cable Modem to requirements on the DPoG System. Note that all requirements written against the vCM are understood to be directly interpreted as DPoG System requirements.

When the DPoG System receives management requests destined to a vCM, it checks whether the given management request requires interaction with the D-ONU. If no interaction is needed, the request is handled locally, but if the request requires an extended Operations Administration and Maintenance (eOAM) message exchange between the DPoG System and the D-ONU, it converts the request into the appropriate eOAM message(s), and sends the eOAM request to the corresponding D-ONU as needed. See [DPoG-OAM] for a full description of the DPoG OAM messaging.

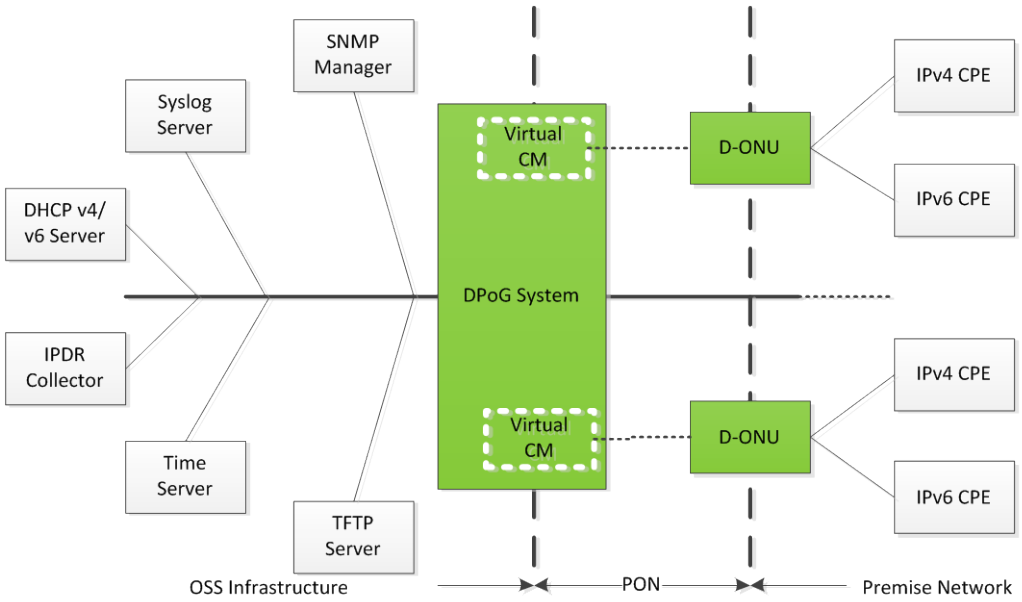

Figure 4 - vCM within the DPoG network

The DPoG System uses DHCPv4 to acquire an IPv4 address and/or uses DHCPv6 to acquire an IPv6 address. This step is followed by TFTP to obtain D-ONU operational parameters. To facilitate compatibility with existing provisioning systems, this process is identical to the DOCSIS CM provisioning process and is further described in Section 9.1.

The fourth stage, registration, involves the DPoG System processing the CM configuration file. The DPoG System validates the contents and configures the DPoG System and D-ONU based on the service provisioning information in the CM configuration file. The vCM is used by the DPoG System to store the registration state, as well as the configuration of the D-ONU.

After the DPoG System completes initialization, the vCM is a manageable network element in the operator's IP network. The vCM supports SNMP (as mentioned previously) and responds to queries directed to the IPv4 and/or IPv6 address that it acquired during initialization.

5.3.3.2 Initialization, Provisioning, and Management of CPEs

DOCSIS specifications assume the use of DHCP for provisioning of CPE devices, as described in [DPoG-ARCH]. To that end, the DPoG System MUST support a DHCP Relay Agent that allows the operator to associate a CPE IP address (DHCP) request with the customer D-ONU MAC address. This feature is also used as the basis of a mechanism that prevents spoofing of IP addresses.

If a CPE client DHCPDISCOVER is received by the DPoG System on an upstream service flow that is configured in an IP-SG, the DPoG System relay agent MUST set the giaddr field in accordance with the IP parameter specified in the IP-SG.

5.3.3.3 Relationship between CMIM and D-ONU Ports

The Cable Modem Interface Mask (CMIM) is a bit mask representing the interfaces of the D-ONU from which the D-ONU classifies traffic in the upstream and sends traffic in the downstream. These interfaces include both physical ports and Logical CPE Interfaces (LCI) on the D-ONU. Any classifier configuration related to these interfaces is provisioned using the CMIM. The vCM is responsible for translating between a CMIM-bit position and the corresponding port on the D-ONU; this translation is needed, as eOAM uses port numbers.

5.3.4 Relationship to the Physical Plant Topology

The DPoG Network uses an all-fiber passive Optical Distribution Network (ODN). Typically there are no active elements in the ODN. The ODN elements include optical splitter/combiners, connectors, and fiber.

In the DOCSIS Network, a MAC Domain is defined as a shared group of upstream and downstream channels. In the DPoG Network, a channel is defined as a wavelength, and a MAC domain is equivalent to the upstream and downstream wavelength on the same PON port. This requires the use of a shared scheduling algorithm for all D-ONUs on those channels. In the upstream direction, the DPoG System MUST allocate unique T-CONTs and (X)GEM ports for all D-ONUs within the same MAC Domain. In the downstream direction, the DPoG System MUST allocate unique (X)GEM ports for all D-ONUs within the same MAC Domain.

The concept of MAC Domain in the DPoG Network is used for the purpose of compatibility with [DPoG-OSSI]. A DPoG System MUST represent each PON port as a single MAC Domain to the DOCSIS OSS in order to provide backwards compatibility with [MULPIv3.0].

The DPoG System MUST ensure the following for a MAC Domain:

- Each D-ONU belongs to one and only one MAC Domain.
- For the purposes of compatibility with [OSSIv3.0] functions, an 8-bit Downstream Channel ID (DCID) is assigned by the DPoG System to each downstream channel (i.e. PON port) within a MAC Domain. Similar to the definition within [MULPIv3.0], the DCID value is unique within the scope of a particular MAC Domain.
- For the purposes of compatibility with [OSSIv3.0] functions, an 8-bit Upstream Channel ID (UCID) is assigned by the DPoG System to each upstream channel (i.e. PON port) within a MAC Domain. Similar to the definition within [MULPIv3.0], the UCID value is unique within the scope of a particular MAC Domain.

The DPoG Network implements the necessary [DOCSIS] functionality via the proxy of these functions on the DPoG System, operating a vCM in place of a CM to emulate the function of the CM for management purposes. In DOCSIS specifications, the MAC Domain is used to directly manage CMs in the MAC Domain, without respect to the IP address of the CM. Likewise, the DPoG specification uses MAC domains to directly manage services on the D-ONU.

6 MEDIA ACCESS CONTROL SPECIFICATION

6.1 Introduction

6.1.1 Overview

A DPoG Network uses the GPON MAC (as defined in [G.984.3]) or XG-PON MAC (as defined in [G.987.3]). Additional MAC requirements, beyond those in the GPON and XG-PON specifications, are provided in this section.

6.2 MAC Frame Formats

6.2.1 Ethernet MAC Frame Format for User Services

User services are provided in Ethernet frames. The only normative document defining the Ethernet MAC frame format in use in the DPoG System is [802.3] Clause 4.

The DPoG System MUST support the maximum Ethernet frame size of 2000 bytes for GPON (as defined in [G.984]). The DPoG System MUST support the maximum Ethernet frame size of 9000 bytes for XG-PON (as defined in [G.987]).

The D-ONU MUST support the maximum Ethernet frame size of 2000 bytes for GPON (as defined in [G.984]). The D-ONU MUST support the maximum Ethernet frame size of 9000 bytes for XG-PON(as defined in [G.987]). These maximum sizes above indicate the size for the whole Ethernet frame including the preamble, DA, SA, Type/Size, Payload, FCS and any [802.1Q] tags (encapsulation) there may be.

The D-ONU MUST drop frames exceeding the supported size of the frame for the given type of PON when received on an S interface. The DPoG System MUST drop frames exceeding the supported frame size of a given MAC Domain (i.e. type of PON). Accounting for all necessary encapsulation and tagging overhead remains the sole responsibility of the operator.

6.2.2 GPON and XG-PON Frame Format

All frames carried on GPON networks MUST support GEM as defined in [G.984.3].

All frames carried on XG-PON networks MUST support XGEM as defined [G.987.3].

6.3 MAC Management Messages

Messages defined in [MULPIv3.0], subsections 6.4.1 through 6.4.36, are not supported by the DPoG System.

6.3.1 OAM Messages in a DPoG Network

6.3.1.1 Background on DPoE OAM Messages

Prior CableLabs specifications include DOCSIS Provisioning over EPON (DPoE) specifications. EPON transports Ethernet frames directly on the PON without further encapsulation. [DPoE-OAMv2.0] requires the use of [802.3] Clause 57 Ethernet OAM protocol for D-ONU management, including Cablelabs-specific extensions referred to as DPoE-OAM or eOAM. The DPoE-OAM messages are used for D-ONU encryption, authentication, and all management purposes, including configuration, reports, notifications and file transfers.

Ethernet OAM frames in a DPoE Network target the slow protocol MAC address and are intercepted by the MAC sublayer. Thus, these frames do not propagate across multiple hops in an Ethernet network, assuring the OAM protocol data units (OAMPDUs) affect only the operation of the OAM protocol itself, leaving the contents of the customer frames unaltered.

6.3.1.2 Background on GPON and XG-PON PLOAM and OMCI

ITU-T GPON and XG-PON standards define three layers of OAM management: Embedded OAM, Physical Layer OAM (PLOAM), and ONU Management and Control Interface (OMCI).

- The GPON embedded OAM channel is provided by well-defined header fields and embedded structures of the downstream TC layer frame and upstream TC layer burst. This 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.
- PLOAM defines a relatively small set of messages between the OLT and ONU for use in ONU activation, encryption configuration, key management, basic alarm management, and the establishment of the ONU Management and Control Channel (OMCC).
- OMCI is defined in [G.988] and is used to manage the service-defining layers that reside above the TC layer. It includes object models for the ONU, the various services carried by the ONU, and an extensive number of Managed Entities to support these object models.

6.3.1.3 DPoG OAM Messages

For DPoG Networks, a new management scheme is defined that can be summarized as follows:

- DPoG-OAM messages are used to manage the D-ONU: a full set of eOAM messages is already defined in [DPoE-OAMv2.0] for D-ONUs that are compatible with DOCSIS Back Office and OSS systems. However, this message set is to be extended to accommodate GPON components that do not exist in EPON, such as (X)GEM Ports and T-CONTs. The resulting message set is referred to in this document as DPoG-OAM.
- OMCI messages are NOT used to manage the D-ONU
- GPON Embedded OAM and PLOAM is used without alteration as defined in [G.984] and [G.987]. There is a small subset of GPON PLOAM/Embedded OAM messages and DPoG-OAM messages that are similar in functionality (see Appendix III for a discussion of the overlaps). For these similar functions, this specification clarifies the DPoG System and D-ONU behavior. Specifically:
    - Dying Gasp (PLOAM): The DPoG System MUST support the Dying_Gasp PLOAM message as defined in [G.984.3] or the DG embedded OAM indicator as defined in [G.987.3]. The D-ONU MUST support the Dying_Gasp PLOAM message as defined in [G.984.3] or the DG embedded OAM indicator as defined in [G.987.3].
    - Reset D-ONU (eOAM): When the D-ONU receives the eOAM message to reset (0xD9/0x0001), the D-ONU MUST enter the Initial State (O1), either directly or immediately following a power cycle. Note: [DPoE-OAMv2.0] describes this message as resetting the D-ONU “as if from power on”.
    - Laser Tx Power Off (eOAM): When the D-ONU receives the eOAM message to turn the Laser Tx Power Off for a non-zero value (0xD9/0x0605), it MUST turn off the PON laser transmitter and initially remain in its current state. Note that subsequently, the D-ONU may transition out of its current state according to the normal state transitions defined in [G.984.3] and [G.987.3]. Likewise, when the D-ONU is not in state (O7) and it receives the eOAM message to turn the Laser Tx Power Off with a zero value (which turns the Laser Tx Power on), it MUST turn on the PON laser transmitter without changing its current D-ONU state. When the D-ONU is in state (O7), it MUST ignore all eOAM messages. Note: State (O7) is the Emergency Stop State, which prohibits the D-ONU from transmitting upstream.

The DPoG System MUST use embedded OAM and PLOAM messages as defined by [G.984.3] and [G.987.3] for D-ONU management unless otherwise specified in this document. The D-ONU MUST use embedded OAM and PLOAM messages as defined by [G.984.3] and [G.987.3] for D-ONU management unless otherwise specified in this document.

The DPoG System MUST use DPoG-OAM messages as defined in [DPoG-OAM] for D-ONU management, unless otherwise specified in this document. The D-ONU MUST use DPoG-OAM messages as defined in [DPoG-OAM] for D-ONU management unless otherwise specified in this document.

7 MEDIA ACCESS CONTROL PROTOCOL OPERATION

The DPoG specifications rely on [G.984] and [G.987] standards and do not introduce any changes to their stipulations. Bandwidth allocation for each T-CONT is controlled using Dynamic Bandwidth Assignment as described therein.

The DPoG specifications provide additional requirements, included in the following subsections, which are not covered by the [G.984] and [G.987] standards, providing definitions of functions outside their scope.

7.1 Timing and Synchronization

Updates to this section are deferred until Commercial Services are supported by the DPoG specifications.

7.2 Upstream Data Transmission

In the upstream direction in GPON and XG-PON, due to the directional properties of passive splitter/combiner devices deployed in the ODN, data packets transmitted from any of the connected D-ONUs only reach the OLT; other D-ONUs cannot access those packets. In this way the properties of the upstream PON channel are similar to those of a standard point-to-point (P2P) link.

However, unlike a true P2P architecture, in the PON Network all D-ONUs belong to a single collision domain. This means that data packets from different D-ONUs transmitted simultaneously still would collide since they are contending for access to a single receiver on the OLT. Therefore, in the upstream direction, the OLT needs to employ some form of medium-access arbitration mechanism to avoid data collisions and fairly share the channel capacity among D-ONUs, subject to specific user service agreements, fairness rules imposed in the network, etc. In GPON and XG-PON this mechanism is described as Dynamic Bandwidth Assignment (DBA) in the [G.984.3] and [G.987.3] standards.

7.2.1 Upstream Bandwidth Assignment

Definition of the DBA mechanism is outside of the scope of the DPoG specifications. The upstream bandwidth allocation mechanism in the OLT relies on the functions described in [G.984.3] for GPON and [G.987.3] for XG-PON.

The GPON D-ONU MUST support DBA Status Reporting – Mode 0 as defined in [G.984].

The XG-PON D-ONU MUST support DBA Status Reporting as defined in [G.987].

7.2.2 Upstream Transmission Request Policies and Contention Resolution

In the PON MAC layer, upstream direction transmissions do not start until the D-ONU gets a grant for transmission from the DPoG System.

7.2.3 Upstream Service Flow Scheduling Services

[MULPIv3.0] defines five Service Flow Scheduling Types:

- Best Effort (BE)
- Real-time Polling Service (RTPS)
- Non-Real-time Polling Service (NRTPs)
- Unsolicited Grant Service (UGS)
- Unsolicited Grant Service-Activity Detection (UGS-AD)

This specification only supports two types: BE and RTPS. The DPoG System MUST support the Service Flow Scheduling Type (TLV 24.15) values for Best Effort (BE) and Real Time Polling Service (RTPS). A DPoG System MAY support other Service Flow Scheduling Type values in a vendor-specific manner. If a DPoG System does not support a specific Scheduling Type and sees the corresponding value in a CM configuration file, it MUST disallow registration of the vCM.

Table 2 details which parameters are applicable for an upstream service flow for each supported Upstream Scheduling Service Type. Default values are also provided. Note that optional parameters may or may not be included in the CM Configuration file.

Table 2 -DPoG Upstream Service Flow Parameters

Service Flow Parameter as Defined in [MULPIv3.0]	Best Effort	Real-Time Polling
Miscellaneous		
Traffic Priority	Optional Default = 0	N/A[1]
Upstream Scheduling Service Type	Optional Default = 2	Mandatory
Request/Transmission Policy	Optional Default = 0	Optional Default = 0
Maximum Rate		
Max Sustained Traffic Rate	Optional Default = 0	Optional Default = 0
Max Traffic Burst	Optional Default = 12800 bytes	Optional Default = 12800 bytes
Minimum Rate		
Min Reserved Traffic Rate	Optional Default = 0	Optional Default = 0
Polls		
Nominal Polling Interval	N/A[1]	Mandatory
[1] N/A means not applicable to this service flow scheduling type.		

If a request for a service flow contains a parameter that is not applicable for the given service flow scheduling type, the DPoG System MUST ignore those parameters. Note that a DPoG System MUST support a Nominal Polling Interval (TLV 24.17) parameter in a CM configuration file when RTPS is the scheduling type. This parameter defines the minimum time between poll requests. The DPoG System is not required to set up a GPON and XG-PON polling interval exactly as configured, and it may use a vendor-specific means to approximate the configured settings. However, the DPoG System MUST report the actual value approximated by the system in the docsQos3ParamSetNomPollInterval MIB field.

7.3 Quality of Service

7.3.1 QoS Model in DPoG

The DPoG Network supports QoS through the concept of a service flow and an aggregate service flow, allowing a two-layer QoS model. These concepts are detailed in the following sections.

7.3.1.1 Definition of a Service Flow

The DPoG Network supports QoS through the concept of a service flow (SF), which is defined as a DPoG MAC-layer transport service that provides unidirectional transport of frames. Frames are transmitted in the upstream direction by a D-ONU and in the downstream direction by the DPoG System. An SF is characterized by a set of QoS parameters provisioned via:

- CM configuration file
- a Service Class definition in the DPoG System
- a combination of both

The Quality of Service Parameter Set Type (TLV 24/25.6) included in the CM configuration file defines the SF states for which the QoS parameters apply. The DPoG System MUST only support a value of 7 in the QoS Parameter Set, which corresponds to a bitmask that sets the Provisioned, Admitted and Active states to a value of 1. This setting means that the configured QoS parameters apply to all three states. A DPoG System that receives a CM configuration file with QoS Parameter Set values other than 7 MUST reject the CM configuration file.

7.3.1.2 Definition of Aggregate Service Flow (ASF)

An aggregate service flow (ASF) is a grouping of one or more SFs. An ASF is typically used for commercial services. ASF is not required in this version of the DPoG specifications.

7.3.1.3 Relationship between SF and T-CONT

The classifier forwards matching traffic into a configured SF. The traffic is transmitted with the (X)GEM port associated with the SF; in the Upstream direction only, the (X)GEM port is autonomously assigned to a T-CONT by the DPoG System.

7.3.1.4 SF Parameters

The Service Flow ID (SFID) serves as the principal identifier of a SF in the DPoG System.

7.3.1.4.1 QoS Parameters

When present in the CM Configuration file, the DPoG System MUST support the following QoS parameters for SFs:

- Maximum Sustained Traffic Rate (TLV 24/25.8) parameter.
- Maximum Traffic Burst (TLV 24/25.9) parameter. This parameter has a minimum value of 1600 bytes and a default value of 12800 bytes.
- Minimum Reserved Traffic Rate (TLV 24/25.10) parameter.
- Request Transmission Policy (TLV 24.16) parameter. This parameter controls scheduling behavior for Upstream Service flows. In GPON systems, this parameter is not applicable because the D-ONU is required to support DBA Status Reporting – Mode 0. When the Request Transmission Policy TLV is provided, the DPoG System MUST ignore it. However, the vCM MUST report the Request Transmission Policy value as per the CM configuration file.

In addition to these QoS parameters, for IP(HSD) services the DPoG System MUST support the following parameters.

- Service Flow Scheduling Type (TLV 24.15) parameter with value of "Best Effort" for all upstream service flows.
- The Traffic Priority (TLV 24/25.7) parameter.

Unless stated otherwise, these parameters are to be interpreted as defined in [MULPIv3.0].

The DPoG System MUST ignore the Maximum Concatenated Burst parameter for SFs.

These parameters apply to the given SF only when the given SF is not associated with a Metro Ethernet Service Profile (MESP) (i.e., when the SF does not contain an instance of the sub TLV 37).

For IP(HSD) services, only the DOCSIS QoS Parameters are used; the MESP parameters are used only with MEF services.

7.3.1.5 SF Requirements

The DPoG System MUST map a SF into one of the available (X)GEM ports and then, for the Upstream direction only, into an T-CONT. The mapping between the SF and the (X)GEM port and the mapping between the (X)GEM port and the T-CONT are vendor-specific processes and outside the scope of this specification.

The DPoG System MUST assign a SFID to a SF as it begins its existence in the DPoG System. The SFID serves as the principal identifier for the SF within the DPoG System. Within a DPoG System, any SF is required to have an assigned SFID, together with the set of QoS parameters, as defined above. An SF cannot exist without an assigned SFID.

The DPoG System MUST support assignment of SIDs to upstream SFs. The SID is an important management identifier in DOCSIS networks. SID Clusters, as defined in [MULPIv3.0], are not supported in the DPoG specifications. The concept of SID in DOCSIS (at a logical level) corresponds to the T-CONT Alloc-ID in the DPoG Network.

In [MULPIv3.0] an SF can be in one of several states: provisioned, admitted, or active. For each of these states the SF may have a different set of QoS parameter values. However, the DPoG System MUST only support SFs that are provisioned, admitted, and active (Quality of Service Parameter Set Type (TLV 24/25.6) value of 7). There are no provisions for deferred admission and activation of SFs. The DPoG System MUST admit and activate SFs when the given SFs are provisioned.

7.3.1.6 QoS for the T-CONT

The OLT grants traffic to the T-CONT using three bandwidth components:

- Fixed Bandwidth: The reserved portion of the PON upstream capacity that the OLT statically allocates to the T-CONT regardless of actual traffic demand or PON traffic load.
- Assured Bandwidth: The portion of the PON upstream capacity that the OLT is always expected to grant to the T-CONT in addition to the Fixed Bandwidth when there is additional unsatisfied traffic demand that the Fixed Bandwidth does not fulfill. If the traffic demand is satisfied by the Fixed Bandwidth, the OLT can reassign the Assured Bandwidth to other T-CONTs in full or in part, according to the overall traffic load on the PON.
- Maximum Bandwidth: The upper limit of the total PON upstream capacity that can be allocated to the T-CONT under any traffic conditions.

The sum of the Fixed Bandwidth and Assured Bandwidth components is referred to as the Guaranteed Bandwidth for the T-CONT. The sum of the Guaranteed Bandwidth of all T-CONTS on the PON cannot exceed the total upstream PON bandwidth. The three bandwidth components are depicted graphically in Figure 7-6 of [G.984.3].

For Upstream SFs, the DPoG System MUST automatically determine the Fixed Bandwidth, Assured Bandwidth and Maximum Bandwidth settings for the T-CONT.

For Best Effort services, such as IP(HSD):

- Since the service is Best Effort, the DPoG System MUST set the T-CONT Fixed Bandwidth parameter to 0 (zero). By setting the T-CONT Fixed Bandwidth component to zero, bandwidth will only be granted for the service when there is demand, and likewise there will be no bandwidth granted when there is no demand.
- When provided in the CM configuration file, the DPoG System MUST set the T-CONT Assured Bandwidth parameter to the SF Minimum Reserved Traffic Rate value. When the SF Minimum Reserved Traffic Rate is not provided in the CM configuration file, then the DPoG System MUST set the T-CONT Assured Bandwidth parameter to 0 (zero).
- When provided in the CM configuration file, the DPoG System MUST set the T-CONT Maximum Bandwidth parameter to the SF Maximum Bandwidth value. When the SF Maximum Bandwidth value is not provided in the CM configuration file, then the DPoG System MUST set the T-CONT Maximum Bandwidth parameter to the maximum rate supported on the PON.
- The DPoG System MUST support the extended Bandwidth Assignment DBA model specified in section 7.4.5 of [G.984.3] to map the SF priority to the T-CONT.

Note that regardless of the DOCSIS service type, bandwidth on the GPON is guaranteed to be granted to the T-CONT when there is demand up to the sum of the Fixed Bandwidth and Assured Bandwidth components. In addition, bandwidth in excess of the Guaranteed Bandwidth is granted subject to availability on the PON up to the value of the T-CONT Maximum Bandwidth setting.

