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Cable Data Services
DOCSIS® Provisioning of EPON Specifications

DPoE™ OAM Extensions Specification

DPoE-SP-OAMv1.0-I02-120607

ISSUED

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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.
Draft	A document in specification format considered largely complete, but lacking review by Members and vendors. Drafts are susceptible to substantial change during the review process.
Issued	A stable document, which has undergone rigorous member and vendor review and is suitable for product design and development, cross-vendor interoperability, and for certification testing.
Closed	A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs.

Trademarks

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1 INTRODUCTION

Comcast Corporation, Time Warner Cable, and Bright House Networks collaborated to develop the interoperability requirements to support business services products using Ethernet Passive Optical Network (EPON) as an access technology.

DOCSIS Provisioning of EPON (DPoE) is a joint effort of operators, vendors, and suppliers to support EPON technology using existing DOCSIS-based back office systems and processes.

Ethernet PON or EPON is an [802.3] standard for a passive optical network (PON). A PON is a specific type of multi-access optical network. A multi-access optical network is an optical fiber based network technology that permits more than two network elements to transmit and receive on the same fiber. Appendix I in [DPoE-SP-ARCHv1.0] has a more detailed explanation of multi-access optical networks.

This version of the DPoE specifications is focused on DOCSIS-based provisioning and operations of Internet Protocol (IP) using DOCSIS High Speed Data (HSD), or IP(HSD) for short, and Metro Ethernet Forum (MEF) services. DPoE Networks offer IP(HSD) services functionally equivalent to DOCSIS networks, where the DPoE System acts like a DOCSIS CMTS and the DPoE System and DPoE Optical Network Unit (ONU) to appear to act like a DOCSIS CM.

1.1 DPoE Technology Introduction

DPoE technology was established with the following common requirements already developed by operators. Each of the participant operators had previously selected 1G-EPON and 10G-EPON as the appropriate technology for one or more applications. EPON is a widely-deployed technology with a sufficient and large supply of vendors offering a variety of products for each component of the access network. 10G-EPON technology is now becoming available and is backwards compatible with 1G-EPON. A 1G-EPON network can be incrementally upgraded to 10G-EPON, adding or replacing ONUs one at a time if required. 1G-EPON and 10G-EPON are compatible with [SCTE 174 (RFoG).

The EPON protocol [802.3ah] and the amendment for 10G-EPON [802.3av] support a centralized operator-based controller (OLT) architecture with low cost Layer 2 access devices (ONU). The basic service mapping architecture in EPON is to map Ethernet (or IP) frame header information (such as addresses, IP DiffServ Code Points, Ethernet Q tag, S-VLAN/C-VLAN ID, ISID, bridge address, or other marking) to a logical circuit called a Logical Link Identifier (LLID) in [802.3ah]. The service function is similar to that used in DOCSIS networks in many ways because it is based on a centralized scheduler and uses an LLID which functions like an SID, supports both unicast and broadcast, and has other similarities.

Existing [802.3ah] EPON systems do interoperate within the strict definitions of 1G-EPON. Experience with lab testing, field trials, and deployments has shown operators that 1G-EPON OLT and ONU systems typically only interoperate with a single port ONU. This is because [802.3ah] specifies the interfaces on the PON (the DPoE TU interface) but does not specify any of the other system interfaces. For example, an OLT from vendor A will register an ONU from vendor B, but it is not possible to construct a VLAN from the DPoE MN interface to an S interface. This is a well-recognized limitation of [802.3ah]. The challenge is that neither 1G-EPON nor 10G-EPON specify OAMP to forward traffic between NNI ports and the PON, or UNI ports and the PON. This is not different from other Ethernet standards. For example, if two Ethernet switches from two different vendors are connected, each switch must typically be configured independently. The challenge for EPON is that the remote device (the ONU) cannot be reached, and therefore cannot be configured. A solution to this problem must then be based on developing a common (standard) method of reaching the controller for the ONU, identifying the ONU capabilities, and providing that information to the OLT so that it can configure a working end to forwarding service (in both directions).

Even if EPON had solved that provisioning challenge, there are no standard management interfaces for the ongoing operations and maintenance of the network, including fault management, performance management, security, etc. Operators already have fully working and scaled-out systems that solve these challenges for DOCSIS networks. One of the primary goals for DPoE specifications is to use the existing DOCSIS back office infrastructure to scale up EPON-based business services.

1.2 Scope

This document defines the interface used for conveying management information between a DPoE System and DPoE ONU. This specification defines message format and contents for the following types of configuration or information collection:

- General management and device capabilities
- Forwarding provisioning
- Statistics collection
- Alarm status
- Security key exchange
- Frame processing and classification
- Quality of Service provisioning

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

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

1.3 Goals

Collectively, the operators started the DPoE specification development to accomplish the following objectives:

- Identify and document the common requirements for triple play services for business customers over EPON.
- Adapt DOCSIS-based back office provisioning and operations models to EPON. This is the core objective of DPoE specifications.
- Develop consensus on additional requirements above and beyond DOCSIS specifications to take advantage of the capabilities of EPON. These are focused in the area of Ethernet services and MEF integration.
- Continue to leverage the supply chain and economic benefits of a large base of suppliers and high-volume supply chain in optics, subsystems, and network systems based on a commodity EPON technology. Doing so requires adapting operator processes and networks to the EPON system rather than making any changes to the EPON systems.
- Positioning DPoE specifications to continue to leverage those same benefits for 10G-EPON.
- Work with the established EPON vendor community to assure that these strategies can be effective to mutually develop DPoE Networks, and to create a marketplace for success for multiple vendors to provide solutions for the variety of needs within the operator environment.

1.4 Requirements

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

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

1.5 Organization of Specifications

The DPoE specifications are organized around existing DOCSIS specifications. The purpose of matching DPoE specification documents to existing CableLabs DOCSIS, IEEE, IETF, and MEF requirements is to facilitate the mapping of services from existing DOCSIS infrastructure to DPoE infrastructure, and to provide an organization that will be easy to maintain as related (referenced) standards, recommendations, or specifications undergo independent changes.

There are two types of documents in the DPoE specifications. The first includes informative and requirements documents called specifications that detail the specific requirements for products claiming compliance with the specifications. The DPoE specifications also include a new kind of document that does not fit into any of the above categories. The IP Network Elements (IP NE) Requirements [DPoE-SP-IPNEv1.0] are a set of common requirements for the management of IP network elements that operators have developed, which are above and beyond the requirements in DOCSIS specifications, but are nonetheless required in DOCSIS CMTS products today. These are not specifications because no new protocols or algorithms are provided. Most of the requirements in IP NE are existing requirements based on IEEE, IETF, or other network management standards.

The DPoE documents are detailed in Section 1.6 of this document and duplicated, for reference, in each of the DPoE specifications.

1.6 DPoE Specifications

This document is one in a series of eight (8) documents comprising the DPoE specifications. Collectively these documents represent the operators' requirements for EPON-based commercial services.

Table 1 - DPoE Specifications

Document	Document Title	Description
DPoE-SP-ARCHv1.0	DPoE Architecture Specification	DOCSIS Provisioning of EPON introduction, architecture, and narrative. Specifies fundamental architectural requirements (those that apply to more than one specification). Explains the purpose of each document below.
DPoE-SP-OAMv1.0	DPoE OAM Extensions Specification	Extensions beyond [802.3ah] and [802.3av] requirements.
DPoE-SP-PHYv1.0	DPoE Physical Layer Specification	Using the EPON PHY, the DPoE PHY specification makes mandatory some options within EPON and adds some additional requirements.
DPoE-SP-SECv1.0	DPoE Security and Certificate Specification	Specifications for support for DOCSIS network and system interfaces to provide transparent support of DOCSIS device authentication, code verification, and additional security for a DPoE implementation.
DPoE-SP-IPNEv1.0	DPoE IP Network Element Requirements	Best practices and operator requirements for IP network element management and operations. This document includes CMTS-like IP router requirements. This document recommends practices not currently covered by any existing DOCSIS specifications.
DPoE-SP-MULPIv1.0	DPoE MAC and Upper Layer Protocols Requirements	Specifications for support of a subset of DOCSIS 3.0 MULPI functionality with additional EPON requirements.
DPoE-SP-MEFv1.0	DPoE Metro Ethernet Forum Specification	Specifications for Metro Ethernet services added to DOCSIS static configuration provisioning model.
DPoE-SP-OSSIv1.0	DPoE Operations and Support System Interface Specification	Specifications for support of a subset of DOCSIS 3.0 OSSI functionality with additional EPON requirements.

1.7 Reference Architecture

The DPoE reference architecture identifies the elements that a DPoE Network minimally requires to illustrate and communicate the physical hardware and logical software interfaces between the functional subsystems of the DPoE architecture. The principal elements in the architecture are the DPoE System that resides in the operator network, and the DPoE ONU which may be an off the shelf EPON ONU, EPON SFP-ONU, or an EPON ONU with additional subsystems. The remaining elements in the architecture are existing servers and systems in the operator's network. All of the server elements have connectivity through an IP (TCP/IP) network. Transport of bearer traffic, and (in some cases) Layer 2 OAM signaling are available through either IP or Layer 2 Ethernet-based Network Interfaces.

