DOCSIS® Provisioning of GPON Specifications
DPoGv1.0

DPoG OAM Extensions Specification

DPoG-SP-OAMv1.0-C01-160830

CLOSED

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Key to Document Status Codes

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

Because the virtual CM (vCM) operates on the DPoG System (instead of the D-ONU), a means of communication from the vCM to the D-ONU is required. The D-ONU does not require an IP stack. Therefore, a suitable alternative operating at a lower layer in the protocol stack was developed for the DOCSIS Provisioning of EPON (DPoE) specifications and is being reused in its entirety by DPoG. In this method [802.3] standard EPON Operations Administration and Maintenance (OAM) is used for messaging between the vCM on the DPoG System and the D-ONU. OAM extensions specified in [DPoE-OAM] provide additional means for such messaging for parameters not supported in the [802.3] standard EPON OAM.

This document describes usage of the DPoE OAM extension feature to provide additional DPoG OAM extensions that support interoperability between all vendors who choose to develop products in accordance with the DPoG specifications. This specification defines the interface used for conveying management information between a DPoG System and D-ONU. It also defines format and contents for the following types of configuration or information collection messages:

- General management and device capabilities
- Forwarding provisioning
- Statistics collection
- Alarm status
- Security key exchange
- Frame processing and classification
- Quality of Service provisioning
- Time Synchronization (ToD, Frequency, and Phase)

Implementations that conform to this specification are required to implement all the features defined in this specification.

Implementations may also implement other [802.3], Clause 57 OAM extensions if desired. DPoG implementations that conform to this specification are required to fully interoperate with other DPoG implementations that conform to this specification, regardless of the presence or absence of other OAM extensions.

1.2 Goals

The goals of the DPoG OAM specification are to:

- Provide a common method of managing D-ONUs from different vendors to ensure interoperability
- Define packet formats and data encodings to support DPoG features
- Provide a "toolkit" of features from which these DPoG features can be constructed (rather than just assigning monolithic blocks of parameters for each feature individually)
- Establish specifications for OAM parameters, behavior, and extended features where such are needed
- Limit complexity and cost of D-ONU devices by adapting L2 management protocols previously used in EPON

DPoE OAM is leveraged as the foundation for DPoG OAM because:

- A common specification for EPON and GPON OAM interfaces is desirable.
- Capabilities of existing DPoE OAM have been proven to meet cable operator requirements.
- Extensibility designed into DPoE OAM allows for tuning in the GPON environment.
- DPoE OAM is an integral part of the DPoE specification suite that DPoG specifications are being built upon.
- The approach will facilitate and simplify interoperability and compliance testing.

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 Specificaftion

1.5 Reference Architecture

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

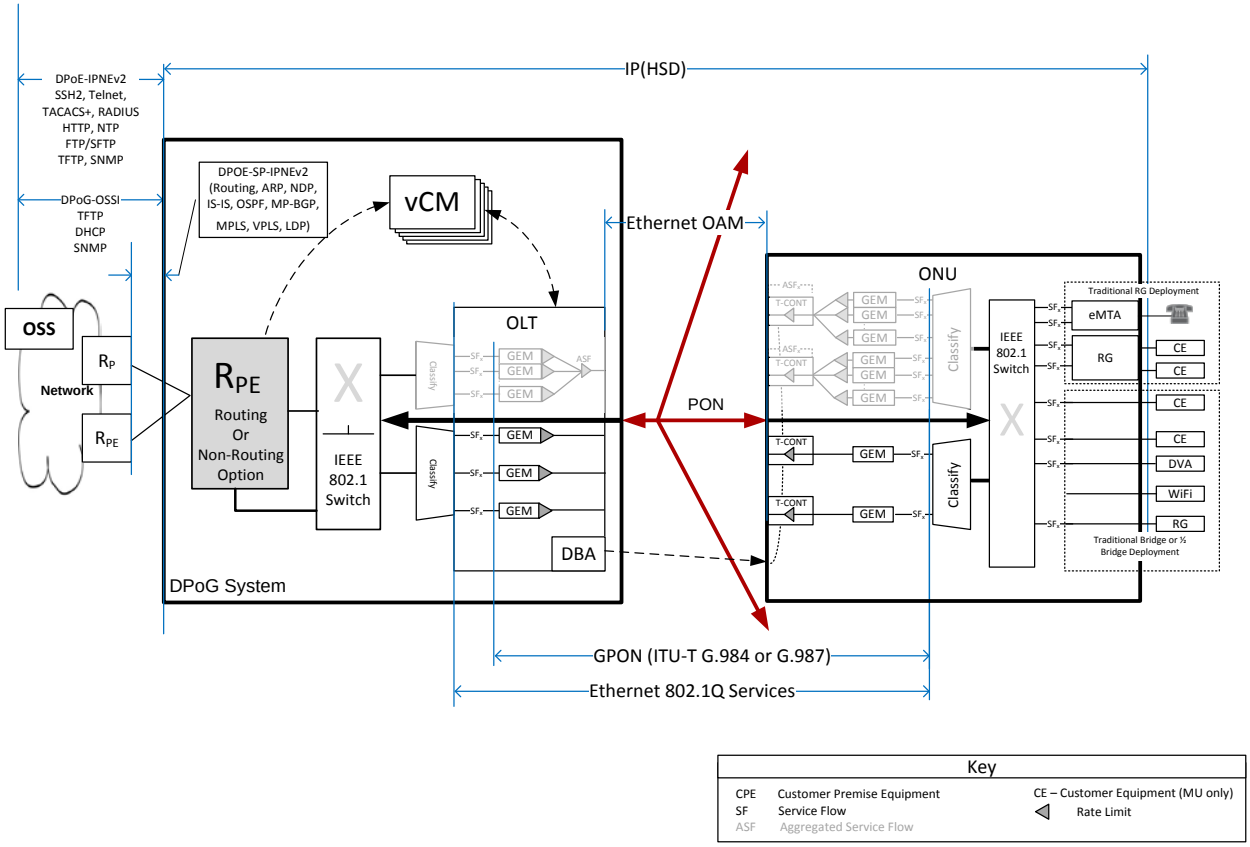

Figure 1 - DPoGv1.0 Reference Architecture

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.

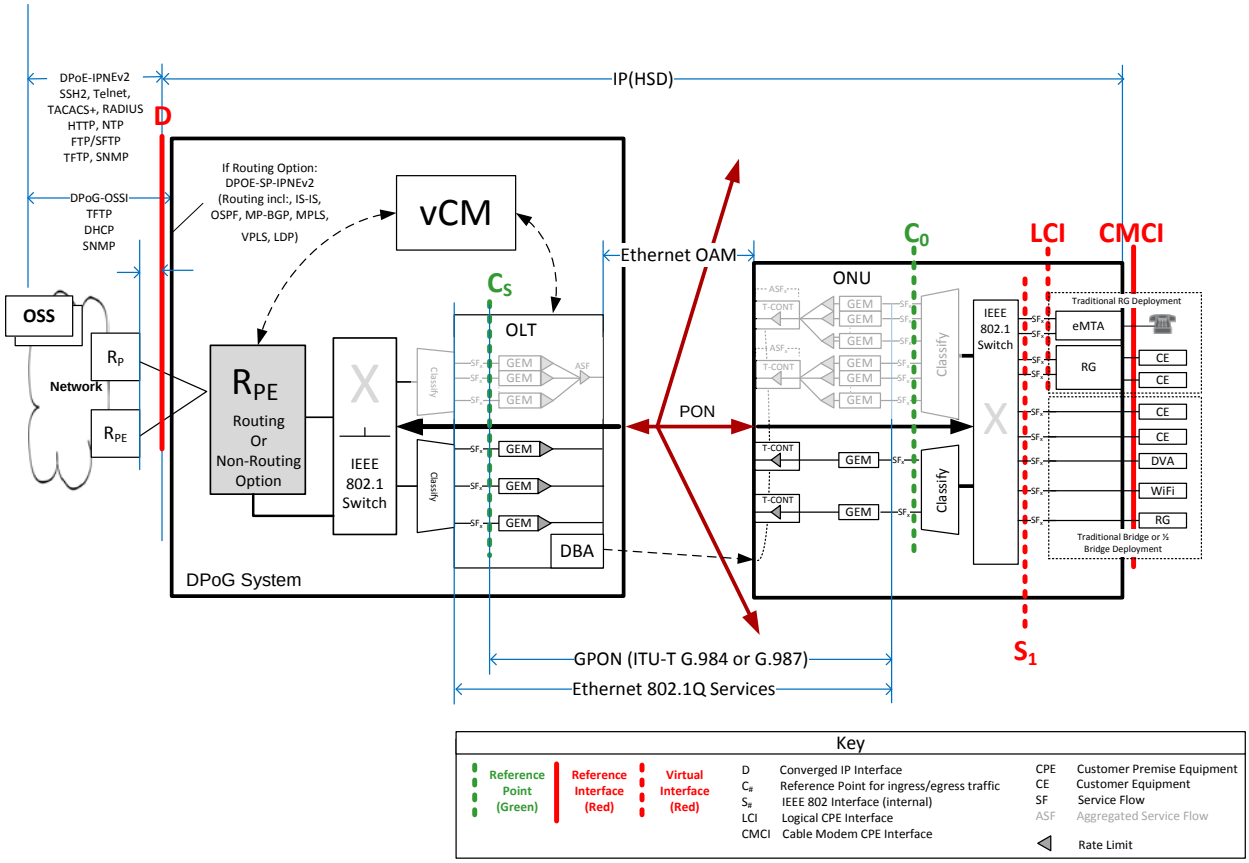

Figure 2 - DPoGv1.0 Interfaces and Reference Points

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.

[802.1]	Refers to entire suite of IEEE 802.1 standards unless otherwise specified.
[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 802.3-2008, Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications, January 2008.
[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
[G.988]	ITU-T Recommendation G.988, ONU Management and Control Interface (OMCI) Specification
[DPoE-OAM]	DOCSIS Provisioning of EPON, OAM Extensions Specification, DPoE-SP-OAMv2.0, Cable Television Laboratories, Inc.
[DPoG-MULPI]	DOCSIS Provisioning of GPON, DPoG MAC and Upper Layer Protocols Interface Specification, Version 1.0
[DPoG-SEC]	DOCSIS Provisioning of GPON, DPoG Security Specification, Version 1.0
[1588v2]	IEEE Std 1588 2008, IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems, July 2008.

2.2 Informative References

This specification uses the following informative references.

[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.

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

[DPoG-ARCH] DOCSIS Provisioning of GPON, DPoG Architecture Specification, Version 1.0

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 terms and definitions.

3.1 DPoG Network Elements

DPoG Network This term means all the elements of a DPoG implementation, including at least one DPoG System, one or more D-ONUs connected to that DPoG System, and possibly one or more DEMARCs

DPoG System This term refers to the set of subsystems within the hub site that provides the functions necessary to meet DPoG specification requirements.

DPoG ONU (D-ONU) This term means a DPoG-capable ONU that complies with all the DPoG specifications.

DEMARC Short form of "Demarcation Device." This term means the device, owned and operated by the operator that provides the demarcation (sometimes called the UNI interface) to the customer. Some architectures describe this device as the CPE (as in DOCSIS) or the NID (as in the MEF model).