7.3.2 Frame Classification and Rule Execution

In the DPoG Network, all operations on data frames related to QoS enforcement and forwarding operations are performed based on classification operations and execution of associated actions. The purpose of the classification process in the DPoG Network is:

- to identify all frames belonging to a given SF
- to determine what actions to take on each frame (e.g., encapsulate / de-encapsulate, convert specific subfields, set bits in specific locations etc.),
- to forward the given frame to the appropriate (X)GEM port (in the upstream and downstream direction alike), and in upstream direction only, forward to the appropriate Alloc-ID.

Independent classification engines execute inside the DPoG System and each D-ONU in the same manner. The DPoG System classification engine is configured jointly via DPoG System mechanisms and CM configuration files. The D-ONU classification engine is configured via DPoG-OAM, where eOAM messages represent translated configuration parameters contained in the CM configuration file.

Each classification engine operates on a set containing at least one classification rule. Each classification rule comprises at least one condition, followed by at least one action to be executed, as shown here:

IF (condition[0] AND condition[1] AND … condition[N]) THEN (action[1], action [2] … action[M])

All conditions are logically ANDed and the action is executed only if all the conditions evaluate to "true". Each condition may compare a particular header field in a frame against a provisioned value, test for existence of a field, or unconditionally return "true" or "false". The same field may be used in multiple comparisons (either in different comparison rules or in different rule conditions of the same comparison rule). There is no conceptual limitation on the complexity of the classification rules, number of classification conditions per single rule, or the number of actions executed on a frame matching the given classification rule. There may be some practical limitations, though, especially in terms of the memory space available for the classification engine, effectively limiting the number of classification rules which can be stored on a single device and their complexity, although such aspects are implementation-dependent and not subject to restriction in the scope of this specification.

All classification rules provisioned on the given classification engine are organized in a data set according to the rule priority. Rules with the highest priority are stored at the head of the data set and tested first, and the rules with the lowest priority are stored at the tail of the data set and tested last.

Each classification engine operates in a sequential manner: an incoming frame is compared against the classification rules stored in the data set maintained by the classification engine, starting from the classification rules with the highest priority until the first successful match is found. When the first successful match is found, actions associated with the given classification rule are executed and the following classification rules are not tested on the given frame. This means that each frame is processed only by actions associated with one classification rule, the conditions of which match the given incoming frame. If the primary SF is not enabled on the D-ONU, frames not matching any of the provisioned classification rules are dropped and counted.

In the upstream direction, the D-ONU MUST classify upstream packets to active SFs. If a primary upstream SF is configured and a frame does not match any configured classification rules (and hence is not classified to any SF), the D-ONU MUST assign such a frame to the primary upstream SF and forward it accordingly. If a primary upstream SF is not configured, any frame not meeting any of the configured classification rules (and hence not classified to any SF) MUST be dropped by the D-ONU so that it is not forwarded to the upstream PON interface.

In the downstream direction, the DPoG System MUST classify downstream packets to active SFs. If a primary downstream SF is configured and a frame does not match any configured classification rules (and hence is not classified to any SF), the DPoG System MUST assign such a frame to the primary downstream SF and forward it accordingly. If a primary downstream SF is not configured, any frame not meeting any of configured classification

rules (and hence not classified to any SF) MUST be dropped by the DPoG System so that it is not forwarded to the downstream PON interface.

The process of frame classification operates only on the fields already present in the given frame when it enters the classification engine. The classification engine does not operate on the fields added to the frame as a result of the successful match of the given classification rule and execution of the associated actions. This means that if the frame matches the given classification rule and, for example, an I-Tag is added to this frame, this frame is not classified based on the newly added I-Tag field.

The list of frame fields accessible by the classification engine, as well as the provisioning of the classification engine, are described in more detail in the Annex C. The list of classifier types below is for information purposes only:

- 802.3 fields: C-SA, C-DA, Ethertype
- IPv4 TOS Byte/IPv6 Traffic Class;
- IPv4 TTL/IPv6 Hop Limit;
- IPv4 Protocol Type;
- IPv4 Source Address;
- IPv6 Source Address;
- IPv4 Destination Address;
- IPv6 Destination Address;
- IPv6 Next Header;
- IPv6 Flow Label;
- TCP/UDP source port;
- TCP/UDP destination port;

In the DPoG Network the classification rules are used for both QoS enforcement and forwarding purposes; i.e., a single classification rule is used to provide QoS-specific processing to frame fields (e.g., set PCP field bits, add or remove fields etc.), forward the frame into the appropriate queue for transmission, or perform frame filtering (selective drop).

7.3.3 Classifiers

In the DOCSIS Network, as specified in [MULPIv3.0], classifiers describe the association of a given frame to a specific SF through a classification rule and associated actions. In a DPoG Network, all the same classifier behavior applies. If no Classifier Rule Priority is specified, the DPoG System MUST use the default Rule Priority of 0 (zero). The DPoG System MUST assign classifier IDs to individual classifiers. The classifier ID is an important management identifier and is specified in [MULPIv3.0].

In addition a frame's classifier references the target SF to which selected frames is associated if the specific classification rule(s) are met.

The classification behavior (i.e., classification of frames into SF at the D-ONU and the DPoG System) follows the requirements specified in [MULPIv3.0]. The vCM MUST support the Upstream Drop Classifiers (TLV 60). The vCM MUST support the Upstream Drop Classifiers Group ID (TLV 62). The vCM MUST configure the D-ONU according to the Upstream Drop Classifiers.

The set of classifiers used by the DPoG Network, applicable to IP(HSD) SFs, are as defined in [MULPIv3.0] with the following exceptions:

- Individual Classifiers cannot be added to the frame classification table using the DOCSIS MAC sublayer service interface, as this interface is not instantiated within the DPoG Network.

- In DPoG Networks classifiers do not support deferred activation; i.e., once the classifier is provisioned, the DPoG System automatically activates it, as described in Section 7.3.1.5.

Figure 5 shows the layer 2 classification fields and corresponding TLVs that are described in Annex C (layer 3 and layer 4 classification fields are not shown). In the current version of the DPoG specifications only untagged packets are expected to be forwarded (i.e. Destination MAC, Source MAC, EtherType); 802.1Q, 802.1ad, and 802.1ah tagged packets would be dropped.

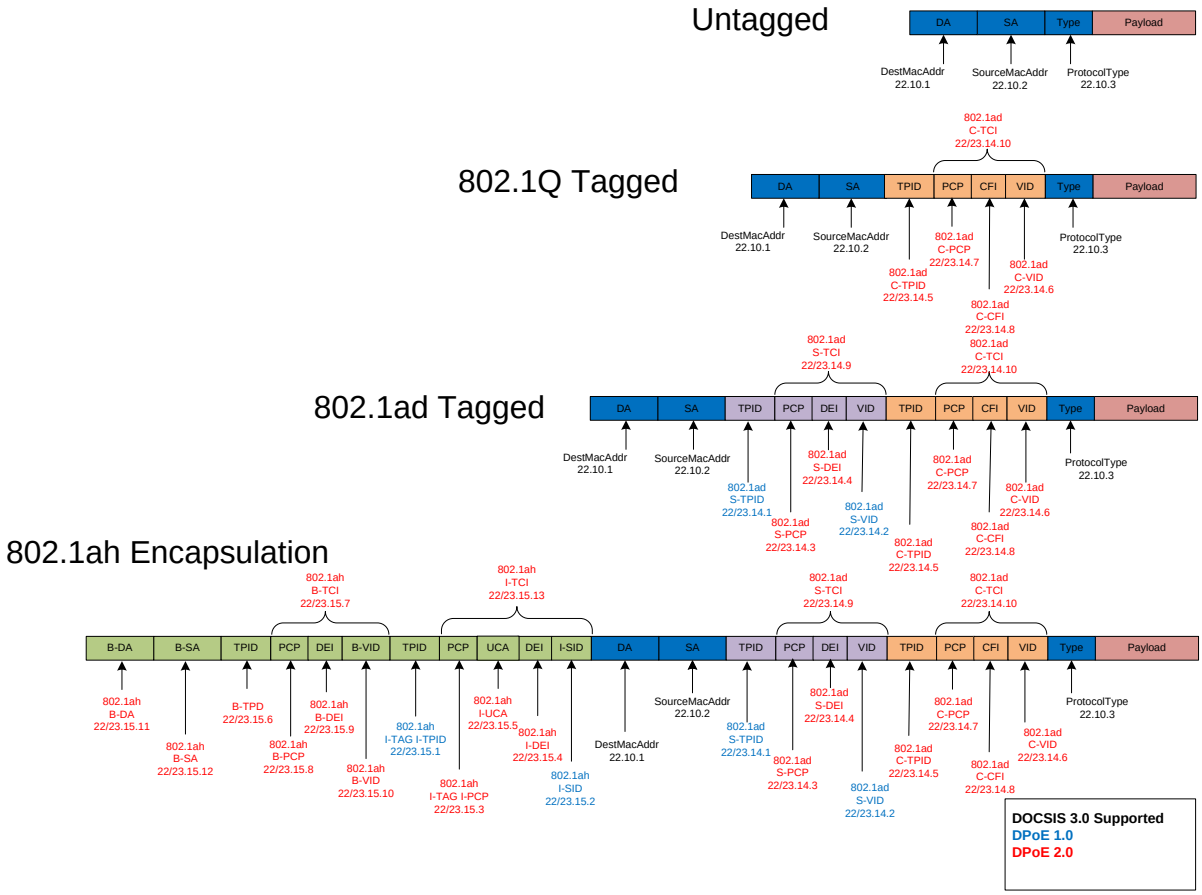

Figure 5 - 802.1ad and 802.1ah Classifiers

7.3.4 Service Classes

The DPoG System MUST support configuration of QoS parameters via Named Service Classes as specified in [MULPIv3.0]. If a Service Flow is configured using both a Named Service Class and a set of MESP parameters, the MESP parameters take precedence over the rate-related parameters and those Service Class parameters are ignored. This functionality allows for the configuration of a common set of QoS parameters for SFs through CMTS MIBs, as opposed to configuring them via CM configuration files. However, the CM configuration file still needs to refer to a specific Service Class Name configured on DPoG System. It is up to the operator to synchronize the definition of Service Class Names in the DPoG System and in the configuration files.

7.3.5 Authorization

In the DPoG Network the SF authorization process is not required because the admission control and resource availability decisions are performed on the DPoG System; the D-ONU does not participate in this process. The D-ONU is controlled by the DPoG System using the master-slave relationship.

7.3.6 SF and Classifiers

The provisioned classification rules associate packets into exactly one SF. The SF encodings provide the QoS Parameters for treatment of those frames on the PON. Service Flow encodings are described in Section 7.3.2 and Annex C.

The definition of a primary SF in the DPoG specifications is different from that in [MULPIv3.0]. A DPoG System supports CM configuration files with and without primary SFs. If a primary SF is present in the CM configuration file, it applies to the interface associated with the lowest bit CMIM interface. In a DPoG Network a primary SF is not identified by its position in the CM configuration file, but rather based on the presence (or lack) of a classifier entry associated with the upstream and downstream SFs in the CM configuration file. In this way, if each SF present in the CM configuration file has an associated classifier entry, then the DPoG System does not create a primary SF and operates without primary SFs for that D-ONU. If there are one or more SFs present in the CM configuration file that do not have an associated classification entry in the CM configuration file, the DPoG System treats the first such SF in the configuration file as the primary SF, while all the other SFs without an associated classifier are ignored; the ignored SFs are not instantiated by the DPoG System.

Support for primary SFs in the DPoG specifications is introduced to maintain partial backward compatibility with the DOCSIS provisioning systems of some operators, who rely on the presence and support of a primary SF for the implementation of IP(HSD) services.

If all of the SFs in the CM configuration file have associated classifiers, then the DPoG System MUST operate without creating any primary SFs for both the upstream and downstream directions. The DPoG System MUST NOT require the existence of a primary downstream SF to perform downstream forwarding. The D-ONU MUST NOT require the existence of a primary upstream SF to perform upstream forwarding. When there is no primary downstream SF configured, the DPoG System MUST drop all unclassified traffic. When there is no primary upstream SF configured, the D-ONU MUST drop all unclassified traffic. The DPoG System MUST set the docsQoSServiceFlowPrimary value to 'false' for all SFs when operating without primary SFs.

If the CM configuration file contains at least one upstream SF without an associated classifier, the DPoG System MUST use the first such SF without an associated classifier entry within the configuration file as the primary upstream SF. If configured by the DPoG System, the D-ONU MUST use the primary upstream SF as the default upstream SF to forward all unclassified traffic.

If the CM configuration file contains at least one downstream SF without an associated classifier, the DPoG System MUST use the first such SF without an associated classifier entry within the configuration file as the primary downstream SF. The DPoG System MUST use the primary downstream SF as the default downstream SF for all unclassified downstream traffic. The DPoG System MUST set the docsQoSServiceFlowPrimary value to true for both the upstream and downstream primary SFs.

Classification of "DOCSIS MAC Management Messages", via the "Ethertype/DSAP/MacType" TLV, does not apply to DPoG Networks. DPoG Systems do not classify OAM or eOAM frames. D-ONUs do not classify OAM or eOAM frames.

7.3.7 QoS Support for Downstream IP Multicast Traffic

QoS support for dynamically joined sessions (using a multicast management protocol such as IGMP/MLD), as well as statically joined sessions (using Static Multicast Session Encodings), is supported as defined in [MULPIv3.0]. For downstream IP multicast traffic, QoS is supported using the concept of group service flows (GSFs). Just as classifiers match and forward unicast traffic onto SFs, group classifier rules (GCRs) match multicast traffic and forward them on GSFs.

For IP multicast QoS a cable operator controls the creation of GCRs and GSFs on each downstream channel by configuring entries in Group Configuration (GC) and Group QoS Configuration (GQC) tables per [DPoE-OSSIv2.0]. These tables only configure the QoS for IP multicast sessions; they do not control how a DPoG System replicates IP multicast traffic onto multicast (X)GEM ports. Replication of IP multicast traffic is determined based on joiners to IP multicast sessions. In the DOCSIS Network, as specified in [MULPIv3.0], the multicast replication is done per downstream channel set within a MAC domain, whereas in the DPoG Network the replication is per downstream channel in the MAC domain (i.e. OLT PON port).

The operator defines the QoS needed for various IP multicast sessions using entries in the GC and GQC tables. When the first client behind the D-ONU sends up a multicast IGMP/MLD join request, the DPoG System MUST use the information in the GC and GQC tables to dynamically create GCRs and GSFs on the appropriate downstream channel. The DPoG System then starts forwarding the multicast stream on that GSF. The DPoG System follows the steps defined in [MULPIv3.0] for controlling QoS for multicast sessions.

Each GQC entry has a QoS Control parameter as defined in [MULPIv3.0] that determines how the DPoG System instantiates GSFs:

- When the QoS Control parameter value is "Single-Session", the DPoG System creates a GSF for each session. In other words, the DPoG System creates a GSF for each unique combination of (Source, Group) IP address that matches the GC entry.
- When the QoS Control parameter value is "Aggregate-Session", the DPoG System creates only one GSF and associates GCR entries as needed with that GSF.

In a "Single Session" GSF, there is only one multicast session per GSF, whereas in "Aggregate Session" GSFs, multiple multicast sessions use the same GSF. See [MULPIv3.0] for details on this behavior.

When the DPoG System creates a new GSF, the DPoG System MUST associate the GSF with a unique multicast (X)GEM port. This multicast (X)GEM port is signaled (along with the multicast filtering and forwarding information) via eOAM to D-ONUs that need to receive and forward the multicast traffic, as specified in [DPoG-OAM].

The DPoG System MUST establish a default GSF as specified in [MULPIv3.0]. All unclassified multicast traffic is forwarded on the default GSF. The DPoG System MUST associate the default GSF with a unique multicast (X)GEM port. This multicast (X)GEM port is signaled via eOAM, to the D-ONUs that need to receive and forward the multicast traffic being sent on the default GSF, as specified in [DPoG-OAM].

7.3.7.1 Forwarding Multicast Control Protocols

The DPoG System supports the downstream forwarding of multicast control traffic per serving group based on the serving group configuration as described in [DPoE-IPNEv2.0]. Examples of multicast control traffic are downstream local network control packets, link-local multicast packets, as well as packets for routing protocols that utilize IP multicast. The DPoG System MUST establish a multicast control traffic GSF for multicast control traffic per IP serving group. The DPoG System MUST create GCRs that support forwarding of multicast control traffic protocols by default, as specified in [MULPIv3.0].

The multicast control protocols specified in [DOCSIS] are allowed by default. The DPoG System MUST support overrides to the default GCR for the configured multicast control traffic protocols as specified in [DPoE-IPNEv2.0]. The [DPoE-IPNEv2.0] configuration is used to override the default behavior to allow or deny forwarding of multicast traffic or control protocols. The DPoG System MUST associate each multicast control traffic GSF with a unique (X)GEM port. This multicast (X)GEM port, along with the multicast filtering and forwarding information, is signaled via eOAM to the D-ONUs that need to receive and forward multicast control traffic being sent on the multicast control GSF, as specified in [DPoG-OAM]. The DPoG System MUST only signal the multicast (X)GEM port for each GSF associated with an IP Serving Group to the D-ONUs associated with that IP Serving Group. The DPoG System MUST only signal the multicast (X)GEM port for each GSF associated with a multicast serving group to the D-ONUs associated with that multicast serving group.

7.3.8 IPv6 Multicast Traffic and Other Multicast

As described in [DPoE-IPNEv2.0], the DPoG System supports multicast for IPv6 protocols, as well as for routing protocols that utilize IP multicast. The DPoG System MUST forward all IPv6 multicast provisioning traffic destined to the CPEs behind a D-ONU on the multicast control GSF associated with the serving group for this D-ONU. QoS support for layer 2 multicast is not defined in this specification.

7.4 D-ONU Capability Acquisition and D-ONU Provisioning

The DPoG System and connected D-ONUs operate in a master-slave relationship, where the DPoG System remains in control of individual D-ONUs.

After the initial discovery, D-ONUs are authenticated. In the DOCSIS Network CMs are authenticated by MAC address. Therefore, in a DPoG Network the D-ONU MUST support a fixed (non-changing) MAC address to identify itself to the DOCSIS back office and OSS. The D-ONU MUST report the MAC address to the OLT as described in Section 9 of this document.

Additionally in DOCSIS, the CM encodes its MAC address in an X.509 certificate that is used for authentication. In order to duplicate that method of authentication for DPoG networks, the D-ONU conveys the X.509 certificate to the OLT, as defined in [DPoG-SEC]. After the D-ONU is discovered, authenticated, and registered, the DPoG System provisions a connected D-ONU as specified by the operator in the associated CM configuration file. This process is driven by the given instance of a vCM associated with the given D-ONU and the capabilities exchange of [DPoG-OAM] messages. This exchange serves the following purposes:

- Obtaining D-ONU configuration parameters and capabilities, including MAC address, software version, number of supported T-CONTs and (X)GEM ports, etc.
- Configuration of D-ONU parameters and capabilities, such as type of traffic scheduling policy for each T-CONT, etc.
- Based on the CM configuration file, establishment of services on the D-ONU and configuration of:
  - associated classification and modification rules
  - queue and (X)GEM port mapping rules
  - T-CONT mapping rules

Definitions of individual D-ONU attributes, as well as the details of the provisioning, configuration and communication mechanism used to exchange information between the D-ONU and the vCM, are specified in [DPoG-OAM].

Note that the D-ONU configuration in the DPoG Network is driven by the DPoG System, and specifically, by the vCM associated with the D-ONU. D-ONU configuration may be executed at any time after the D-ONU has been registered on the DPoG Network, based on current operator requirements, operator demand (on-demand polling), etc. The DPoG System MUST acquire D-ONU capabilities before provisioning any of the services defined in the CM configuration file. To guarantee interoperability between the DPoG System and D-ONU devices from various suppliers, it is necessary to guarantee interoperability at the PON interface; this interoperability is ensured by the definitions and requirements specified in the [DPoG-OAM] specification.

7.5 D-ONU Capabilities

D-ONU capabilities are queried by the DPoG System as described in the previous section. The D-ONU MUST support reporting the following capabilities to the DPoG System:

- DPoG Version Number
- Maximum Number of T-CONTs
- Maximum Number of Unicast (X)GEM Ports
- Maximum Number of Multicast (X)GEM Ports
- Number of S1 ports on D-ONU

The DPoG System MUST support reporting these capabilities to the provisioning system using DHCP messages. Annex C documents TLV definitions.

7.6 Data Link Encryption Support

The procedures to support data-link encryption for GPON are defined in [G.984.3] for GPON. The procedures to support data-link encryption for XG-PON are defined in [G.987.3].

8 DATA FORWARDING

The basic architecture for DPoG Networks is described in [DPoG-ARCH]. For MEF services the DPoG Network uses GPON technology to provide P2P Ethernet connections between the DPoG System and a D-ONU. P2P Ethernet connections in the form of Ethernet virtual connections (EVCs) are the underlying transport technology for Metro Ethernet services in the DPoG Network. IP(HSD) is a DPoG service that transports IP packets in the same manner as traditional DOCSIS and does not require the use of EVCs and [802.1ad] tagging across the PON interface. Since GPON has a point-to-multi-point architecture at the physical layer, P2P services are emulated through the use of (X)GEM ports, as described in [G.984.3] and [G.987.3].

8.1 MEF Forwarding Requirements

Updates to this section are deferred until MEF Services are supported by the DPoG specifications.

8.2 Multicast Forwarding

8.2.1 Introduction

The DPoG Network supports IP multicast for IP(HSD) services by adopting the IP multicast model defined in [MULPIv3.0]. As defined in the [MULPIv3.0] model, the D-ONU does not proxy or snoop messages to track layer-3 IP multicast group membership and has no IP multicast control protocol awareness. The D-ONU transparently forwards IGMP/MLD control messages received from client CPEs to the DPoG System.

Support of the IP multicast control protocols and tracking of layer-3 IP multicast group membership is centralized and performed on the DPoG System. The DPoG System forwards downstream all packets from a set of multicast sessions on the multicast (X)GEM port assigned to that particular set of multicast sessions. From the DPoG System perspective, a multicast (X)GEM port identifies a set of multicast sessions that may be received by a set of D-ONUs. The multicast (X)GEM port is used by the D-ONU to filter and forward multicast packets. The DPoG System controls the multicast forwarding of downstream multicast packets to specific interfaces through configuration of the D-ONU. The DPoG System configures the D-ONU with the multicast (X)GEM port and associated group forwarding attributes to specify the forwarding of IP multicast packets.

8.2.2 Downstream Multicast Forwarding

This section outlines the DPoG System and D-ONU requirements for downstream multicast forwarding. In the DOCSIS Network, as specified by [MULPIv3.0], the DSID is used to restrict forwarding of multicast sessions through CMs with multicast clients that have joined the session; in a DPoG Network the DSID is replaced by the multicast (X)GEM port.

The DPoG System assigns multicast (X)GEM ports to GSFs. The DPoG System MUST assign multicast (X)GEM ports uniquely per MAC Domain (i.e. GPON OLT port).

The DPoG System MUST forward IP multicast packets if the session has active group membership. Active group membership is determined by the presence of a multicast listener (client) behind a D-ONU.

8.2.2.1 Labeling Multicast Packets with Multicast (X)GEM Port IDs

The DPoG System MUST tag all downstream multicast packets with a multicast (X)GEM port ID. The DPoG System signals the needed multicast (X)GEM port IDs to the appropriate D-ONU via eOAM. Packets with a known multicast (X)GEM port ID are received by the D-ONU and further filtered and forwarded to the set of CMIM-interfaces (S-interfaces) associated with this multicast session. Packets with an unknown multicast (X)GEM port ID are discarded by the D-ONU.

In [MULPIv3.0] each replication of an (S,G) IP multicast session to a particular downstream channel set is assigned a unique DSID label within a MAC Domain. In DPoG Networks each GSF is assigned a unique multicast (X)GEM port ID within a MAC Domain (i.e. GPON OLT port). This is an important difference. In DOCSIS Networks, the DSID is unique to an individual (S,G) IP multicast session; in DPoG Networks the multicast (X)GEM port ID is

unique to the GSF. A GSF and the assigned multicast (X)GEM port ID can be used to forward one or many IP multicast sessions downstream.