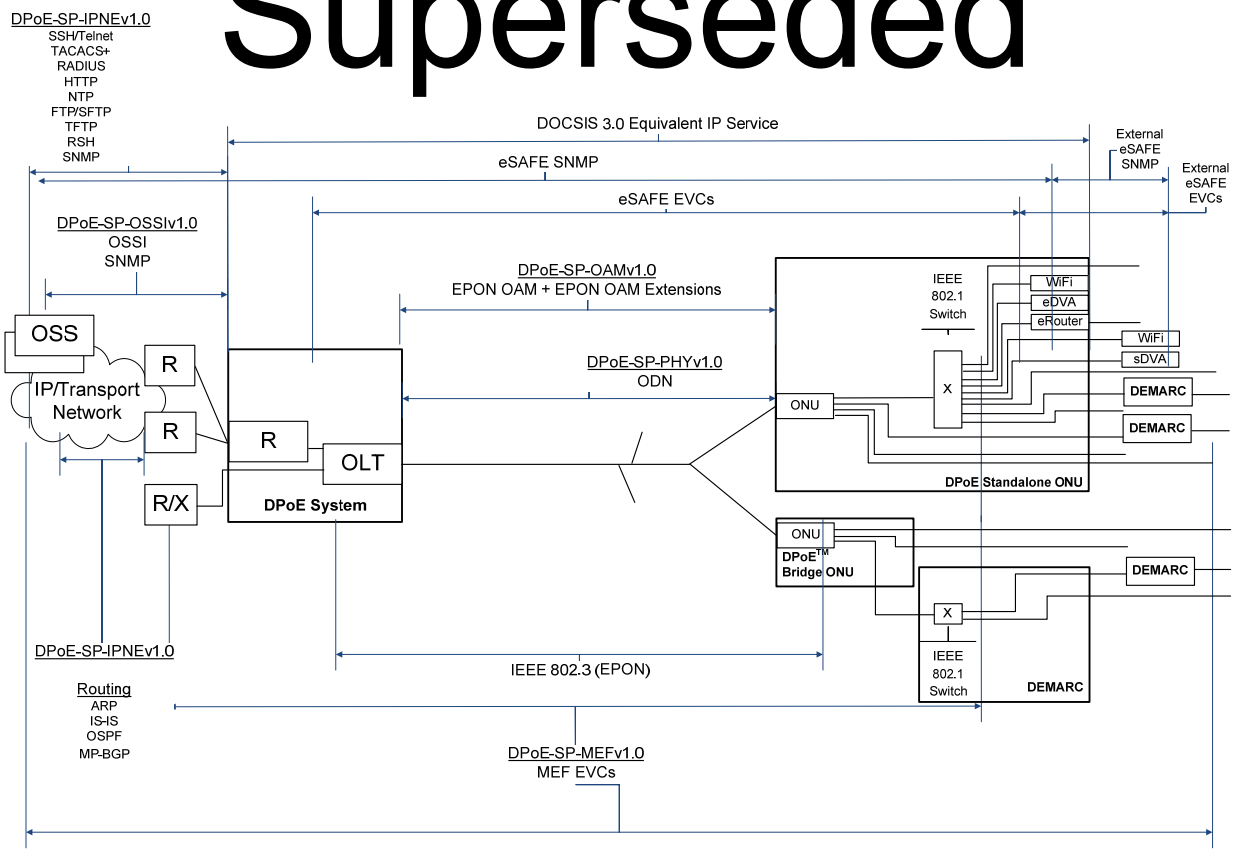

Figure 1 - DPoE Reference Architecture

1.8 DPoE Interfaces and Reference Points

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

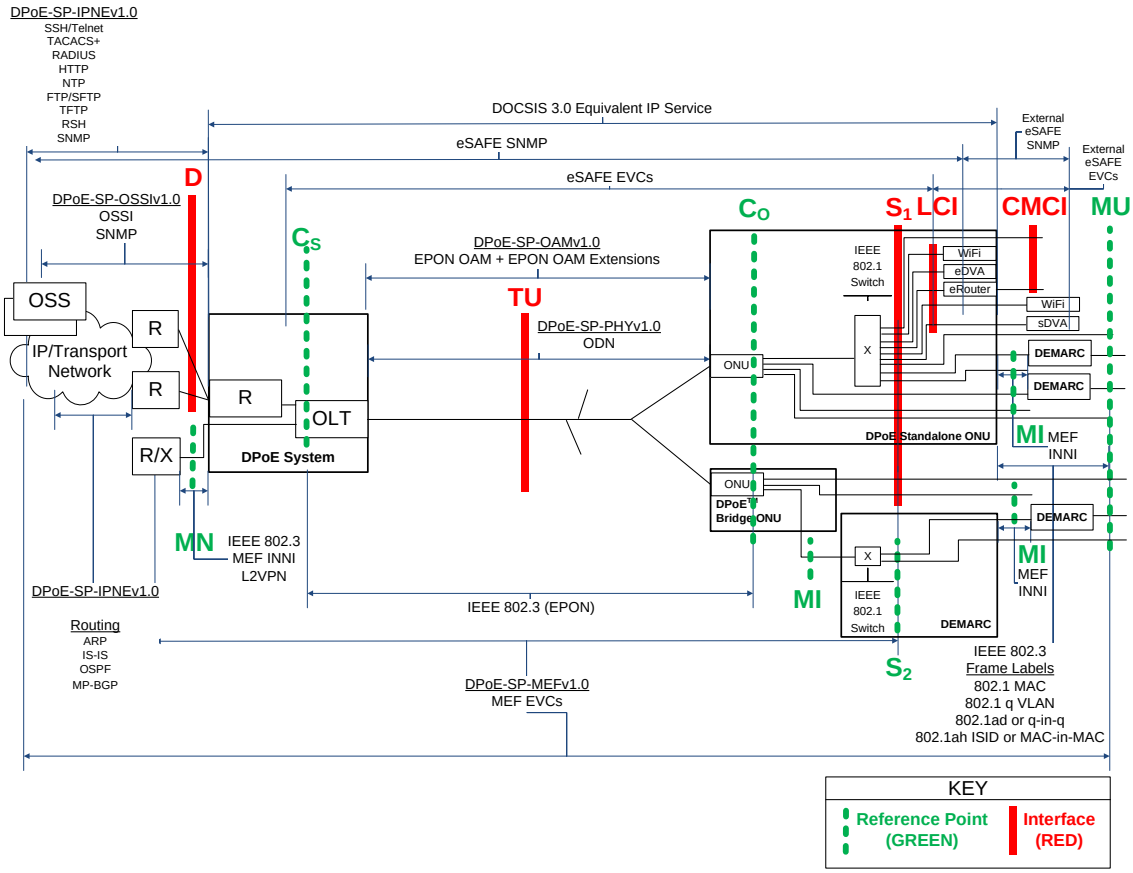

Figure 2 - DPoE Interfaces and Reference Points

Table 2 - DPoE Interface and Reference Point Descriptions

Interface or Reference Point		Interface or Reference Point Description
MN		The MN interface is an [802.3] interface for Ethernet (or MEF or L2VPN emulated) services only. It serves the role of a MEF INNI or L2VPN NSI. It is an NNI for Metro Ethernet services only.
D		The D interface is the DOCSIS IP NNI interface. It is an operator network facing interface, sometimes called a Network to Network Interface (NNI) or Network Systems Interface (NSI) in DOCSIS specifications. The D interface allows a DPoE System to communicate with an IP network. The D interface carries all IP management traffic including OSSI and IP NE traffic. The D interface carries all DOCSIS IP service traffic.
TU		The TU interface is a short form of expressing the interface between the DPoE System and the DPoE ONU.
C		The C reference point is used for explanation of traffic ingress to a DPoE classifier.
	C_O	The C_O reference point is used for explanation of traffic ingress to a DPoE ONU upstream classifier.
	C_S	The C_S reference point is used for explanation of traffic ingress to a DPoE System downstream classifier.
S		The S interface is an IEEE 802 interface. The S interface may be an internal interface (such as [802.3] across a GMII SERDES or XGMII interface in an SFP-ONU, SFP+ONU or XFP-ONU) or it may be an external Ethernet interface. S_1 is an interface for a DPoE Standalone ONU. S_2 is a reference point used for explanation of services with the DPoE Bridge ONU.
	S_1	The S_1 interfaces are the general case of all interfaces on a DPoE Standalone ONU. S_1 interfaces may be CMCI, LCI, MI, or MU interfaces.
	S_2	The S_2 reference point is used for explanation of traffic ingress to and egress from interfaces on a DEMARC device in a DPoE System. Although there are no specifications or requirements for the S_2 reference point, informative text refers to the S_2 reference point to provide the full context for the use of a DPoE Bridge ONU in a DEMARC device providing Metro Ethernet services.
LCI		The Logical CPE Interface (LCI) interface is an eDOCSIS interface as defined in [eDOCSIS]. The eDOCSIS architecture is [802.1d] MAC based according to the DOCSIS 3.0 specifications; however, DOCSIS L2VPN clearly supports [802.1q] switching. In practice, therefore, the eDOCSIS interface consists of a DOCSIS classifier and [802.1] switch as illustrated. The function of a DOCSIS classifier is in part replaced by forwarding (tagging and encapsulation) in MEF and in part covered by classifiers in [DPoE-SP-MULPIv1.0].
CMCI		CMCI is the DPoE interface equivalent of the DOCSIS Cable Modem CPE Interface as defined in [CMCIv3.0]. This is the service interface for DOCSIS-based IP services.
MI		MI is usually an S interface (or S reference point) that operates as a MEF INNI. A DPoE ONU that provides a MEF INNI has an MI interface. A DPoE ONU can have MU as an interface and an MI reference point on different S interfaces in a single DPoE ONU. The MI interface or reference point is an [802.3] interface (or reference point) between a DPoE ONU and a DEMARC device.
MU		MU is usually an S interface (or S reference point) that operates as a MEF UNI. A DPoE ONU that directly provides a MEF UNI (MU) interface has MU as an interface. A DPoE ONU can have MU as an interface and an MI reference point on different S interfaces in a single DPoE ONU. The MU interface or reference point is an [802.3] interface (or reference point) between a DPoE ONU or a DEMARC device and a customer's equipment.

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.

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

[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-2009, IEEE Standard for Local and Metropolitan Area Networks-Virtual Bridged Local Area Networks, January 2010.

[802.3] IEEE 802.3-2008, Carrier Sense Multiple Access with Collision Detection (CSMA/CD) access method and Physical Layer specifications, January 2008.

[802.3ah] IEEE 802.3ah™-2004: Amendment to IEEE 802.3™-2005: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks, now part of [802.3].

[802.3av] IEEE 802.3AV-2009, IEEE Standard for Information technology-Telecommunications and information systems-Local and metropolitan area networks-Specific requirements, Part3 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10Gb/s Passive Optical Networks.

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.

[802.1ag] IEEE Std 802.1ag–2007, IEEE Standard for Local and metropolitan Area Networks – Virtual Bridged Local Area Networks Amendment 5: Connectivity Fault Management, December 2007.

[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.

[802.1p] IEEE 802.1p-2004, LAN Layer 2 QoS/CoS Protocol For Traffic Prioritization

[802.3ah] IEEE 802.3ah™-2004: Amendment to IEEE 802.3™-2005: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks, now part of [802.3].

[802.3av] IEEE 802.3AV-2009, IEEE Standard for Information technology-Telecommunications and information systems-Local and metropolitan area networks-Specific requirements, Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10Gb/s Passive Optical Networks.

[CMCIv3.0]	Data-Over-Cable Service Interface Specifications, Cable Modem to Customer Premise Equipment Interface Specification, CM-SP-CMCIv3.0, Cable Television Laboratories, Inc.
[DOCSIS]	Refers to entire suite of DOCSIS 3.0 specifications unless otherwise specified.
[DPoE-SP-ARCHv1.0]	DPoE-SP-ARCHv1.0, DOCSIS Provisioning of EPON, DPoE Architecture Specification, Cable Television Laboratories, Inc.
[DPoE-SP-IPNEv1.0]	DPoE-SP-IPNEv1.0, DOCSIS Provisioning of EPON, IP Network Element Requirements, Cable Television Laboratories, Inc.
[DPoE-SP-MEFv1.0]	DPoE-SP-MEFv1.0, DOCSIS Provisioning of EPON, Metro Ethernet Forum Specification, Cable Television Laboratories, Inc.
[DPoE-SP-MULPIv1.0]	DPoE-SP-MULPIv1.0, DOCSIS Provisioning of EPON, MAC and Upper Layer Protocols Requirements, Cable Television Laboratories, Inc.
[DPoE-SP-OSSIv1.0]	DPoE-SP-OSSIv1.0, DOCSIS Provisioning of EPON, Operations and Support System Interface Specification, Cable Television Laboratories, Inc.
[DPoE-SP-PHYv1.0]	DPoE-SP-PHYv1.0, DOCSIS Provisioning of EPON, Physical Layer Specification, Cable Television Laboratories, Inc.
[DPoE-SP-SECv1.0]	DPoE-SP-SECv1.0, DOCSIS Provisioning of EPON, Security and Certificate Specification, Cable Television Laboratories, Inc.
[eDOCSIS]	Data-Over-Cable Service Interface Specifications, eDOCSIS Specification, CM-SP-eDOCSIS, 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.
[OSSIv3.0]	Data-Over-Cable Service Interface Specifications, Operations Support System Interface Specification, CM-SP-OSSIv3.0, Cable Television Laboratories, Inc.
[PHYv3.0]	Data-Over-Cable Service Interface Specifications, Physical Layer Specification, CM-SP-PHYv3.0, Cable Television Laboratories, Inc.
[SCTE 174]	SCTE 174 2010, Radio Frequency over Glass Fiber-to-the-Home Specification
[SECv3.0]	Data-Over-Cable Service Interface Specifications, Security Specification, CM-SP-SECv3.0, Cable Television Laboratories, Inc.
[SFF-8077i]	SFF-8077i 10 Gigabit Small Form Factor Pluggable Module, Revision 4.0, released April 13, 2004.
[SFF-8472]	SFF-8472 Specification for Diagnostic Monitoring Interface for Optical Transceivers, Revision 10.4, released January 2009.
[SFP MSA]	INF 8074i Rev 1.0, Small Form-factor Pluggable Multi-Source Agreement, released 12 May 2001.