3.2 Other Terms

Critical OAM Messages and attributes in the DPoG OAM extension set that are necessary for the network to work properly.

Customer Premise Equipment (CPE) Customer Premise Equipment as defined in [DOCSIS]

DPoG OAM Extension of DPoE OAM that supports DPoG System remote configuration and management of GPON-based D-ONUs.

DPoE OAM Extension of IEEE 802 Link OAM that creates a specialized set of messages and an information model that allows a DPoE System to remotely configure and manage D-ONUs on behalf of cable operator back office systems.

Network Interface Device (NID) A DEMARC device in DPoG specifications

OAM Discovery OAM Discovery occurs immediately after registration. D-ONUs are to indicate support for DPoG OAM extensions during the OAM Discovery phase to be admitted onto the network.

Object Context The particular instance of an object is to be identified in DPoG OAM messages to provide context for the attributes or actions that follow.

Service Flow A unidirectional flow of packets from the upper layer service entity to the RF with pre-defined QoS traffic parameters.

User Port The User Port object identifies one of the S interfaces or references points on the device (if any).

Variable Container A Variable Container begins with a Variable Descriptor, which is followed by a Length field and then data that indicates the value of the attribute.

Variable Descriptor A Variable Descriptor is composed of "branch" and "leaf" codes that uniquely identify the attribute, at least within the IEEE-controlled numbering space.

4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

Alloc-ID	Allocation IDentifier
BWmap	BandWidth map
CDR	Clock and Data Recovery
CoS	Class of Service
CM	Cable Modem
CPE	Customer Premise Equipment
CRC	Cyclic Redundancy Check
DA	Destination Address
DBA	Dynamic Bandwidth Allocation
DPoG	DOCSIS Provisioning of GPON
DHCP	Dynamic Host Configuration Protocol
D-ONU	DPoE ONU
DPoE	DOCSIS Provisioning of EPON
DS	DownStream
EAP-TLS	Extensible Authentication Protocol-Transport Layer Security
eOAM	extended OAM
EPON	Ethernet Passive Optical Network
FEC	Forward error correction
GEM	GPON Encapsulation Method
GPON	Gigabit PON
G-PON	Gigabit-PON
HEC	Header Error Control
HSD	High Speed Data
IANA	Internet Assigned Numbers Authority
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IP(HSD)	High Speed Data (Broadband Internet Access using DOCSIS)
IPMC	IP MultiCast
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
I-SID	[802.1ah] I-Component Service IDentifier
ISP	Internet Service Provider
KI	Key Index
L2	Layer 2
L2CP	Layer 2 Control Protocol
L3	Layer 3
L4	Layer 4
LAN	Local Area Network

LF	Last Fragment indicator
LLID	Logical Link Identifier
LOS	Loss Of Signal
LSE	Label Stacking Entry
MAC	Media Access Control
MEF	Metro Ethernet Forum
MIB	Management Information Base
MPLS	Multi-Protocol Label Switching
NID	Network Interface Device
NVS	Non-volatile Storage
OAM	EPON Operations Administration and Maintenance
OLT	Optical Line Termination
OMCC	ONT Management Control Channel
OMCI	ONT Management Control Interface
ONU	Optical Network Unit
OUI	Organizationally Unique Identifier
PDU	Protocol Data Unit
PHY	Physical Layer
PLI	Payload Length Indicator
PLOAM	Physical Layer Operations, Administration and Maintenance
PON	Passive Optical Network
PTI	Payload Type Indicator
RTT	Round Trip Time
S_1	802 S Interface
SA	Source Address
SNAP	Sub-Network Access Protocol
SNMP	Simple Network Management Protocol
SP	Strict Priority
TC	Transmission Convergence
T-CONT	Traffic Container
TCP	Transmission Control Protocol
TFTP	Trivial File Transfer Protocol
TLV	Type-Length-Value
ToD	Time of Day
TOS	Type Of Service
TPID	Tag Protocol Identifier
TTL	Time To Live
Tx	Transmit
UDP	User Datagram Protocol
UNI	User Network Interface
US	UpStream

vCM	Virtual Cable Modem
VID	VLAN Identifier
VLAN	Virtual Local Area Network
WFQ	Weighted Fair Queuing
XGEM	XG-PON Encapsulation Method
XG-PON	10 Gigabit-capable GPON

5 OAM BACKGROUND

DPoE OAM extends IEEE 802 Link OAM to create a specialized set of messages and an information model that allows a DPoE System to remotely configure and manage D-ONUs on behalf of cable operator back office systems. DPoE OAM is extensible and allows modifications to the information model and, if needed, to the message set as well. DPoG OAM, as specified in this document, is built on top of DPoE OAM.

IEEE 802 Link OAM is Ethernet-based, and is therefore transported in Ethernet frames between the OLT and ONU. In DPoG there is a single logical OAM channel per OLT-ONU association. This channel is carried in the D-ONU default Alloc-ID/GEM port, where GPON OMCI is transported in Telco-based GPON applications. Since DPoG OAM functionally replaces GPON OMCI in a cable operator environment, this specification reuses the same ONT Management Control Channel (OMCC) logical channel for DPoG OAM, carrying DPoG OAM as Ethernet frames encapsulating the GEM frames on that channel.

For normative requirements relating to the establishment and maintenance of the DPoG logical OAM channel, refer to [DPoG-MULPI]. See also: Appendix I - D-ONU Initialization and Configuration (Informative).

5.1 IEEE 802 Link OAM for EPON

An overview of the IEEE 802 Link OAM used and extended by DPoE is given in the IEEE 802 Link OAM for EPON section of [DPoE-OAM].

5.2 [802.3], Clause 57 OAM PDUs

An overview of [802.3], Clause 57 OAM PDUs used and extended by DPoE is given in the [802.3], Clause 57 OAM PDUs section of [DPoE-OAM].

5.3 D-ONU Model

For management purposes, a D-ONU is considered to have the logical structure depicted in Figure 3.

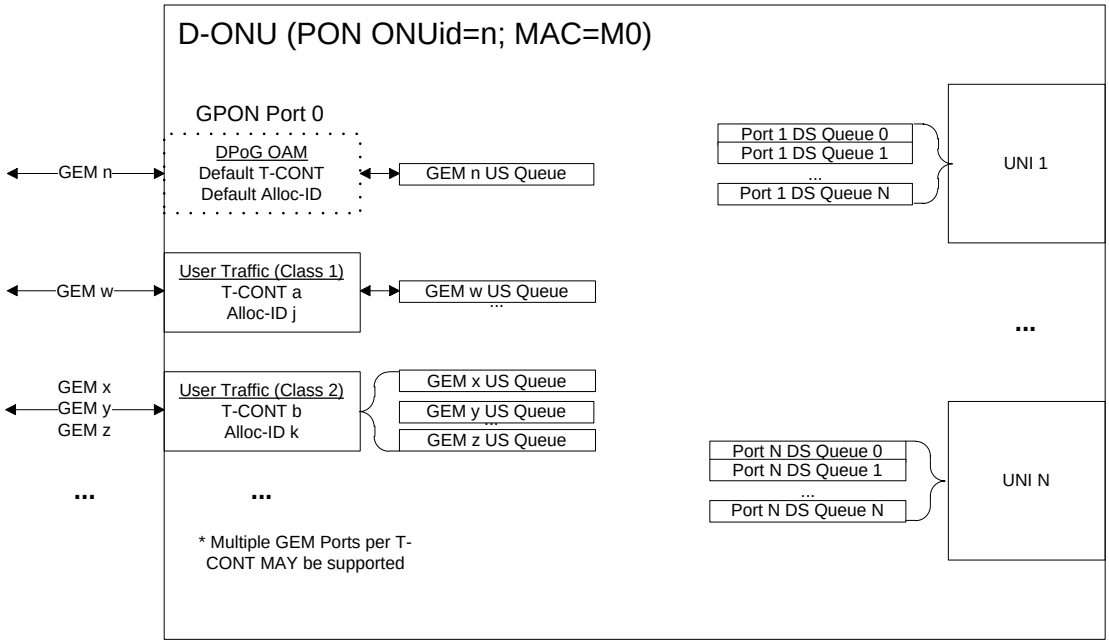

Figure 3 - D-ONU Model

A D-ONU is a device that has:

- one MAC interface per PON interface
- one or more MAC interfaces on the user side S interfaces or reference points.

S interfaces usually have one MAC per each physical port. A switch internal to the D-ONU connects the PON and S interface ports to transfer frames between the individual MACs.

The D-ONU PON interface is fed with upstream traffic by the DPoG OAM GEM port and by one or more T-CONTs, which could provide different classes of service. A given T-CONT can serve one or more GEM ports, each of which maps to its own upstream queue. Each of the S interface MACs is fed with downstream user traffic by one or more priority queues associated with the S interface. These PON ports, UNI ports, GEM ports, T-CONTs, and queues each have OAM attributes that allow remote management.

While each of the GEM ports supports bi-directional (transmit/receive) traffic, D-ONUs typically treat one or more as receive-only links. Such links are used to flood traffic downstream on the PON, including unknown MAC addresses for [802.1d] bridging or true Ethernet multicast.

5.4 Frame Processing

The DPoG System MUST support the requirements specified for DPoE Systems in the Frame Processing section of [DPoE-OAM].

The D-ONU MUST support the requirements specified for DPoE D-ONUs in the Frame Processing section of [DPoE-OAM].

6 OAM OPERATION

6.1 OAM Discovery

The DPoG System MUST support the requirements specified for DPoE Systems in the OAM Discovery section of [DPoE-OAM].

The D-ONU MUST support the requirements specified for DPoE D-ONUs in the OAM Discovery section of [DPoE-OAM].

6.2 OAM Timeout

The DPoG System MUST support the requirements specified for DPoE Systems in the OAM Timeout section of [DPoE-OAM].

The D-ONU MUST support the requirements specified for DPoE D-ONUs in the OAM Timeout section of [DPoE-OAM].

6.3 Critical OAM

Of the hundreds of messages and attributes in the DPoG OAM extension set, a few are deemed "critical" OAM. A successful response to these OAM messages is necessary for the network to work properly. A D-ONU that does not acknowledge these critical OAM commands is not operating correctly (by definition) and will be deregistered by the DPoG System. These critical OAM commands are required as part of the claim of support for DPoG OAM extensions. A D-ONU that claims support for DPoG OAM extensions is also promising to respond to these OAM commands in particular, as well as others in this document.

Critical OAM messages are sent immediately after D-ONU ranging and OAM port configuration by PLOAM; they can also be sent at other times during D-ONU operation.

Table 2 - Critical OAM Attributes

Attribute	Description	Value (hex)
Device ID	Unique physical device identification number (i.e. D-ONU MAC Address)	0xD7/0x0002
Set OAM Rate	Changes maximum allowed OAM PDU rate	0xD7/0x000D
Max T-CONTs	Maximum number of T-CONTs supported on the D-ONU	0xC7/0x0001
Max GEM Ports	Maximum number of GEM ports (bidirectional and unidirectional flows) supported on the D-ONU	0xC7/0x0002
DBA Report Encoding	Controls mode and resolution of the T-CONT queue occupancy status reports	0xC7/0x0003

The critical OAM messages are described in the following subsections.

6.3.1 D-ONU Capabilities

Most of the information in the Extended Info PDU is primarily of interest to the network management system. However, a few of these attributes are snooped by DPoG System firmware and are necessary for the DPoG System to manage D-ONUs.