8.2.2.2 Communicating Multicast (X)GEM Port IDs, Filtering and Forwarding Attributes to a D-ONU

The DPoG System is responsible for signaling to the D-ONU the required parameters for filtering and forwarding multicast traffic, including the multicast (X)GEM port ID and all of the filtering and forwarding parameters associated with each GSF. The process for communicating the required parameters for dynamic multicast sessions and static multicast sessions is described here.

After the DPoG System successfully authorizes a dynamic IP multicast session, the DPoG System MUST communicate the multicast (X)GEM port ID and required filtering and forwarding parameters to the D-ONU. The DPoG System MUST configure the D-ONU using methods defined in [DPoG-OAM] with the following filtering and forwarding parameters:

- Multicast (X)GEM port ID
- Source address
- IP multicast group address
- Client MAC Address.

The client MAC Address sent by the DPoG System is based on the IGMP/MLD join messages for a particular IP Multicast session. The D-ONU uses this information to deduce the set of CMIM interfaces to which the multicast sessions are forwarded. When a dynamic session is no longer active, the DPoG System MUST communicate the multicast (X)GEM port ID, IP multicast group address and client MAC address for the inactive session using methods defined in [DPoG-OAM]. If the dynamic IP multicast session is no longer active on any of the CPE devices attached to the D-ONU, the DPoG System MUST direct the D-ONU to remove the multicast (X)GEM port ID and all associated filtering and forwarding parameters using methods defined in [DPoG-OAM].

For static multicast sessions, the DPoG System MUST configure the D-ONU using methods defined in [DPoG-OAM] with the following filtering and forwarding parameters:

- Multicast (X)GEM port ID
- Source address
- IP multicast group address
- CMIM Interface

The CMIM interface sent by the DPoG System is specified in the configuration of the static multicast session. The D-ONU uses this information to identify the set of CMIM interfaces used to forward the multicast traffic associated with a multicast (X)GEM port ID. When a static session is removed, the DPoG System MUST communicate the multicast (X)GEM port ID, IP multicast group address and CMIM interface for the inactive session using methods defined in [DPoG-OAM].

8.2.2.3 Multicast (X)GEM Port-Based Filtering and Forwarding by a D-ONU

The D-ONU filters downstream IP multicast packets based on the multicast (X)GEM port ID, Source address, and IP Multicast group address that it has been configured to process. The D-ONU MUST discard all multicast packets that do not match a configured multicast (X)GEM Port ID, source address, and IP multicast group address.

The D-ONU MUST only replicate filtered IP multicast packets once, based on the D-ONU's CMIM interface map. The D-ONU CMIM interface map is the union of CMIM interfaces with active multicast session members based on the configured static and dynamic multicast sessions. If the D-ONU does not have any CMIM interface associated with a filtered IP multicast packet, the D-ONU MUST discard the multicast packet.

8.2.2.4 Forwarding Local Network Control and Link-Local Multicast Addresses

The DPoG System determines which GSF to transmit downstream local network control and link-local multicast packets based on the destination multicast address.

Downstream local network control packets addressed to the "all hosts" multicast address and link-local multicast packets addressed to the "all nodes" address MUST be transmitted by the DPoG System on the multicast control traffic GSF and the associated multicast (X)GEM port ID to each IP(HSD) and multicast serving group. The DPoG System MUST support the downstream forwarding of the local network control and link-local multicast control protocols on the multicast control GSF, based on the serving group configuration as specified in [DPoE-IPNEv2.0].

For packets that are destined to a multicast group specific address, the DPoG System MUST signal the appropriate multicast (X)GEM port ID to only the D-ONUs with active membership in the associated multicast group. The DPoG System MUST forward all downstream local network control and link-local multicast packets addressed to specific multicast group addresses on the same multicast (X)GEM port assigned by the DPoG System for the multicast data for this group address. Downstream local network control and link-local multicast packets addressed to a specific multicast group address are not transmitted on the multicast control traffic GSF or the associated multicast (X)GEM port ID.

8.2.3 Downstream Multicast Encryption

Downstream multicast encryption is not supported in G.984 GPON, but is optionally supported in G.987 XG-PON. The procedures to support IP multicast encryption and the necessary signaling associations are defined in [DPoG-SEC].

8.2.4 Upstream Multicast Forwarding and Encryption

In this version of DPoG specifications, there are no special requirements around forwarding of upstream multicast packets. When a D-ONU receives multicast packets on its S1 interface, it forwards upstream data packets to the DPoG System on the unicast (X)GEM Port ID. In this version of DPoG specifications, there are no requirements for the encryption of upstream multicast packets.

8.2.5 Static Multicast Session Encodings

The cable operator can configure the D-ONU to join static multicast sessions using CMTS Static Multicast Session Encodings (TLV64) as defined in [MULPIv3.0]. The DPoG System MUST configure the forwarding of a static multicast session on the D-ONU as part of the vCM registration process. During the vCM registration process, the DPoG System configures the D-ONU as defined in [DPoG-OAM] with the following parameters:

- Multicast (X)GEM port ID
- Source address
- IP multicast group address
- CMIM-Interface map

If the static IP multicast session is encrypted, the DPoG System MUST enable encryption for this multicast (X)GEM port ID as part of the vCM registration process. The procedures to enable multicast encryption for static multicast sessions are defined in [DPoG-SEC].

8.2.6 IGMP and MLD Support

In the DPoG Network the DPoG System is the single point of control for IP multicast operations. This alleviates the need for any IGMP or MLD support in the D-ONU. From a multicast client’s perspective the DPoG System operates as an IGMP/MLD querier and as an IPv4/IPv6 multicast router. The DPoG System MUST provide IP multicast querier and router support for IPv4 using IGMPv3. The DPoG System MUST provide IP multicast querier and router support for IPv6 using MLDv2.

A DPoG System's support for IGMP/MLD backwards compatibility is configured per serving group, as specified in [DPoE-IPNEv2.0]. If the configuration specifies that the DPoG Network limits IGMP/MLD support to IGMPv3/MLDv2, then the DPoG System MUST NOT support backwards compatibility with IGMPv1/v2 and MLDv1. If the DPoG System is not operating in IGMP version backwards compatibility mode, the DPoG System MUST discard all IGMP packets other than IGMPv3 packets. If the DPoG System is not operating in MLD version backwards compatibility mode, the DPoG System MUST discard all MLD packets other than MLDv2 packets. If the configuration specifies that the DPoG Network supports IGMP/MLD backwards compatibility, the DPoG System MUST support IGMPv1/v2 clients and MLDv1 clients as specified in IGMPv3 [RFC 3376] and MLDv2 [RFC 3810].

Multicast clients send IGMP/MLD membership reports when they want to start or stop receiving an IP multicast session. A D-ONU MUST transparently pass IGMP/MLD membership reports on the GPON interface to the DPoG System.

The forwarding of IGMPv3/MLDv2 packets is based on the following requirements:

The DPoG System MUST forward all downstream IGMP/MLD messages sent to the "all hosts" address and "all nodes" address on the OLT GPON interface using the multicast (X)GEM port ID for multicast control traffic for each IP serving group.

The DPoG System MUST forward all downstream IGMP/MLD messages sent to a group specific address on the OLT GPON interface using the multicast (X)GEM port ID for that session. This is the multicast (X)GEM port ID assigned by the DPoG System for the forwarding of multicast data for that group specific address.

The D-ONU MUST bridge all upstream IGMP/MLD message on the D-ONU GPON interface using the upstream unicast (X)GEM Port ID corresponding to the CMIM interface that the D-ONU received the packet on.

8.2.6.1 IGMP/MLD Leave Processing

When the DPoG System determines that there are no multicast clients for a dynamic IP multicast session behind a D-ONU, the DPoG System MUST delete the multicast (X)GEM port ID and associated filtering and forwarding parameters for this D-ONU using the messages defined in [DPoG-OAM]. When the DPoG System determines that there are no multicast clients for an IP multicast session on any D-ONU, the DPoG System MAY choose to release the multicast (X)GEM port ID and reuse it as needed.

8.2.7 Explicit Tracking of CPEs Joined to a Multicast Group

The centralized model described here enables the DPoG System to perform tracking of multicast sessions on a per user basis; see the multicast MIB objects defined in [DPoG-OSSI] for further details on this tracking.

8.2.8 IPv6 Multicast Traffic: Neighbor Discovery, Router Solicitation, etc.

Some of the IPv6 traffic used for DHCPv6, Neighbor Solicitation (DAD), and IPv6 Router Advertisements (RAs) are sent using IP multicast. The DPoG System MUST send all multicast IPv6 provisioning traffic using a separate multicast (X)GEM port ID reserved for this purpose. The DPoG System signals the IPv6 provisioning traffic multicast (X)GEM port ID to D-ONUs to support forwarding of this traffic. The multicast (X)GEM port ID and the set of D-ONUs that receive the multicast (X)GEM port ID are chosen in a vendor-specific manner.

8.3 Requirements for IP(HSD) Forwarding

The DPoG System MUST support forwarding IPv4 frames that belong to an IP(HSD) service using a combination of [802.1d] bridging and layer-3 routing. Within the DPoG System there are two modes of transmitting frames from the OLT to the router. If the IP serving group associated with the upstream service flow specifies an S-VID parameter, the DPoG System OLT MUST add an S-Tag using the specified S-VID to the IP(HSD) frame and transmit the frame to the router. If the IP serving group associated with the upstream service flow does not specify an S-VID parameter, the DPoG System OLT does not add an S-Tag and transmits the frame to the router without further modification.

The D-ONU MUST support forwarding IP(HSD) frames that have an IPv4 format. The D-ONU is intended to forward upstream IP(HSD) frames using [802.1d] bridging. The D-ONU uses the combination of dynamic MAC address learning and static MAC provisioning to properly select the UNI port for downstream frames.

8.3.1 IP Serving Group

An IP serving group (IP-SG) represents a collection of one or more IP(HSD) upstream service flows whose traffic is associated with a DPoG System physical or virtual router interface. The configuration of an IP-SG is specified in [DPoE-IPNEv2.0]. The IP(HSD) frames are associated with an IP-SG based on the service flow attribute mask parameter configured in both the associated upstream service flow and the IP-SG. If an upstream service flow is not associated with an IP-SG, the DPoG System MUST use the default IP-SG configured for this service flow.

9 DPOG SYSTEM AND D-ONU INTERACTION

9.1 D-ONU and vCM Initialization and Reinitialization

9.1.1 Scan for Downstream Channel

Upon initialization a D-ONU MUST NOT transmit any CPE traffic until it is discovered by the DPoG System, ranged, registered, and granted access to the DPoG Network. When powered on, the D-ONU starts receiving the downstream channel data stream in order to:

1. Acquire and align the receive path clock to the data clock retrieved from the downstream transmission.
2. Synchronize its data path to the incoming frames.

Since multi-channel operation is not supported in the DPoG System, there is no need to store any last operational parameters in non-volatile storage. Every time the D-ONU is initialized, it MUST go through a complete initialization, discovery, ranging, registration, and granting process until it is fully operational. There may be exceptions to this rule in the case of support of advanced power-saving modes – details are outside of the scope of the DPoG specifications and are considered vendor-specific.

9.1.2 Continue Downstream Scanning

Functions related to channel scanning are not supported in the DPoG Network. A D-ONU MUST NOT select any other transmission channel apart from the channel meeting the requirements of the [DPoG-PHY] specification.

9.1.3 Service Group Discovery and Initial Ranging

In the DPoG System, "D-ONU Discovery" represents the time when the D-ONU has been ranged and reached the operation state, and the MAC address has been authenticated as described in this section.

For a [G.984] GPON D-ONU, after power-up a D-ONU transitions from the initial state to the standby state to the serial number state, as shown in Figure 6 and specified in clause 10 of [G.984.3]. The OLT in the DPoG System will periodically open up a "quiet window" and send a broadcast serial number request. A D-ONU in the serial number state will respond with its serial number and, upon receiving its ONU-ID, transition to the ranging state. The OLT will again open up a "quiet window" and send a ranging request to a specific ONU-ID. A D-ONU in the ranging state with the specific ONU-ID will respond to the ranging request and transition to the operation state. The OLT will send a Request_Password PLOAM command and the D-ONU will respond with its MAC address as the password, with the octet normally sent first in time in an Ethernet frame corresponding to octet 3 of the PLOAM Password message. This MAC address is used by the OLT to initiate an EAP authentication session, as described in [DPoG-SEC]. Once authenticated, the OLT will pass the D-ONU MAC address to the vCM entity to create a vCM. The vCM uses this MAC address in the 'chaddr' field of the DHCP request. A [G.984] GPON D-ONU MUST support the PLOAM Password message and populate the Password field with the MAC address of the D-ONU. See clause 10 of [G.984.3] for more detailed information on D-ONU activation.

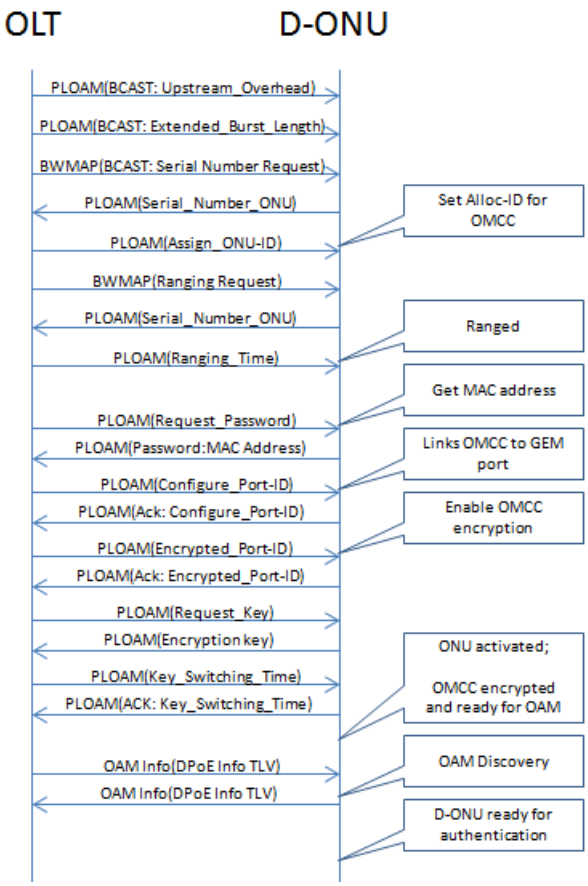

Figure 6 - D-ONU Activation ([G.984] GPON)

For a [G.987] XG-PON D-ONU, activation is specified in Clause 12 of [G.987.3] and shown in Figure 7. Similarly to GPON, the D-ONU MAC address is sent to the OLT in the PLOAM Registration message, with the octet normally sent first in time in an Ethernet frame corresponding to octet 5 of the PLOAM Registration message. A [G.987] XG-PON D-ONU MUST support the PLOAM Registration message and populate the Registration_ID field with the MAC address of the D-ONU.

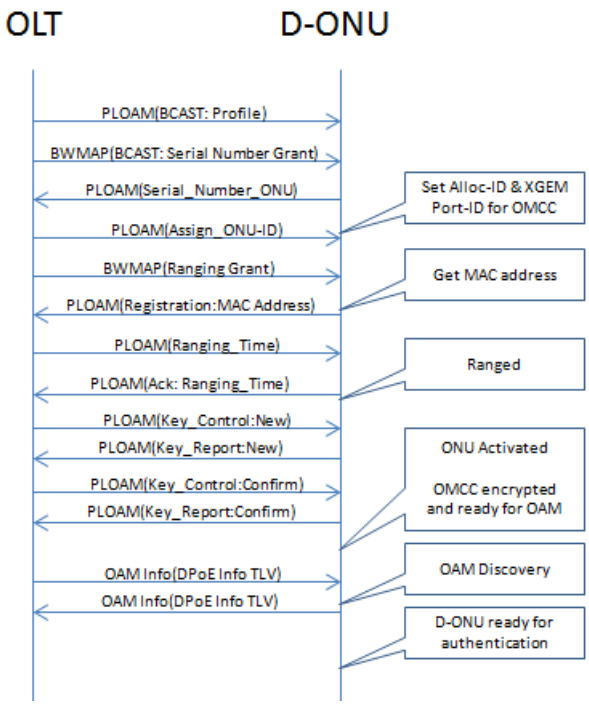

Figure 7 - D-ONU Activation ([G.987] XG-PON)

DOCSIS-specific service group discovery and initial ranging functions are not supported in the DPoG System. The DPoG System MUST NOT determine the service group of a DOCSIS CM for channel bonding and load balancing, since such functions are not supported by the underlying GPON transport layer.

9.1.4 Authentication

See [DPoG-SEC] for details.

9.1.5 Establishing IP Connectivity

The D-ONU does not contain an IP stack and is not directly addressable using IP. The vCM MUST obtain an IP address (management) on behalf of the D-ONU. The vCM performs IP provisioning for each D-ONU as they are discovered across the TUL interface. The vCM MUST maintain the IP address and associated parameters for the D-ONU.

Upon successful completion of IP address assignment, the DPoG System obtains the vCM configuration file via TFTP, followed by the processing of the DOCSIS CM configuration file. Figure 6 and Figure 7 show an overview of the DPoG System establishing IP connectivity, which takes place for each discovered D-ONU.

DPoG provisioning is almost identical to what is specified in previous versions of [MULPIv3.0]. This section specifies only requirements that are new or different from [MULPIv3.0] with respect to a DPoG Network. The DPoG System performing IP provisioning on behalf of a D-ONU MUST follow the operational flow of Figure 6 for [G.984] D-ONUs and Figure 7 for [G.987] D-ONUs.

The DPoG System on behalf of the vCM MUST perform IP provisioning in one of two modes: IPv4 only or IPv6 only. Alternate Provisioning Mode and Dual Provisioning Mode, as defined in [MULPIv3.0], are not supported by the vCM. The DPoG System MUST determine the IP provisioning mode via the 'MdCfg' management object defined in [DPoG-OSSI]. The vCM exists virtually on the DPoG System and therefore no DOCSIS MDD messaging, as defined in [MULPIv3.0], is required to inform the vCM of which IP Provisioning Mode to use during registration.

The vCM performing IP provisioning MUST follow the operational flow of Figure 8 through Figure 11 to arrive at an 'IP Connectivity Successful' or 'IP Connectivity Failed' state. Figure 8 shows the selection of the provisioning modes. Figure 9 through Figure 11 show the steps the vCM takes in each of the provisioning modes. The acquisition of an IPv4 address, done through DHCPv4, is shown as part of Figure 9. Figure 10 and Figure 11 show the process the vCM follows for acquiring an IPv6 address.