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
- SCTE, Society of Cable Telecommunications Engineers Inc., 140 Philips Road, Exton, PA 19341
  Phone: +1-800-542-5040, Fax: +1-610-363-5898, Internet: http://www.scte.org/
- Small Form Factor Committee (SFF), http://www.sffcommittee.com

3 TERMS AND DEFINITIONS

3.1 DPoE Elements

DPoE Network This term means the entire network described in Figure 3 from the D or MN interface to the LCI, S, MI, or MU interface (see Figure 2 for interface and reference points), depending on the service being described. In no case does the term DPoE Network ever include a DEMARC device.

DPoE System This term means all of the collected elements that provide the DPoE function within the operator's network facilities. This includes the EPON OLT function, DOCSIS service functions required for the D interface, Metro Ethernet service functions required for the MN interface, and IP NE element management, routing and forwarding functions specified in [DPoE-SP-IPNEv1.0]. The DPoE System is depicted in Figure 3.

DPoE ONU This term means a DPoE-capable ONU that complies with all of the DPoE specifications. There are two types of DPoE ONUs. These are the DPoE Standalone ONU and the DPoE Bridge ONU.

DPoE Standalone ONU This term means a DPoE ONU that is a standalone ONU capable of providing IP or Ethernet services directly to customer premise equipment or transport of traffic to an external DEMARC device.

DPoE Bridge ONU This term means a DPoE ONU that is capable of [802.1] forwarding but cannot do all of the encapsulation functions required to be a DPoE Standalone ONU. Examples include an SFP-ONU and some simple EPON chipset-only based ONUs.

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, DSL, or Broadband Forum Models) or the NID (as in the MEF model).

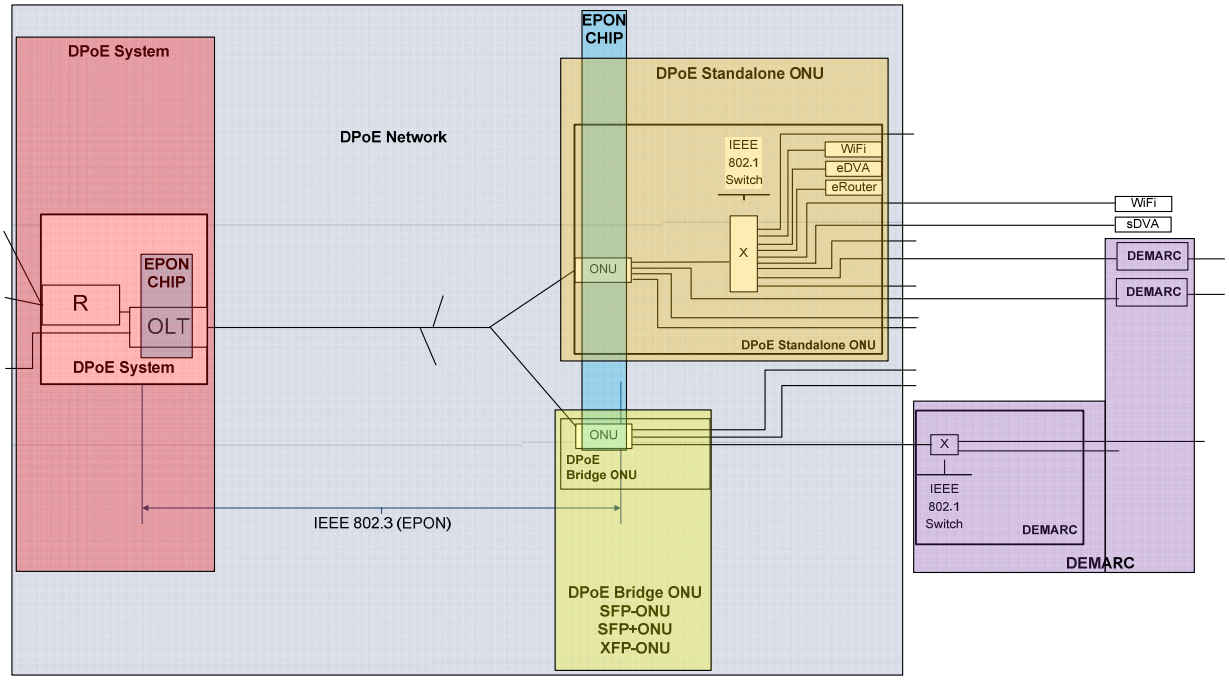

Figure 3 - DPoE Elements

3.2 Other Terms

1G-EPON	EPON as defined in [802.3ah]
10G-EPON	EPON as defined in [802.3ah] and amended in [802.3av]
Cable Modem CPE Interface	CMCI as defined in [MULPIv3.0]
Customer Premise Equipment (CPE)	Customer Premise Equipment as defined in [DOCSIS]
Multi-Layer Switching (MLS)	A switch that can switch based on Layer 2, Layer 3, Layer 4, etc.
Ethernet Passive Optical Network (EPON)	Refers to both 1G-EPON and 10G-EPON collectively
EPON Operations and Maintenance Messaging (OAM)	EPON OAM messaging as defined in [802.3ah] and this document; Ethernet OAM is not the same as EPON OAM; Ethernet OAM is [802.1ag]
Logical CPE Interface	LCI as defined in [eDOCSIS]
Network Interface Device (NID)	A DEMARC device in DPoE specifications

4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

BCD	Binary Coded Decimal
CFI	Canonical Format Indicator (in IEEE 802.1Q tag)
CMCI	Cable Modem CPE Interface
CoS	Class of Service
CPE	Customer Premise Equipment
DIA	Dedicated Internet Access
DoS	Denial of Service
DPoE	DOCSIS Provisioning of EPON
DR	Default Router
DSx	Digital Signal (DS1 or DS3)
eCM	embedded Cable Modem
eDVA	embedded Digital Voice Adapter
ENNI	External Network to Network Interface
EPL	Ethernet Private Line
EPON	Ethernet Passive Optical Network
EP-VLAN	Ethernet Private Virtual Local Area Network
eSAFE	embedded Service/Application Functional Entity
ESP	Ethernet Service Path
EVC	Ethernet Virtual Connection
E-VPL	Ethernet Virtual Private Line
EVP-LAN	Ethernet Virtual Private LAN
FEC	Forward error correction
GBd	Gigabaud
Gbps	Gigabits per second (as used in the industry)
INNI	Internal Network to Network Interface
IP	Internet Protocol
IP(HSD)	High Speed Data (Broadband Internet Access using DOCSIS)
I-SID	[802.1ah] I-Component Service IDentifier
LCI	Logical CPE Interface
LLID	Logical Link IDentifier
MAC	Media Access Control
MPCPDU	Multi-Point Control Protocol Data Unit
MEF	Metro Ethernet Forum
MI	MEF INNI Interface at a customer premise

MN	MEF INNI Interface to operator's MEN
MPCP	Multi-Point Control Protocol
MU	MEF UNI Interface
NID	Network Interface Device
NNI	Network to Network Interface
OAM	EPON Operations Administration and Maintenance
ODN	Optical Distribution Network
OLT	Optical Line Termination
ONU	Optical Network Unit
OSC	Optical Splitter Combiner
PDU	Protocol Data Unit
PHY	Physical Layer
PON	Passive Optical Network
R	IP Router
SA	Source Address
SFP	Small Form-factor Pluggable
SFP+	Small Form-factor Pluggable Plus (+)
TLV	Type-Length-Value
TPID	Tag Protocol Identifier
TU	Interface between DPoE System and DPoE ONU, roughly "the PON fiber"
UNI	User Network Interface
vCM	Virtual Cable Modem
VID	VLAN Identifier
VLAN	Virtual Local Area Network
WSC	Wireless Switching Center
X	IEEE Ethernet Switch (Generic)
XFP	X Form-factor Pluggable

5 BACKGROUND

5.1 IEEE 802 Link OAM

Traditional network management architecture requires the ONU to support the appropriate network management protocol or protocols. The protocol is usually SNMP, and hence would require IP layer connectivity. This requirement can result in extensive network maintenance to support every ONU on the management network at layer 3. An IP address would be assigned on the service provider's management network to each connected ONU, and ARP/RARP/DHCP issues must be addressed, as well as L3 security over the management channel. L3 management also places a larger burden on the ONU software stack, resulting in greater cost in the high-volume components of the network. The DPoE management architecture terminates network-side management protocols at the DPoE System, carrying out management functions over the TU interface using OAM. By re-using the [802.3] Clause 57 OAM packet format, the ONU does not need to support additional protocol families for every possible management protocol, simplifying implementation and limiting interoperability problems.

Since [802.3] is a MAC layer standard, Clause 57 OAM messages for Ethernet links are confined in scope of control to the lower half of the data link layer. This is problematic for managing a full network, as a practical EPON ONU will likely serve as an Ethernet bridge and will have remote ports used to connect a customer LAN to EPON. Service providers running EPON need to remotely manage the entire ONU, and not just the EPON MAC. This exactly matches the requirements of the DPoE Network.

The IEEE provides a standard mechanism for extending [802.3] Clause 57 OAM, allowing other organizations to define specific extensions. One Protocol Data Unit (PDU) opcode (0xFE) is reserved for such extensions. Also, organization-specific TLVs can be added to some standard [802.3] Clause 57 PDUs. The organization defining the extension is identified by an IEEE OUI following the PDU extension opcode or TLV type. The remainder of the PDU format is then defined by the organization identified by the OUI for the frame. This document defines the format used for extensions under the DPoE OUI 0x001000.

Another advantage to extending the [802.3] Clause 57 OAM protocol is its inherent increased security. Without the extensions, an ONU functioning at L3 as a typical SNMP-managed device would extend the service provider's management network to the customer LAN. This creates potential security problems, especially with the open character of SNMP, where users could potentially gain access to the operator's management channels. Per [802.1d], [802.3] Clause 57 OAM cannot be forwarded by a bridge, and so use of this protocol keeps the service provider's management network on the network side of the ONU and insulated from the subscriber interfaces. They also isolate the L3 user data network from the management network at a L2 protocol level, providing increased security over the management channel.

5.2 [802.3] Clause 57 OAM PDUs

The standard [802.3] Clause 57 PDUs are reviewed in the following sections. All OAM messages have a common header format, with EtherType 0x8809, Subtype 0x03, a Flags field that carries information about OAM state, and an opcode that defines the type of PDU. The body of each PDU depends on the opcode.