The Device ID provides the MAC address associated with the D-ONU to the DPoG System.

The number of T-CONTs and GEM ports is necessary for a DPoG System to correctly manage D-ONUs of different configurations.

If a D-ONU does not positively acknowledge these attributes, it cannot be tracked and managed by the DPoG System, and is therefore deregistered by the DPoG System to deny its entry onto the DPoG Network.

6.3.2 DBA Report Encoding

The DPoG System requests status reports (buffer occupancy behind a T-CONT) in the BWmap to D-ONUs. D-ONUs respond in the corresponding upstream frame. This is all handled by the DBA process in the OLT.

The DBA Report Encoding allows DPoG Systems to determine D-ONU queue occupancy status report mode and resolution in [G.984]. DPoG Systems can set queue occupancy status report resolutions or can use the D-ONU default. DPoG Systems cannot set queue occupancy status report mode as it is a read-only attribute of the D-ONU.

The DBA Report Encoding is not used in [G.987], where queue occupancy status report mode and resolution are fixed values. A D-ONU that receives, but fails to acknowledge, the DBA Report Encoding attribute when requested to do so by the DPoG System is deregistered to deny its entry onto the DPoG Network.

6.3.3 Set OAM Rate

[802.3], Clause 57 and its annexes specify a maximum rate of 10 frames/second for OAM traffic. DPoE OAM extensions allow this limit to be increased or waived entirely. However, both the DPoG System and D-ONU have to agree on the actual OAM frame rate to be used. If the D-ONU and DPoG System use different OAM frame rates, the useful PDU rate would be limited by the lower of the two, as the D-ONU would either fail to acknowledge OAM commands (when the DPoG System rate was higher than the D-ONU) or be unable to use the increased limit (because the DPoG System would not send commands as often as the D-ONU might be willing to accept).

6.4 OAM keep-alive Failure

DPoG Systems and D-ONUs use an OAM keep-alive mechanism to detect when OAM layer processing has failed. OAM is typically implemented in software, so failures at this layer can happen independently from PLOAM layer failures. Therefore, it is assumed that the PLOAM layer keep-alive and the OAM layer keep-alive are not necessarily redundant capabilities and that both exist in a DPoG Network.

DPoG System processing of OAM keep-alive failure is as specified in [DPoG-MULPI].

D-ONU processing of OAM keep-alive failure is as specified in [DPoG-MULPI].

6.5 OAM and Logical Links

The DPoG System MUST use the OMCC for transporting OAM messages.

The D-ONU MUST respond to OAM messages on the same OMCC on which the command was received.

7 [802.3] OAM PDU

In addition to the [802.3] organization-specific extension PDU opcode (0xFE), which allows definition of entirely new PDUs in addition to the standard [802.3], Clause 57 PDUs, two of the other [802.3], Clause 57 PDUs contain TLVs that allow for extensions. The Info OAM PDU and the Event Notification OAM PDU are each composed of a series of TLVs. Each type of PDU allows an organization-specific TLV with contents as defined by that organization.

The DPoE specifications defines TLVs for both the [802.3] Info PDU and the [802.3] Event Notification OAM PDU, in addition to DPoE OAM extension PDU types (hereafter called DPoE OAM PDU types). As per [802.3], DPoE OAM extension TLVs use TLV type 0xFE and DPoE OUI 0x001000.

7.1 Info PDU

All DPoE Info TLVs have as their first type an additional TLV type that allows for multiple different types of DPoE Info TLVs. Format of additional data in the TLV depends on this DPoE TLV type.

Table 3 - DPoE Info TLV Format

Width (Octets)	Field	Value (hex)
1	TLV Type	0xFE (Info TLV extension)
1	Length	Includes Type and Length fields, plus data to follow
3	OUI	0x001000
1	DPoE Info TLV Type	See Table 4

The DPoE Info TLV types are shown in Table 4.

Table 4 - DPoE Info TLV Types

DPoE TLV Type	Value (hex)
DPoE OAM Support	0x00

7.1.1 DPoE Info TLV: DPoE OAM Support (0x00)

Presence of this TLV in the Info frames during OAM discovery, coupled with the fact that the system is operating using GPON, indicates that the DPoG System or D-ONU supports DPoG OAM. Support for the OAM PDUs also implies support for the feature set required for the DPoG System.

The DPoE OAM Version field indicates the version of the eOAM supported by the given device. In a GPON environment this field indicates the DPoG OAM version. This field represents a major/minor version number, with the major number in bits [7:4] and the minor number in bits [3:0]. For example, in a GPON application the value of 0b00010000 (0x10) stored in the 'DPoE OAM Version' field represents a major version 1, minor version 0 of the DPoG OAM.

The DPoG System MUST deregister a D-ONU that reports an unsupported version of the DPoG OAM.

Table 5 - DPoE OAM Support TLV Format

Width (Octets)	Field	Value (hex)
1	TLV Type	0xFE (Info TLV extension)
1	Length	Varies
3	OUI	0x001000
1	DPoE Info TLV Type	0x00
1	DPoE OAM Version	Bits [7:4] represent the major version number Bits [3:0] represent the minor version number The following values are defined in a GPON context: 0x10 – OAM compliant with DPoGv1.0 specification. Other values are reserved and treated as unsupported.

7.2 Event Notification PDU

The DPoE Event Notification TLV is used in an [802.3] Event Notification OAMPDU to provide more detailed alarm information than is possible with only the [802.3], Clause 57 OAM.

All alarms have a common format. The current condition of the alarm is indicated as "raised" when the condition is detected and "cleared" when the condition is no longer present. The object affected by the condition is included as an object type and instance number that matches the object context leaf codes and instance parameters specified in section 8.1.

Table 6 - DPoE Link Event TLV Format

Width (Octets)	Field	Value (hex)
1	TLV Type	0xFE (Event Notification TLV extension)
1	Length	Varies
3	OUI	0x001000
1	Event Code	See Table 7
1	Raised	Boolean; TRUE if the condition currently exists; FALSE if it has been cleared
2	Object Type	Affected object (leaf code for object context, branch D6)
2 or 4	Object Instance	Affected instance of this type of object. Queue object type requires four (4) bytes, other object types require two (2) bytes.

Possible values for the Event Code are shown in Table 7. These alarm codes are grouped into Link Faults, Critical Events, and Dying Gasp alarm types, with code values numbered accordingly.

In addition to this standard header, individual alarm types may contain further alarm-type-specific information in the TLV.

Table 7 - DPoE/DPoG Event Codes

DPoE Event Code	Value (hex)	Description	Object Context	Requirement	Reference
Link Fault Alarms					
LOS	0x11	Loss of received optical power by the transceiver (D-ONU PON port) Link down on Ethernet PHY (D-ONU UNI port)	D-ONU Network PON Port User Port	MUST	[DPoE-OAM]
Key Exchange Failure	0x12	D-ONU did not observe a switch to a new key after key exchange	GEM Port	MUST	[DPoE-OAM]
Reserved	0x13..0x1F	Reserved	-	-	-
Critical Event Alarms					
Port Disabled	0x21	Ethernet port is disabled by management action	Network PON Port User Port	MUST	[DPoE-OAM]
Reserved	0x22..0x3F	Reserved	-	-	-
Dying Gasp Alarms					
Power Failure	0x41	Loss of power at the D-ONU (Dying Gasp)	NA	MUST NOT	7.2.2
Reserved	0x42..0x7F	Reserved	-	-	-
Other Alarms					
Statistics Alarm	0x81	Statistic has crossed defined alarm thresholds	Network PON Port GEM Port T-CONT User Port Queue	MUST	[DPoE-OAM]
D-ONU Busy	0x82	D-ONU is busy and unable to acknowledge or process further OAM until alarm clears	D-ONU	MUST	[DPoE-OAM]
MAC Table Overflow	0x83	D-ONU MAC table has seen more addresses than it can hold	D-ONU Network PON Port User Port	MUST	[DPoE-OAM]
Reserved	0x84..0xFF	Reserved	-	-	-

The following subsections describe event codes that are either new or modified for the DPoG specifications relative to the DPoE definitions.

7.2.1 Key Exchange Failure (0x12)

The Key Exchange Failure alarm indicates that a scheduled key exchange has failed to successfully complete. Encryption continues with the previous key for another key exchange interval. Another key exchange will be attempted at the next key exchange time. See [DPoG-SEC] for details on key exchange procedures and detection of failure conditions.

7.2.2 Power Failure (0x41)

A Power Failure alarm indicates that the D-ONU has lost power and will imminently depart the DPoG Network. In DPoG specifications the PLOAM Dying Gasp message will be used to indicate power failure of a D-ONU at the DPoG System. The use of OAM Power Failure is redundant and will not be supported in the DPoG specifications.

8 DPOE OAM PDUS

DPoG Systems MUST support the requirements specified for DPoE Systems in the DPoE OAM PDUs section of [DPoE-OAM], except as noted in the following subsections.

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the DPoE OAM PDUs section of [DPoE-OAM], except as noted in the following subsections.

8.1 Object Context (Branch 0xD6)

DPoE OAM extensions can manage several D-ONU objects. Also, since a D-ONU typically supports multiple ports, any given attribute such as "Bytes Received" can have many instances, one for each port on the D-ONU. Therefore, the particular instance of an object has to be identified to provide context for the attributes or actions.

An object context tuple in an OAM PDU sets the object to which all subsequent Variable Descriptors or Containers apply. This remains unchanged until the next object context in the PDU is processed or the message ends. If no object context is supplied, the default context is the OAM logical link itself, defined here as the GEM port context associated with the DPoG OAM channel.

It is not necessary for the DPoG System to know the MAC addresses of the user ports to manage them via DPoE OAM.

Table 8 - Object Context

Leaf (HEX)	Attribute	Description	Requirement	Reference
0x00 00	D-ONU	D-ONU	MUST	[DPoE-OAM]
0x00 01	Network PON Port	A PON port on the network side of the device	MUST	[DPoE-OAM]
0x00 02	Unicast Logical Link	A unicast GEM port instance index	MUST	[DPoE-OAM]
0x00 03	User Port	User-side Ethernet port	MUST	[DPoE-OAM]
0x00 04	Queue	A single queue	MUST	8.1.1
0x00 05	MEP	A Service OAM frame generator maintenance end point (MEP)	MUST NOT	NA
0x00 06	Multicast Logical Link	Multicast (unidirectional) logical link	MUST	
0x00 07	T-CONT	A single T-CONT	MUST	8.1.3

The following subsections describe attributes that are either new or modified for the DPoG specifications relative to their DPoE definitions.

8.1.1 Unicast Logical Link Object (0xD6/0x0002)

The Unicast Logical Link object identifies one of the unicast logical links registered by the D-ONU. A Unicast Logical Link instance in DPoG specifications is identified by an index that matches a Unicast GEM Port Instance Index in the GEM Port ID Configuration (0xC7/0x0102). GEM port instance indices are numbered sequentially starting from number 0 (default GEM Port for OMCC), up to the value G-1, where G is the maximum number of GEM Ports defined in Section 9.1.3.

Table 9 - Unicast Logical Link Object

Width (Octets)	Field	Value (hex)
1	Unicast GEM Port Instance Index	0..G-1

8.1.2 Queue Object (0xD6/0x0004)

The DPoG System MUST support the requirements specified for DPoE Systems in the Queue Object section of [DPoE-OAM], with the exception that the LLID Object Type is replaced by the T-CONT Object Type.