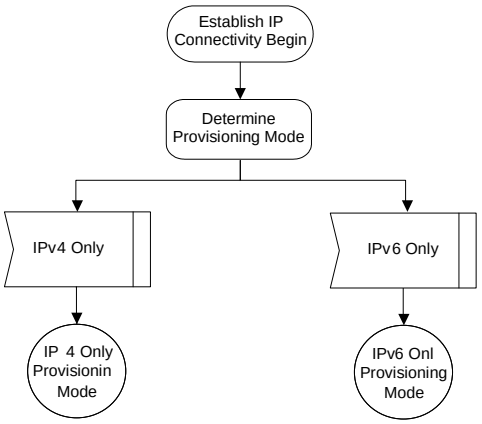

Figure 8 - Establish IP Connectivity

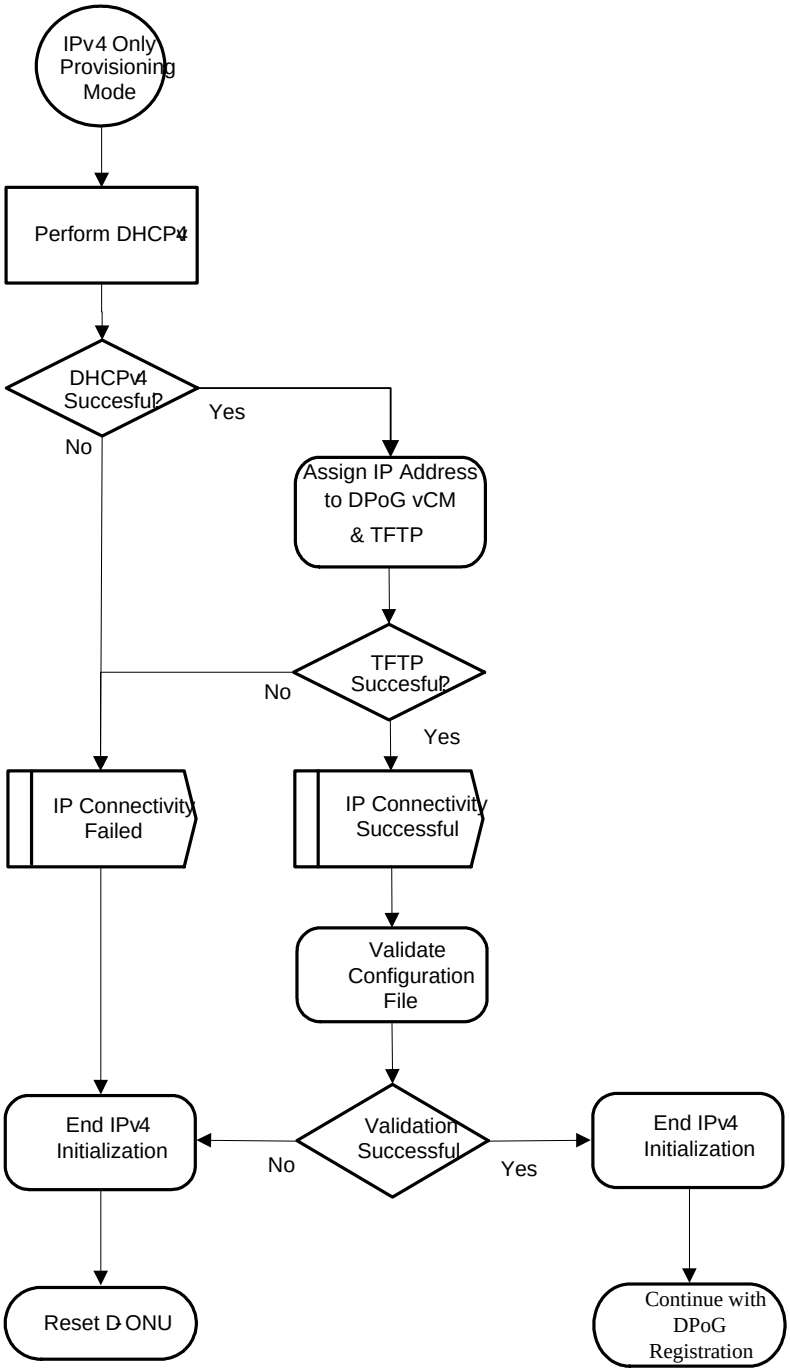

Figure 9 - IPv4-only Provisioning Mode

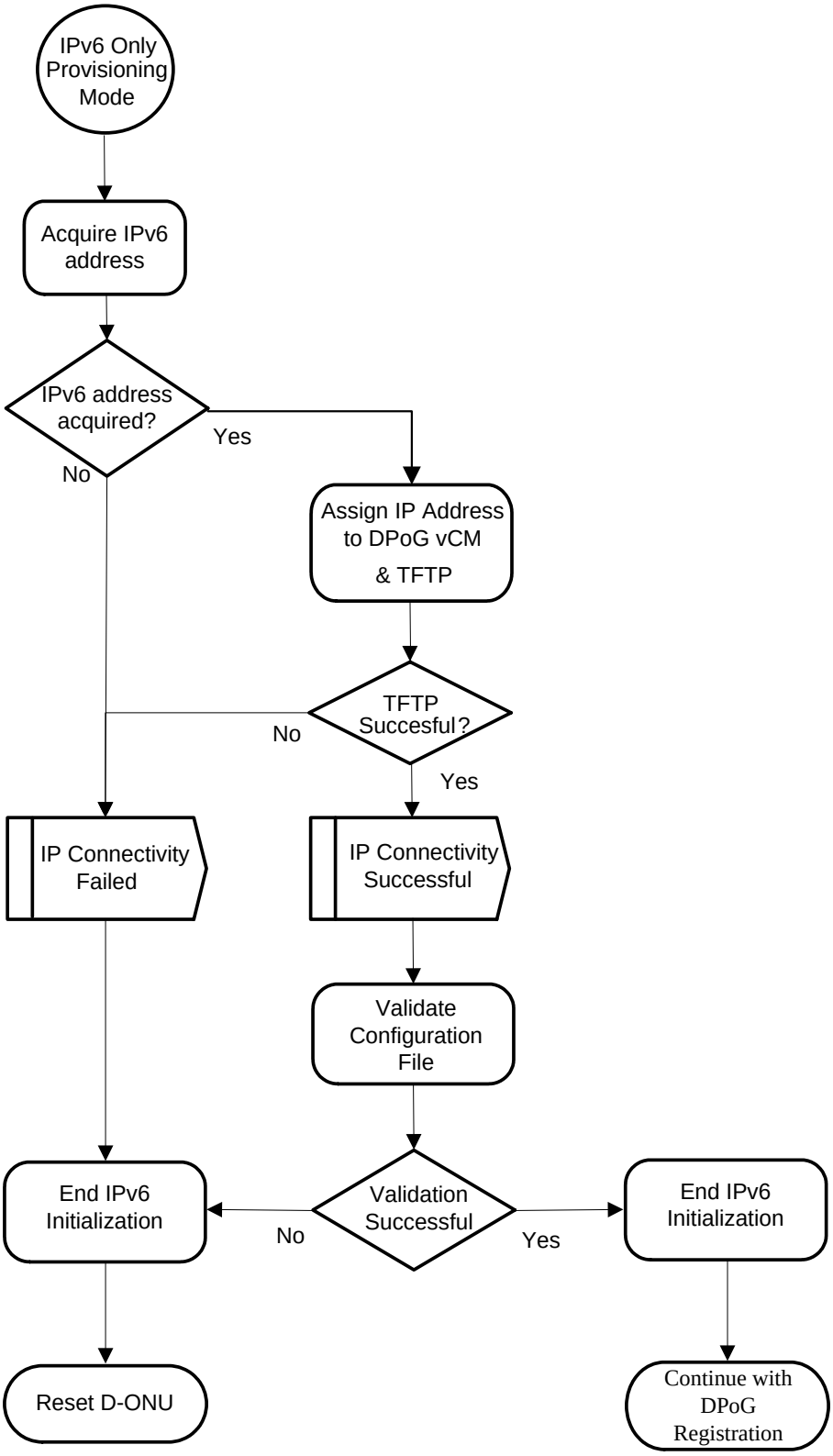

Figure 10 - IPv6-only Provisioning Mode

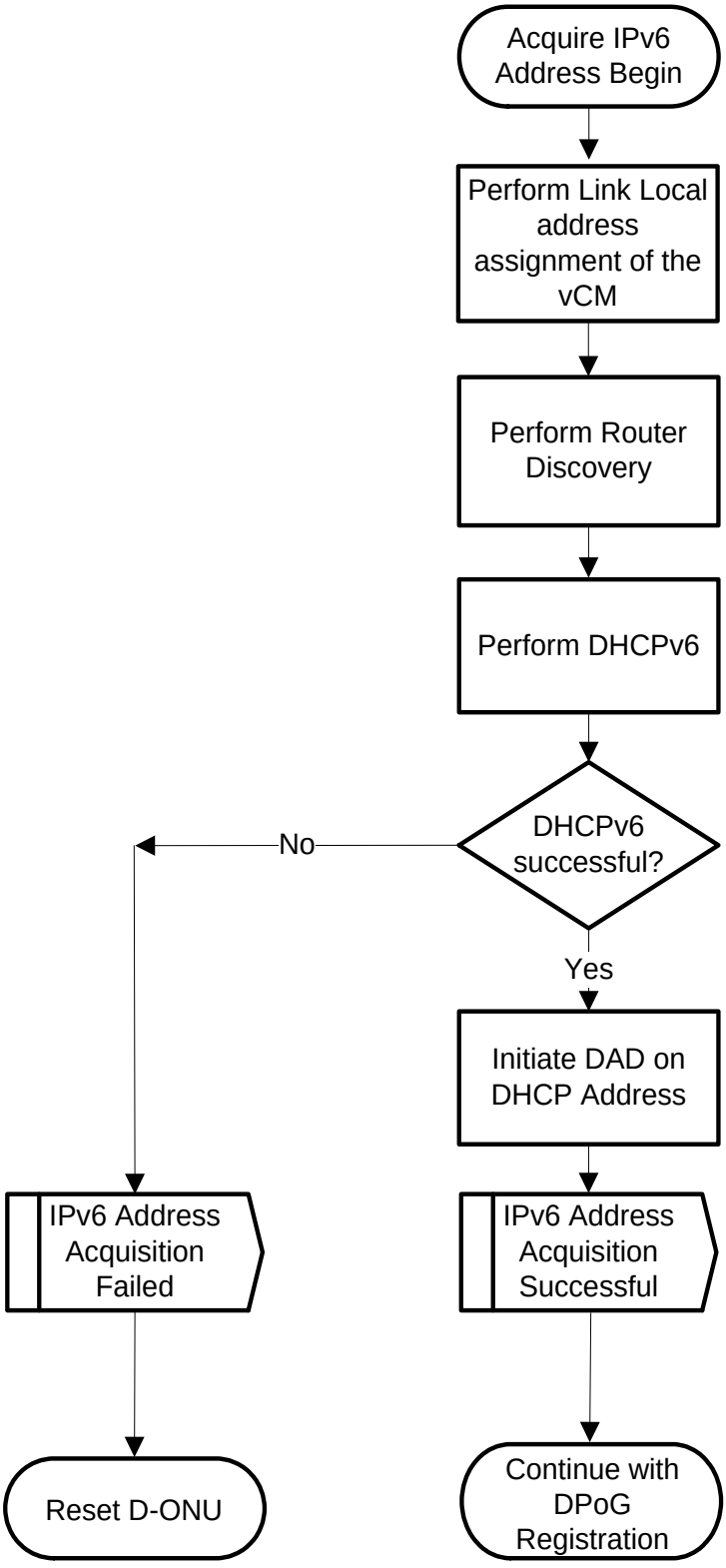

Figure 11 - IPv6 Address Acquisition

Once the vCM is registered, any applications and services running on the vCM(e.g., SNMP) use either IPv4 or IPv6. The vCM uses IPv4 or IPv6 to obtain the CM configuration file. The behavior for specific management and service applications will depend on how the applications are configured on the DPoG System; see [DPoE-IPNEv2.0] for additional details.

9.1.5.1 Establish IPv4 Network Connectivity

This section describes how the DPoG System provisions an IPv4 address and associated parameters as a vCM on behalf of a D-ONU. Since the vCM and the DHCPv4 Relay Agent exist on the DPoG System, the Broadcast and Request phases of DHCPv4 address assignment are generated by the vCM and directed to the DHCPv4 Server as unicast packets by the Relay Agent. Refer to Figure 12 for DHCPv4 message flow detail. The vCM MUST support the IPv4 network connectivity requirements specified in [MULPIv3.0]. Figure 12 shows the DHCPv4 message sequence for a DPoG System. The vCM MUST establish IPv4 network connectivity only after D-ONU discovery.

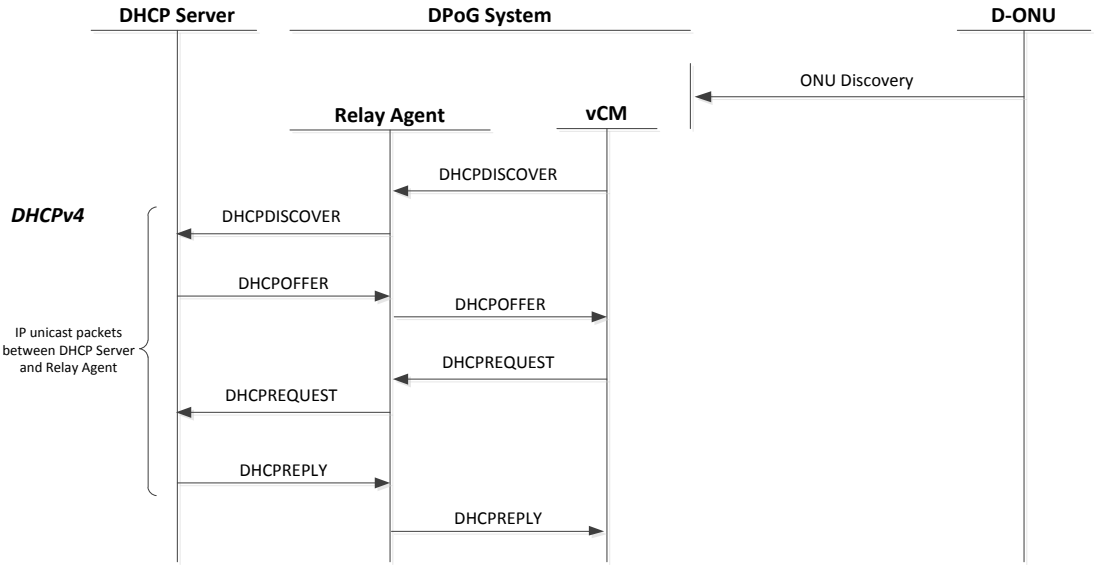

Figure 12 - Establishment of IPv4 Network Connectivity

As detailed in [DPoG-OSSI], the DPoG System MUST maintain the appropriate DOCSIS state for each vCM known to the DPoG System. The following requirements specify the DPoG System view of the vCM ('docsIf3CmtsCmRegStatusValue' object of the DOCS-IF3-MIB):

- When the DPoG System generates a DHCPv4 Discover message to obtain an IP address for the vCM, the DPoG System MUST transition the vCM to the "startDhcpv4" state.
- Upon successful completion of IPv4 address assignment for the vCM, the DPoG System MUST transition the vCM to the "dhcpv4Complete" state.
- If the DHCPv4 address assignment fails, the DPoG System MUST reset the vCM and D-ONU, and then transition the vCM to the "other" state.

As detailed in [DPoG-OSSI], the DPoG System MUST maintain the appropriate DOCSIS state on behalf of the vCM. The following requirements specify the vCM view of its own internal state (docsIf3CmStatusValue of the DOCS-IF3-MIB):

- When the DPoG System generates a DHCPv4 Discover message to obtain an IP address for the vCM, the DPoG System MUST transition the vCM to the "dhcpv4inProgress" state.
- Upon successful completion of IPv4 address assignment for the vCM, the DPoG System MUST transition the vCM to the "dhcpv4Complete" state.

- If DHCPv4 address assignment fails, the DPoG System MUST reset the vCM and the D-ONU, and transition the vCM to the "other" state.

A vCM with an unexpired IPv4 address MUST send a DHCPRELEASE message as described in [RFC 2131] immediately prior to a reset caused by the docsDevResetNow attribute being set.

9.1.5.1.1 DHCPv4 Fields Used by the vCM

The vCM MUST support the DHCP requirements specified in the DHCPv4 Fields Used by the CM section of [MULPIv3.0], except where specified differently in this section.

The vCM MUST include the following fields in the DHCPDISCOVER and DHCPREQUEST messages from the vCM:

- chaddr: The client hardware address, set to the 48-bit MAC address of the D-ONU.
- parameter request list: The option codes are defined in [RFC 2132] and [RFC 4361]. The following options/sub-options are required:
  - Log Server Option (option code 7)
  - DHCPv4 Vendor-Identifying Vendor-specific Information Option (option code 125), with sub-option code 1, the DHCPv4 Option Request. The DHCPv4 Option Request sub-option will include the following sub-options:
    - DHCPv4 TFTP Servers Option (Sub-option code 2)
    - Modem Capabilities Encoding for DHCPv4 (Sub-option code 5)
- vendor class identifier (Option code 60): set to an ASCII-encoded string with the value "docsis3.0"

The vCM MAY include the following option codes in the parameter request list:

- Subnet Mask (Option code 1)
- Time Offset (Option code 2)
- Router (Option code 3)
- Time Server Option (Option code 4).

9.1.5.1.2 Use of T1 and T2 Timers

The vCM MUST comply with the DHCP T1/T2 requirements defined in [MULPIv3.0] for DHCPv4.

9.1.5.1.3 DHCPv4 Renew Fields Used by the vCM

During the DHCPv4 renew process, it is possible that the vCM will receive updated fields in the DHCPACK message. If the IP address (yiaddr), the Subnet Mask, or the Next Hop Router (router option) are different in the DHCPACK than the current values used by the DPoG System for the vCM, the DPoG System MUST do one of the following:

- Reinitialize the associated D-ONU.
- Change the vCM's addressing to use the new values without reinitializing the associated D-ONU.

During the DHCP renew process, if the configuration file name or the SYSLOG server address is different in the DHCPACK than the current values used by the DPoG System for the vCM, the vCM MUST ignore the new values in the DHCPACK.

If the Time Offset value or Time Server Address value is different in the DHCPACK than the current values used by the DPoG System for the vCM, the DPoG System MUST ignore these new values, as they do not apply for the DPoG System.

9.1.5.1.4 DPoG System DHCP Requirements

The DPoG System MUST support DHCPv4 Option 43 sub-options specified in [CANN-DHCP-Reg] and [eDOCSIS]. The DPoG System MUST support the DHCPv4 Relay Agent requirements as specified in [MULPIv3.0], except where specified differently in this section.

In order to assist the DHCPv4 server in differentiating between a DHCPDISCOVER sent from a vCM and a DHCPDISCOVER sent from a CPE, the DPoG System has to support the following requirements:

- The DPoG System Relay Agent MUST include the DHCP Relay Agent Information Option (RAIO), as specified in [RFC 3046]. Specifically, the DPoG System DHCPv4 Relay Agent will add an RAIO to the DHCPDISCOVER message before relaying the message to a DHCP server.
- In the DHCPDISCOVER message, the DPoG System MUST include the 48-bit MAC address of the D-ONU in the agent remote ID sub-option field ([RFC 3046]) in the RAIO.
- The DPoG System MUST support "DHCPv4 Relay Agent CMTS capabilities option" as specified in [CANN-DHCP-Reg], including the following sub-options:
  - CMTS DOCSIS Version Number
  - DPoG System Version Number
  - CMTS CM Service Class
  - CMTS MSO Defined Text
- The DPoG System MUST set the 'CMTS DOCSIS Version Number' sub-option to "3.0".
- The DPoG System MUST set the 'DPoG System Version Number' sub-option to "1.0".

The DPoG System MUST support the D-ONU eOAM Version Number option, as specified in [CANN-DHCP-Reg], and include it in messages to the DHCP server. The D-ONU eOAM Version Number option contains the combined value that forms the eOAM Version Number Identifier. The value of the 'major vers' field is retrieved from the four upper bits of the 'DPoG OAM Version' field in the 'DPoG OAM Support' TLV, defined in [DPoG-OAM], and placed in the four lower bits of the field, padded with zeros. The value of the 'minor vers' field is retrieved from the four lower bits of the 'DPoG OAM Version' field in the 'DPoG OAM Support' TLV, defined in [DPoG-OAM], placed in the four lower bits of the field, padded with zeros.

The DPoG System MUST support DHCPv4 Option 43 sub-options as identified in [eDOCSIS] per [CANN-DHCP-Reg]. The DPoG System SHOULD support DHCPv4 Option 43 sub-option 55-60 as defined in [CANN-DHCP-Reg].

D-ONUs that are (optionally) eDOCSIS devices MUST support DHCPv4 Option 43 sub-options as identified in [eDOCSIS] per [CANN-DHCP-Reg]. D-ONUs that are (optionally) eDOCSIS devices SHOULD support DHCPv4 Option 43 sub-option 55-60 as defined in [CANN-DHCP-Reg].

9.1.5.1.5 DPoG DHCPv4 Fields and Options

9.1.5.1.5.1 DHCPv4 Discover/Request Message Example

Table 3 - Example DHCPv4 Discover/Request Fields

Field Name	Option	Sub-Option	Value(s)	Size
htype (hardware type)	n/a	-	"01" = Ethernet	8 bits
hlen (hardware address)	n/a	-	"06" = MAC address length	8 bits
chaddr (client hardware address)	n/a	-	D-ONU MAC address	48 bits

Field Name	Option	Sub-Option	Value(s)	Size
parameter request list * may be present	55	-	Subnet Mask (1)* Time Offset (2)* Router (3)* Time Server (4)* Log Server (7) DHCPv4 Vendor-Identifying Vendor-specific Information (125)	48 bits
vendor class identifier	60	-	"docsis3.0"	80 bits
client-identifier	61	-	htype +chaddr per [RFC 4361]	56 bits
agent information option	82	1	Agent Circuit ID (vendor-specific string)	String
	82	2	Agent Remote ID (D-ONU MAC)	48 bits
	82	4491.9.1	"30" – DOCSIS 3.0 (major, minor version #)	16 bits
	82	4491.9.2	"10" – DPoG 1.0 (major, minor version #)	16 bits
vendor-specific information	125	4491.1	ORO "02" – Request TFTP Server IP Address	8 bits
	125	4491.5	D-ONU Capabilities (see Annex C.2)	Variable
Note: Sub-option 4491 is defined in [CANN-DHCP-Reg].				

9.1.5.1.5.2 DHCPv4 Offer/Ack Message Example

Table 4 - Example DHCPv4 Response

Field Name	Option	Sub-Option	Value(s)	Size
yiaddr (ip address)	n/a	-	Client IP Address	32 bits
siaddr (next server)	n/a	-	TFTP Server IP Address	32 bits
file (boot file name)	n/a	-	vCM (D-ONU) Boot File Name	Variable
sub-net mask	1	-	Client Sub-Net Mask	32 bits
time-offset	2	-	Unsigned 32 bit (2^32 – seconds)	32 bits
router	3	-	Next Hop Router IP Address	32 bits
time-server	4		Time Server IP Address	32 bits
log-server	7		Syslog Server IP Address	32 bits
agent information option	82	1	Agent Circuit ID (vendor-specific string)	String
	82	2	Agent Remote ID (D-ONU MAC)	48 bits
	82	4491.9.1	"30" – DOCSIS 3.0 (major, minor version #)	16 bits
	82	4491.9.2	"10" – DPoG 1.0 (major, minor version #)	16 bits
vendor-specific information	125	4491.1	Option Request Option "02"	8 bits
	125	4491.2	TFTP Server IP Address	32 bits
Note: Sub-option 4491 is defined in [CANN-DHCP-Reg].				

9.1.5.2 Establish IPv6 Network Connectivity

This section describes how the DPoG System provisions an IPv6 address and associated configuration parameters on behalf of a D-ONU. The requirements in this section apply only to vCMs instructed to use IPv6 provisioning. A vCM uses IPv6 provisioning when the DPoG System indicates 'IPv6 Only' provisioning. The vCM MUST support the IPv6 provisioning requirements specified in [MULPIv3.0]. Figure 13 shows the DHCPv6 message sequence for a DPoG System. The vCM MUST establish IPv6 Network Connectivity only after discovery of the D-ONU.

Since the vCM and the Relay Agent exist on the DPoG System, the Link-Local and Router Discovery phases of DHCPv6 address assignment are contained within the DPoG System. The DHCPv6 SOLICIT, ADVERTISE,

REQUEST, and REPLY messages are generated by the vCM and relayed to the DHCP Server by means of the Relay Agent on the DPoG System. Refer to Figure 13 for additional details on the DHCPv6 message flow.

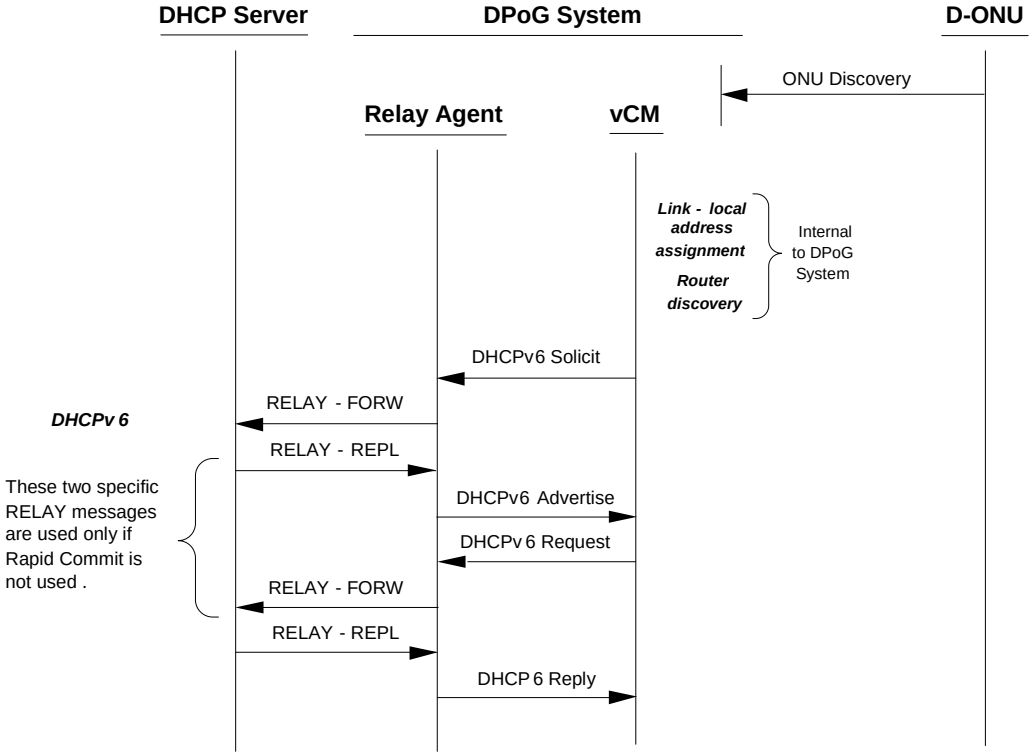

Figure 13 - Establishment of IPv6 Network Connectivity

The DPoG System MUST establish IPv6 connectivity, including the assignment of:

- Link-local address
- Default router
- IPv6 management address and other IPv6 configuration

These steps are described in the following subsections.

The vCM and its default router are internal to the DPoG System; therefore, router discovery and forwarding for the vCM are not specified.

9.1.5.2.1 Obtain Link-Local Address

The process of obtaining a link-local address occurs within the DPoG System. Within the DPoG System the vCM MUST construct a link-local address for its management interface according to the procedure specified in [RFC 4862]. The vCM MUST use the EUI-64 (64-bit Extended Unique Identifier) derived from the D-ONU MAC address as a link-local address for its management interface as described in [RFC 3513].

9.1.5.2.2 Obtain Default Routes

The process of obtaining default routers occurs within the DPoG System. The process works as defined in [MULPIv3.0].

9.1.5.2.3 Obtain IPv6 Management Address and Other Configuration Parameters

As specified in [DPoG-OSSI], the DPoG System MUST maintain the appropriate DOCSIS state for each vCM known to the DPoG System. The following requirements specify the DPoG System view of the vCM (docsIf3CmtsCmRegStatusValue of the DOCS-IF3-MIB):

- When the DPoG System generates a DHCPv6 Solicit message to obtain an IP address for the vCM, the DPoG System MUST transition the vCM to the "startDhcpv6" state.
- Upon successful completion of IPv6 address assignment for the vCM, the DPoG System MUST transition the vCM to the "dhcpv6Complete" state.
- If the DHCPv6 address assignment fails, the DPoG System MUST reset the vCM and D-ONU, and then transition the vCM to the "other" state.

As specified in [DPoG-OSSI], the DPoG System MUST maintain the appropriate DOCSIS state on behalf of the vCM. The following requirements specify the vCM view of its own internal state (docsIf3CmStatusValue of the DOCS-IF3-MIB):

- When the DPoG System generates a DHCPv6 Solicit message to obtain an IP Address for the vCM, the DPoG System MUST transition the vCM to the "dhcpv6inProgress" state.
- Upon successful completion of IPv6 address assignment for the vCM, the DPoG System MUST transition the vCM to the "dhcpv6Complete" state.
- If DHCPv6 address assignment fails, the DPoG System MUST reset the vCM and D-ONU, and then transition the vCM to the "other" state.

9.1.5.2.4 DHCPv6 Fields Used by the vCM

The vCM MUST support DHCPv6 requirements specified in [MULPIv3.0], except where specified otherwise in this section.