Table 3 - IEEE Link OAM Messages Format

Width (Octets)	Field	Value (hex)
6	Ethernet DA (Destination Address)	0180C2-000002 ([802.3] OAM multicast address)
6	Ethernet SA (Source Address)	As per sending MAC
2	EtherType	8809 (Ethernet Slow Protocol)
1	Subtype	03 ([802.3] OAM)
2	Flags	As per [802.3]
1	PDU Type	See Table 4

Width (Octets)	Field	Value (hex)
Varies	Data/Pad	As defined for the Opcode. Pad in OAM frames must be zero per [802.3].
4	FCS	Standard FCS generated by the [802.3] MAC

Table 4 - [802.3] Clause 57 PDU Types

IEEE Info TLV Type	Value (hex)
Information	00
Event Notification	01
Variable Request	02
Variable Response	03
Loopback Control	04
Reserved	05..FD
Organization Specific	FE
Reserved	FF

5.2.1 Info PDU

The Info PDU, defined in [802.3] Clause 57.4.3.1, is primarily used during the OAM Discovery phase just after a link is established, in which the OAM peers discover each other's existence and negotiate the maximum OAM frame length. Info PDUs are also periodically transmitted (once per second) as a keep-alive heartbeat for the OAM layer.

The contents of an Info PDU are a series of TLVs. [802.3] Clause 57 defines three TLV types. "Local" and "Remote" information TLVs are always present in an Info PDU, and convey basic information about the OAM channel state. [802.3] Clause 57 also defines a TLV type for an Organization-Specific TLV, which contains an OUI to denote the particular organization which defines the contents of that TLV. DPoE OAM defines an Info TLV type.

Table 5 - [802.3] Info TLV

Width (Octets)	Field	Value (hex)
1	TLV Type	See Table 6
1	Length	Includes Type and Length fields, plus data to follow
Varies	Depends on TLV Type	Depends on TLV Type

Table 6 - [802.3] Info TLV Types

[802.3] Info TLV Type	Value (hex)
End of TLV marker	00
Local Information	01
Remote Information	02
Reserved	03..FD
Organization-Specific	FE
Reserved	FF

5.2.2 Event Notification PDU

The [802.3] Clause 57 Event Notification PDU is used to indicate the occurrence of events at one end of a link to the peer at the other end. Typically this is "alarm" information sent from the ONU to the DPoE System. The Event Notification PDU format, like the Info PDU format, contains a series of Link Event TLVs. [802.3] Clause 57 defines five types of Link Event TLV. The first four are variations on the theme of reporting link fault counts (where a link fault is any of several errors that can occur in an Ethernet, such as CRC errors or frame length errors). The fifth type is reserved for organization-specific TLVs. The DPoE specification defines an extended alarm TLV type used in this PDU to convey more detailed alarm information.

Recall that all OAM frames carry three bits in the standard OAM header which indicate "link fault", "critical event", and "dying gasp" conditions at the sender. The [802.3] Clause 57 Event Notification PDU, as an OAM PDU, contains these bits, but also contains TLVs that provide more detailed information about the conditions that are present.

Table 7 - [802.3] Event Notification TLV

Width (Octets)	Field	Value (hex)
1	TLV Type	See Table 8
1	Length	Includes Type and Length fields, plus data to follow
Varies	Depends on TLV Type	Depends on TLV Type

Table 8 - [802.3] Link Event TLV Types

[802.3] Link Event TLV Type	Value (hex)
End of TLV Marker	00
Errored Symbol Period Event	01
Errored Frame Event	02
Errored Frame Period Event	03
Errored Frame Seconds Summary	04
Reserved	05..FD
Organization-Specific	FE
Reserved	FF

5.2.3 Variable Request/Response PDUs

The Variable Request PDU is the means by which an OAM peer can query the attributes defined in [802.3] Clause 30, which are typically frame counters and error counters, along with basic control state of the MAC layer, such as link status or auto-negotiation results. The Variable Response PDU contains data in response to these requests. Note that in the standard protocol, all attributes are read-only. That is, the Variable Request message can retrieve values, but cannot set them.

The Variable Request PDU consists of a series of "Variable Descriptors" that identify the particular attribute to be retrieved. A Variable Descriptor is composed of "branch" and "leaf" codes that uniquely identify the attribute, at least within the IEEE-controlled numbering space. The Variable Descriptor is essentially a compound, three-byte attribute type code.

The Variable Response PDU consists of a number of Variable Containers. 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. Thus, the Variable Container is a kind of Type-Length-Value (TLV) format, where the Type is a three-byte code, and reserved values in the Length field serve as error codes.

For compatibility with standard PDUs and attribute numbering, DPoE OAM reuses these structures in its Get and Set PDU types. The contents of these standard PDUs are legal contents for the body of DPoE Get and Get Response

PDUs, although they are a subset of the possible legal responses. In this document, Variable Descriptors and Variable Containers will often be referred to simply as "TLVs".

DPoE OAM implementations MUST NOT generate such requests with the optional "package" format, as opposed to individual attributes. DPoE OAM implementations need not support the package format requests and responses.

5.2.4 Loopback Control PDU

The [802.3] Clause 57 Loopback PDU is used to put an individual logical link into a loopback state for testing purposes. The Info PDU is also used as a response when establishing or tearing down a loopback, as it carries state information that is useful during the transitions.

5.2.5 Organization-Specific PDU

The [802.3] Clause 57 OAM PDU opcode 0xFE is defined to indicate an Organization-Specific PDU. The contents of an Organization-Specific PDU are defined by the organization indicated by the OUI in this PDU. DPoE OAM makes use of this feature to add many extended features to the basic IEEE logical link management. This document contains the definition for the format of data in organization-specific PDUs and TLVs marked by the DPoE OUI 0x001000.

An EPON ONU may support many organization-specific OAM message sets. Behavior and requirements of other OAM extension sets are outside the scope of this document.

DPoE ONUs MAY support OAM extensions in addition to DPoE OAM. DPoE Systems MUST NOT require support for non-DPoE extensions. Similarly, DPoE ONUs MUST NOT require support for non-DPoE extensions. DPoE ONUs that support message sets other than DPoE extensions MUST NOT be deregistered simply for that reason. Similarly, DPoE-compliant ONUs MUST NOT fail to register with a DPoE System that supports DPoE OAM, even if that DPoE System lacks support for some other OAM message set that the DPoE ONU would like to use.

ONUs that do not support DPoE OAM MUST NOT be allowed to register by the DPoE System.

5.3 DPoE ONU Model

For management purposes, a DPoE ONU is considered to have the logical structure depicted below.

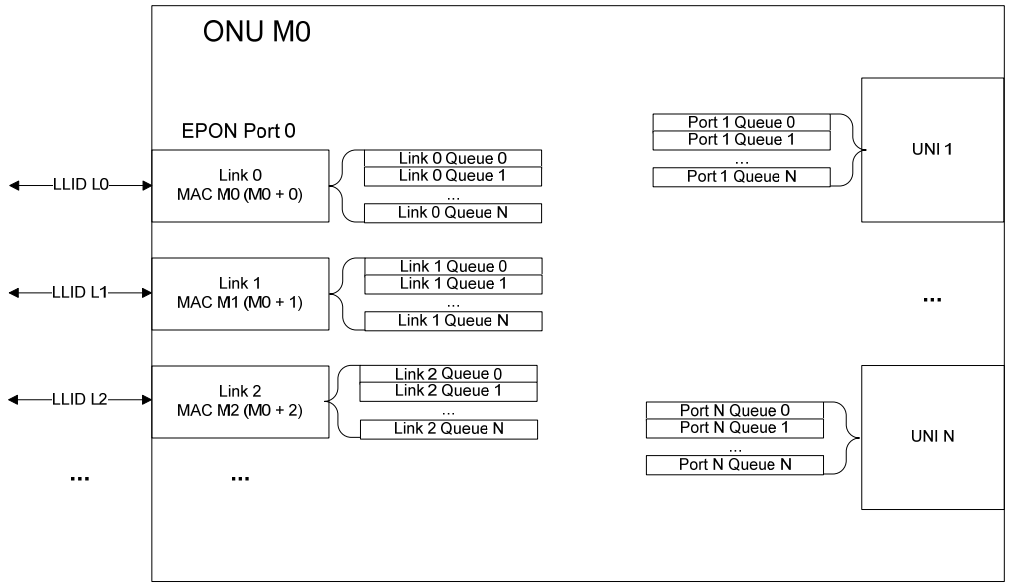

Figure 4 - DPoE ONU Model

A DPoE ONU is a device that has one or more MAC interfaces per TU interface (logical links, or just links for short), and one or more MAC interfaces on the user side (DPoE S interfaces or reference points). A switch connects the ports to transfer frames between individual MACs.

The TU interface is a single physical port shared by several MACs, each with an associated Logical Link, whereas the S interfaces (or reference points) usually have one MAC per physical port. Each of these MACs is fed by one or more priority queues. These ports, links, and queues each have OAM attributes that allow remote management.

In addition to the bidirectional (transmit/receive) links shown, DPoE ONUs support one or more 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

Frame processing refers to the collective behavior of a DPoE ONU that occurs as a frame proceeds through it. Frame processing is performed to accomplish tasks such as classification in which the relative priority of a frame is determined, usually by inspecting fields within the frame, filtering frames (discarding frames with undesirable characteristics), access control (forwarding frames with desirable characteristics), or frame modification, such as adding and removing Virtual Local Area Network (VLAN) tags or other encapsulations, or changing priority values with a frame.

For the purpose of describing this behavior, the DPoE OAM specification adopts an abstract model of DPoE ONU behavior. The DPoE OAM messages define frame processing in terms of rules that match fields in a frame, and if the fields match the given values, apply a particular result to the frame. The rule results can forward or discard a frame, set a destination queue, or change the frame by adding or deleting fields. DPoE ONU software parses these rules and programs the DPoE ONU implementation-specific hardware to achieve the specified effect.

Using these rules as primitives, it is possible to construct many features. For example, an Access Control List (ACL) is a list of rules that match MAC and/or IP source addresses and forward matching frames. Traffic classification is a matter of matching frames and forwarding the frame into an appropriate priority queue based on the frame contents. Adding a VLAN tag might be unconditional, as in the case of a default VLAN tag for a port, or the tag value might be based on other attributes of the frame to tag frames according to protocol type. Rather than specify distinct OAM messages for all of these features, a primitive-oriented approach is used to permit construction of additional features in the future with no additional DPoE OAM message definitions required.

It is not expected that DPoE ONU hardware processes these rules in software or exactly in the format presented. To be compliant with this specification, any hardware or software implementation may be used, but the resulting observable behavior MUST be as specified by the rule set in this model.

Conceptually, these packet processing rules are applied to frames as they enter ports, whether the TU interface port in the downstream or a User Network Interface (UNI) port in the upstream. For consistency, the field values as used in the rule conditions are always the values in the frame as it enters the port. Any changes to the frame from rule results are considered not to take effect until frame processing has been completed. Thus, the effect of a rule set does not depend on the order of the rules in that set.

All of the rules in a port ingress rule table are applied to each frame that enters the port. The results of all rules that match are applied to the frame.

To resolve ambiguity when more than one rule or contradictory rules match the same frame, each rule is associated with a precedence value. The result is that only the highest precedence rule that matches a frame and has a particular result will be applied. Thus, for example, by using two precedence levels, it is possible to establish a single rule that provides a default classification for a frame (all frames by default belong to the DOCSIS Primary Service Flow) and then override that classification by matching specific control fields with a higher precedence rule (as with DOCSIS classifiers that select traffic into Secondary Service Flows). The precedence of one type of rule result (say, modifying an output field) does not conflict with the precedence of other types of result (say, forwarding the frame, or setting an output queue).