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the Queue Object section of [DPoE-OAM], with the exception that the LLID Object Type is replaced by the T-CONT Object Type.

8.1.3 T-CONT Object (0xD6/0x0006)

The T-CONT Object identifies one of the T-CONT instances on the D-ONU. T-CONTs are management level entities with unique numbering per D-ONU. T-CONT IDs are numbered sequentially from 0 up to T-1, where T is the maximum number of T-CONTs defined in section 9.1.2. The value 0 is reserved for the default T-CONT (i.e. reserved for the default Alloc-ID/GEM Port).

Table 10 - T-CONT Object

Width (Octets)	Field	Value (hex)
1	T-CONT Instance ID	0..T-1

9 OAM ATTRIBUTES BY FUNCTION

This section further details each DPoE OAM attribute. Attribute names are listed by their Branch/Leaf designation. For example, "Get Firmware Version (D7/80)," where the first number (D7) is the branch and the second number (80) is the leaf. These branch/leaf values are in hexadecimal format. Where applicable, units of measurement and allowed ranges are specified.

Some attributes, particularly capabilities, are read-only. These attributes are denoted by an "R" after their branch/leaf. Some writeable attributes are non-volatile, which is to say they persist after the D-ONU has been reset. These attributes are marked with an "NV".

9.1 D-ONU Management

Table 11 - DPoG D-ONU Management Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Device ID	0xD7/0x0002 R	D-ONU	MUST	[DPoE-OAM]
Firmware Info	0xD7/0x0003 R	D-ONU	MUST	[DPoE-OAM]
Chip Info	0xD7/0x0004 R	D-ONU	MUST	[DPoE-OAM]
Date of Manufacture	0xD7/0x0005 R	D-ONU	MUST	[DPoE-OAM]
Manufacturer Info	0xD7/0x0006 R	D-ONU	MUST	[DPoE-OAM]
Max EPON Logical Links	0xD7/0x0007 R	NA	MUST NOT	NA
Number of Network Ports	0xD7/0x0008 R	D-ONU	MUST	[DPoE-OAM]
Number of S1 Interfaces	0xD7/0x0009 R	D-ONU	MUST	[DPoE-OAM]
D-ONU Packet Buffer	0xD7/0x000A R	D-ONU	MUST	9.1.1
Report Thresholds	0xD7/0x000B R	NA	MUST NOT	NA
Logical Link Forwarding State	0xD7/0x000C R	T-CONT, Unicast Logical Link	MUST	[DPoE-OAM]
OAM Frame Rate	0xD7/0x000D	D-ONU	MUST	[DPoE-OAM]
ONU Manufacturer Organization Name	0xD7/0x000E	D-ONU	MUST	[DPoE-OAM]
Firmware Mfg Time Varying Controls	0xD7/0x000F NV	D-ONU	MUST	[DPoE-OAM]
D-ONU Port Type	0xD7/0x0010	D-ONU	MUST	[DPoE-OAM]
Vendor Name	0xD7/0x0011 R	D-ONU	MUST	[DPoE-OAM]
Model Number	0xD7/0x0012 R	D-ONU	MUST	[DPoE-OAM]
Hardware Version	0xD7/0x0013 R	D-ONU	MUST	[DPoE-OAM]
Reset	0xD9/0x0001	D-ONU	MUST	[DPoE-OAM]
Max T-CONTs	0xC7/0x0001 R	D-ONU	MUST	9.1.2
Max GEM Ports	0xC7/0x0002 R	D-ONU	MUST	9.1.3
DBA Report Encoding	0xC7/0x0003 R*	D-ONU	MUST	9.1.4
Traffic Scheduling Options	0xC7/0x0004 R	D-ONU	MUST	9.1.5

The following subsections describe attributes that are either new or modified for the DPoG specifications relative to the DPoE definitions.

9.1.1 D-ONU Packet Buffer (0xD7/0x000A) R

Objects: D-ONU

This message provides a means for the D-ONU to convey information about packet buffer capabilities to the DPoG System.

Table 12 - D-ONU Packet Buffer

Size	Name	Description
1	Upstream Queues	Total number of queues available to be assigned to T-CONTs in the upstream direction
1	Up Queues Max Per Link	Maximum number of queues that can be assigned to a single T-CONT in the upstream direction (will always be set to 1)
1	Up Queue Increment	The smallest increment of packet buffer memory that can be allocated in the upstream direction, in kilobytes
1	Downstream Queues	Total number of queues available to be assigned to UNI ports in the downstream direction
1	Dn Queues Max Per Port	Maximum number of queues that can be assigned to a single UNI port in the downstream direction
1	Dn Queue Increment	The smallest increment of packet buffer memory that can be allocated in the downstream direction, in kilobytes
2	Total Packet Buffer	Total packet buffer memory on the D-ONU, in kilobytes
2	Up Packet Buffer	Maximum amount of packet buffer memory that can be allocated to upstream queues
2	Dn Packet Buffer	Maximum amount of packet buffer memory that can be allocated to downstream queues

9.1.2 Max T-CONTs (0xC7/0x0001) R

Objects: D-ONU

The maximum number of T-CONTs the D-ONU supports. This number includes one T-CONT (T-CONT 0) for the default Alloc-ID used for the OMCC.

Table 13 - Max T-CONTs

Size	Name
1	Max Number of T-CONTs

9.1.3 Max GEM Ports (0xC7/0x0002) R

Objects: D-ONU

The maximum number of GEM ports the D-ONU supports. The Total GEM Ports count includes one GEM port for the OMCC.

Table 14 - Max GEM Ports

Size	Name	Description
2	Total GEM Ports	Maximum number of GEM Ports, inclusive of the multicast-capable GEM port count

9.1.4 DBA Report Encoding (0xC7/0x0003) R*

Objects: D-ONU

DBA Report Encoding is only used in [G.984] DPoG Networks.

DBA queue occupancy status report mode, Mode 0 or Mode 0+1, cannot be set by the DPoG System. It is a read-only attribute of the D-ONU. Queue occupancy status report resolution (i.e. GEM Block Length) can be set by the DPoG System on the D-ONU. This attribute specifies the queue occupancy reporting granularity for DBA, in units of bytes. The value is used for all T-CONTs on the D-ONU. The default value set on the D-ONU is 48.

In [G.987] there is only a single report mode, Mode 0, and the resolution is fixed at 4. As a result the DBA Report Encoding attribute is not used in [G.987] systems. See [G.984.3] clause 8.4.2 and [G.988] clause 9.2.1 for details.

Table 15 - DBA Report Encoding

Size	Description	Units	Default	Min	Max
1	Report Mode (* READ ONLY)		Mode 0	0 (Mode 0)	1 (Mode 0+1)
2	GEM Block length (multiplier for queue occupancy length encoding in DBA Report)	Bytes	48	1	0xFFFF

9.1.5 Traffic Scheduling Options (0xC7/0x0004) R

Objects: D-ONU

This attribute identifies the traffic scheduling options the D-ONU supports.

Table 16 - Traffic Scheduling Options

Size	Name	Description
1	Upstream	Bitmask of scheduling options (1: supported, 0: not supported)* Bit 0: Strict Priority (SP) Bit 1: Weighted Fair Queuing (WFQ) Bit 2: Two-level scheduling : SP + WFQ
1	Downstream	Same as above
* In this version of the DPoG specifications, the D-ONU MUST report “Strict Priority SP "support only in both upstream and downstream directions.		

9.2 Bridging

Table 17 - DPoG Bridging Management Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Dynamic Learning Table Size	0xD7/0x0101 R	D-ONU	MUST	[DPoE-OAM]
Dynamic Address Age Limit	0xD7/0x0102	D-ONU	MUST	[DPoE-OAM]
Dynamic MAC Table	0xD7/0x0103 R	User Port	MUST	[DPoE-OAM]
Static MAC Table	0xD7/0x0104 R	User Port	MUST	[DPoE-OAM]
S_1 Interface Port Auto-negotiation	0xD7/0x0105	Network Port, User Port	MUST	[DPoE-OAM]
Source Address Admission Control	0xD7/0x0106	User Port	MUST	[DPoE-OAM]
MAC Learning Min Guarantee	0xD7/0x0107	User Port	MUST	[DPoE-OAM]
MAC Learning Max Allowed	0xD7/0x0108	User Port	MUST	[DPoE-OAM]

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
MAC Learning Aggregate Limit	0xD7/0x0109	D-ONU	MUST	[DPoE-OAM]
Len Error Discard	0xD7/0x010A	User Port	MUST	[DPoE-OAM]
Flood Unknown	0xD7/0x010B	D-ONU	MUST	[DPoE-OAM]
Local Switching	0xD7/0x010C	User Port	MUST	[DPoE-OAM]
Firmware Filename	0xD7/0x010E NV	D-ONU	MUST	[DPoE-OAM]
MAC Table Full Behavior	0xD7/0x010F	User Port	MUST	[DPoE-OAM]
Clear Dynamic MAC Table	0xD9/0x0101	D-ONU, User Port	MUST	[DPoE-OAM]
Add Dynamic MAC Address	0xD9/0x0102	User Port	MUST	[DPoE-OAM]
Delete Dynamic MAC Address	0xD9/0x0103	User Port	MUST	[DPoE-OAM]
Clear Static MAC Table	0xD9/0x0104	D-ONU, User Port	MUST	[DPoE-OAM]
Add Static MAC Address	0xD9/0x0105	User Port	MUST	[DPoE-OAM]
Delete Static MAC Address	0xD9/0x0106	User Port	MUST	[DPoE-OAM]
LLID and Queue Configuration	0xD7/0x010D	NA	MUST NOT	NA
GPON Adaptation and Queue Configuration	0xC7/0x0101	D-ONU	MUST	9.2.1
GEM Port ID Configuration	0xC7/0x0102	D-ONU	MUST	9.2.2

The following subsections describe attributes that are new for the DPoG specifications.

9.2.1 GPON Adaptation and Queue Configuration (0xC7/0x0101)

Objects: D-ONU

This attribute can be used to get/set GPON adaptation and upstream/downstream queues for a given D-ONU. This attribute will span multiple Variable Containers (see Table 18).

The first Variable Container sent MUST be of a subtype Header. The Header Variable Container MUST be followed by a sequence of containers with subtype T-CONT (see Table 19), one for each T-CONT on the D-ONU. The sequence of T-CONT Variable Containers MUST be followed by a sequence of containers with subtype T-CONT Queue (see Table 21). The sequence of T-CONT Queue Variable Containers MUST be followed by a sequence of containers with subtype User Port (see Table 20); one for each user port on the D-ONU. The sequence of User Port Variable Containers MUST be followed by a sequence of containers with subtype User Port Queue (see Table 22). The sequence of Variable Containers MUST end with a container of subtype Terminator.

For Set operations, the DPoG System MUST send the entire configuration of the given D-ONU in a single message.

If the result of a Get response does not fit within a single OAM frame, the D-ONU MUST use the “Multiple Part OAM Response” mechanism defined in [DPoE-OAM].

A D-ONU can have one or more T-CONTs and each T-CONT has one or more queues. (Note that in this version of the DPoG specifications each T-CONT only uses one queue). T-CONT 0 is always associated with the OMCC and the default Alloc-ID; it is not configurable. For traffic in the downstream direction, each user port can have one or more queues.