Minimally, the vCM MUST include the following fields in the DHCPv6 Solicit and Request messages from the vCM:

- A Rapid Commit Option (option 14) indicating that the vCM is willing to perform a 2-message DHCPv6 message exchange with the server.
- A Client Identifier Option (option 1) containing the DUID (DHCP Unique Identifier) for this vCM as specified by [RFC 3315]. The vCM can choose any one of the rules to construct the DUID according to section 9.1 of [RFC 3315].
- An IA_NA (Identity Association for Non-temporary Addresses) Option (option 3) to obtain its IPv6 management address
- chaddr: The client hardware address, set to the MAC address of the D-ONU
- A Vendor Class Option (option 16) containing 32-bit number 4491 (the Cable Television Laboratories, Inc. enterprise number) and the string "docsis3.0";
- A Vendor-specific Information Option (option 17): This option will contain the following sub-options as defined in [CANN-DHCP-Reg]:
    - Modem Capabilities (sub-option 35) - TLV5 Encoding containing the encoded TLV5s describing the capabilities of vCM information option in Annex C.1.3.1; (Optional)
    - Device Identifier (sub-option 36), containing the MAC address of the D-ONU
    - Option Request (sub-option 1) with the following vendor-specific options:
        a. Sub Option 32 – tftp_server_addresses
        b. Sub Option 33 – config_file_name
        c. Sub Option 34 – syslog_server_addresses

d. Sub Option 37 – time_protocol_servers (Optional)
e. Sub Option 38 – time_offset (Optional)

The vCM MUST use the following values for retransmission of the Solicit message (see [RFC 3315] for details):

- IRT (Initial Retransmission Time) = SOL_TIMEOUT
- MRT (Maximum Retransmission Time) = SOL_MAX_RT
- MRC (Maximum Retransmission Count) = 4
- MRD (Maximum Retransmission Duration) = 0

9.1.5.2.5 DHCPv6 Renew Fields Used by the vCM

During the DHCPv6 renew operation, it is possible that the vCM will receive updated fields in the DHCPv6 Reply message.

If the vCM IPv6 Management Address (IA_NA option) is different in the DHCP Reply than the current value used by the vCM, the vCM MUST do one of the following:

- Change the vCM's IPv6 Management Address to the new value without reinitializing the vCM
- Reinitialize vCM

During the DHCP renew process, if any of the following values are different in the DHCP Reply than the current values used by the vCM, the vCM MUST ignore the new fields:

- TFTP configuration file name (Vendor-Specific Option)
- Syslog servers (Vendor-Specific Option)
- Reconfigure Accept option

The vCM SHOULD NOT support the Time Protocol Servers option in the DHCP Reply because ToD is maintained by the DPoG System.

9.1.5.2.6 IP Provisioning Mode Override

The DPoG System does not require support for the IP Provisioning Mode Override feature; the vCM exists virtually on the DPoG System and the IP Provisioning Mode is part of the DPoG System configuration.

9.1.5.2.7 Use of T1 and T2 Timers

The vCM MUST comply with the DHCPv6 T1/T2 requirements defined in [MULPIv3.0].

9.1.5.2.8 DPoG System DHCPv6 Relay Agent Requirements

The DPoG System MUST send the following DHCPv6 Options when acting as a DHCPv6 Relay Agent, in any Relay-Forward messages used to forward messages from the vCM (DPoG System) to the DHCPv6 Server:

- Interface-ID option, as specified in [RFC 3315]
- CMTS DOCSIS Version Number option, containing the value "3.0", as specified in [CANN-DHCP-Reg]
- DPoG System version number option containing the value "1.0" as specified in [CANN-DHCP-Reg]
- CM MAC address option set to the value of the D-ONU MAC address, as specified in [CANN-DHCP-Reg]
- Remote-ID option, as specified in [RFC 4649].

The DPoG System MUST set the Remote-ID option to the MAC address of the D-ONU for the vCM generating the DHCPDISCOVER sent in the CL_Option_Device_ID sub-option field, as defined in [CANN-DHCP-Reg].

9.1.5.2.9 Prefix Stability at the DPoG System

The DPoG System MUST support the prefix stability requirements as specified for a CMTS in [MULPIv3.0].

9.1.5.2.10 DPoG DHCPv6 Fields and Options

9.1.5.2.10.1 DHCPv6 Solicit/Request Message Example

Table 5 - Example DHCPv6 Solicit/Request Options

Field Name	Option	Sub-Option	Value(s)	Size
client-id	1	-	- duid_type ("00 03" link layer address) - htype ("00 01" ethernet) - link_layer_address (48 bit D-ONU MAC)	16 bits 16 bits 48 bits
ia_na	3	-	- iaid – least significant 32 bits of D-ONU MAC address. - t1 – in seconds, time before contacting server where IA_NA addresses were obtained to extend lifetime. - t2 – in seconds, time before contacting any server to extend lifetime of IA_NA addresses.	32 bits 32 bits 32 bits
option_request	6	-	vendor-specific information (17)	variable
rapid_commit	14	-	no associated value, length zero	-
vendor_class	16	4491	"docsis3.0"	string
vendor-specific information	17	4491.35	tlv5 (d-onu capabilities)	variable
	17	4491.36	device_id (d-onu mac address)	48 bits
	17	4491.1	option_request - option 32 (tftp_server_addresses) - option 33 (config_file_name) - option 34 (syslog_server_addresses)	variable
reconfigure_accept	20	-	no associated value, length zero	-

9.1.5.2.10.2 DHCP Advertise/Confirm Message Example

Table 6 - Example DHCPv6 Advertise/Confirm Fields

Field Name	Option	Sub-Option	Value(s)	Size
client-id	1	-	- duid_type ("00 03" link layer address) - htype ("00 01" ethernet) - link_layer_address (D-ONU MAC)	16 bits 16 bits 48 bits
server_identifier	2	-	- duid_type ("00 01" link layer address plus time) - htype ("00 01" ethernet) - time (date, time and zone) - link_layer_address (D-ONU MAC)	16 bits 16 bits 32 bits 48 bits

Field Name	Option	Sub-Option	Value(s)	Size
ia_na	3	-	- iaid - least significant 32 bits of D-ONU MAC address. - t1 – in seconds, time before contacting server where IA_NA addresses were obtained to extend lifetime. - t2 – in seconds, time before contacting any server to extend lifetime of IA_NA addresses.	32 bits 32 bits 32 bits
	3	5	ia_address (IPv6 address, preferred lifetime, valid lifetime)	192 bits
vendor-specific information	17	4491.32	tftp_server_addresses	variable
	17	4491.33	config_file_name	variable
	17	4491.37	syslog_server_addresses	variable

9.1.5.3 Dual-stack Provisioning Mode (DPM)

Dual-stack Provisioning Mode is not required for DPoG.

9.1.5.4 Establish Time of Day

The DPoG System MUST supply a time reference for each vCM based on the already established DPoG System time. Each vCM in the DPoG System MUST use the time reference from the DPoG System for time-related purposes, such as time stamping in log files. The use cases for time references are vendor-specific and outside the scope of this specification.

9.1.5.5 Transfer of Operational Parameters

The vCM MUST obtain the CM configuration file for the applicable D-ONU, as specified in [MULPIv3.0].

As specified in [DPoG-OSSI], the DPoG System MUST maintain the appropriate DOCSIS state for each vCM known to the DPoG System. The following requirements specify the DPoG System view of the vCM (docsIf3CmtsCmRegStatusValue of the DOCS-IF3-MIB).

- When the DPoG System generates a TFTP request to obtain the CM configuration file, the DPoG System MUST transition the vCM to the "startConfigFileDownload" state.
- Upon successful TFTP transfer of the CM configuration file for the vCM, the DPoG System MUST transition the vCM to the "configFileDownloadComplete" state.
- If the TFTP transfer of the CM configuration file fails, the DPoG System MUST reset the D-ONU and transition the vCM to the "other" state.

As specified in [DPoG-OSSI], the DPoG System maintains appropriate DOCSIS state on behalf of the vCM. The following requirements specify the vCM view of its own internal state (docsIf3CmStatusValue of the DOCS-IF3-MIB).

- Upon successful TFTP transfer of the CM configuration file for the vCM, the DPoG System transitions the vCM to the "configFileDownloadComplete" state.
- If TFTP transfer of the CM configuration file fails, the DPoG System resets the D-ONU and transition the vCM to the "other" state.

9.1.5.6 CM Configuration File Processing

After downloading the CM configuration file, and prior to commencing the OMCC provisioning process, the DPoG System (or vCM) performs several processing steps with the CM configuration file on behalf of D-ONU. The DPoG System MUST support the parsing and processing of CM configuration files.

The DPoG System MUST support the TLV encodings specified in Annex C of this document. The DPoG System MUST perform TLV validation according to Annex C in [MULPIv3.0]. Examples of such validation include TLV range checking, parameter applicability, and parameter interdependency checks.

The DPoG System performs operations to verify the validity of a CM configuration file and MUST reject a CM configuration file that is invalid. An invalid CM configuration file can have any of the following characteristics:

- Lacks one or more mandatory items, as defined in this specification and [MULPIv3.0].
- Has one or more SNMP MIB Object encodings (TLV 11) that cannot be processed and cause rejection of the file.
- Contains a SNMPv3 Access View Configuration encoding (TLV 54) that causes rejection of the file as defined in [MULPIv3.0].
- Contains specifications for a number of SFs that cannot be supported due to the number of maximum number of GPON T-CONTs supported by the D-ONU.

The DPoG System MAY reject a CM configuration file that has an invalid CM MIC, CMTS MIC, or Extended CMTS MIC, as defined in [MULPIv3.0].

If the CM configuration file validation fails, the DPoG System MUST reset the D-ONU.

9.1.5.7 Post-Registration Failures to Renew IP Address

The vCM MUST support the Post-Registration Failures and IP Address Renew requirements for either IPv4 or IPv6 as specified in [MULPIv3.0] with no exceptions.

9.1.6 Registration with the DPoG System

Once the CM configuration file is validated, the DPoG System performs registration. The DOCSIS-specified Registration process of Registration Request, Response, and Acknowledgement between the DPoG System and vCM is processed internally within the DPoG System, and thus is not mandated or specified by this document. Figure 14 shows the DPoG System Registration process.

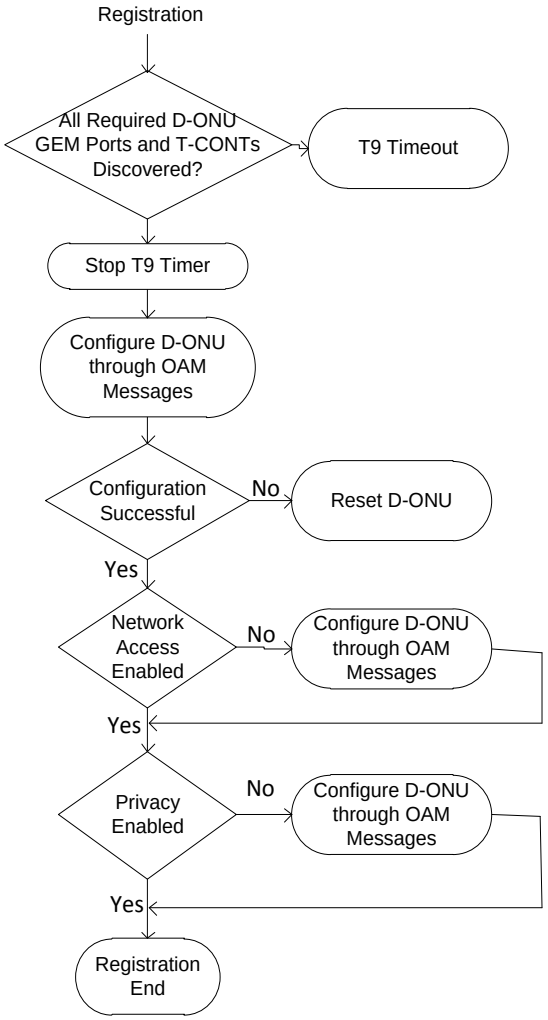

Figure 14 - Registration of a D-ONU in the DPoG System

9.1.6.1 DPoG System vCM Requirements

The DPoG System MUST transition the state of the vCM (docsIf3CmStatusValue) to the "operational" state upon completion of successful registration. Successful registration is defined as the successful completion of processing the CM configuration file by the DPoG System and the successful configuration of the D-ONU using the DPoG OAM messages.

The DPoG System MUST NOT transition the state of the vCM (docsIf3CmStatusValue) to the "operational" state upon unsuccessful completion of registration. Unsuccessful registration is defined as the failed processing of the CM configuration file by the DPoG System or the unsuccessful configuration of the D-ONU using the DPoG OAM messages.

If the CM configuration file specifies that network access is disabled, the DPoG System will:

- continue to configure the D-ONU with the parameters specified in the CM configuration file
- block all frame forwarding from S-interfaces on the D-ONU.

If the CM configuration file specifies that network access is disabled, the DPoG System MUST also transition the vCM state (docsIf3CmStatusValue) to "forwardingDisabled".

9.1.6.2 DPoG System Requirements

Upon the successful validation of the CM configuration file, the DPoG System MUST transition the vCM state (docsIf3CmtsCmRegStatusValue) to "startRegistration". During registration, the vCM MUST configure both itself and the D-ONU based on the TLVs specified in the CM configuration file. The DPoG System MUST configure the D-ONU using the appropriate OAM messages.

If there are any failures during the configuration of the vCM or D-ONU, the DPoG System MUST reset the D-ONU and transition the DPoG System view of the vCM (docsIf3CmtsCmRegStatusValue) to the "other" state.

During the configuration of the D-ONU, the DPoG System MUST discover all of the required D-ONU T-CONTs during the T9 timeout period. If the T9 timer expires, the DPoG System MUST reset the D-ONU and transition the vCM (docsIf3CmtsCmRegStatusValue) to the "other" state.

If the CM configuration file specifies that network access is disabled, the DPoG System MUST configure both the DPoG System and D-ONU with the parameters specified in the CM configuration file and block all frame forwarding from S-interfaces on the D-ONU. If the CM configuration file specifies that network access is disabled, the DPoG System MUST transition the vCM state (docsIf3CmtsCmRegStatusValue) to "forwardingDisabled".

If the CM configuration file specifies that privacy is disabled, the DPoG System MUST disable encryption on all of the (X)GEM ports of the D-ONU being used to carry ASFs/SFs.

Upon successful completion of registration processing, the DPoG System MUST transition the vCM state (docsIf3CmtsCmRegStatusValue) to "operational" for the D-ONU. The DPoG System MUST NOT allow the transmission of data until successful registration is complete.

9.1.7 Service IDs During vCM Initialization

The DPoG System MUST reserve a primary Service ID (SID) and assign it to a vCM when the vCM is instantiated by the DPoG System. This primary SID is associated with the OMCC. The DPoG System MUST reserve additional SIDs (for secondary upstream SFs and upstream ASFs) and assign after TFTP transfer of the configuration file and prior to OAM provisioning.

9.1.8 D-ONU Deregistration

There are several instances in [DPoG-OAM] requiring a D-ONU to be deregistered. To deregister a GPON or XG-PON D-ONU the DPoG System MUST send a Deactivate_ONU-ID PLOAM message. The D-ONU MUST respond as specified in [G.984.3] or [G.987.3], as appropriate.

9.2 Periodic Maintenance

In the DPoG Network, periodic maintenance of the underlying GPON transport layer is limited to continuous updating of the equalization delay from the drift of the upstream window (see section 10.3.5 in [G.984.3] and section 12 in [G.987.3]). This allows the DPoG System to dynamically adjust to any changes in the path delay without the need to bring the D-ONU down. In this way, the GPON system guarantees timely and accurate information on the D-ONU specific path delay without affecting the carried services.

Additionally, each DPoG System has the ability to determine when a D-ONU has gone out of service or is exhibiting serious errors at the physical or PLOAM layers.

As described in clause 11.1.1 of [G.984.3], the DPoG System MUST deregister a G.984-compliant D-ONU when it detects the following conditions:

- LOSi (Loss of Signal from ONUi), when the OLT does not support POP UP or when the LOSi condition does not clear up after three POP UP messages
- LOFi (Loss of Frame from ONUi)
- LOAi (Loss of Acknowledgment from ONUi)
- LOKi (Loss of Key Synchronization from ONUi)

- TIWi (Transmission Interference Warning for ONUi)
- SFi (Signal Failure – excessive bit error rate from ONUi)
- LOAMi (Loss of PLOAM for ONUi)

As described in clause 14.2.1 of [G.987.3], if the DPoG System detects the following conditions on a G.987-compliant D-ONU, the DPoG System MUST take steps to recover from the error:

- LOBi (Loss of Burst from ONUi)
- TIWi (Transmission Interference Warning for ONUi)
- SUFi (Startup Failure for ONUi)
- LOPCi (Loss of PLOAM Channel for ONUi)

The steps the DPoG System takes to recover could deregister the D-ONU.

The DPoG System uses a keep-alive heartbeat mechanism specified in [802.3] Clause 57, using OAM frames to detect failures of the OAM channel. Once every second, the DPoG System exchanges at least one Info PDU with each registered D-ONU. When the DPoG System fails to receive an Info PDU from a D-ONU within 5 seconds ±10%, the OAM channel is considered failed, and the DPoG System MUST deregister the D-ONU (refer to [802.3] Clause 57.3.1.5, local_lost_link_timer).

Note that when a D-ONU is deregistered, the DPoG system triggers certain conditions as described in Section 9.4 of this document.

Other DOCSIS-specific maintenance functions, including periodic ranging, are not supported in the DPoG System.

9.3 Fault Detection and Recovery

9.3.1 MAC Layer Error-Handling

This section describes the procedures that are required when an error occurs at the MAC framing level.

The most obvious type of error occurs when the FCS in the MAC frame fails. In such a case, Ethernet-specific handling is performed, per [802.3] definitions. Specifically, a corrupted Ethernet frame (where calculated FCS does not match the received FCS) is always dropped at the MAC layer to prevent error propagation across Ethernet links.

GPON encapsulates Ethernet frames into (X)GEM frames. Bit errors in the various fields in a (X)GEM frame are handled as specified in clause 8 of [G.984.3] for GPON or clause 8 of [G.987.3] for XG-PON.

9.4 vCM and D-ONU Operational Relationship

Once D-ONU and vCM initialization and registration is complete, it's possible for the state of a vCM on the DPoG System to change as the result of an operator request. Similarly, the D-ONU could experience a change in state as the result of an operator request or loss of power. When one of these related elements, a vCM or D-ONU, experiences a transition from a fully operational state, the DPoG System is responsible for ensuring that the associated element experiences a similar transition.

When a vCM is reset, the DPoG System MUST:

- Trigger a reset of the associated D-ONU
- Transition the docsIf3CmtsCmRegStatusValue to the "other" state for the affected vCM
- Drop packets destined to the vCM IP address
- Cease generating packets sourced from the vCM IP address

When a D-ONU is reset, it reboots and restarts the initialization and registration process. When IP connectivity is reestablished for the D-ONU during the initialization and registration process, the DPoG System MUST allow packets destined to or sourced from the vCM IP addresses.

When a DPoG System deregisters a D-ONU, the DPoG System MUST:

- Transition docsIf3CmtsCmRegStatusValue to the "other" state for the affected vCM
- Drop packets destined to the associated vCM IP address
- Cease generating packets sourced from the associated vCM IP address

9.5 Dynamic D-ONU Configuration Update Mechanism

During the course of operations, the services already configured and operating on a D-ONU might need to change. These changes could include modification of bandwidth parameters assigned to a single customer, adding a new service to a customer, enabling services on multiple ports where the given service was not available before, deleting an EVPL instance, etc. The dynamic configuration update feature is intended to configure changes or add services without affecting existing services that are not being modified. In other words, any changes to the vCM and D-ONU configuration SHOULD NOT cause reboot of these devices or changes in QoS parameters or operational state for any existing and configured services on the DPoG Network.

If the new CM configuration file has TLVs that are service impacting (i.e., cause a reboot), the D-ONU will reboot and affect all services. This specification aims to describe the general behavior around dynamic configuration updates, but does not specify the behavior for each type of change possible.

9.5.1 High Level Operation

The DPoG System configures the initial set of services on the D-ONU based on the CM configuration file downloaded by the vCM after the D-ONU goes through the registration process.

Once the operator identifies the need to add/modify/delete services on a D-ONU, the CM (D-ONU) configuration file is edited and placed on the provisioning system. Using the network management system, the operator triggers the vCM to download the new DOCSIS CM configuration file, using the 'dpogVcmDynCfgNow' MIB object, specified in [DPoG-OAM].

The vCM obtains TFTP server and file name values via the DHCPREQUEST mechanism and downloads the new CM configuration file. The new CM configuration file is compared with the running configuration and the differences to the services provisioned on the D-ONU are identified. The vCM validates the configuration file integrity, then verifies that resources are available, checking that the requested changes can be applied to the D-ONU under the current conditions. Once the configuration feasibility for the delta configuration is confirmed, the vCM updates the D-ONU configuration, modifying the necessary parameters. Figure 15 provides a high-level overview of this process.

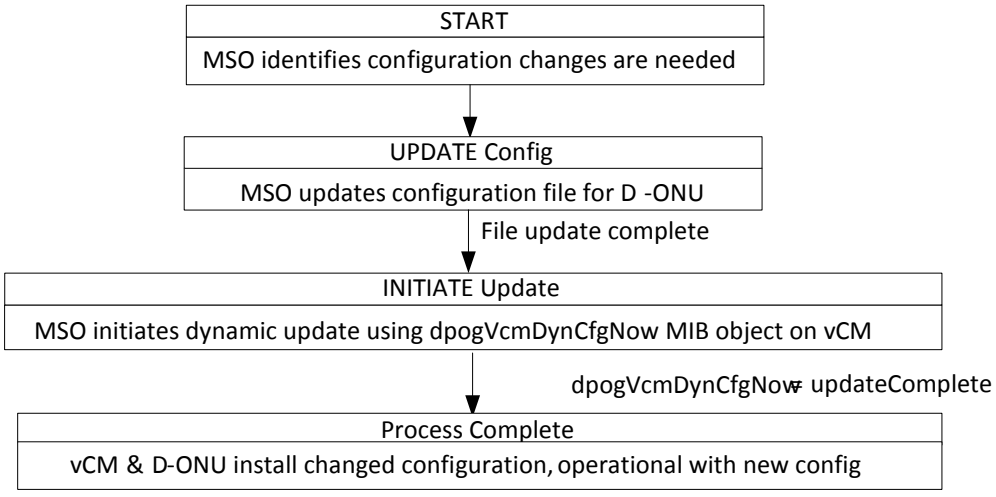

Figure 15 - BackOffice System Operation

Examples of service-related changes that need to be executed without causing D-ONU reboot include:

- Changes in the bandwidth profile parameters associated with the given service, e.g., increasing or decreasing allocated bandwidth
- Removing a service instance, e.g., removal of an EP-LINE instance on the given D-ONU, or in more generic terms, removing or adding an EVC on the given D-ONU
- Modification, adding or removing specific frame-related operations associated with the given SF or ASF, e.g., changing CoS assignment for the given SF, changing TPID translation value, changing encapsulation parameters for the given SF
- Modification of other SF and non-SF related parameters, including NACO, EVC names, designation of service names

Please note that this list is by no means intended to be exhaustive and presents only examples of changes considered to be critical from the operational point of view.

9.5.2 Dynamic Configuration Update Steps

The dynamic configuration update process is divided into the following steps.