6 OAM OPERATION

6.1 OAM Discovery

The OAM discovery process defined in [802.3] has a state machine for a certain progression of OAM discovery state bits in the header for OAM messages. OAM is considered an optional feature of [802.3], but support for DPoE OAM is mandatory for all ONUs conforming to this standard. A DPoE ONU that does not actually complete OAM Discovery in a stable state, as per this standard, MUST be deregistered by the DPoE System after 5 seconds of attempting OAM discovery, measured from the initial OAM Info PDU sent by the OLT. ONUs that do not negotiate support for DPoE OAM MUST be deregistered by the DPoE System.

During OAM discovery, support for DPoE extensions is declared by adding an Info TLV to the Info PDUs exchanged with the DPoE System as defined in Section 5.2.1. Presence of this DPoE extension support TLV is a declaration of willingness to adhere to the requirements of the DPoE OAM extension set, including the rules on critical OAM and DPoE ONU behavior in this section. Lack of this TLV means that the ONU is not capable of supporting DPoE extensions, and subsequently will be deregistered.

A DPoE ONU MUST include the DPoE OAM Support Info TLV in all OAM Info frames exchanged during the OAM Discovery phase. The DPoE ONU SHOULD NOT insert this TLV into keep-alive Info frames after OAM Discovery has completed.

6.2 OAM Frame Rate

OAM is a subtype of the "Ethernet Slow Protocol" set of protocols. By definition, Slow Protocols have a maximum transmission rate of 10 frames/second. DPoE OAM allows for a higher rate of OAM PDUs if so configured; the default rate is 10 frames/second.

Per [802.3], the OAM frame rate is measured per logical link, not per ONU.

For purposes of precisely defining "rate", the DPoE System is considered to accumulate one PDU transmission credit for each interval of 1/Max Rate, accumulating a maximum of Max Rate credits. The DPoE System consumes one transmission credit for each PDU sent. The DPoE System may send OAM PDUs at any time that it has a non-zero transmission credit balance, while still limited by the "one outstanding PDU" rule. OAM exchanges thus may burst as quickly as a DPoE ONU can send responses until transmission credits are exhausted. (This behavior is somewhat different than the same rate defined as one PDU per interval.)

To relieve the protocol of complexity in handling out-of-order requests and overall pacing for different DPoE ONUs, a DPoE System may have only one outstanding OAM request per logical link at any given time. The DPoE ONU must reply, or the OAM timer expires, before the DPoE System can send another OAM PDU to the DPoE ONU.

6.3 OAM Timeout

Unless otherwise specified, a DPoE ONU MUST respond to an OAM request from a DPoE System within one second.

If a DPoE ONU cannot respond before the OAM timeout, it MUST raise the DPoE ONU Busy alarm. Failure to respond to OAM results in an error at the DPoE System; handling of this error is implementation-specific, but MUST NOT include deregistering the DPoE ONU. The exception to this rule is "critical" OAM. Failure to respond to critical OAM is a reason to deregister a DPoE ONU.

6.4 Critical OAM

Of the hundreds of messages and attributes in the DPoE OAM extension set, a few are deemed "critical" OAM. A successful response to these OAM messages is necessary for the network to work properly. An ONU that does not acknowledge these critical OAM commands is not operating correctly (by definition) and will be deregistered by the DPoE System. These critical OAM are required as part of the claim of support for DPoE extensions. An ONU that

claims support for DPoE extensions is also promising to respond to these OAM in particular, as well as others in this document.

Critical OAM messages are sent immediately after link registration, and may also occur at other times during the DPoE ONU operation.

Table 9 - Critical OAM Attributes

Attribute	Description	Value (hex)
ONUID	Unique physical ONU identification number	D7/0002
Max Number Of Logical Links	Maximum number of logical links (bidirectional LLIDs) supported on the ONU	D7/0007
ONU Report Thresholds	Controls format of MPCP REPORT PDU	D7/000B
Set OAM Rate	Changes maximum allowed OAM PDU rate	D7/000D

The critical OAM messages are described in detail below.

6.4.1 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 DPoE System firmware, and are necessary for the DPoE System to manage ONUs.

The ONU base MAC address is considered to be the ONU ID that ties multiple logical links on the same DPoE ONU physical device. Similarly, the number of links is necessary for a DPoE System to correctly manage DPoE ONUs of different configurations.

If a DPoE ONU does not positively acknowledge these attributes, it cannot be tracked and managed by the DPoE System, and so is deregistered to deny its entry into the DPoE Network.

6.4.2 Set ONU Report Threshold

The report threshold limits the size of the frame boundary that is reported to the DPoE System. A DPoE System scheduler generally has some maximum size it is willing to grant (the DBA token size) in order to maintain service guarantees on the PON. If the DPoE ONU report threshold exceeds this maximum size, then the DPoE ONU will report a frame boundary larger than the DPoE System can grant. In the best case, EPON efficiency is lost due to loss of frame alignment with the DPoE ONU, as the DPoE System limits the grant to the maximum size. The next worst effect is that SLAs cannot be correctly enforced, if the DPoE System attempts to grant to the reported frame boundary despite the fact that it is too large given the current demands on the network.

When increasing bandwidth limits, the DPoE System must first increase the OLT token size, and only then increase the ONU threshold. Conversely, to decrease the bandwidth limits, the ONU report threshold must be lowered before the OLT token size can be decreased. A positive acknowledgement from the ONU is necessary to be sure this report threshold has been adjusted before the OLT can be updated. If a DPoE ONU does not respond to this command, the OLT cannot be certain of the report threshold at the ONU. Rather than risk correct network behavior for all other ONUs registered on the PON, the ONU that fails to acknowledge this command is deregistered.

6.4.3 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 DPoE System and DPoE ONU must agree on the actual OAM frame rate to be used. If the DPoE ONU and DPoE System use different OAM frame rates, the useful PDU rate would be limited by the lower of the two, as the ONU would either fail to acknowledge OAM commands (when the DPoE System rate was higher than the DPoE ONU) or be unable to use the increased limit (as the DPoE System would not send commands as often as the DPoE ONU might be willing to accept).

6.5 OAM Keep-alive Failure

[802.3] requires that the OAM layer return to the initial state of the OAM Discovery state machine on OAM heartbeat failure, but says nothing specifically about the Multi-Point Control Protocol (MPCP) layer in this case. It is conceivable that the OAM layer fails because of some fault in the underlying Ethernet layer controlled by MPCP. If this layer cannot transport frames, it cannot transport OAM frames, and thus resetting only the OAM layer is not likely to recover the ONU if the problem lies with MPCP or the Ethernet layer.

DPoE Systems MUST deregister ONUs at the MPCP layer if an OAM layer failure is detected. DPoE ONUs MUST deregister and re-register at the MPCP layer if an OAM layer failure is detected.

6.6 OAM and Logical Links

The DPoE System MAY use any logical link that terminates at the appropriate DPoE ONU to send OAM commands. The DPoE ONU MUST respond to commands on the same logical link on which the command was received.

7 [802.3] OAM PDUS

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, which 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.

This DPoE specification defines TLVs for both the [802.3] Info PDU and the [802.3] Event Notification PDU, in addition to DPoE PDU types. As per IEEE [802.3], DPoE extension TLVs use TLV type of 0xFE and the 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 10 - 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 11

The DPoE Info TLV types are shown in Table 11.

Table 11 - DPoE Info TLV Types

DPoE TLV Type	Value (hex)
DPoE OAM Support	00

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

Presence of this TLV in the Info frames during OAM discovery indicates the DPoE System or DPoE ONU supports DPoE OAM. Support for the OAM PDUs also implies support for the feature set required for the DPoE System.

Table 12 - 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	00
1	DPoE OAM Version	01

7.2 Event Notification PDU

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

All DPoE alarms have a common format. The current condition of the alarm is indicated as "raised" when the condition is detected, and "clear" when the condition is no longer present. The object affected by the condition is included as a two-byte object type and instance number, which matches the DPoE object context leaf codes in Section 8.14.

Table 13 - 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 14
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	Object Instance	Affected instance of this type of object

Possible values for the Event Code are shown in Table 14. 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 14 - DPoE Event Codes

DPoE Event Code	Value (hex)	Description
Link Fault Alarms		
LOS	11	Loss of received optical power by the transceiver (ONU EPON port) Link down on Ethernet PHY (ON UUNI port)
Key Exchange Failure	12	ONU did not observe a switch to a new key after key exchange
Reserved	13..1F	Reserved
Critical Event Alarms		
Port Disabled	21	Ethernet port is disabled by management action
Reserved	22..3F	Reserved
Dying Gasp Alarms		
Power Failure	41	Loss of power at the ONU (Dying Gasp)
Reserved	42..7F	Reserved
Other Alarms		
Statistics Alarm	81	Statistic has crossed defined alarm thresholds
ONU Busy	82	ONU is busy and unable to acknowledge or process further OAM until alarm clears
Reserved	83..FF	Reserved

7.2.1 LOS (0x11)

For the TU interface port, a Loss Of Signal (LOS) condition is detected by lack of incoming optical power or loss of CDR lock to the downstream bit clock. On an S interface (or reference point), the LOS condition corresponds to the Link Down condition detected by the S interface (or reference point) PHY.

7.2.2 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 [DPoE-SP-SECv1.0] for details on key exchange procedures and detection of failure conditions.

7.2.3 Port Disable (0x21)

The Port Disabled alarm indicates that a DPoE ONU port has been disabled by management action. If the TU interface port is disabled, then OAM cannot be transmitted, and this alarm will be visible only locally on the DPoE ONU.

7.2.4 Power Failure (0x41)

A Power Failure Alarm indicates that the DPoE ONU has lost power, and will imminently depart the DPoE Network. A DPoE ONU will exercise its best effort to send an Event Notification PDU with this TLV when it detects loss of power. A DPoE ONU might not be able to actually send the message if the required transmission grants are not allocated by the DPoE System before the DPoE ONU has exhausted its endurance.

7.2.5 Statistics Alarm (0x81)

The Statistics Alarm indicates a crossing of predefined thresholds on some statistic (indicated in the alarm TLV). Typically, these thresholds would be set for counters for error conditions such as CRC errors. The Statistics Alarm TLV carries the following fields after the standard DPoE alarm TLV fields.

Table 15 - Statistics Alarms Additional Fields

Width (Octets)	Field	Value (hex)
1	Branch	Branch of statistic that crossed threshold
2	Leaf	Leaf of statistic that crossed threshold

7.2.6 ONU Busy (0x82)[1]

The ONU Busy alarm may be raised by a DPoE ONU to inform the DPoE System that it has become busy for an extended period and may not respond to further OAM requests in the usual timely fashion.

The DPoE System MUST ignore any OAM or eOAM timeout alarms as long as the “ONU Busy” alarm is active (raised), but not longer than 300 seconds from the last reception of the "ONU Busy" alarm.

[1] Revised per OAMv1.0-N-12.0016-2 on 3/30/12 by JB.