The DPoG System sends this attribute to perform the following operations:

- Change the number of T-CONTs and User Ports to be registered, adding or subtracting T-CONTs as the network configuration requires.
- Configure T-CONT and User Port traffic scheduling policy. Valid values are:
  - 0: SP
  - 1: WFQ
  - 2: Two-level scheduling SP + WFQ (optional). When a T-CONT or user port works in SP + WFQ mode, multiple queues can be assigned to the same priority. Queues assigned to the same priority will be scheduled according to weights.
- Configure the T-CONT to PLOAM layer Alloc-ID mapping. For GPON systems the default Alloc-ID value is 0x00FF or 0xFFFF; for XG-PON systems the default Alloc-ID is 0xFFFF. The default Alloc-ID value indicates if the T-CONT is removed or not assigned.
- Configure upstream queues associated with each T-CONT, as well as the downstream queues on the D-ONU. The upstream queue holds frames destined for a given T-CONT. The downstream queues hold frames destined to user ports. Queues are numbered relative to their egress port. Queue numbers start with the value 0, up to the value N-1, where N is the number of queues that terminate on a port.

Both upstream and downstream queue configurations include:

- Queue priority: The range of priority is 0 to 0xFF. The value 0 is the highest priority and 0xFF is the lowest priority. The queue priority is meaningful only when the associated T-CONT or user port policy is set to SP or SP + WFQ.
- Queue weight: This represents weight for WFQ scheduling. This weight is meaningful if the associated T-CONT or user port policy is WFQ or SP + WFQ. The range of weight is 1 to 100. Default value is set to 1.
- Queue size: This is expressed in units of 1K bytes.

Upstream queue configuration also includes the following additional information:

- GEM Port ID value: A GEM Port ID value of 0xFFFF indicates the GEM port instance is removed or not assigned.

Table 18 - GPON Adaptation and Queue Configuration – Subtypes

Size	Name	Description
1	Subtype	Type of data in this Variable Container: 0: Terminator – Use to end a queue configuration container chain. 1: Header – Used to start a queue configuration container chain. 2: T-CONT – Used to define a T-CONT configuration. 3: User Port – Used to define a User Port configuration. 4: T-CONT Queue – Used to define a T-CONT queue configuration. 5: User Port Queue – Used to define a User Port queue configuration.
0	Header Subtype	
4	T-CONT Subtype	T-CONT configuration, T-CONT instance ID starting from 1
2	User Port Subtype	User port configuration, user port number starting from 0.
7	T-CONT Queue Subtype	Queue configuration for current T-CONT.
5	User Port Queue Subtype	Queue configuration for current user port.
0	Terminator Subtype	

Table 19 - GPON Adaptation and Queue Configuration – T-CONT Subtype Configuration

Size	Description	Units	Default	Min	Max*
1	T-CONT instance ID		-	1	T-1
1	Policy†	-	0	0	2
2	Alloc-ID	-	0x00FF or 0xFFFF (GPON) 0xFFFF (XG-PON)	0x0100(GPON) 0x0400 (XG-PON)	0x0FFF (GPON) 0x3FFF (XG-PON)
* For different D-ONUs with same type of services, the structure of this attribute will remain identical, except for the actual Alloc-ID values. The DPoG System MAY use a template to replace Alloc-ID values for each ONU. † In this version of the DPoG OAM specification, the DPoG System MUST only set the Policy value to 0 (SP).					

Table 20 - GPON Adaptation and Queue Configuration - User Port Subtype Configuration

Size	Description	Units	Default	Min	Max
1	User Port Number			0	N-1
1	Policy*	-	0	0	2
* In this version of DPoG OAM specification, the DPoG System MUST only set the Policy value to 0 (SP).					

Table 21 - GPON Adaptation and Queue Configuration - T-CONT Queue Subtype Configuration

Size	Description	Units	Default	Min	Max
1	Queue Number	-	-	0	Q-1*
1	Queue Priority	-	0	0	0xFF
1	Queue Weight*	-	1	1	100
2	Queue Size	1KB	-	0	0xFFFF
2	Queue GEM Port ID	-	0xFFFF	0	0..0x0FFF (GPON) 0..0xFFFE (XG-PON)
* In this version of DPoG OAM specification, the DPoG System MUST only set the Queue Weight value to 1.					

Table 22 - GPON Adaptation and Queue Configuration - User Port Queue Subtype Configuration

Size	Description	Units	Default	Min	Max*
1	Queue Number	-	0	0	Q-1*
1	Queue Priority	-	0	0	0xFF
1	Queue Weight†	-	1	1	100
2	Queue Size	1KB	-	0	0xFFFF
* The Maximum value is subject to available queues. † In this version of DPoG OAM specification, the DPoG System MUST only set the Queue Weight value to 1.					

The D-ONU MUST reject a GPON Adaptation and Queue Configuration message if any of the following are true:

- Changes queue numbers or sizes for any T-CONTs / queues that have port ingress rules that use those queues.
- Has a sum of queue sizes that exceeds the size reported in the Get D-ONU Information.
- Has a sum of T-CONTs that exceeds the size reported in the Get D-ONU Information.
- Has a sum of bi-directional GEM ports that exceeds the size reported in the Get D-ONU Information.
- Causes the same Alloc-ID value to be used in multiple T-CONT configurations.

- Causes the same GEM Port ID value to be used in multiple upstream queue configurations.
- Defines scheduling policies that the D-ONU does not support.
- Defines GEM Port ID values that are not configured by GEM Port ID Configuration Message.

The vCM MUST delete all port ingress rules that forward traffic to particular queues before those queues can be renumbered, deleted (including by removing their T-CONT), or resized.

9.2.2 Unicast GEM Port ID Configuration (0xC7/0x0102)

Objects: D-ONU

This attribute either creates or deletes one or multiple unicast GEM ports on a D-ONU (Set), or returns configured GEM ports from a D-ONU (Get). For the Get operation, the entire GEM Port ID configuration table will be represented as a large attribute, as defined in [DPoE-OAM].

Table 23 - GEM Port ID Configuration

Size		Description	Units	Default	Min	Max
2		G, the number of GEM ports to configure (the following fields are repeated this number of times)		-	1	G-1
1		Flags: 0x00: Delete/Deregister/Removed 0x01: Create/Register/Configured			0	1
G*5	2	Unicast GEM Port Instance Index Assigned by DPoG System, refer to Section 8.1.3. It is strongly recommended that GEM port instance indices are assigned sequentially in ascending order.			1	G-1
	2	GEM Port ID Assigned by DPoG System This field is meaningful only when the “Flags” field is set to “Create”	-	0xFFFF	0	0..0x0FFF (GPON) 0..0xFFFE (XG-PON)
	1	GEM Port Direction: - Upstream only (1) - Downstream only (2) - Bidirectional (3) This field is meaningful only when the “Flags” field is set to “Create”.	-	-	1	3
* For downstream-only broadcast and multicast GEM port configurations, the DPoG System MUST use the Multicast Registration message specified in Section 10. For a bi-directional GEM port, the DPoG Systems MUST ensure that the GEM port is created prior to its assignment in the GPON Adaptation and Queue Configuration attribute.						

The D-ONU MUST reject a GEM Port ID configuration message when a GEM port that is still used in GPON Adaptation and Queue Configuration attribute is deleted.

9.3 Statistics and Counters

Many counter attributes can be used with different object contexts to provide various granularities on the statistics. For example, a "frames transmitted" counter attribute might be applicable to queues or ports. A D-ONU MAY implement the coarser granularity counters by summing up all the finer-grained objects that feed into the coarser ones.

Table 24 - DPoG Statistics and Counters Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Rx Frames Green	0xD7/0x0201	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Tx Frames Green	0xD7/0x0202	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Rx Frame Too Short	0xD7/0x0203	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 64	0xD7/0x0204	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 65_127	0xD7/0x0205	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 128_255	0xD7/0x0206	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 256_511	0xD7/0x0207	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 512_1023	0xD7/0x0208	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 1024_1518	0xD7/0x0209	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frame 1519 Plus	0xD7/0x020A	Network Port, User Port	MAY	[DPoE-OAM]
Tx Frame 64	0xD7/0x020B	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 65_127	0xD7/0x020C	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 128_255	0xD7/0x020D	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 256_511	0xD7/0x020E	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 512_1023	0xD7/0x020F	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 1024_1518	0xD7/0x0210	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frame 1519 Plus	0xD7/0x0211	Network Port, User Port	MAY	[DPoE-OAM]
Queue Delay Threshold	0xD7/0x0212	Queue	MAY	[DPoE-OAM]
Queue Delay	0xD7/0x0213	Queue	MAY	[DPoE-OAM]
Frames Dropped	0xD7/0x0214	Queue	MUST	[DPoE-OAM]
Bytes Dropped	0xD7/0x0215	Queue	MAY	[DPoE-OAM]
Bytes Delayed	0xD7/0x0216	Queue	MAY	[DPoE-OAM]
Tx Bytes Unused	0xD7/0x0217	T-CONT	MAY	[DPoE-OAM]
Optical Mon Temperature	0xD7/0x021D	Network Port	MUST	[DPoE-OAM]
Optical Mon Vcc	0xD7/0x021E	Network Port	MUST	[DPoE-OAM]
Optical Mon Tx Bias Current	0xD7/0x021F	Network Port	MUST	[DPoE-OAM]
Optical Mon Tx Power	0xD7/0x0220	Network Port	MUST	[DPoE-OAM]
Optical Mon Rx Power	0xD7/0x0221	Network Port	MUST	[DPoE-OAM]
Rx Frames Yellow	0xD7/0x0222	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Tx Frames Yellow	0xD7/0x0223	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Tx Bytes Green	0xD7/0x0224	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Rx Bytes Yellow	0xD7/0x0225	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Rx Bytes Green	0xD7/0x0226	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Tx Bytes Yellow	0xD7/0x0227	Network Port, User Port, Unicast Logical Link, T-CONT, Queue	MAY	[DPoE-OAM]
Tx Frames Unicast	0xD7/0x0228	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frames Multicast	0xD7/0x0229	Network Port, User Port	MUST	[DPoE-OAM]
Tx Frames Broadcast	0xD7/0x022A	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frames Unicast	0xD7/0x022B	Network Port, User Port	MUST	[DPoE-OAM]

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Rx Frames Multicast	0xD7/0x022C	Network Port, User Port	MUST	[DPoE-OAM]
Rx Frames Broadcast	0xD7/0x022D	Network Port, User Port	MUST	[DPoE-OAM]
Number of Programmable Counters	0xD7/0x022E R	D-ONU	MUST	[DPoE-OAM]
L2CP Frames Rx	0xD7/0x022F	Network Port, User Port	MAY	[DPoE-OAM]
L2CP Octets Rx	0xD7/0x0230	Network Port, User Port	MAY	[DPoE-OAM]
L2CP Frames Tx	0xD7/0x0231	Network Port, User Port	MAY	[DPoE-OAM]
L2CP Octets Tx	0xD7/0x0232	Network Port, User Port	MAY	[DPoE-OAM]
L2CP Frames Discarded	0xD7/0x0233	Network Port, User Port	MAY	[DPoE-OAM]
L2CP Octets Discarded	0xD7/0x0234	Network Port, User Port	MAY	[DPoE-OAM]
Tx L2 Errors	0xD7/0x0235	Network Port, User Port	MUST	[DPoE-OAM]
Rx L2 Errors	0xD7/0x0236	Network Port, User Port	MUST	[DPoE-OAM]
Clear Counters	0xD9/0x0201	D-ONU	MUST	[DPoE-OAM]
Programmable Frame/Byte Counter	0xD8/0xnnnn	D-ONU	MUST	[DPoE-OAM]

9.4 Alarms

An alarm is indicated by the D-ONU to the DPoG System using a DPoE Event Notification TLV, defined in in [802.3], Clause 57 Event Notification OAMPDU.