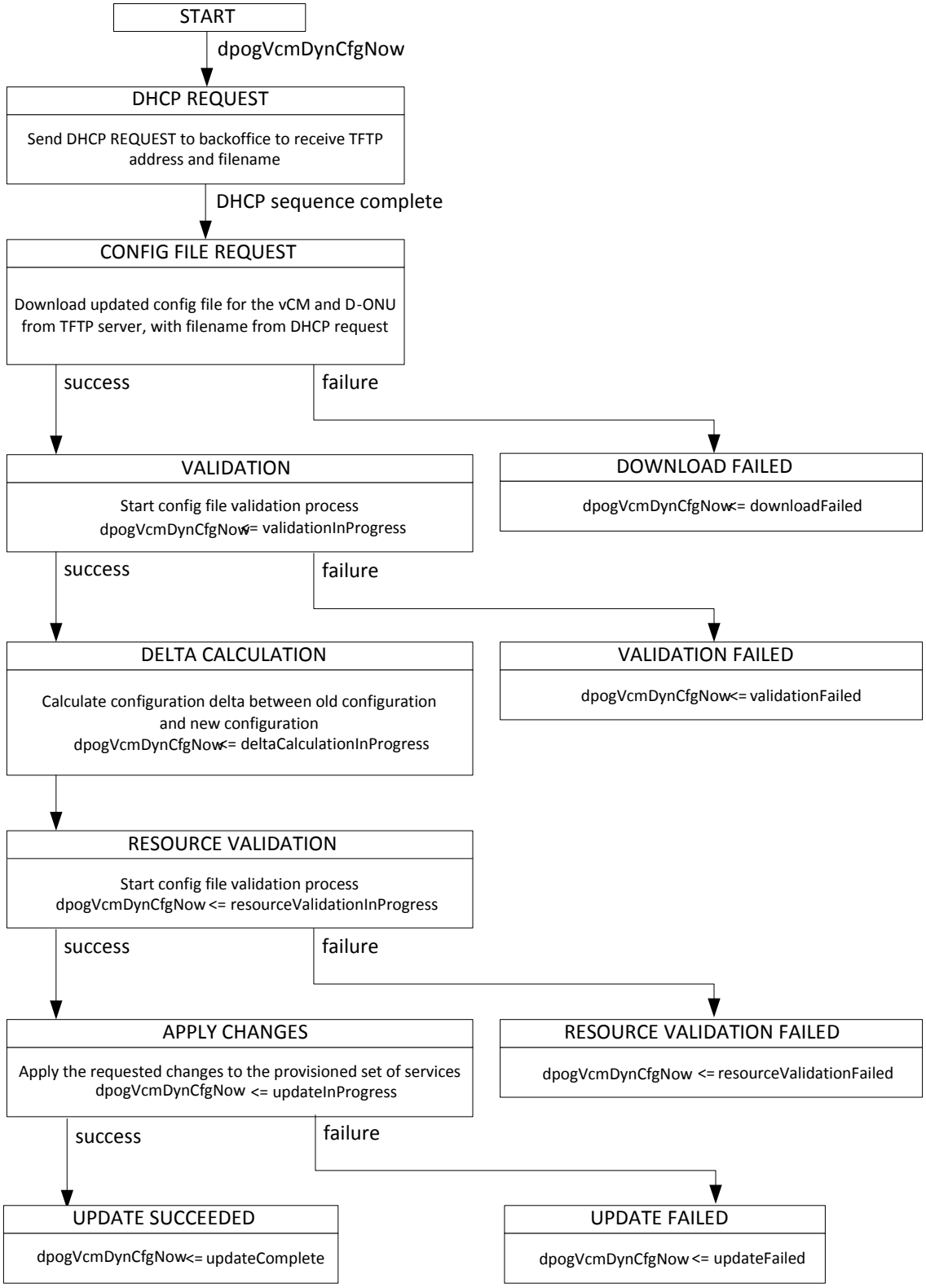

Figure 16 - Operation of the vCM

9.5.2.1 CM Configuration File Download

The vCM MUST initiate the CM configuration file download process when triggered by the 'dpogVcmDynCfgNow' object, defined in [DPoG-OSSI]. The vCM MUST change the 'dpogVcmDynCfgState' object value, defined in [DPoG-OSSI], to "downloadInProgress". The TFTP file download process followed by the vCM during dynamic configuration update MUST be the same as the initial boot up process described in Section 9.1.5.5, Transfer of Operational Parameters.

The vCM MUST maintain the current active CM configuration file while processing the new CM configuration file. At any time, the vCM MUST maintain two configuration storage locations, one for the current active CM configuration file, which is currently loaded and provisioned on the D-ONU, and another one for the newly downloaded CM configuration file. The vCM MUST carry out the comparison operations between the current active CM configuration file and the newly downloaded CM configuration file. This guarantees that the vCM can continue to operate with the current active configuration if errors are detected in the newly downloaded CM configuration file.

If the CM configuration file download process fails during the dynamic configuration update process, the vCM MUST:

- Abort the dynamic configuration update process and keep the current active configuration (i.e., the vCM and the D-ONU stays with existing configuration)
- Report the "Dyn Config Failed – Download" event as specified in [DPoG-OSSI]
- Change the value of dpogVcmDynCfgState to "downloadFailed".

9.5.2.2 CM Configuration File Validation

After the CM configuration file download completes successfully during the dynamic configuration update process, the vCM MUST validate the correctness of the configuration file, as described in Section 9.1.5.6, CM Configuration File Processing. The vCM MUST change the 'dpogVcmDynCfgState' object value to "validationInProgress" at the start of the validation process.

If there are any errors in the DOCSIS CM configuration file during the dynamic configuration update process, the vCM MUST:

- Abort the dynamic configuration update process and keep the current active configuration (i.e., the vCM and the D-ONU stays with existing configuration)
- Report event "Dyn Config Failed – Validation" as specified in [DPoG-OSSI]
- Change the value of 'dpogVcmDynCfgState' object to "validationFailed".

9.5.2.3 Configuration Delta and Resource Validation

As part of the dynamic configuration update process, the vCM MUST calculate the differences between the currently active configuration and the newly downloaded CM configuration file, identifying the necessary changes to the D-ONU configuration in order to support the new/modified services specified in the new CM configuration file. This difference in configuration is used to drive the D-ONU update process.

During the dynamic configuration update process, the DPoG System SHOULD validate the availability of the requested resources prior to introducing any changes to the D-ONU configuration based on the new CM configuration file. The DPoG system makes sure that the DPoG System and the D-ONU have the needed resources and capabilities to provision and support those services. The vCM MUST change the 'dpogVcmDynCfgState' object value to "resourceValidationInProgress" at the start of the configuration delta calculation and resource validation process.

If the resource validation process returns any errors, the vCM MUST:

- Abort the dynamic configuration update process and keep the current active configuration without performing any configuration changes on the D-ONU
- Report the "Dyn Config Failed – Resource Validation" event as specified in [DPoG-OSSI]
- Change the value of 'dpogVcmDynCfgState' to "resourceValidationFailed".

If the resource validation is successful, the DPoG System MUST start the process of applying changes to the D-ONU.

9.5.2.4 Applying Validated Configuration Changes

Once the DPoG System has completed validating the configuration file, capabilities, and the resources needed, it uses the validated CM configuration file to setup the services on the D-ONU. The vCM MUST change the 'dpogVcmDynCfgState' object value to "updateInProgress" before dynamic configuration updates are applied to the D-ONU and DPoG System. The DPoG System MUST convert the set of dynamic configuration updates needed into a sequence of eOAM control message as defined in [DPoG-OAM], sent to the D-ONU to add/modify/delete specific service instances.

During a dynamic configuration update, the D-ONU SHOULD apply the requested changes to the provisioned set of services without disrupting or affecting any other existing and operating services. Once the provisioning is successful, the vCM MUST discard the previous CM configuration file and store the new CM configuration file in its place.

If the services are unable to be provisioned during the eOAM update process, the vCM MUST NOT revert to the old CM configuration file; the D-ONU stays with the new CM configuration file, even if the resulting service configuration is invalid or not fully functional.

If there are any errors during the sequence of service provisioning messages, the DPoG System SHOULD stop making changes to the vCM/D-ONU after the first failed provisioning message.

If an error is encountered during the application of configuration changes, the vCM MUST report the "Dyn Config Failed – Update" event as specified in [DPoG-OSSI] and change the state of 'dpogVcmDynCfgState' to "updateFailed".

If the update operation is successful, the vCM MUST report the "Dyn Config Complete" event as specified in [DPoG-OSSI] and change the state of 'dpogVcmDynCfgState' to "updateComplete".

9.5.3 Operational State

The vCM MUST only initiate dynamic updates when in the "Operational" or "Forwarding Disabled" states and the 'dpogVcmDynCfgState' is "notStarted" or "updateComplete".

The DPoG System MUST maintain the appropriate state in the docsIf3CmtsCmRegStatusValue of the DOCS-IF3-MIB for each vCM known to the DPoG System throughout the dynamic configuration update process. The dynamic configuration process does not affect the registration state of vCMs. If the dynamic configuration process fails, the DPoG System SHOULD NOT change the registration status of the vCM due to the failure.

If the vCM registration status changes during the dynamic configuration process to a value other than "Operational" or "Forwarding Disabled", the vCM MUST:

- Abort the dynamic configuration update process
- Change the state of dpogVcmDynCfgState to "notStarted".

During the process of dynamic configuration updates, the vCM/D-ONU SHOULD preserve the packet counters and statistics of various services, as well as related management identifiers that are being changed.

10 DOWNLOADING CABLE MODEM OPERATING SOFTWARE

The protocol requirements are included in [DPoG-OAM], with further requirements included in [MULPIv3.0], [DPoG-OSSI], and [DPoG-SEC].

The internal structure of the software package, delineation process, etc., are vendor-specific and outside the scope of the DPoG specifications.

Annex A Well-Known Addresses (Normative)

In the DPoG specifications, the list of well-known addresses is composed of definitions included in section A.1.1 of [MULPIv3.0], with the additional extensions mentioned below.

- Slow Protocols Multicast address, used as MAC DA in DPoG OAMPDUs: 0x01-80-C2-00-00-02

Annex B Parameters and Constants (Normative)

The DPoG System SHOULD support the following parameters from Table B-1 of [MULPIv3.0], Annex B, as appropriate:

- TFTP Backoff Start
- TFTP Backoff End
- TFTP Request Retries
- TFTP Download Retries
- TFTP Wait
- T9 Timer

Annex C Common TLV Encodings (Normative)

The DPoG System MUST parse and apply the provisioning parameters defined by the TLVs contained within the CM provisioning files as part of the CM registration process and the dynamic configuration update process. Note that other TLVs are defined in Annex C of [MULPIv3.0], but those are not intended to be present in the configuration file and, therefore, are not covered in this section.

Sections C.2 through C.10 contain tables which enumerate whether support is required for a particular TLV by the DPoG System in this version of the DPoG specifications. Four columns are provided in the table; they are:

- TLV – TLV Number as defined in Annex C of [MULPIv3.0],
- Name – Descriptive Name associated with the TLV,
- Support Needed – indicating whether the support for the given TLV is required or not,
- Comments – Additional information regarding limitations for the support of the TLV or an explanation as to why the TLV need not be supported.
- Reference – Indicates the specification in which details of the item can be found.

When the DPoG System encounters a TLV that is not supported, then the DPoG System MUST ignore the TLV and allow the D-ONU to register normally, following the DPoG Network registration process.

C.1 Top Level TLVs

Table 7 - Top Level TLVs

TLV	Name	Support Needed	Comments	Reference
0	Pad	MUST		[MULPIv3.0]
1	Downstream Frequency	MUST NOT	Not applicable, as there is only one downstream channel, the PON itself.	N/A
2	Upstream Channel ID	MUST NOT	Not applicable, as there is only one upstream channel, the PON itself.	N/A
3	Network Access Control Object	MUST		[MULPIv3.0]
4	DOCSIS 1.0 Class of Service	MUST NOT	Not supported in the DPoG specifications.	N/A
5	Modem Capabilities	MUST	Added to DPoG to support TLV 5.42 D-ONU Capabilities Encoding. Note that these are NOT in the CM Configuration file, but in the DHCP from vCM to DHCP Server.	C.2
6	CM Message Integrity Check	MAY	The operator network is considered to be secure and this TLV is not needed as the DPoG System is getting the file directly from the TFTP Server. This TLV may be supported for backwards compatibility.	[MULPIv3.0]
7	CMTS Message Integrity Check	MAY	The operator network is considered to be secure and this TLV is not needed as the DPoG System is getting the file directly from the TFTP Server. This TLV may be supported for backwards compatibility.	[MULPIv3.0]
9	SW Upgrade Filename	MUST		[MULPIv3.0]
10	SNMP Write Access Control	SHOULD NOT	Operator feedback was that this TLV is not needed for this version of the specifications.	N/A
11	SNMP MIB Object	MUST	See the TLV 11 section for more details.	[MULPIv3.0]
14	CPE Ethernet MAC Address	SHOULD NOT	Operator feedback was that this TLV is not needed for this version of the specifications.	N/A
17	Baseline Privacy	MUST NOT	Encryption is different on PON, and configurable controls are limited. You can configure Traffic Key lifetime per-PON and per-Link. This doesn't correspond directly to TLV 17 items, however. See Annex C for more details.	N/A
18	Max Number of CPEs	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
19	TFTP Server Timestamp	MUST NOT	ONUs do not access the configuration file server, so there's no middle man or hackable entity like a CM to worry about.	N/A
20	TFTP Server Provisioned Modem IPv4 Address	MUST NOT	ONUs have IP addresses proxied by the DPoG System. Thus this TLV has little value.	N/A
21	SW Upgrade IPv4 TFTP Server	MUST		[MULPIv3.0]
22	Upstream Packet Classification	MUST	See Annex C.4 for more details.	C.4
23	Downstream Packet Classification	MUST	See Annex C.4 for more details.	C.4
24	Upstream SF	MUST	See Annex C.5 for more details.	C.5
25	Downstream SF	MUST	See Annex C.5 for more details.	C.5
26	Payload Header Suppression	MUST NOT	PON doesn't define header suppression.	N/A
28	Maximum Number of Classifiers	SHOULD NOT	This is admission control for classification resources.	[MULPIv3.0]
29	Privacy Enable	MUST	This TLV enables/disables device certificate authentication and traffic encryption functions on the DPoG System and D-ONU. See [DPoG-SEC] for more detail.	
32	Manufacturer Code Verification Certificate	MUST		
33	Co-Signer Code Verification Certificate	MUST		[MULPIv3.0]
34	SNMPv3 Kickstart Value	SHOULD		[MULPIv3.0]
35	Subscriber Mgmt Control	MUST		[MULPIv3.0]
36	Subscriber Mgmt CPE IPv4 List	MUST		[MULPIv3.0]
37	Subscriber Mgmt Filter Groups	MUST		[MULPIv3.0]
38	SNMPv3 Notification Receiver	MUST		[MULPIv3.0]
39	Enable 2.0 Mode	MUST NOT	PON PHY is not DOCSIS PHY.	N/A
40	Enable Test Modes	MUST NOT	Not applicable to D-ONUs.	N/A
41	Downstream Channel List	MUST NOT	ONUs lock to a single DS PON channel.	N/A
42	Static Multicast MAC Address	SHOULD		[MULPIv3.0]
43	DOCSIS Extension Field	MUST	See Annex C.7, Annex C.8, and Annex C.9 for more detail.	[MULPIv3.0]
45	Downstream Unencrypted Traffic (DUT) Filtering	SHOULD NOT	Not required for DPoG 1.0	N/A
53	SNMPv1v2c Coexistence	MUST		[MULPIv3.0]
54	SNMPv3 Access View	MUST		[MULPIv3.0]
55	SNMP CPE Access Control	SHOULD NOT	Not required for DPoG 1.0	N/A
56	Channel Assignment	MUST NOT	There is no channel bonding in PON.	N/A
58	SW Upgrade IPv6 TFTP Server	MUST		[MULPIv3.0]
59	TFTP Server Provisioned Modem IPv6 Address	MUST		[MULPIv3.0]
60	Upstream Drop Packet Classification	MUST	See Annex C.10 for more details	C.10
61	Subscriber Mgmt CPE IPv6 Prefix List	MUST		[MULPIv3.0]
62	Upstream Drop Classifier Group ID	MUST		[MULPIv3.0]
63	Subscriber Mgmt Control Max CPE IPv6 Prefix	MUST		[MULPIv3.0]
64	CMTS Static Multicast Session Encoding	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
65	L2VPN MAC Aging Encoding	MUST NOT	Not required for DPoG 1.0	N/A
66	Management Event Control Encoding	SHOULD NOT	Not required for DPoG 1.0	N/A
67	Subscriber Mgmt CPE IPv6 List	MUST		[MULPIv3.0]
70	US Aggregate Service Flow	MUST NOT	Not required for DPoG 1.0	N/A
71	DS Aggregate Service Flow	MUST NOT	Not required for DPoG 1.0	N/A
72	Metro Ethernet Service Profile	MUST NOT	Not required for DPoG 1.0	N/A
73	Network Timing Profile	MUST NOT	Not required for DPoG 1.0	N/A
255	End-of-Data	MUST		[MULPIv3.0]

C.2 D-ONU Capabilities Encoding

The D-ONU Capabilities Encoding describes the capabilities of a particular D-ONU; i.e., implementation dependent limits on the particular features or number of features, which the D-ONU can support. It consists of a number of encapsulated type/length/value fields; these sub-types define the specific capabilities for the D-ONU in question.

These capabilities are reported by the D-ONU to the DPoG System via specific OAM messages; defined in [DPoG-OAM]. The DPoG System MUST use the values reported by the D-ONU via OAM messages to populate the corresponding DHCP TLVs, when sending these DHCP TLVs in the DHCP messages from the local vCM.

TLV	Name	Support Needed	Comments	Reference
5.42.1	DPoG Version Number	MUST	Shared with DPoE	C.2.1
5.42.2	Reserved	MUST NOT	Reserved	[DPoE-MULPIv2.0]
5.42.3	Reserved	MUST NOT	Reserved	[DPoE-MULPIv2.0]
5.42.4	MESP Support	MUST NOT	Shared with DPoE	[DPoE-MULPIv2.0]
5.42.5	Number of D-ONU ports (S1 interfaces)	MUST	Shared with DPoE	[DPoE-MULPIv2.0]
5.42.6	PON Data Rate	MUST	Shared with DPoE	[DPoE-MULPIv2.0]
5.42.7	Service OAM	MUST NOT	Shared with DPoE	[DPoE-MULPIv2.0]
5.42.10	Number of T-CONTs Supported	MUST	DPoG only	C.2.2
5.42.11	Total Number of (X)GEM Ports Supported	MUST	DPoG only	C.2.3

Type	Length	Value
5.42	n	Capability sub-TLVs

NOTE: DOCSIS CM Capabilities are included under TLV 5. All the DPoG D-ONU Capabilities Encodings are included under TLV 5.41. The sub-type fields defined are only valid within the encapsulated capabilities configuration setting string

The set of possible D-ONU Capability sub-TLVs are described below.

The vCM MUST include all of these capabilities within the Modem Capabilities option, within option 125 (for DHCPv4) and or option 17 (for DHCPv6) unless the description of the capability explicitly prohibits this. DPoG Networks does not support DOCSIS Registration Response messaging and therefore D-ONU capabilities are communicated only via DHCP messaging.

C.2.1 DPoG Version Number

The DPoG Version number is a one byte value representing the DPoG OAM version supported by the D-ONU. Bits[7:4] of the value in this TLV represent the major version number, while Bits[3:0] of the value in this TLV represent the minor version number.

Type	Length	Value
5.42.1	1	major version: minor version

Field name	Description	Size
majver	Major version	4 bits
minver	Minor version	4 bits

C.2.2 Number of T-CONTs Supported

This field shows the maximum number of T-CONTs that the D-ONU supports.

Type	Length	Value
5.42.10	1	

NOTE: The minimum number of T-CONTs that a D-ONU supports is defined in [DPoG-ARCH].

C.2.3 Total Number of (X)GEM Ports Supported

This field shows the maximum number of (X)GEM Ports that the D-ONU supports. It includes the number of Multicast-capable (X)GEM ports, and one (X)GEM port used for OMCC.

Type	Length	Value
5.42.11	2	

NOTE: The minimum number of (X)GEM Ports that a D-ONU supports is defined in [DPoG-ARCH].

C.3 TLV 11

The following table, Table 8, specifies those TLV-11 CM SNMP MIB objects that MUST be supported by the DPoG System. Please refer to [DPoG-OSSI] for detailed requirements. The intent is to list only those objects that are currently in use (or planned to be in use) in CM provisioning files.

Table 8 - TLV 11

TLV-11 OID Name	Support Needed	Comments	Reference
docsDevFilterIpDefault	MUST	A value of 'accept' MUST be supported. A value of 'discard' MAY be supported. A DPoE System MUST ignore TLV 11 with the docsDevFilterIpDefault SNMP object with the value of 'discard', if this value is not supported.	[MULPIv3.0]
docsDevFilterIpStatus	MUST		[MULPIv3.0]
docsDevFilterIpControl	MUST	'Policy' control is not required. Only 'accept' and 'discard' MUST be supported in this version of the specifications.	[MULPIv3.0]
docsDevFilterIpIfIndex	MUST		[MULPIv3.0]
docsDevFilterIpDirection	MUST		[MULPIv3.0]

TLV-11 OID Name	Support Needed	Comments	Reference
docsDevFilterIpBroadcast	MUST	A value of 'false' MUST be supported. A value of 'true' MAY be supported.	[MULPIv3.0]
docsDevFilterIpSaddr	MUST		[MULPIv3.0]
docsDevFilterIpSmask	MUST		[MULPIv3.0]
docsDevFilterIpDaddr	MUST		[MULPIv3.0]
docsDevFilterIpDmask	MUST		[MULPIv3.0]
docsDevFilterIpProtocol	MUST		[MULPIv3.0]
docsDevFilterIpSourcePortLow	MUST		[MULPIv3.0]
docsDevFilterIpSourcePortHigh	MUST		[MULPIv3.0]
docsDevFilterIpDestPortLow	MUST		[MULPIv3.0]
docsDevFilterIpDestPortHigh	MUST		[MULPIv3.0]
docsDevFilterIpTos	MUST		[MULPIv3.0]
docsDevFilterIpTosMask	MUST		[MULPIv3.0]
docsDevFilterIpContinue	SHOULD NOT	No "policy" treatment	N/A
docsDevFilterIpPolicyId	SHOULD NOT	No "policy" treatment	N/A
docsDevFilterLLCUnmatchedAction	MUST		[MULPIv3.0]
docsDevFilterLLCIfIndex	MUST		[MULPIv3.0]
docsDevFilterLLCProtocol	MUST		[MULPIv3.0]
docsDevFilterLLCProtocolType	MUST		[MULPIv3.0]
docsDevFilterLLCStatus	MUST		[MULPIv3.0]
docsDevNmAccessCommunity	MUST		[MULPIv3.0]
docsDevNmAccessControl	MUST		[MULPIv3.0]
docsDevNmAccessInterfaces	MUST		[MULPIv3.0]
docsDevNmAccessIp	MUST		[MULPIv3.0]
docsDevNmAccessIpMask	MUST		[MULPIv3.0]
docsDevNmAccessStatus	MUST		[MULPIv3.0]

C.4 Classification (TLVs 22 and 23)

Table 9 - TLV 22 and 23

TLV	Name	Support Needed	Comments	Reference
22.1 23.1	Classifier Reference	MUST		[MULPIv3.0]
22.3 23.3	SF Reference	MUST		[MULPIv3.0]
22.5 23.5	Rule Priority	MUST		[MULPIv3.0]
22.6 23.6	ClassifierActivationState	SHOULD NOT	Without deferred activation, there's no reason to support this TLV in this version of the specifications.	N/A
22.9.1 23.9.1	IPv4 TOSRange and Mask	MUST		[MULPIv3.0]
22.9.2 23.9.2	IP Protocol	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
22.9.3 23.9.3	IPv4 Source Address	MUST		[MULPIv3.0]
22.9.4 23.9.4	IPv4 Source Mask	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
22.9.5 23.9.5	IPv4 Destination Address	MUST		[MULPIv3.0]
22.9.6 23.9.6	IPv4 Destination Mask	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
22.9.7 23.9.7	TCP/UDP Source Port Start	MUST		[MULPIv3.0]
22.9.8 23.9.8	TCP/UDP Source Port End	MUST		[MULPIv3.0]
22.9.9 23.9.9	TCP/UDP Destination Port Start	MUST		[MULPIv3.0]
22.9.10 23.9.10	TCP/UDP Destination Port End	MUST		[MULPIv3.0]
22.10.1 23.10.1	Ethernet DMAC	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
22.10.2 23.10.2	Ethernet SMAC	MUST		[MULPIv3.0]
22.10.3 23.10.3	Ethertype/DSAP/MacType	MUST	type=1 MUST be supported. type=3 does not apply to PON. Other values MAY be supported.	[MULPIv3.0]
22.10.4 23.10.4	Slow Protocol Subtype	MUST NOT	Not required for DPoG 1.0	N/A
22.11.1 23.11.1	**Error! Reference source not found.** User Priority	MUST NOT	Not required for DPoG 1.0	N/A
22.11.2 23.11.2	[802.1Q] VLAN ID	MUST NOT	Not required for DPoG 1.0	N/A
22.12.1 23.12.1	IPv6 TrafficClassRange and Mask	MUST		[MULPIv3.0]
22.12.2 23.12.2	IPv6 Flow Label	MUST		[MULPIv3.0]
22.12.3 23.12.3	IPv6 Next Header Type	MUST		[MULPIv3.0]
22.12.4 23.12.4	IPv6 Source Address	MUST		[MULPIv3.0]
22.12.5 23.12.5	IPv6 Source Prefix Length	MUST		[MULPIv3.0]
22.12.6 23.12.6	IPv6 Destination Address	MUST		[MULPIv3.0]
22.12.7 23.12.7	IPv6 Destination Prefix Length	MUST		[MULPIv3.0]
22.13 23.13	CM Interface Mask (CMIM) Encoding	MUST		[MULPIv3.0]
22.14 23.14	[802.1ad] S-VLAN Packet Classification Encodings	MUST NOT	TLV for [802.1ad] S-VLAN classifier. Not required for Phase 1DPoG.	N/A
22.14.1 23.14.1	[802.1ad] S- TPID	MUST NOT	Not required for DPoG 1.0	N/A
22.14.2 23.14.2	[802.1ad] S-VID	MUST NOT	Not required for DPoG 1.0	N/A