8 DPOE OAM PDUS

All DPoE OAM messages follow the [802.3] Clause 57 defined method of extending the OAM protocol. That is, the messages are contained in [802.3] Clause 57-defined Organization-Specific OAM frames, followed by the DPoE OUI 0x001000. See Section 5.2 for more details on [802.3] Clause 57 OAM PDU formats.

Table 16 - DPoE Extended OAM PDU Format

Width (Octets)	Field	Value (hex)
6	Ethernet DA	0180C2-000002 ([802.3] OAM multicast address)
6	Ethernet SA	As per sending MAC
2	EtherType	8809 (Ethernet Slow Protocol)
1	Subtype	03 ([802.3] OAM)
2	Flags	As per [802.3]
1	Opcode	FE
3	OUI	0x001000
1	DPoE Opcode	See Table 17

Each DPoE OAM message type is identified by a one-byte opcode immediately following the DPoE OUI. Data per individual extended DPoE OAM PDU type then follows as defined for that particular DPoE opcode (see Table 17).

Table 17 - DPoE Opcodes

DPoE Opcode	Value (hex)
Reserved	00
Get Request	01
Get Response	02
Set Request	03
Set Response	04
Multicast Request	05
Multicast Register	06
Multicast Register Response	07
Key Exchange	08
File Transfer	09

Most management functions in DPoE Systems are carried out by reading and writing individual attributes of objects in the ONU with the Get and Set PDUs. Setting an S interface (or reference point) port speed, for example, would be performed by setting the port speed attribute of the proper port object. These PDUs are essentially lists of TLVs, where each TLV represents an attribute. Since more than one instance of an object could exist in the ONU, the packet also contains TLVs that identify the object to which later attributes in the PDU will apply. That is, some TLVs set the current object context to which later attributes apply. Since the PDU is a list format, it is possible to conduct a number of operations on one object or several objects with just one PDU. See Section 8.10 for a description of Variable Descriptors and Variable Containers as found in the Get and Set PDUs.

Other OAM PDU types exist for specialized purposes that do not fit the object as well, such as file transfer.

8.1 Get Request

The Get Request permits reading of both [802.3] Clause 30 and DPoE extended attributes in a single PDU. The data field of the PDU contains a null-terminated series of Variable Descriptors, as defined in [802.3] Clause 57 Variable Request messages.

8.2 Get Response

This Get Response OAM PDU is a response to a Get Request. The data field of the PDU contains a null-terminated series of Variable Containers, as defined in [802.3] Clause 57 Variable Request messages, where the values in the Containers are the value of the queried attributes, or possibly an error response code.

8.3 Set Request

[802.3] Clause 57 does not include means to set variables with OAM messages. It can only retrieve them with a Variable Request message. The DPoE OAM supports the setting of variables.

The format of the Set OAM PDU is similar to the Variable Response PDU. A null-terminated list of Variable Containers specifies which variables to set. The values in the Variable Containers provide new values to be set for the attribute.

The Set Request OAM PDU may contain Actions (branch 0x09 or 0xD9) as well as attributes. Actions instruct the receiving device to execute a procedure, such as clearing a table or resetting. The management actions specified in [802.3] Clause 30 are not supported in the [802.3] Clause 57 PDUs. The DPoE extensions allow these standard management actions and extended actions to be requested. Actions that have parameters (as defined for each action) have those parameters as the body of the Variable Container for the action. Actions that do not have parameters are represented as a Variable Container of zero length (length code 0x80).

Actions are distinct from setting variables, though they can have similar effects. An SNMP MIB contains "trigger attributes" that create the same effect as an action. For example, in SNMP, setting a Boolean "Reset" attribute to TRUE for a device instructs the management system to reset the device. Similarly, some attributes in [802.3] Clause 30 can be used to change system settings. For example, setting the AdminState of a PHY can turn the device on or off.

8.4 Set Response

A Set Response OAM PDU contains a null-terminated series of Variable Containers. The response codes correspond to individual Set requests or Actions in the Set Request PDU. The container typically consists of the Branch/Leaf identifier and the Width field. The Width field contains an error code.

8.5 Multicast LLID Request

The Multicast Request OAM PDU reserves the opcode for future use and for symmetry with MPCP unicast registration, but is not used in this version of the DPoE OAM specification. Multicast Logical Link Identifiers (LLIDs) are pushed from the DPoE System rather than pulled by the ONU.

8.6 Multicast LLID Registration

The Multicast Registration OAM PDU associates a multicast LLID with a unicast LLID assigned by the standard MPCP registration process. The default multicast LLID for a unicast link on 1G-EPON is 0x7FFF (the standard broadcast LLID), while the default multicast LLID for 10G-EPON is 0x7FFE, as per [802.3].

8.7 Multicast LLID Response

The Multicast Response OAM PDU is returned by the DPoE ONU to acknowledge receipt of the Multicast Registration PDU.

8.8 Key Exchange

The Key Exchange PDU is used by encryption firmware to exchange keys and synchronize key switchover. See [DPoE-SP-SECv1.0] for details on the key exchange protocols used by the DPoE Network.

8.9 File Transfer

The File Transfer PDU is used by the file transfer protocol used to upgrade DPoE ONU firmware. See Section 12 for details on file transfer PDUs and protocol specifications.

8.10 Attribute List

The DPoE OAM Get Request and Set Request PDUs and corresponding Get Response and Set Response OAM PDUs consist of a list of Variable Descriptors or Variable Containers, as defined in [802.3] Clause 57 for the contents of the standard Variable Request and Variable Response PDUs.

A Variable Descriptor is a 3-byte value composed of a one-byte "branch" code and a two-byte "leaf" code, which uniquely identifies a particular attribute.

Table 18 - Variable Descriptor

Width (Octets)	Field	Value (hex)
1	Branch Code	0: end of list
2	Leaf Code	00 00 .. FF FF

Variable Containers consist of a branch/leaf pair, followed by a one byte field that represents the length of data in the container, followed by the actual data that is the value for that attribute. Thus, a Variable Container has a typical Type-Length-Value (TLV) structure, with a compound Type field. A Variable Descriptor is just the Type portion of this TLV.

Table 19 - Variable Container

Width (Octets)	Field	Value (hex)
1	Branch Code	
2	Leaf Code	
1	Length	00: length of data to follow is 128 bytes 01..7F: length of data to follow in bytes 80..FF: Response/error code (implies zero length of data follows)
varies	Value	Present only when length is greater than zero; format as defined for the branch/leaf code

For brevity, the acronym "TLV" is used to refer to either Variable Descriptors or Variable Containers, even though Variable Descriptors do not actually have a length or value field.

The series of TLVs in a PDU is terminated by a Variable Container or Variable Descriptor with branch, leaf, and length values of 0.

As per [802.3] Clause 57 OAM Variable Containers, Variable Container length values from 1-127 represent the length of data in the container. Zero represents a length of 128 bytes. Values 128 (0x80) and higher represent a

response code to the request indicating the result of the attempted action. All response codes imply a length of zero for the data length.

Table 20 - DPoE Variable Response Codes

DPoE Variable Response Codes	Meaning	Value (hex)
No Error	The operation was successfully completed	80
Too Long	Length of result exceeded OAM PDU data field available	81
Bad Parameters	Parameters for the requested action fail error checking	86
No Resources	The device does not currently have the resources (table entries, memory, etc.) to perform the requested action	87
System Busy	The device is not currently in the proper state to perform the requested action	88
Undetermined Error	Unknown or unlisted Attribute error	A0
Unsupported	The Attribute requested is not supported on this device	A1
May Be Corrupted	The value of an Attribute counter may be invalid due to reset	A2
Hardware Failure	An Attribute hardware error prevented the operation from completing	A3
Overflow	Requested Attribute experienced overflow error	A4

8.11 Data Formats

Variable Containers contain data of several common types. This section describes the format of these data types.

8.11.1 Integers

Integers are represented in two's-complement form, most significant byte first. Note that Containers are variable length; as a result, attributes that are integers do not have a fixed width. The transmitter MAY suppress leading zero bytes of integers. The receiver MUST handle an integer in a Variable Container of any legal width (1..128 bytes). If a Variable Container is smaller than the receiving device representation, the value is extended as necessary. If the Variable Container is larger than the receiving device representation, the result is implementation-defined.

8.11.2 Enumerated Values

Enumerated values take one of a number of bit patterns with predefined meanings. Enumerated values are always represented in a Container with a width equal to that necessary for the largest possible such value in that particular enumerated value, with leading zeros as necessary when the actual value is shorter than the maximum possible.

8.11.3 Sequences

A "sequence" is a series of values, usually enumerated values. Every element in a sequence must have the same width. The number of elements in the sequence can thus be determined from the width of the Variable Container.

8.12 Large Values

The maximum length of data that can fit into a single Variable Container is 128 bytes. Some attribute values may be larger. Values larger than 128 bytes long are represented by a contiguous series of Variable Containers with a repeated branch/leaf code for the attribute in question. This series of TLVs is terminated by a TLV with the same branch/leaf code, and a length of zero, to indicate the end of the large value.

The attribute value is segmented into the several TLVs as described for particular attributes. For ease of segmentation and reassembly, the value for tables of items is not necessarily broken at 128 byte boundaries, but rather the closest boundary that contains an integral number of table items. For example, a MAC address table consisting of a large number of entries, each 6 bytes long, can hold at most 21 whole MAC addresses in whole TLV

(21 x 6 = 126 bytes). Rather than break the 22nd MAC address across two TLVs, the first TLV would contain 126 bytes and the next the remainder of the value.

Example

A Get PDU contains a single Var Container to request the MAC address table from a DPoE ONU:D7 01 03.

Assume further that the polled DPoE ONU currently has 23 learned MAC addresses, and returns the response using three Variable Containers in the PDU, 21 addresses in the first TLV and 2 in the second, followed by the large value terminator:

```
D7 01 03 7E 11 12 13 14 15 16....
D7 01 03 0C 21 22 23 24 25 26 31 32 33 34 35 36
D7 01 03 80
```

8.13 Multiple Part OAM Responses

Certain responses from the DPoE ONU to a single PDU from the DPoE System may not fit within a single OAM frame. (Variable Containers are larger than Variable Descriptors, and some values can be much larger than a single frame. Such attributes include DPoE ONU rule tables and learning tables.) In this case, the ONU must split its response across multiple OAM PDUs. The ONU must then inform the DPoE System that the complete response was not sent in one frame; in addition, the DPoE System must be able to detect missing OAM PDUs from a series needed to form the complete response.

To indicate that further response messages are forthcoming, the DPoE ONU adds a particular TLV known as a Sequence TLV to its response PDU.

Sequence TLVs SHOULD NOT be inserted into single part response frames.

The Sequence TLV has the following format:

Table 21 - Multiple Part OAM Response TLV

Field	Description	Value (hex)
Branch	Branch Attribute	D7
Leaf	Multi-Part Response Sequence Number	00 D8
Length	One 16-bit unsigned integer	02
Sequence #	Bit 15, when set, indicates that this is the last message of its sequence. Bits 0-14 are a 15 bit sequence number.	(variable)

To send a multiple part response requiring N PDUs, the DPoE ONU does the following:

```
For the first PDU in the sequence:

      Set seqNum = 0


For the last PDU of the sequence:

      Set bit 15 of the sequence number


For all PDUs in the sequence:

      Add a sequence TLV with the value {D7, D8, seqNum}
      Send the OAM PDU
      Increment seqNum
```

Figure 5 presents a sample message exchange.