Table 25 - DPoG Alarms Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Port Stat Threshold	0xD7/0x0301	Network Port, User Port	MUST	[DPoE-OAM]
Link Stat Threshold	0xD7/0x0302	T-CONT, Unicast Logical Link	MUST	[DPoE-OAM]
Suspend/Resume Alarm Reporting	0xD7/0x0303	D-ONU, User Port, PON Port, Queue, T-CONT, Unicast Logical Link	MUST	[DPoE-OAM]
Retrieve Current Alarm Summary	0xD9/0x0301	D-ONU	MUST	[DPoE-OAM]

9.5 Security

Security attributes control encryption on the PON. Details of encryption methods and their use can be found in [DPoG-SEC].

Table 26 - Security Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Encryption Key Expiry Time	0xD7/0x0401	NA	MUST NOT	NA
Encryption Mode	0xD7/0x0402	NA	MUST NOT	NA
Encryption State	0xC7/0x0401 R	Unicast Logical Link	MUST	9.5.1
Encryption Key Ring	0xC7/0x0402	Unicast Logical Link	MUST	9.5.2

The following subsections describe attributes that are new for DPoG relative to the DPoE definitions.

9.5.1 Encryption State (0xC7/0x0401) R

Objects: GEM Port

This attribute indicates the current state of GEM port encryption. Note: Encryption is controlled via the PLOAM layer.

Table 27 - Encryption State

Size	Description	Units	Default	Min	Max
1	Encryption State 0: Unencrypted 1: Encrypted	Enum	0	0	1

9.5.2 Encryption Key Ring (0xC7/0x0402)

Objects: GEM Port

This attribute sets the encryption method to be used on a particular GEM Port. This attribute is only used by XG-PON ([G.987]) systems.

Table 28 - Encryption Key Ring

Size	Description	Units	Default	Min	Max
1	Encryption Method 0: None 1: Unicast payload encryption in both directions. Keys are generated by the D-ONU and transmitted to the OLT via the PLOAM channel. 2: Broadcast (multicast) encryption. Keys are generated by the OLT and distributed via OAM 3: Unicast encryption, downstream only. Keys are generated by the D-ONU and transmitted to the OLT via the PLOAM channel.	Enum	0	0	3

9.6 Frame Processing

Table 29 - DPoG Frame Processing Rule Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Port Ingress Rule	0xD7/0x0501	Network Port, User Port	MUST	9.6.1
Custom Field	0xD7/0x0502	Network Port, User Port	MAY	9.6.2
C-VLAN TPID	0xD7/0x0503	Network Port, User Port	MAY	[DPoE-OAM]
S-VLAN TPID	0xD7/0x0504	Network Port, User Port	MAY	[DPoE-OAM]
IPMC Forwarding Rule Configuration	0xD7/0x0505	D-ONU	MUST	9.6.3
I-TPID	0xD7/0x0506	Network Port, User Port	MAY	[DPoE-OAM]
B-TPID	0xD7/0x0507	Network Port, User Port	MAY	[DPoE-OAM]
Clear Port Ingress Rules	0xD9/0x0501	Network Port, User Port	MUST	[DPoE-OAM]
Add Port Ingress Rule	0xD9/0x0502	Network Port, User Port	MUST	[DPoE-OAM]
Delete Port Ingress Rule	0xD9/0x0503	Network Port, User Port	MUST	[DPoE-OAM]

The following subsections describe attributes that are modified for DPoG relative to the DPoE definitions.

9.6.1 Port Ingress Rule (0xD7/0x0501)

Objects: Network Port, User Port

This attribute represents a rule in the ingress table of the current port.

The DPoG System MUST support the requirements specified for DPoE Systems in the Port Ingress Rule section of [DPoE-OAM], except as noted here.

A DPoG D-ONU MUST support the requirements specified for DPoE D-ONUs in the Port Ingress Rule section of [DPoE-OAM], except as noted here.

9.6.1.1 Rule Attribute – Clause Subtype

Rule clauses define the conditions that, when they evaluate to true for the rule, match a frame.

Table 30 - Field Codes

Value (hex)	Description	Multiple?	Requirement	Reference
0x00	LLID Index	N	MUST NOT	NA
0x01	L2 Destination MAC address	N	MUST	[DPoE-OAM]
0x02	L2 Source MAC address	N	MUST	[DPoE-OAM]
0x03	L2 Type/Len	N	MUST	[DPoE-OAM]
0x04	B-DA ([802.1ah])	N	MUST	[DPoE-OAM]
0x05	B-SA ([802.1ah])	N	MUST	[DPoE-OAM]
0x06	I-Tag ([802.1ah])	N	MUST	[DPoE-OAM]
0x07	S-VLAN Tag	Y	MUST	[DPoE-OAM]
0x08	C-VLAN Tag	Y	MUST	[DPoE-OAM]
0x09	MPLS Label Stacking Entry (LSE)	Y	MUST	[DPoE-OAM]
0x0A	IPv4 TOS/IPv6 Traffic Class	N	MUST	[DPoE-OAM]
0x0B	IPv4 TTL/IPv6 Hop Limit	N	MUST	[DPoE-OAM]
0x0C	IPv4/IPv6 Protocol Type *	N	MUST	[DPoE-OAM]
0x0D	IPv4 Source Address	N	MUST	[DPoE-OAM]
0x0E	IPv6 Source Address	N	MUST	[DPoE-OAM]
0x0F	IPv4 Destination Address	N	MUST	[DPoE-OAM]
0x10	IPv6 Destination Address	N	MUST	[DPoE-OAM]
0x11	IPv6 Next Header	Y†	MUST	[DPoE-OAM]
0x12	IPv6 Flow Label	N	MUST	[DPoE-OAM]
0x13	TCP/UDP source port	N	MUST	[DPoE-OAM]
0x14	TCP/UDP destination port	N	MUST	[DPoE-OAM]
0x15	B-Tag ([802.1ah])	N	MUST	[DPoE-OAM]
0x16	Reserved	-	-	NA
0x17	Reserved	-	-	NA
0x18	Custom field 0	N	MUST	[DPoE-OAM]
0x19	Custom field 1	N	MUST	[DPoE-OAM]
0x1A	Custom field 2	N	MUST	[DPoE-OAM]
0x1B	Custom field 3	N	MUST	[DPoE-OAM]
0x1C	Custom field 4	N	MUST	[DPoE-OAM]
0x1D	Custom field 5	N	MUST	[DPoE-OAM]
0x1E	Custom field 6	N	MUST	[DPoE-OAM]
0x1F	Custom field 7	N	MUST	[DPoE-OAM]

Value (hex)	Description	Multiple?	Requirement	Reference
0x20	GEM Port Instance Index	N	MUST	9.6.1.1.1
* IPv6 Protocol Type represents the Next Header field of the last extension header in the chain, which might contain any number of optional extension headers. † IPv6 extension headers are instanced in the sense that there can be a variable number of them. However, they are not ordered in a frame. The instance number for this field is not the usual 0..N-1th instance of an instanced field, but is instead the Next Header value for that header type assigned by the IANA.				

The following subsection describes an attribute that is new for DPoG relative to the DPoE definitions.

9.6.1.1.1 GEM Port Instance Index (0x20)

This rule clause requires the GEM Port ID in the GEM header to match the GEM Port ID value associated with the GEM Port Instance Index (refer to section 9.2.2) specified for the rule to match the frame.

9.6.2 Custom Field (0xD7/0x0502)

Objects: Network Port, User Port

This attribute represents the fields parsed from each frame that are used in frame processing rules to filter or classify the frames.

The DPoG System MUST support the requirements specified for DPoE Systems in the Custom Field section of [DPoE-OAM], except as noted here.

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the Custom Field section of [DPoE-OAM], except as noted here.

Table 31 - Custom Field Layer Values

Layer Value	Name	Description
0x0	GEM Header/L2	GEM Port ID, DA, SA, SNAP headers (if present)
0x1	GEM Header/[802.1ah]	GEM Port ID, B-DA, B-SA, I-Tag
0x2	EtherType	L2 protocol type of remainder of the frame
0x3	S-VLAN Tags	All S-VLAN tags in the frame
0x4	C-VLAN Tags	All C-VLAN tags in the frame
0x5	MPLS LSEs	MPLS LSEs, if any, in the frame
0x6	IPv4	Frames with EtherType 0800
0x7	IPv6	Frames with EtherType 86DD
0x8	Generic L3	Payload of a frame that is not IPv4 or IPv6, according to the EtherType
0x9	TCP/UDP	IPv4 or IPv6 frames containing UDP or TCP (according to the IP protocol type field)
0xA	Generic L4	Payload of IP frames that is not TCP or UDP

9.6.2.1 GEM Header/L2 Header

The GEM Header/L2 Header layer consists of the GEM frame header and L2 Ethernet header fields of the received frame. This layer also contains the SNAP headers if they are present. Figure 4 shows the offsets within this layer when the frame is encapsulated in [G.984] GEM format and does not have SNAP encapsulation. Figure 5 shows the offsets when the frame is encapsulated in [G.987] XGEM format and does not have SNAP encapsulation.

Note: GEM header fields are only applicable to/useful in downstream rules.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI												GEM Port ID												PTI			HEC				
HEC								L2 DA [47:24]																							
L2 DA [23:0]																								L2 SA [47:40]							
L2 SA [39:8]																															
L2 SA [7:0]								L2 Type Field [15:0]																Start of Datagram…							

Figure 4 - GEM Header ([G.984])/L2 without SNAP

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI														KI		XGEM Port ID															
Options																			LF	HEC											
L2 DA [47:16]																															
L2 DA [15:0]																L2 SA [47:32]															
L2 SA [31:0]																															
L2 Type Field [15:0]																Start of Datagram…															

Figure 5 - GEM Header ([G.987])/L2 without SNAP

Figure 6 and Figure 7 show the offsets into this layer when the frames have SNAP encapsulation.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI												GEM Port ID												PTI			HEC				
HEC								L2 DA [47:24]																							
L2 DA [23:0]																								L2 SA [47:40]							
L2 SA [39:8]																															
L2 SA [7:0]								L2 Length Field [15:0]																DSAP [7:0]							
SSAP [7:0]								CTL [7:0]								OUI [23:8]															
OUI [7:0]								L2 Type Field [15:0]																Start of Datagram…							

Figure 6 - GEM Header ([G.984])/L2 with SNAP

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI																KI		XGEM Port ID													
Options																						LF	HEC								
L2 DA [47:16]																															
L2 DA [15:0]																L2 SA [47:32]															
L2 SA [31:0]																															
L2 Length Field [15:0]																DSAP [7:0]								SSAP [7:0]						
CTL [7:0]								OUI [23:0]																							
L2 Type Field [15:0]																Start of Datagram…															

Figure 7 – GEM Header ([G.987])/L2 with SNAP

9.6.2.2 GEM Header [802.1ah]

The [802.1ah] layer consists of the [802.1ah] "MAC-in-MAC" encapsulation header, including the B-DA, B-SA, and I-Tag fields. This layer exists only in [802.1ah] encapsulated frames, as determined by the presence of the I-Tag (a TPID value of 0x88E7 immediately following the SA). Figure 8 shows the offsets within this layer when the frame is encapsulated in [G.984] GEM format. Figure 9 shows the offsets when the frame is encapsulated in [G.987] XGEM format.