TLV	Name	Support Needed	Comments	Reference
22.14.3 23.14.3	[802.1ad] S-PCP	MUST NOT	Not required for DPoG 1.0	N/A
22.14.4 23.14.4	[802.1ad] S-DEI	MUST NOT	Not required for DPoG 1.0	N/A
22.14.5 23.14.5	[802.1ad] C-TPID	MUST NOT	Not required for DPoG 1.0	N/A
22.14.6 23.14.6	[802.1ad] C-VID	MUST NOT	Not required for DPoG 1.0	N/A
22.14.7 23.14.7	[802.1ad] C-PCP	MUST NOT	Not required for DPoG 1.0	N/A
22.14.8 23.14.8	[802.1ad] C-CFI	MUST NOT	Not required for DPoG 1.0	N/A
22.14.9 23.14.9	[802.1ad] S-TCI	MUST NOT	Not required for DPoG 1.0	N/A
22.14.10 23.14.10	[802.1ad] C-TCI	MUST NOT	Not required for DPoG 1.0	N/A
22.15 23.15	[802.1ah] I-TAG Packet Classification Encodings	MUST NOT	TLV for [802.1ah] I-TAG classifier. Not required for Phase 1DPoG.	N/A
22.15.1 23.15.1	[802.1ah] I-TPID	MUST NOT	Not required for DPoG 1.0	N/A
22.15.2 23.15.2	[802.1ah] I-SID	MUST NOT	Not required for DPoG 1.0	N/A
22.15.3 23.15.3	[802.1ah] I-TCI	MUST NOT	Not required for DPoG 1.0	N/A
22.15.4 23.15.4	[802.1ah] I-PCP	MUST NOT	Not required for DPoG 1.0	N/A
22.15.5 23.15.5	[802.1ah] I-DEI	MUST NOT	Not required for DPoG 1.0	N/A
22.15.6 23.15.6	[802.1ah] I-UCA	MUST NOT	Not required for DPoG 1.0	N/A
22.15.7 23.15.7	[802.1ah] B-TPID	MUST NOT	Not required for DPoG 1.0	N/A
22.15.8 23.15.8	[802.1ah] B-TCI	MUST NOT	Not required for DPoG 1.0	N/A
22.15.9 23.15.9	[802.1ah] B-PCP	MUST NOT	Not required for DPoG 1.0	N/A
22.15.10 23.15.10	[802.1ah] B-DEI	MUST NOT	Not required for DPoG 1.0	N/A
22.15.11 23.15.11	[802.1ah] B-VID	MUST NOT	Not required for DPoG 1.0	N/A
22.15.12 23.15.12	[802.1ah] B-DA	MUST NOT	Not required for DPoG 1.0	N/A
22.15.13 23.15.13	[802.1ah] B-SA	MUST NOT	Not required for DPoG 1.0	N/A
22.16 23.16	ICMPv6	MUST		[MULPIv3.0]
22.17.1 23.17.1	MPLS TC bits	MUST NOT	Not required for DPoG 1.0	N/A
22.17.2 23.17.2	MPLS Label	MUST NOT	Not required for DPoG 1.0	N/A
22.43 23.43	Vendor-specific Classifier Parameters	MUST		[MULPIv3.0]
23.43.5.1	VPN Identifier	MUST NOT	Not required for DPoG 1.0	N/A
23.43.8	General Extension Information	MUST	Vendor ID of 0xFFFFFF	[MULPIv3.0]

C.5 Service Flows and Aggregate (TLVs 24, 25, and 70, 71)

Table 10 - TLV 24, 25, and 70, 71

TLV	Name	Support Needed	Comments	Reference
24.1 25.1	SF Reference	MUST		[MULPIv3.0]
70.1 71.1	ASF Reference	MUST NOT	Not required for DPoG 1.0	N/A
24.4 25.4	Service Class Name	MUST		[MULPIv3.0]
24.6 25.6	Quality of Service Parameter Set Type	MUST	A value of 0x7 MUST be supported. Registration MUST be denied if a value other than 0x7 is received.	[MULPIv3.0]
24.7 25.7	Traffic Priority	MUST		[MULPIv3.0]
24.8	Upstream Max Sustained Traffic Rate	MUST		[MULPIv3.0]
25.8	Downstream Max Sustained Traffic Rate	MUST		[MULPIv3.0]
24.9 25.9	Maximum Traffic Burst	MUST		[MULPIv3.0]
24.10 25.10	Minimum Reserved Traffic Rate	MUST		[MULPIv3.0]
24.11 25.11	Assumed Min Rate Packet Size	SHOULD NOT		N/A
24.12 25.12	Timeout for Active QoS Parameters	SHOULD NOT	There is no deferred admission/activation behavior in this version of the specifications.	N/A
24.13 25.13	Timeout for Admitted QoS Parameters	SHOULD NOT	There is no deferred admission/activation behavior in this version of the specifications.	N/A
24.14	Maximum Concatenated Burst	MUST NOT	This is a DOCSIS network specific parameter which does not translate to a DPoG network.	N/A
25.14	Maximum Downstream Latency	SHOULD NOT		N/A
24.15	SF Scheduling Type	MUST	Two values MUST be supported for this version of the specifications: 2 for Best Effort 4 for Real Time Polling Service Other values MAY be supported.	[MULPIv3.0]
24.16	Request/Transmission Policy	MUST	The only bit that MUST be supported is Bit 4 (not to piggyback requests).	[MULPIv3.0]
24.17	Nominal Polling Interval	MUST	This TLV is used with the Real Time Polling Scheduling Type.	[MULPIv3.0]
25.17	Downstream Resequencing	MUST NOT	Not applicable to PON.	N/A
24.18	Tolerated Poll Jitter	SHOULD NOT		N/A
24.19	Unsolicited Grant Size	SHOULD NOT	This TLV is not needed to support the BE and RTP scheduling types.	N/A
24.20	Nominal Grant Interval	SHOULD NOT	This TLV is not needed to support the BE and RTP scheduling types.	N/A
24.21	Tolerated Grant Jitter	SHOULD NOT	This TLV is not needed to support the BE and RTP scheduling types.	N/A
24.22	Grants Per Interval	SHOULD NOT	This TLV is not needed to support the BE and RTP scheduling types.	N/A

TLV	Name	Support Needed	Comments	Reference
24.23 25.23	IP ToS Overwrite	MUST	A "tos-and-mask" value of 0x00 MUST be supported. Other values MAY be supported.	[MULPIv3.0]
24.26	Multiplier to Number of Bytes Requested	MUST NOT	Not applicable to PON.	N/A
24.27	Upstream Peak Traffic Rate	SHOULD NOT		N/A
25.27	Downstream Peak Traffic Rate	SHOULD NOT		N/A
24.31 25.31	SF Required Attribute Mask	MUST	This attribute is used to steer SFs to an IP-SG.	[MULPIv3.0], [DPoE-IPNEv2.0]
24.32 25.32	SF Forbidden Attribute Mask	MAY	The use of this attribute is not required, though may be used to, steer SFs to an IP-SG.	[MULPIv3.0], [DPoE-IPNEv2.0]
24.33 25.33	SF Attribute Aggregation Rule Mask	MUST NOT	Not applicable to PON.	N/A
24.34 25.34	Application Identifier	SHOULD NOT	This TLV is used to extend admission control decisions based on PCMM policies. There is no PCMM support in this version of the specifications.	N/A
24.36 25.36	Aggregate Service Flow Reference	MUST NOT	Not required for DPoG 1.0	N/A
24.37 25.37 70.37 71.37	MESP Reference	MUST NOT	Not required for DPoG 1.0	N/A
24.43	Vendor-specific QoS Parameters	MUST		[MULPIv3.0]
24.43.5.1	VPN Identifier	MUST NOT	Not required for DPoG 1.0	N/A
24.43.8	General Extension Information	MUST	Vendor ID of 0xFFFFFF	[MULPIv3.0]

C.6 Device Management (TLVs 38, 53 and 54)

Table 11 - TLV 38, 53 and 54

TLV	Name	Support Needed	Comments	Reference
34.1	SNMPv3 Kickstart Security Name	SHOULD	SNMPv3 support is not mandatory	[MULPIv3.0]
34.2	SNMPv3 Kickstart Manager Public Number	SHOULD	SNMPv3 support is not mandatory	[MULPIv3.0]
38.1	SNMPv3 Notification Receiver IPv4 Address	MUST		[MULPIv3.0]
38.2	SNMPv3 NotificationReceiverUDPPort Number	MUST		[MULPIv3.0]
38.3	SNMPv3 Notification Receiver Trap Type	MUST		[MULPIv3.0]
38.4	SNMPv3 Notification Receiver Timeout	MUST		[MULPIv3.0]
38.5	SNMPv3 Notification Receiver Retries	MUST		[MULPIv3.0]
38.6	SNMPv3 Notification Receiver Filtering Parameters	MUST		[MULPIv3.0]
38.7	SNMPv3 Notification Receiver Security Name	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
38.8	SNMPv3 Notification Receiver IPv6 Address	MUST		[MULPIv3.0]
53.1	SNMPv1v2c Community Name	MUST		[MULPIv3.0]
53.2	SNMPv1v2c Transport Address Access	MUST		[MULPIv3.0]
53.2.1	SNMPv1v2c Transport Address	MUST		[MULPIv3.0]
53.2.2	SNMPv1v2c Transport Address Mask	MUST		[MULPIv3.0]
53.3	SNMPv1v2c Access View Type	MUST		[MULPIv3.0]
53.4	SNMPv1v2c Access View Name	MUST		[MULPIv3.0]
54.1	SNMPv3 Access View Name	MUST		[MULPIv3.0]
54.2	SNMPv3 Access View Subtree	MUST		[MULPIv3.0]
54.3	SNMPv3 Access View Mask	MUST		[MULPIv3.0]
54.4	SNMPv3 Access View Type	MUST		[MULPIv3.0]

C.7 TLV 43

Table 12 - TLV 43

TLV	Name	Support Needed	Comments	Reference
43.1	CM Load Balancing Policy ID	MUST NOT	Not applicable to PON.	N/A
43.2	CM Load Balancing Priority	MUST NOT	Not applicable to PON.	N/A
43.3	CM Load Balancing Group ID	MUST NOT	Not applicable to PON.	N/A
43.4	CM Ranging Class ID Extension	MUST NOT	Not applicable to PON.	N/A
43.5	L2VPN Encoding	MUST NOT	Not required for DPoG 1.0	N/A
43.6	Extended CMTS MIC Configuration Setting	MAY	ONUs do not request configuration files, thus tampering is not a concern. This TLV may be supported for backwards compatibility.	[MULPIv3.0]
43.7	Source Address Verification Authorization Encoding	MUST		[MULPIv3.0]
43.8	General Extension Information	MUST		[MULPIv3.0]
43.9	Cable Modem Attribute Masks	MUST NOT	This is bonding-specific, thus not applicable to PON.	N/A
43.10	IP Multicast Join Authorization Encoding	MUST		[MULPIv3.0]
43.11	Service Type Identifier	SHOULD NOT	This TLV is not applicable to DPoG Networks in this version of the specifications.	N/A

C.8 [DPoE-MEFv2.0] and [L2VPN] (TLVs 43.5, 45, and 65)

This version of the DPoG specifications does not require these TLVs.

Table 13 - TLV 43.5, 45, and 65

TLV	Name	Support Needed	Comments	Reference
43.5.1	VPN Identifier	MUST NOT	Not required for DPoG 1.0	NA
43.5.2	NSI Encapsulation Subtype	MUST NOT	Not required for DPoG 1.0	NA

TLV	Name	Support Needed	Comments	Reference
43.5.2.1	Other	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.2	[802.1Q]	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.3	[802.1ad]	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.4	MPLS Peer	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.5	L2TPv3 Peer	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6	[802.1ah]	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.1	[802.1ah] I-Tag TCI	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.2	[802.1ah] B-DA	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.3	[802.1ah] B-TCI	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.4	[802.1ah] I-TPID	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.5	[802.1ah] I-PCP	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.6	[802.1ah] I-DEI	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.7	[802.1ah] I-UCA	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.8	[802.1ah] I-SID	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.9	[802.1ah] B-TPID	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.10	[802.1ah] B-PCP	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.11	[802.1ah] B-DEI	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.6.12	[802.1ah] B-VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.2.8	[802.1ad] S-TPID	MUST NOT	Not required for DPoG 1.0	NA
43.5.3	Enable eSAFE DHCP Snooping	MUST NOT	Not required for DPoG 1.0	NA
43.5.4	CM Interface Mask	MUST NOT	Not required for DPoG 1.0	NA
43.5.5	Attachment Group ID	MUST NOT	Not required for DPoG 1.0	NA
43.5.6	Source Attachment Individual ID	MUST NOT	Not required for DPoG 1.0	NA
43.5.7	Target Attachment Individual ID	MUST NOT	Not required for DPoG 1.0	NA
43.5.8	Ingress User Priority	MUST NOT	Not required for DPoG 1.0	NA
43.5.9	UserPriorityRange	MUST NOT	Not required for DPoG 1.0	NA
43.5.10	L2VPN SA-Descriptor	MUST NOT	Not required for DPoG 1.0	NA
43.5.13	L2VPN Mode	MUST NOT	Not required for DPoG 1.0	NA
43.5.14	DPoE TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.1	Upstream outmost TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.2	Downstream outmost TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.3	Upstream S-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.4	Downstream S-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.5	Upstream B-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.6	Downstream B-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.7	Upstream I-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.14.8	Downstream I-TPID Translation	MUST NOT	Not required for DPoG 1.0	NA
43.5.15.1	L2CP Tunnel Mode	MUST NOT	Not required for DPoG 1.0	NA
43.5.15.2	L2CP DA MAC	MUST NOT	Not required for DPoG 1.0	NA
43.5.15.3	L2CP Replacing DA MAC	MUST NOT	Not required for DPoG 1.0	NA
43.5.16	DAC Disable/Enable	MUST NOT	Not required for DPoG 1.0	NA
43.5.18	Pseudowire-Class	MUST NOT	Not required for DPoG 1.0	NA

TLV	Name	Support Needed	Comments	Reference
43.5.19	Service Delimiter	MUST NOT	Not required for DPoG 1.0	NA
43.5.19.1	C-VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.19.2	S-VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.19.3	I-SID	MUST NOT	Not required for DPoG 1.0	NA
43.5.19.4	B-VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.20.1	VPLS Class	MUST NOT	Not required for DPoG 1.0	NA
43.5.20.2	E-Tree Role	MUST NOT	Not required for DPoG 1.0	NA
43.5.20.3	E-Tree Root VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.20.4	E-Tree Leaf VID	MUST NOT	Not required for DPoG 1.0	NA
43.5.21.1	Route Distinguisher	MUST NOT	Not required for DPoG 1.0	NA
43.5.21.2	Route Target(import)	MUST NOT	Not required for DPoG 1.0	NA
43.5.21.3	Route Target(export)	MUST NOT	Not required for DPoG 1.0	NA
45.1	Downstream Unencrypted Traffic (DUT) Control	MUST NOT	Not required for DPoG 1.0	NA
45.2	Downstream Unencrypted Traffic (DUT) CMIM	MUST NOT	Not required for DPoG 1.0	NA
65.1	L2VPN MAC Aging Mode	MUST NOT	Not required for DPoG 1.0	NA

C.9 Customer (Subscriber) Management (TLV 43.7)

Table 14 - TLV 43.7

TLV	Name	Support Needed	Comments	Reference
43.7.1	SAV Group Name Subtype	MUST		[MULPIv3.0]
43.7.2	SAV Static Prefix Rule Subtype	MUST		[MULPIv3.0]
43.7.2.1	SAV Static Prefix Address Subtype	MUST	IPv4 and IPv6.	[MULPIv3.0]
43.7.2.2	SAV Static Prefix Length Subtype	MUST	IPv4 and IPv6.	[MULPIv3.0]

C.10 Upstream Drop Classification (TLV 60)

Table 15 - TLV 60

TLV	Name	Support Needed	Comments	Reference
60.1	Classifier Reference	MUST		[MULPIv3.0]
60.5	Rule Priority	MUST		[MULPIv3.0]
60.9.1	IPv4 TOSRange and Mask	MUST		[MULPIv3.0]
60.9.2	IP Protocol	MUST		[MULPIv3.0]
60.9.3	IPv4 Source Address	MUST		[MULPIv3.0]
60.9.4	IPv4 Source Mask	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
60.9.5	IPv4 Destination Address	MUST		[MULPIv3.0]
60.9.6	IPv4 Destination Mask	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
60.9.7	TCP/UDP Source Port Start	MUST		[MULPIv3.0]
60.9.8	TCP/UDP Source Port End	MUST		[MULPIv3.0]
60.9.9	TCP/UDP Destination Port Start	MUST		[MULPIv3.0]
60.9.10	TCP/UDP Destination Port End	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
60.10.1	Ethernet DMAC	MUST	Mask can't be arbitrary bits. Must be used to define "most significant bits" a la IPv6 Prefix.	[MULPIv3.0]
60.10.2	Ethernet SMAC	MUST		[MULPIv3.0]
60.10.3	Ethertype/DSAP/MacType	MUST	type=1 MUST be supported. type=3 does not apply to PON. Other type values MAY be supported.	[MULPIv3.0]
60.11.1	**Error! Reference source not found.** User Priority	MUST		[MULPIv3.0]
60.11.2	[802.1Q] VLAN ID	MUST		[MULPIv3.0]
60.12.1	IPv6 TrafficClassRange and Mask	MUST		[MULPIv3.0]
60.12.2	IPv6 Flow Label	MUST		[MULPIv3.0]
60.12.3	IPv6 Next Header Type	MUST		[MULPIv3.0]
60.12.4	IPv6 Source Address	MUST	.	[MULPIv3.0]
60.12.5	IPv6 Source Prefix Length	MUST		[MULPIv3.0]
60.12.6	IPv6 Destination Address	MUST		[MULPIv3.0]
60.12.7	IPv6 Destination Prefix Length	MUST		[MULPIv3.0]
60.13	CM Interface Mask (CMIM) Encoding	MUST		[MULPIv3.0]
60.14	[802.1ad] S-VLAN Packet Classification Encodings	MUST	TLV for [802.1ad] S-VLAN classifier.	[MULPIv3.0]
60.14.1	[802.1ad] S- TPID	MUST		[MULPIv3.0]
60.14.2	[802.1ad] S-VID	MUST		[MULPIv3.0]
60.14.3	[802.1ad] S-PCP	MUST		[MULPIv3.0]
60.14.4	[802.1ad] S-DEI	MUST		[MULPIv3.0]
60.14.5	[802.1ad] C-TPID	MUST		[MULPIv3.0]
60.14.6	[802.1ad] C-VID	MUST		[MULPIv3.0]
60.14.7	[802.1ad] C-PCP	MUST		[MULPIv3.0]
60.14.8	[802.1ad] C-CFI	MUST		[MULPIv3.0]
60.14.9	[802.1ad] S-TCI	MUST		[MULPIv3.0]
60.14.10	[802.1ad] C-TCI	MUST		[MULPIv3.0]
60.15.	[802.1ah] I-TAG Packet Classification Encodings	MUST	TLV for [802.1ah] I-TAG classifier.	[MULPIv3.0]
60.15.1	[802.1ah] I-TPID	MUST		[MULPIv3.0]
60.15.2	[802.1ah] I-SID	MUST		[MULPIv3.0]
60.15.3	[802.1ah] I-TCI	MUST		[MULPIv3.0]
60.15.4	[802.1ah] I-PCP	MUST		[MULPIv3.0]
60.15.5	[802.1ah] I-DEI	MUST		[MULPIv3.0]
60.15.6	[802.1ah] I-UCA	MUST		[MULPIv3.0]
60.15.7	[802.1ah] B-TPID	MUST		[MULPIv3.0]
60.15.8	[802.1ah] B-TCI	MUST		[MULPIv3.0]
60.15.9	[802.1ah] B-PCP	MUST		[MULPIv3.0]
60.15.10	[802.1ah] B-DEI	MUST		[MULPIv3.0]
60.15.11	[802.1ah] B-VID	MUST		[MULPIv3.0]
60.15.12	[802.1ah] B-DA	MUST		[MULPIv3.0]
60.15.13	[802.1ah] B-SA	MUST		[MULPIv3.0]
60.16	ICMPv6	MUST		[MULPIv3.0]

TLV	Name	Support Needed	Comments	Reference
60.17.1	MPLS TC bits	MUST		[MULPIv3.0]
60.17.2	MPLS Label	MUST		[MULPIv3.0]
60.43	Vendor-specific Classifier Parameters	MUST	These TLVs will be "supported" in that vendor-proprietary TLVs can be specified in the configuration file, but their implementation is up to the vendor. There currently are no standard DPoG vendor-specific classifier parameters.	[MULPIv3.0]

Annex D eSAFE DHCP Snooping (Normative)

Does not apply to the DPoG 1.0 Specifications.

Appendix I Illustration of Service Flow aggregation (Informative)

This appendix applies to commercial services and is currently not supported by the DPoG specifications.

Appendix II DPoG Multicast Flow Diagrams (Informative)

This appendix includes diagrams which explain how multicast for IP(HSD) works in the DPoG Network.