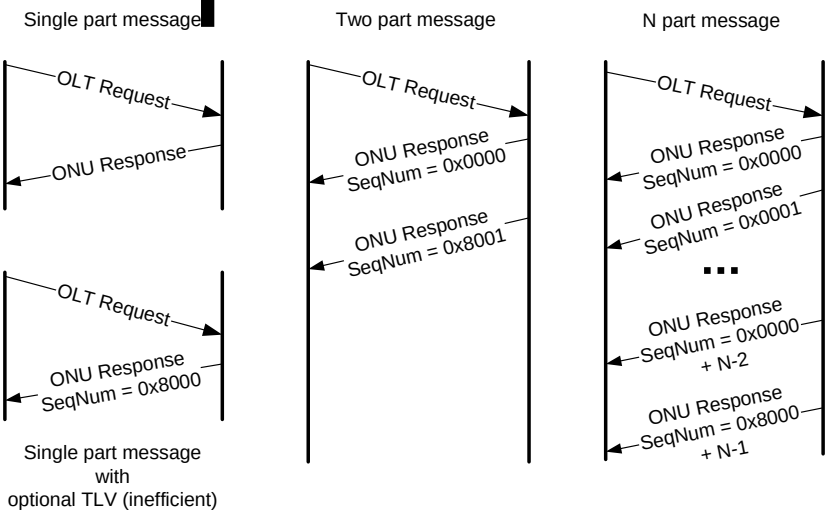

Figure 5 - Sample Message Exchange

8.14 Object Context (Branch D6)[2]

DPoE OAM extensions can manage objects other than the immediate EPON MAC instance. Also, since a DPoE ONU typically supports multiple ports, any attribute such as "Bytes Received" may have many instances, one for each port on the ONU. Therefore, the particular instance of an object must 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 TU interface port and link on which the OAM PDU was received.

A DPoE ONU is assumed to have 1 or more Ethernet interfaces in addition to the TU interface. TU Interfaces and Ethernet interfaces are identified by a 16-bit ID number that ranges from 0..N-1, using two separate numbering spaces for TU interface and Ethernet interfaces. The relationship of interface numbers to actual physical interfaces is defined by the DPoE ONU, but the relationship is always the same for any given DPoE ONU.

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

Table 22 - Object Context

Leaf (HEX)	Attribute	Description
00 00	ONU Object	ONU
00 01	Network PON Port	A PON port on the network side of the device
00 02	Logical Link Object	OAM logical link context
00 03	User Port Object	User-side Ethernet port
00 04	Queue Object	A single queue

[2] Revised per OAMv1.0-N-12.0007-2 on 3/30/12 by JB.

8.14.1 DPoE ONU Object (D6/00 00)

The DPoE ONU object identifies the DPoE ONU as a whole. In most cases, this object is obvious because the DPoE ONU is the one processing the DPoE OAM message. In some cases, a DPoE OAM PDU may want to make the current context less specific for a particular attribute. The DPoE ONU Object is also necessary for some other uses, such as in an alarm TLV.

The instance number for the DPoE ONU object is always 0.

8.14.2 Network Port Object (D6/00 01)

The Network Port object identifies one of the network-side PON ports (TU interface) on the device. Network Ports are numbered sequentially starting from 0. Network Port 0 is the same object as the port identified by Port object (D6/03) value 0. This object cannot identify S_1 interfaces.

Table 23 - Network Port Object

Width (Octets)	Field	Value (hex)
1	PON Number	0..N-1

8.14.3 Link Object (D6/00 02)

The link object identifies one of the logical links supported by the ONU, numbered starting from 0 up to L-1, where L is the number of logical links supported by the ONU. The default link is the link on which the OAM PDU was received.

Table 24 - Link Object

Width (Octets)	Field	Value (hex)
1	Link Number	0..L-1

8.14.4 User Port Object (D6/00 03)

The User Port object identifies one of the S interfaces or references points on the device (if any). S_1 interfaces are numbered sequentially starting from 0.

Table 25 - User Port Object

Width (Octets)	Field	Value (hex)
1	UNI Number	0..N-1

8.14.5 Queue Object (D6/00 04)

Queues are numbered relative to their egress port. Queue numbers start with the value 0, which is the highest priority queue, up to the value N-1, where N is the number of queues that terminate on a port. The value 0xFFFF is a special value that means "all queues for this port". This context is primarily useful for bulk statistics queries from all queues at once, as it saves setting a queue context for each queue.

Table 26 - Queue Object

Width (Octets)	Field	Value (hex)
2	Object Type	See Section 8.14. (Only User Ports and Logical Link have queues.)
1	Object Instance	0..N-1
1	Queue Number	0..Q-1

9 OAM ATTRIBUTES BY FUNCTION

This section further details each DPoE OAM attribute. Each attribute name is listed by its 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. Where applicable, units for measurement and allowed ranges are specified.

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

9.1 DPoE ONU Management

9.1.1 Sequence Number (D7/00 01)

See Section 8.13.

9.1.2 DPoE ONU ID (D7/00 02)

The ONU ID is a non-volatile number that uniquely identifies a physical DPoE ONU. By definition, the DPoE ONU ID is the lowest (numerically smallest) MAC address among all MAC addresses associated with the TU interface port of a DPoE ONU. All logical links on a DPoE ONU report the same DPoE ONU ID, despite having different link MAC addresses (per [802.3]).

9.1.3 Firmware Info (D7/00 03)

This attribute represents the DPoE ONU firmware version. The version number uniquely identifies a particular version of the ONU firmware. Format is defined by the ONU vendor. DPoE Systems can compare this value for equality with a provisioned value for the currently correct firmware version. "Newer than" or "compatible with" comparisons depend on version number format and should not be performed with a simple comparison. Version values 0x0000 and 0xFFFF are reserved, and indicate loads that are not installed or are not available.

Table 27 - Firmware Info

Size	Name	Description
2	Boot Version	Version of bootstrap loader (if any)
4	Boot CRC-32	CRC-32 of boot loader serves as additional unique identifier and verification
2	Application Version	Version of main application software running on the DPoE ONU
4	Application CRC-32	CRC-32 of application software serves as unique ID and verification

9.1.4 EPON Chip Info (D7/ 00 04)

This attribute represents the type of EPON chip used on the DPoE ONU.

Table 28 - EPON Chip Info

Size	Name	Description
2	JEDEC ID	16-bit chip manufacturer ID code as assigned by JEDEC
4	Chip Model	Identifies the particular kind of EPN chip. Format defined by chipset vendor
4	Chip Version	Identifies the version or stepping of the chip model. Format defined by chipset vendor

9.1.5 Date of Manufacture (D7/00 05)

The date the DPoE ONU was manufactured, encoded in Binary Coded Decimal (BCD) digits as YYYYMMDD. For example, June 24, 2010, would be represented as 20 10 06 24.

Table 29 - Date of Manufacture

Size	Name	Description
2	Year	BCD
1	Month	BCD
1	Day	BCD

9.1.6 Manufacturer Info (D7/00 06)

This attribute holds manufacturer-specific information that identifies this individual ONU. This attribute typically contains a serial number, and possibly other manufacturing information, such as lot numbers or component revisions. Format is defined by the ONU vendor.

9.1.7 Max Logical Links (D7/00 07)

The maximum number of logical links the ONU supports on the EPON.

Table 30 - Max Logical Links

Size	Name	Description
2	Bidirectional	Maximum number of links which can both transmit and receive.
2	Downstream-only	In addition to the bidirectional links, the maximum number of LLIDs which can receive data, but not transmit (unidirectional, downstream only)

9.1.8 Number of Network Ports (D7/00 08)

This attribute provides the total number of TU interface ports on the ONU.

9.1.9 Number of S_1 interfaces (D7/00 09)

This attribute provides the number of S_1 interfaces on the DPoE ONU.

9.1.10 DPoE ONU Packet Buffer (D7/00 0A)

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

Table 31 - ONU Packet Buffer

Size	Name	Description
1	Upstream Queues	Total number of queues available to be assigned to logical links in the upstream direction
1	Up Queues Max Per Link	Maximum number of queues which can be assigned to a single logical link in the upstream direction
1	Up Queue Increment	The smallest allocatable increment of packet buffer memory in the upstream direction, in kilobytes.
1	Downstream Queues	Total number of queues available to be assigned to logical links in the downstream direction
1	Dn Queues Max Per Port	Maximum number of queues which can be assigned to a single UNI port in the downstream direction
1	Dn Queue Increment	The smallest allocatable increment of packet buffer memory in the downstream direction, in kilobytes.
2	Total Packet Buffer	Total packet buffer memory on the ONU (KB)
2	Up Packet Buffer	Maximum amount of packet buffer memory which can be allocated to upstream queues
2	Dn Packet Buffer	Maximum amount of packet buffer memory which can be allocated to downstream queues

9.1.11 Report Thresholds (D7/00 0B)

This attribute represents the threshold levels used to generate REPORT MPCPDUs. The format corresponds closely to the format of the REPORT MPCPDU, except that the bitmaps for report values present are omitted. The message specifies the number of queue sets and the number of report values in each queue set to be used on the link. A DPoE System MUST insure the number of report values in each queue set is the same. For each queue set and report value, a threshold is specified.

A DPoE System MUST insure the report thresholds for successive queue sets are increasing and are cumulative. For example, Report Threshold 0 for Queue Set 1 must be equal to or greater than Report Threshold 0 in Queue Set 0. A higher numbered queue set includes all the data reported in earlier queue sets, plus possibly some additional data.

Table 32 - Report Thresholds

Size	Description	Units	Default	Min	Max
1	Number of Queue Sets		4	1	4
1	Report Values Per Queue Set		1	1	8
2	Report Threshold 0 for Queue Set 0	EPON TQ	2048	0	FFFF
	…				
2	Report Threshold n-1 for Queue Set 0	EPON TQ	-	0	FFFF
	…				
2	Report Threshold 0 for Queue Set n-1	EPON TQ	-	0	FFFF
	…				
2	Report Threshold n-1 for Queue Set n-1	EPON TQ	-	0	FFFF

9.1.12 LLID Forwarding State (D7/00 0C)[3]

This attribute represents the current traffic state for an LLID. User data traffic may be enabled (normal operation) or disabled (discarded by the DPoE ONU). Only OAM and MPCP remain enabled regardless of the LLID forwarding state.

Table 33 - Link State

Size	Description	Units	Default	Min	Max
1	Link State (0=Disable, 1=Enable)	Boolean	0	0	1

9.1.13 OAM Frame Rate (D7/00 0D)

This attribute represents the maximum rate at which OAM PDUs are transmitted on a link.

Setting the Maximum OAM Frame Rate to 0 disables rate control.

The Minimum OAM Frame Rate is the heartbeat rate. This is the rate at which OAM PDUs are sent between the ONU and DPoE System, using an Info PDU as a "heartbeat" if there is no other OAM activity, as per [802.3]. The heartbeat rate is specified as one heartbeat PDU per specified time interval. The time interval is specified as the value provisioned in the message x 100ms. Therefore, setting the Minimum OAM Frame Rate to 10 specifies a rate of 1 PDU per 10 x 100ms. This equals 1 PDU per 1 second.

The DPoE ONU implementation maintains one instance of the OAM rate. This rate applies to all links on the ONU.