NOTE: GEM header fields are only applicable to/useful in downstream rules.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI												GEM Port ID												PTI			HEC				
HEC								B-DA [47:24]																							
B-DA [23:0]																								B-SA [47:40]							
B-SA [39:8]																															
B-SA [7:0]								I-Tag TPID [15:0]																Reserved (Always 0)							
I-SID [23:0]																								Start of Datagram…							

Figure 8 - GEM Header ([G.984])/Layer

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PLI																KI		XGEM Port ID													
Options																						LF	HEC								
B-DA [47:16]																															
B-DA [15:0]																B-SA [47:32]															
B-SA [31:0]																															
I-Tag TPID [15:0]																Reserved (Always 0)								I-SID [23:16]						
I-SID [15:0]																Start of Datagram…															

Figure 9 - GEM Header ([G.987])/ Layer

9.6.3 IPMC Forwarding Rule Configuration (0xD7/0x0505)

Objects: D-ONU

The DPoG System MUST support the requirements specified for DPoE Systems in the IPMC Forwarding Rule Configuration section of [DPoE-OAM] except that Bit 0 corresponds to GEM Port ID rather than LLID.

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the IPMC Forwarding Rule Configuration section of [DPoE-OAM], except that Bit 0 corresponds to GEM Port ID rather than LLID.

9.7 Service Level Agreements

Table 32 - DPoG Service Level Agreements Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Broadcast Rate Limit	0xD7/0x0601	User Port	MUST	[DPoE-OAM]
Queue Committed Information Rate	0xD7/0x0604	Queue	MAY	[DPoE-OAM]
FEC Mode	0xD7/0x0605	NA	MUST NOT	NA
Queue Excess Information Rate	0xD7/0x0606	Queue	MAY	[DPoE-OAM]
Queue Color Marking	0xD7/0x0607	Queue	MAY	[DPoE-OAM]
Queue Rate Limiter Capabilities	0xD7/0x0608 R	D-ONU	MAY	[DPoE-OAM]
Coupling Flag	0xD7/0x0609	Queue	MAY	[DPoE-OAM]
Enable User Traffic	0xD9/0x0601	D-ONU, GEM Port, T-CONT	MUST	[DPoE-OAM]
Disable User Traffic	0xD9/0x0602	D-ONU, GEM Port, T-CONT	MUST	[DPoE-OAM]
Loopback Enable	0xD9/0x0603	GEM Port, User Port	MUST	[DPoE-OAM]
Loopback Disable	0xD9/0x0604	GEM Port, User Port	MUST	[DPoE-OAM]
Laser Tx Power Off	0xD9/0x0605	Network Port	MUST	[DPoE-OAM]

9.8 Clock Transport

Table 33 - Clock Transport Attributes

Attribute Name	Branch/Leaf	Object Context	Requirement	Reference
Clock Transport Capabilities	0xD7/0x0701 R	User Port	MUST	[DPoE-OAM]
Enable Clock Transport	0xD7/0x0702	User Port	MUST	[DPoE-OAM]
Time Transfer	0xD7/0x0703	NA	MUST NOT	NA
Propagation Parameters	0xD7/0x0704	NA	MUST NOT	NA
RTT	0xD7/0x0705	NA	MUST NOT	NA
Time of Day	0xC7/0x0701	D-ONU	MUST	9.8.1

The following subsection describes an attributes that is new DPoG relative to the DPoE definitions.

9.8.1 Time of Day (0xC7/0x0701)

Objects: D-ONU

This attribute provides the information required to achieve time of day synchronization between a reference clock at the OLT and a local clock at the D-ONU. See [G.988] clause 9.12.2, [G.984.3] clause 10.4.6, and [G.987.3] clause 13.2 for details. This attribute is comprised of two fields:

- GEM superframe sequence number (SFC).
- TstampN, which represents a positive time with respect to the epoch, using the timestamp format of [1588v2], clause 5.3.3. The value 0 in all bytes is reserved as a null value.

Table 34 - Time of Day

Size	Description	Units	Default	Min	Max
4	SFC		-	0	0xFFFF FFFF
10	TstampN	-	-	-	-

9.9 DEMARC Automatic Configuration

This section contains attributes to support DEMARC devices subtended from a D-ONU.

The DPoG System MAY support the requirements specified for DPoE Systems in the DEMARC Automatic Configuration section of [DPoE-OAM].

DPoG D-ONUs MAY support the requirements specified for DPoE D-ONUs in the DEMARC Automatic Configuration section of [DPoE-OAM].

10 MULTICAST REGISTRATION

The DPoG System MUST support the requirements specified for DPoE Systems in the Multicast LLID Registration section of [DPoE-OAM], except that the two-byte LLID field is replaced with a two-byte Multicast GEM Port ID field.

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the Multicast LLID Registration section of [DPoE-OAM], except that the two-byte Logical Link field is replaced with a two-byte Multicast GEM Port ID field.

11 SECURITY

The [DPoG-SEC] specification details encryption, key exchange, authentication, and other requirements related to security and authentication.

11.1 Key Exchange

XG-PON ([G.987]) systems can support multicast/broadcast GEM port encryption. Unlike unicast encryption, the key exchange takes place over OAM rather than PLOAM. The Key Exchange PDU begins with a subtype code to distinguish PDU types used in the key exchange protocol.

The Key Assignment PDU is used to transmit a key value to the D-ONU for use in the broadcast/multicast key ring. The Key Assignment PDU is as specified in the Security section of [DPoE-OAM], except that the DPoG System MUST replace the two-byte LLID field with a two-byte GEM Port field.

The Key Assignment Acknowledgement PDU is as specified in the Security section of [DPoE-OAM], except that the D-ONU MUST replace the two-byte LLID field with a two-byte GEM Port field.

12 FILE TRANSFER

DPoE extensions enable D-ONUs to download new firmware upgrades and other files from the DPoG System using a simple file transfer protocol.

The DPoG System MUST support the requirements specified for DPoE Systems in the File Transfer section of [DPoE-OAM].

DPoG D-ONUs MUST support the requirements specified for DPoE D-ONUs in the File Transfer section of [DPoE-OAM].

Appendix I D-ONU Initialization and Configuration (Informative)

The diagram below illustrates the initialization and configuration sequence for a D-ONU, covering discovery, establishment of the OAM channel, and configuration of the first of potentially many GEM ports to carry user data traffic. It is merely an informative example, and is specific to [G.984]. Initialization in [G.987] differs somewhat in the D-ONU Discovery and OAM Channel Configuration steps. Normative requirements appear in [DPoG-MULPI].

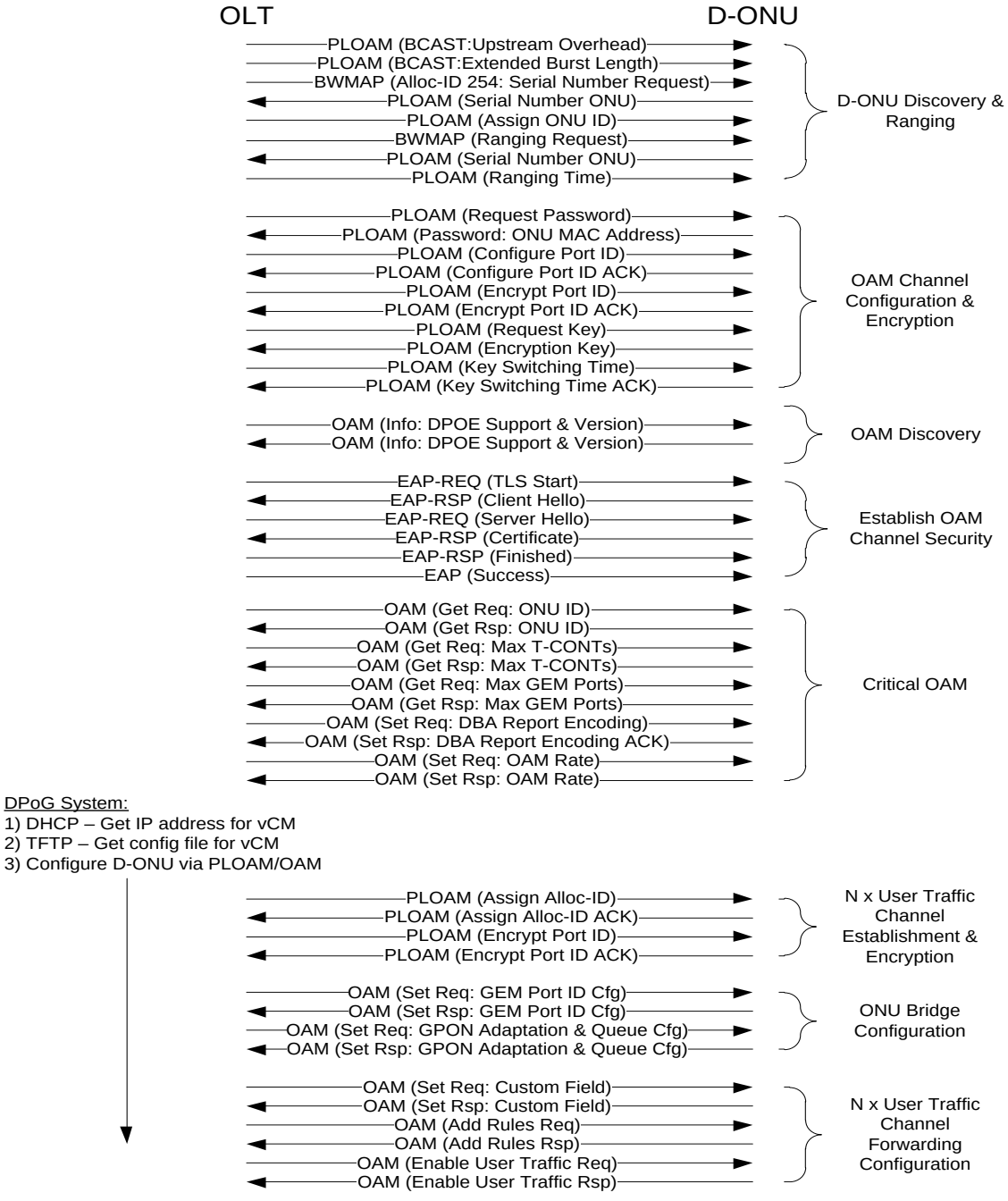

Figure 10 - ONU Initialization and Configuration

I.1 D-ONU Discovery and Ranging

Initial detection and ranging of a D-ONU occurs under PLOAM control as specified in [G.984.3]. The ONU Serial Number is retrieved by the OLT from the D-ONU, and a Transmission Convergence Layer ONU ID is assigned. The MAC address of the D-ONU is obtained by the OLT via PLOAM as well.