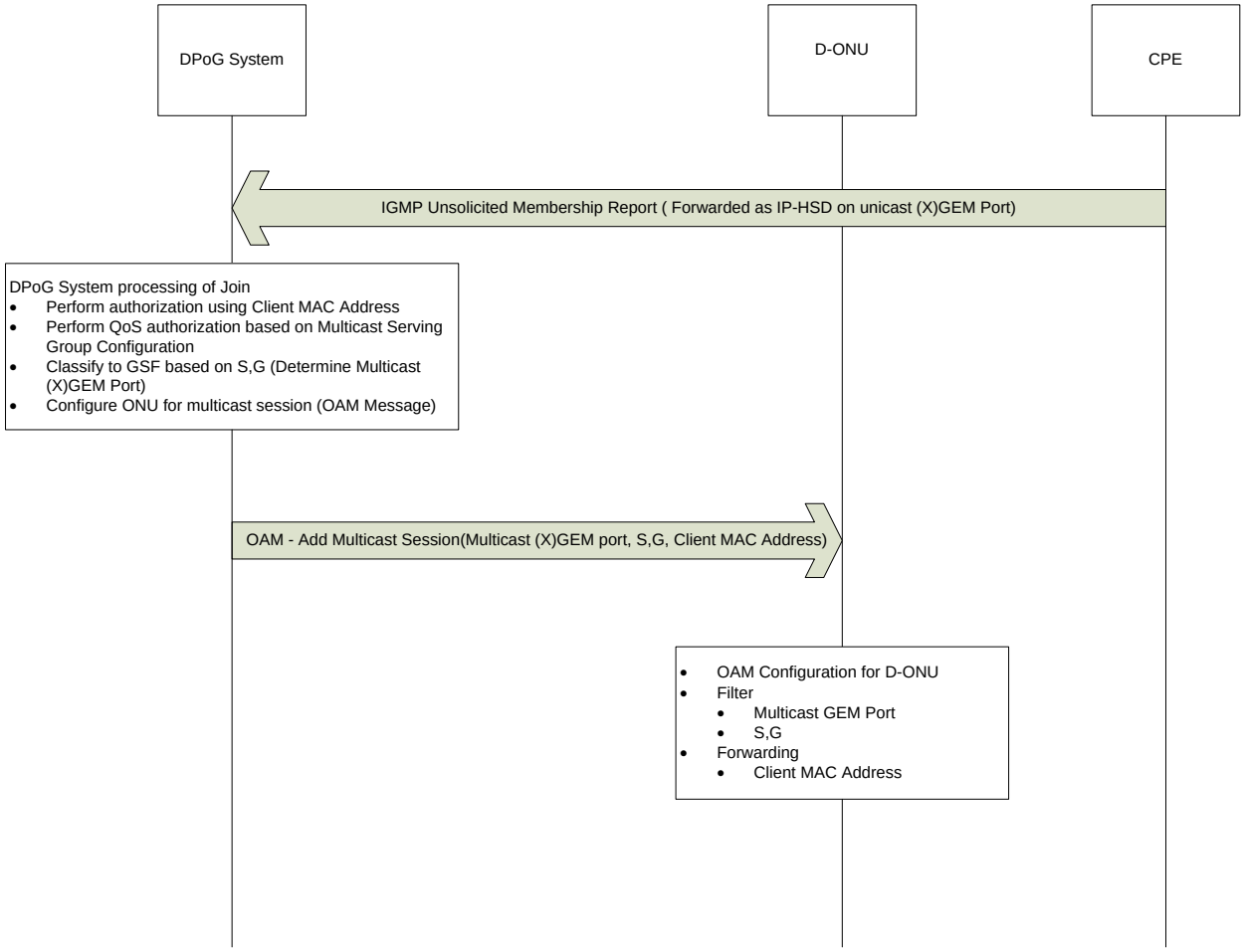

Figure 17 - Dynamic Join

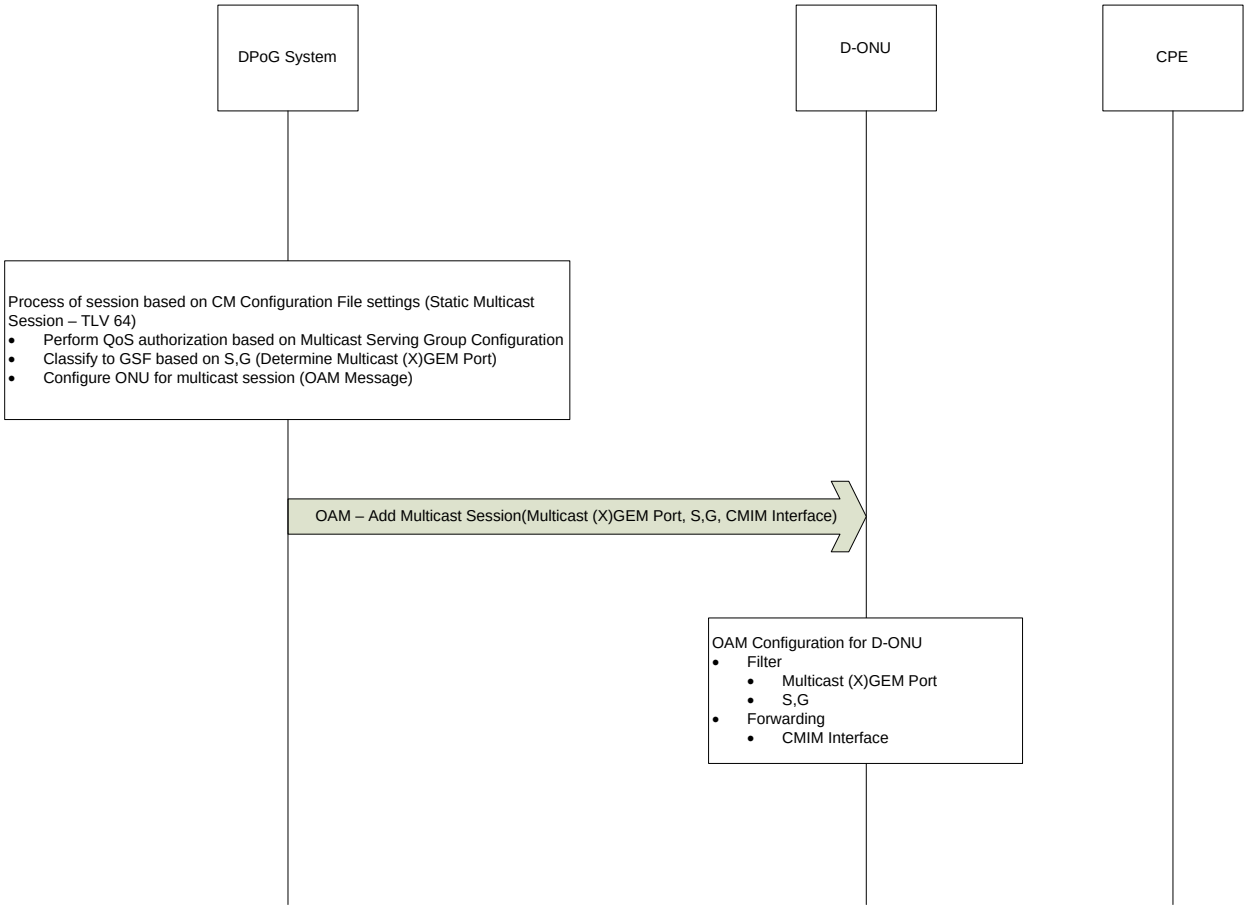

Figure 18 - Static Session

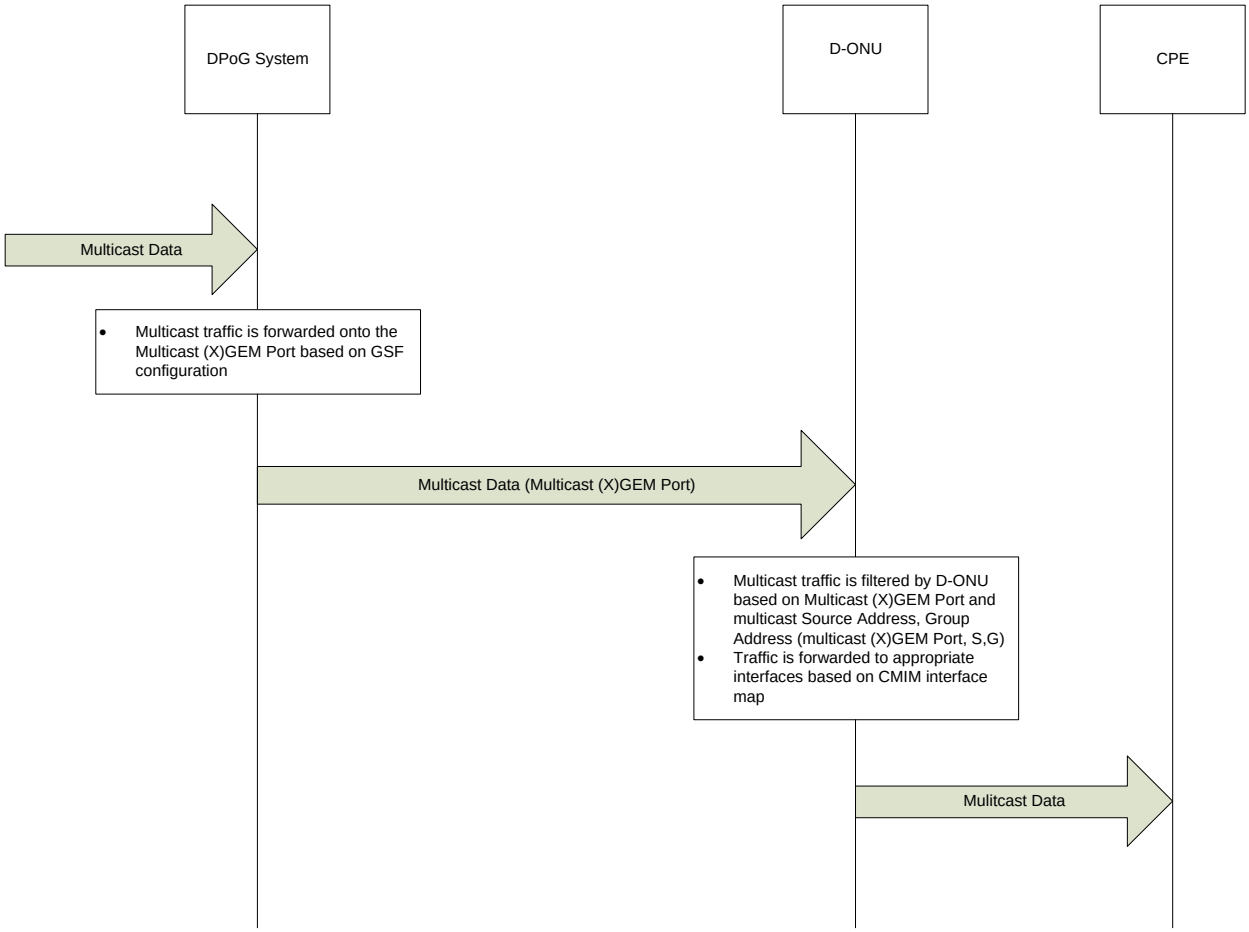

Figure 19 - Downstream Multicast Data Traffic Forwarding

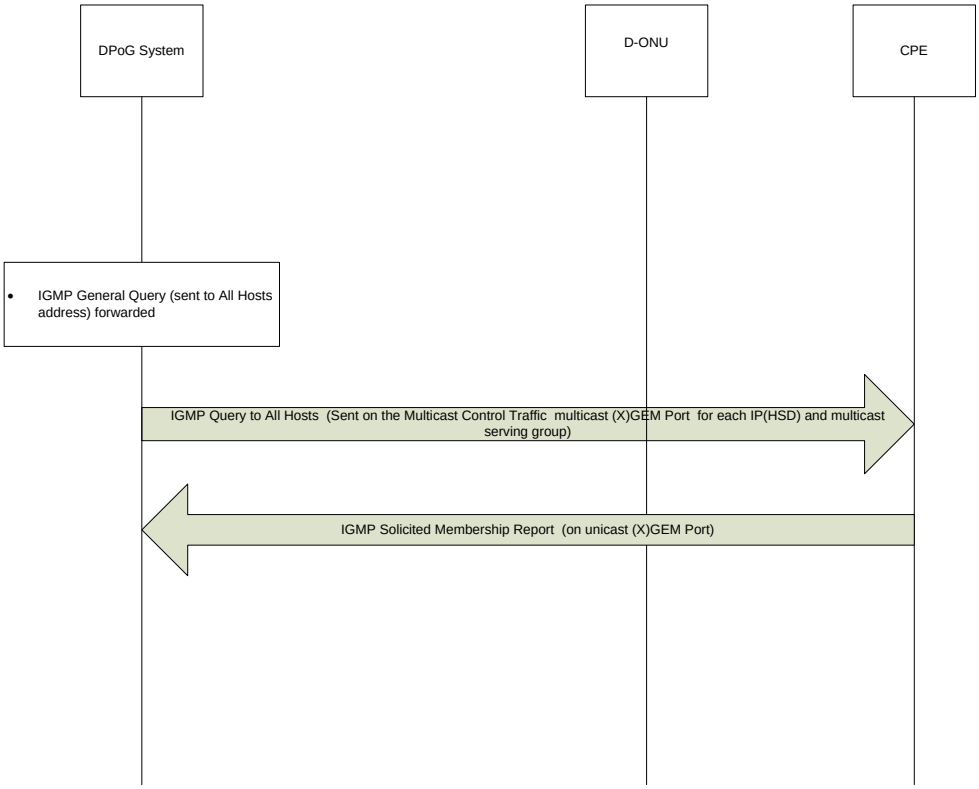

Figure 20 - Downstream Multicast Control

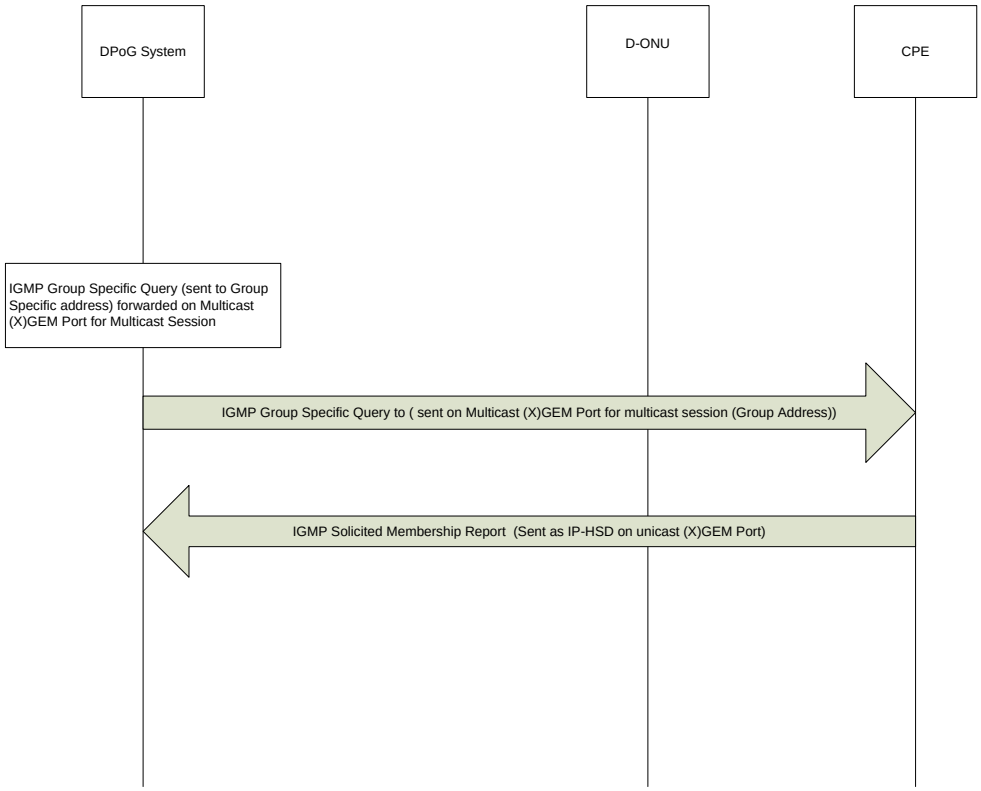

Figure 21 - Multicast Group Specific Messages

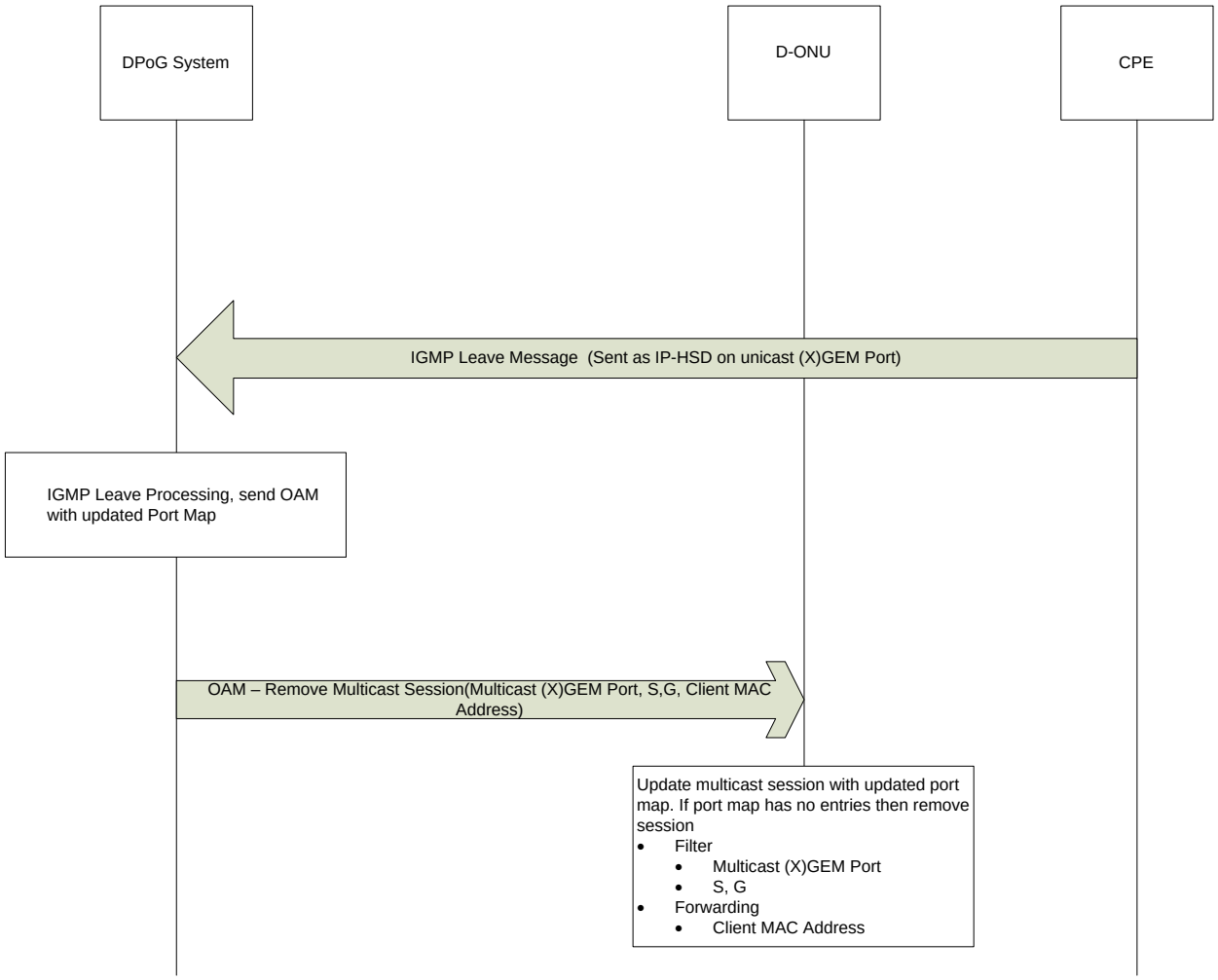

Figure 22 - Multicast Leave Processing

Appendix III Similar PLOAM and DPoG-OAM Messages (Informative)

The following table describes the subset of GPON/XG-PON PLOAM and Embedded GPON/XG-PON OAM messages that are similar to eOAM messages defined in [DPoG-OAM]. A recommendation is provided for which type of message to use for the desired action.

ITU-T Reference	PLOAM Message name	PLOAM Comments	Similar DPoG-OAM Message	DPoG-OAM Comments	Recommendation
G.984.3, G.987.3	Deactivate_ONU-ID (downstream)	Returns ONU to State (O2) which re-initializes ranging. Can be broadcast to all ONUs on the PON	Reset a single D-ONU (0xD9/0x0001)	Message resets the ONU as if from power on.	Both types of messages can be used. - PLOAM returns the ONU state to (O2) - DPoG-OAM returns the ONU state to (O1)
G.984.3, G.987.3	Disable_Serial_Number (downstream)	If enabled, disables the ONU by putting the ONU into Emergency Stop State (O7). If in state (O7), enables the ONU by moving it to state (O2), which re-initializes the ranging process.	Laser Tx Power Off (0xD9/0x0605)	Message turns off the laser transmit power for the specified time for diagnostic purposes.	Both types of messages can be used. Note that the DPoG-OAM Laser Tx Power Off message disables the Tx laser for the duration indicated by the message, but does not directly change the ONU state. The ONU state may transition once the laser is enabled or disabled, according to the state transitions defined in [G.984.3] and [G.987.3].
G.984.3	Dying_Gasp (upstream)	ONU notifies the OLT that it is powering off or entering a low power or battery conservation mode. The OLT uses this indication to notify the OSS.	"Dying Gasp Alarm" is raised as an event code (0x41) in the DPoG Event Notification PDU		The PLOAM Dying_Gasp is required per Section 6.3.1.3 DPoG OAM Messages. The eOAM Dying Gasp alarm can also be used.
G.984.3	Physical_Equipment_Error (PEE) (upstream)	ONU notifies the OLT that it is unable to send both GEM frames and OMCC frames in the direction from GEM to TC layer. OLT uses this indication to raise an alarm for loss of PHY to the ONU	"D-ONU Busy" is raised as an event code (0x82) in the DPoG Event Notification PDU	DPoG System ignores OAM timeouts for the ONU when the "D-ONU Busy" was asserted less than 300 second from the last reception of a "D-ONU Busy" alarm.	Both types of messages (PLOAM or DPoG-OAM) can be used.
G.987.3	EMBEDDED OAM DG Indication (not PLOAM) (upstream)	EMBEDDED OAM communicates this in the IND field of the XGTC header. In G.987.3, this equates to the Dying_Gasp and PEE PLOAM messages defined for G.984.3	"Dying Gasp Alarm" is raised as an event code (0x41) in the DPoG Event Notification PDU		G.987.3 EMBEDDED OAM is required per Section 6.3.1.3 for Dying Gasp. Additionally, the DPoG-OAM "Dying Gasp Alarm" can also be used. Both types of messages can be used for PEE.
G.984.3	Encrypted_Port-ID (downstream)	Indicates to the ONU which channels are encrypted.	Encryption Mode (0xD7/0x0402)	Not used for GPON	PLOAM messages are required to establish unicast GEM port encryption per [DPoG-SEC].

ITU-T Reference	PLOAM Message name	PLOAM Comments	Similar DPoG-OAM Message	DPoG-OAM Comments	Recommendation
G.984.3	Request_Key (downstream)	Used by the OLT to trigger the ONU to generate a new encryption key and send it upstream.	Encryption Key Expiry Time (0xD7/0x0401)	Not used for GPON	PLOAM messages are required to establish unicast GEM port encryption per [DPoG-SEC].
G.984.3	Key_Switching_ Time (downstream)	Used by the OLT to notify the ONU when to begin using the new encryption key.	Encryption Key Expiry Time (0xD7/0x0401)	Not used for GPON	PLOAM messages are required to establish unicast GEM port encryption per [DPoG-SEC].
G.984.3	Encryption key (upstream)	Used by the ONU to send fragments of the new encryption key to the OLT after receiving the OLT Request_Key message.	Encryption Key Expiry Time (0xD7/0x0401)	Not used for GPON	PLOAM messages are required to establish unicast GEM port encryption per [DPoG-SEC].
G.987.3	Key_Control (downstream)	Used by the OLT to request that the ONU generate a new encryption key of a specified length and send it upstream. The same message may be used to confirm an existing key.	Key Assignment PDU	Used to transmit a key value to the D-ONU for use in the broadcast/ multicast key ring.	PLOAM messages are required to establish unicast XGEM port encryption per [DPoG-SEC]. Refer to the last row in this table for the key exchange used for a multicast/broadcast XGEM port.
G.987.3	Key_Report (upstream)	Used by the ONU to send a fragment of a new encryption key to the OLT. This message can also be used to verify an existing key.	Key Assignment Ack PDU	Used to acknowledge the receipt of the Key Assignment PDU.	PLOAM messages are required to establish unicast XGEM port encryption per [DPoG-SEC]. Refer to the last row in this table for the key exchange used for a multicast/broadcast XGEM port.
n/a			Encryption Key Ring (0xC7/0x0402)	Sets the encryption method and key ring to be used on an XGEM port only (i.e. only [G.987.3].	Used for enabling the optional [G.987.3] multicast/broadcast encryption. Refer to [DPoG-SEC], section 11 for details on how the keys are exchanged using Key Assignment PDUs and Key Assignment Ack PDUs.

Appendix IV Acknowledgements (Informative)

On behalf of our industry, we would like to thank the following individuals for their contributions to the development of this specification, listed in alphabetical order of company affiliation.

Contributor	Company Affiliation
Richard Goodson	Adtran
Arkin Aydin, Rex Coldren, Michael Shaffer	Alcatel-Lucent
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