I.2 OAM Channel Configuration and Encryption

The D-ONU OAM channel is configured to a GEM port and OAM traffic is encrypted under PLOAM control as specified in [G.984.3]. In standard Telco GPON, this OAM channel is the OMCI channel. For DPoG GPON, the OAM channel is [802.3] Ethernet OAM, as extended by [DPoE-OAM] and DPoG OAM.

I.3 OAM Discovery

Per [802.3], Clause 57, OAM Discovery occurs immediately after registration. DPoG Systems and D-ONUs support DPoG OAM extensions. Support for these extensions is indicated by including a DPoG Info TLV in each Info PDU during discovery. As the active device, the DPoG System always transmits the first OAM PDU. The D-ONU begins transmitting its own Info PDUs once it receives a PDU from the DPoG System. Note that the ONU PDU is not strictly a response to the DPoG System; these PDUs are sent based on a local timer, but that timer does not start until the first PDU arrives from the DPoG System.

The state machine in [802.3], Clause 57 requires two PDUs from each side to progress to the in-service state. It would be unusual for more than two PDUs to be required, as there is not a lot of negotiation to be carried out in this step.

I.4 Establish OAM Channel Security

EAP-TLS mechanisms are used between the DPoG System and D-ONU to authenticate the OAM channel.

I.5 Critical OAM

A few items are considered to be Critical OAM required for basic processing of a D-ONU in a DPoG Network. These items include maximum numbers of T-CONTs and GEM ports supported by the D-ONU and the establishment of an agreed upon OAM PDU transmission rate. For [G.984] the queue status reporting mode is read from the D-ONU and the queue status report resolution is set by the OLT if a non-default value is required. Failure to complete the Critical OAM phase results in a D-ONU being deregistered and not being allowed access to the PON.

At this point the OAM channel is operational. GPON allows but recommends against user traffic being carried on the OAM channel. The DPoG specifications do not permit user traffic on the OAM channel.

I.6 D-ONU Configuration

Before proceeding further, the DPoG System would need to have downloaded via TFTP a CM Configuration File for the vCM associated with the D-ONU. The DPoG System would use this configuration information to determine the appropriate number and properties of user traffic channels on the D-ONU.

I.7 User Traffic Channel Establishment and Encryption

D-ONU user traffic channels are assigned Alloc-IDs and GEM ports. The Alloc-ID is used by the DPoG System to identify upstream transmission opportunities to the D-ONU. There can be multiple GEM ports sharing a given Alloc-ID.

User traffic is encrypted under PLOAM control as specified in [G.984.3].

I.8 ONU Bridge Configuration

The DPoG System consults its database and configures the D-ONU as required to support the services authorized for this user. Commands would be sent to the D-ONU to establish the basic bridging configurations for each Alloc-ID, queue and GEM port on the device.

I.9 User Traffic Channel Forwarding Rules Configuration

The DPoG System sends commands to the D-ONU to establish traffic classification and forwarding rules. User traffic is then enabled per configured GEM port.

Appendix II ONU Bridge Configuration Examples (Informative)

This appendix illustrates the format and usage of GPON Adaptation and Queue Configuration for service configuration. In this version of the DPoG OAM specification, each T-CONT only uses one GEM port and one queue. In order to illustrate that the message definition is flexible, the given examples use multiple T-CONTs, and each T-CONT has one or multiple GEM ports.

The following table illustrates the variable container sequences in a GPON Adaptation and Queue Configuration Set message.

Description	OAM PDU Content
	+ DPoE PDU OpCode.....03 (Set)
Object Context TLV	+ TLV Branch.....d6 (Object Context) Leaf.....00 00 (D-ONU) Width.....02 Value.....00 00 (**D-ONU instance**)
Subtype: Header	+ TLV Branch.....c7 Leaf.....01 01 Width.....01 Value.....01 (Header)
Subtype: T-CONT (T-CONT 1) Policy=0(SP) ALLOC-ID=257	+ TLV Branch.....c7 Leaf.....01 01 Width.....05 Value.....02 01 00 01 01
Subtype: T-CONT Queue One or more T-CONT queues	+ TLV Branch.....c7 Leaf.....01 01 Width.....08 Value.....04 00 00 01 00 0A 01 42 (Queue 0)
Subtype: T-CONT (T-CONT 2) Policy=0 (SP) ALLOC-ID=258	+ TLV Branch.....c7 Leaf.....01 01 Width.....05 Value.....02 02 00 01 02
Subtype: T-CONT Queue One or more T-CONT queues	+ TLV Branch.....c7 Leaf.....01 01 Width.....08 Value.....04 00 00 01 00 0A 01 42 (Queue 0) + TLV Branch.....c7 Leaf.....01 01 Width.....08 Value.....04 01 01 01 00 14 01 43 (Queue 1)
…	…
Subtype: User Port (User Port 0)	…
Subtype: User Port Queues One or more User Port queues	…
Subtype: User Port (User Port 1)	…
Subtype: User Port Queues One or more User Port queues	…

Description	OAM PDU Content
…	…
Subtype: Terminator	+ TLV Branch......c7 Leaf........01 01 Width.......01 Value.......00
Null terminated Variable container	+ TLV Branch......00 (Branch null (terminator)) Leaf........00 00 (Leaf null (terminator))

II.1 Example 1

DPoG System configures three services on D-ONU:

- Service A uses one T-CONT and one GEM port; Service B uses one T-CONT with two GEM ports; Service C uses one T-CONT with four GEM ports.
- T-CONT scheduling policy is set to Strict Priority.
- GEM ports 321, 323 and 326 are encrypted.
- The GEM port is used for downstream classification.

The contents of a GPON Adaptation and Queue Configuration attribute will be:

T-CONT 1 configuration:

Size	Description	Value
1	T-CONT instance ID	1
1	Policy	0
2	Alloc-ID	257

T-CONT 1 queue configuration:

Size	Description	Value
1	Queue Number	0
1	Queue Priority	0
1	Queue Weight	1
2	Queue Size	10
2	Queue GEM Port ID	321

T-CONT 2 configuration:

Size	Description	Value
1	T-CONT instance ID	2
1	Policy	0
2	Alloc-ID	258

T-CONT 2 queue configuration:

Size	Description	Value
1	Queue Number	0
1	Queue Priority	0
1	Queue Weight	1
2	Queue Size	10

Size	Description	Value
2	Queue GEM Port ID	322
1	Queue Number	1
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	323

T-CONT 3 configuration:

Size	Description	Value
1	T-CONT instance ID	3
1	Policy	0
2	Alloc-ID	259

T-CONT 3 queue configuration:

Size	Description	Value
1	Queue Number	0
1	Queue Priority	7
1	Queue Weight	1
2	Queue Size	10
2	Queue GEM Port ID	324
1	Queue Number	1
1	Queue Priority	4
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	325
1	Queue Number	2
1	Queue Priority	2
1	Queue Weight	1
2	Queue Size	5
2	Queue GEM Port ID	326
1	Queue Number	3
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	327

D-ONU T-CONT table:

T-CONT Instance ID	1	2	3					
Alloc-ID	257	258	259					

D-ONU GEM Ports table:

GEM Port Instance Index	1	2	3	4	5	6	7	
GEM Port ID	321	322	323	324	325	326	327	
Encryption State	1	0	1	0	0	1	0	

D-ONU Port Ingress Rules:

Flow	1	2	3	4	5	6	7	
US Rule Result Queue (instance. number)	(1.0)	(2.0)	(2.1)	(3.0)	(3.1)	(3.2)	(3.3)	
DS Rule Clause (GEM Port Instance Index)	1	2	3	4	5	6	7	

NOTE: Downstream configuration is skipped in the example.

II.2 Example 2

Continue with example 1: DPoG System deletes Service A and the fourth flow in Service C from the D-ONU.

The contents of a GPON Adaptation and Queue Configuration attribute will be:

T-CONT 2 configuration:

Size	Description	Value
1	T-CONT instance ID	2
1	Policy	0
2	Alloc-ID	258

T-CONT 2 queue configuration:

Size	Description	Value
1	Queue Number	0
1	Queue Priority	0
1	Queue Weight	1
2	Queue Size	10
2	Queue GEM Port ID	322
1	Queue Number	1
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	323

T-CONT 3 configuration:

Size	Description	Value
1	T-CONT instance ID	3
1	Policy	0
2	Alloc-ID	259

T-CONT 3 queue configuration:

Size	Description	Value
1	Queue Number	1
1	Queue Priority	4
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	325
1	Queue Number	2
1	Queue Priority	2
1	Queue Weight	1
2	Queue Size	5
2	Queue GEM Port ID	326
1	Queue Number	3
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	327

D-ONU T-CONT table:

T-CONT Instance ID	1	2	3					
Alloc-ID	0xFFFF	258	259					

D-ONU GEM Port table:

GEM Port Instance Index	1	2	3	4	5	6	7	
GEM Port ID	0xFFFF	322	323	0xFFFF	325	326	327	
Encryption State	0	0	1	0	0	1	0	

D-ONU Port Ingress Rules:

Flow	1	2	3	4	5	6	7	
US Rule Result Queue (instance. number)		(2.0)	(2.1)		(3.1)	(3.2)	(3.3)	
DS Rule Clause (GEM Port Instance Index)		2	3		5	6	7	

NOTE: Downstream configuration is skipped in the example.

II.3 Example 3:

Continue with example 2: DPoG System adds one queue to T-CONT 2 and creates a new GEM Port for T-CONT 2.

The contents of a GPON Adaptation and Queue Configuration attribute will be:

T-CONT 2 configuration:

Size	Description	Value
1	T-CONT instance ID	2
1	Policy	0
2	Alloc-ID	258

T-CONT 2 queue configuration:

Size	Description	Value
1	Queue Number	0
1	Queue Priority	0
1	Queue Weight	1
2	Queue Size	10
2	Queue GEM Port ID	322
1	Queue Number	1
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	323
1	Queue Number	2
1	Queue Priority	2
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	328

T-CONT 3 configuration:

Size	Description	Value
1	T-CONT instance ID	3
1	Policy	0
2	Alloc-ID	259

T-CONT 3 queue configuration:

Size	Description	Value
1	Queue Number	1
1	Queue Priority	4
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	325
1	Queue Number	2
1	Queue Priority	2

Size	Description	Value
1	Queue Weight	1
2	Queue Size	5
2	Queue GEM Port ID	326
1	Queue Number	3
1	Queue Priority	1
1	Queue Weight	1
2	Queue Size	20
2	Queue GEM Port ID	327

D-ONU T-CONT table:

T-CONT Instance ID	1	2	3					
Alloc-ID	0xFFFF	258	259					

D-ONU GEM Port table:

GEM Port Instance Index	1	2	3	4	5	6	7	
GEM Port ID	328	322	323	0xFFFF	325	326	327	
Encryption State	0	0	1	0	0	1	0	

D-ONU Port Ingress Rules:

Flow		2	3	4	5	6	7	8
US Rule Result Queue (instance. number)		(2.0)	(2.1)		(3.1)	(3.2)	(3.3)	(2.2)
DS Rule Clause (GEM Port Instance Index)		2	3		5	6	7	8

NOTE: Downstream configuration is skipped in the example.

Appendix III Acknowledgements

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