Table 34 - OAM Frame Rate

Size	Description	Units	Default	Min	Max
1	Maximum OAM rate	PDUs/100ms	1	0 (Unlimited rate)	25

[3] Revised per OAMv1.0-N-12.0009-1 on 3/30/12 by JB.

Size	Description	Units	Default	Min	Max
1	Minimum OAM rate	Number of 100ms	10	0 (no OAM) heartbeat)	10

9.1.14 ONU Manufacturer Organization Name (D7/00 0E)[4]

This attribute represents the organization which manufactured the D-ONU. The attribute is an ASCII string, with no null terminator. It is used to validate the manufacturer CVC during secure software download. The value must exactly match the subject organizationName value in the firmware manufacturer CVC. See [SECv3.0] for details.

Table 35 - ONU Manufacturer Organization Name

Size	Description	Units	Default	Min	Max
varies	Organization name	string	-	-	-

9.1.15 Firmware Mfg Time Varying Controls (D7/00 0F)[5]

This attribute represents the firmware CVC and CVS validity times as programmed into the D-ONU. The TVC affects the validity of firmware updates. See [SECv3.0] for details.

Time values are ASCII strings representing the time in UTC in the format YYMMDDhhmmssZ. Per [SECv3.0], dates range from the year 1950 to 2050; the upper two digits of the year are implied.

Table 36 - Firmware Mfg Time Varying Controls

Size	Description	Units	Default	Min	Max
13	Code Access Start	Seconds	-	500101000000Z	491231235959Z
13	CVC Access Start	Seconds	-	500101000000Z	491231235959Z

9.1.16 Reset DPoE ONU (D9/00 01)

This attribute resets the ONU, as if from power on.

9.2 Bridging

9.2.1 Dynamic Learning Table Size (D7/01 01)

This attribute represents Dynamic MAC learning table size.

Table 37 - Dynamic Learning Table Size

Size	Description	Units	Default	Min	Max
2	Dynamic MAC learning table size	Entries	n/a	1	FFFF

9.2.2 Dynamic Address Age Limit (D7/01 02)

This attribute represents Dynamic MAC learning table age limit.

Table 38 - Dynamic Address Age Limit

Size	Description	Units	Default	Min	Max
2	Dynamic MAC learning table age limit	8.75 ms	2000	0	8000

[4] Section added per OAMv1.0-N-12.0009-1 on 3/30/12 by JB.
[5] Section added per OAMv1.0-N-12.0009-1 on 3/30/12 by JB.

9.2.3 Dynamic MAC Table (D7/01 03) R

This attribute represents the dynamically learned MAC address rules of one Ethernet port. MAC address are repeated within a single attribute until that attribute is full (21 addresses = 126 bytes). If necessary, such attributes are repeated as an attribute list until the entire table has been reported.

Table 39 - Dynamic MAC Table

Size	Description	Units	Default	Min	Max
6	MAC address 0	-	--	-	-
...	MAC address 1	-	-	-	-

9.2.4 Static MAC Table (D7/01 04) R

This attribute represents the statically provisioned MAC address table. The data structure is the same as the Get Dynamic MAC Table attribute above.

9.2.5 S_1 Interface Port Auto-negotiation (D7/01 05)

This attribute represents the auto-negotiation advertisement values used by a port. The set command specifies the values to advertise, while the get command returns the current values along with the values the port can physically support.

Table 40 - S1 Interface Port Auto-Negotiation

Size	Description	Units	Default	Min	Max
2	Bit array of maximum capabilities, returned only in the Get response (see Table 41).	Bitmap	Depends on port	-	-
2	Bit array of current capabilities (see Table 41). A capability is advertised as supported when its bit = 1.	Bitmap	Depends on port	-	-

Table 41 - Port Capabilities

Auto-Negotiation Capability	
Half Duplex	Bit 0 (LSB)
Full Duplex	Bit 1
10 Mbps	Bit 2
100 Mbps	Bit 3
1000 Mbps	Bit 4
10 Gbps	Bit 5
Flow Control	Bit 6
Auto MDI/MDI-X	Bit 7
Unused (set to 0)	Bit 8-15

9.2.6 Source Address Admission Control (D7/01 06)[6]

This attribute controls the operation of the MAC Source Address-based admission control function operating on the DPoE ONU port in context in the upstream direction.

Table 40 - Source Address Admission Control

Size	Description	Units	Default	Min	Max
1	Indicates whether the Source Address Admission Control for the given DPoE ONU port is enabled or not. 0 = disabled 1 = enabled	enum	0	0	1

The MAC Source Address-based admission control function operating on the selected DPoE ONU port in the upstream direction controls what frames received from DPoE ONU ports are admitted for upstream transmission. When the MAC Source Address-based admission control function is disabled, all frames received from the DPoE ONU port are admitted for upstream transmission. When the MAC Source Address-based admission control function is enabled, the DPoE ONU MUST drop any frame received from the DPoE ONU ports if the MAC Source Address for such a frame is not present in the MAC address admission control table on the DPoE ONU. The said table may be filled through dynamic MAC learning or configured through provisioning.

9.2.7 MAC Learning Min Guarantee (D7/01 07)

This attribute represents minimum number of MAC addresses that can be learned on an individual UNI port.

Table 42 - MAC Learning Min Guarantee

Size	Description	Units	Default	Min	Max
2	Minimum guaranteed limit	Entries	40	0	40

9.2.8 MAC Learning Max Allowed (D7/01 08)

This attribute represents maximum allowed number of MAC addresses on an individual S_1 port.

Table 43 - MAC Learning Max Allowed

Size	Description	Units	Default	Min	Max
2	Maximum allowed limit	Entries	n/a	0	FFFF

9.2.9 MAC Learning Aggregate Limit (D7/01 09)

This message represents the aggregate dynamic MAC address limit for the DPoE ONU as a whole. This is the maximum number of addresses that can be learned by all ports combined.

Table 44 - MAC Learning Aggregate Limit

Size	Description	Units	Default	Min	Max
2	The ONU aggregate dynamic MAC address limit	Entries	0	0	FFFF

9.2.10 Len Error Discard (D7/01 0A)

This attribute represents the Length Error Discard Enable status of the DPoE ONU ports. Length errors occur when the layer 2 length does not match the frame length.

[6] Revised per OAMv1.0-N-12.0016-2 on 3/30/12 by JB.

Table 45 - Len Error Discard

Size	Description	Units	Default	Min	Max
1	If Length Error Discard Enable 0: Frames with a Length Error will be passed 1: Frames with a Length Error will be discarded	Boolean	1	0	1

9.2.11 Flood Unknown (D7/01 0B)

This message represents the configuration for flooding of downstream frames whose destination addresses have not been learned. Disabling will cause these frames to be discarded.

Table 46 - Flood Unknown

Size	Description	Units	Default	Min	Max
1	Flood Unknown DA option 0: Drop unknown MAC DA 1: Flood unknown MAC DA	Boolean	1	0	1

9.2.12 Local Switching (D7/01 0C)

This attribute represents the configuration of a port for local switching. With local switching enabled, a port may send traffic to any other user-side port of the ONU. This feature should be used with caution for unknown flooding.

Table 47 - Local Switching

Size	Description	Units	Default	Min	Max
1	Local Switching option 0: Disable local switching 1: Enable local switching	Boolean	0	0	1

9.2.13 Queue Configuration (D7/01 0D)

This action configures the upstream and downstream queues on the DPoE ONU. The upstream queues hold frames destined for the Logical Links. The downstream queues hold frames destined for the UNI Ethernet ports. Queue sizes are specified in the order of queue priority, where the first queue has the highest priority.

The DPoE ONU MUST reject a queue configuration message that changes queue numbers or size for any LLIDs/queues that have port ingress rules that use those queues. The vCM MUST delete all port ingress rules that forward traffic to particular queues before those queues can be deleted (including by removing their LLID) or resized. [7]

Table 48 - Queue Configuration

Size	Description			Units	Default	Min	Max*
Upstream Configuration							
1	N, the number of logical links to configure.			Logical Links	1	1	32768
	Link 0 Configuration						
	1	M, the number of upstream queues for Link 0		queues	1	1	8
	M	1	Queue 0 Size	4KB			
		…	…				

[7] Paragraph updated per OAMv1.0-N-12.00261-1 on 5/25/12 by PO

Size	Description			Units	Default	Min	Max*
		1	Queue M - 1 Size	4KB		1	-
	Link 1 Configuration						
	…						
	Link N - 1 Configuration						
Downstream Configuration							
1	P, the number of Ports to configure.					1	-
	Port 0 Configuration (i.e., Ethernet port 1)						
	1	J, the number of downstream queues for Port 0		queues	8	0	8
	J	1	Queue 0 Size	4KB		1	-
		…	…				
		1	Queue J - 1 Size	…4KB		1	-
	Port 1 Configuration						
	…						
	Port P – 1 Configuration						

(*) The Maximum value is subject to available queues. Some of these queues are required by the system for internal use, especially depending on the number of links to register.

The message above consists of two configuration sections: Upstream and Downstream. The upstream section of the message specifies link configuration. The TU interface port registers one or more logical links, and each link can be assigned one or more queues. The downstream section specifies UNI port configuration. Each port can be assigned one or more queues:

- The sum of queue sizes must not exceed the size reported in the Get ONU Information.
- The following example shows the contents of a command that configures two links and two UNI ports:
- Upstream Configuration: N (number of links) = 2
- Link 0 configuration: [M=2, (Queue 0 Size=10, Queue 1 size=10)]
- Link 1 configuration: [M=1, (Queue 0 Size = 5)]}
- Downstream Configuration: P (number of ports) = 2
- Port 0 (i.e., UNI port 1) configuration: [J=2, (Queue 0 Size=5, Queue 1 Size=5)]
- Port 1 (i.e., UNI port 2) configuration: [J=1, (Queue 0 Size=8)]

9.2.14 Firmware Filename (D7/01 0E) NVS

Non-Volatile Storage attributes represent memory on the ONU that is rewriteable and will survive a power-on reset. The DPoE System can set values for this attribute and retrieve that value after a reset, unlike most attributes, which revert to default values after a reset.

The filename is a null-terminated ASCII string representing the name of the file as received from the OSS by the virtual Cable Modem (vCM).

9.2.15 Clear Dynamic MAC Table (D9/01 01)

This action clears the dynamically learned MAC addresses table for the object in context, either a particular port, or the DPoE ONU as a whole (all S_1 ports on the DPoE ONU).

9.2.16 Add Dynamic MAC Address (D9/01 02)

This attribute adds one or more dynamic MAC addresses to the table for the port in context.

Table 49 - Add Dynamic MAC Address

Size	Description	Units	Default	Min	Max
6	MAC address 0	--	-	-	-
...	MAC address 1	-	-	-	-

9.2.17 Delete Dynamic MAC Address (D9/01 03)

This attribute deletes one or more dynamic MAC addresses to the table for the port in context. Format is the same as for Add Dynamic MAC Address.

9.2.18 Clear Static MAC Table (D9/01 04)

This action clears the entire static MAC address table for the object in context, either a particular port, or the DPoE ONU as a whole (all S_1 ports on the DPoE ONU).

9.2.19 Add Static MAC Address (D9/01 05)

This attribute adds one or more static MAC addresses from the forwarding table for the port in context.

Table 50 - Add Static MAC Address

Size	Description	Units	Default	Min	Max
6	MAC address 0	-	-	-	-
...	MAC address 1	-	-	-	-

9.2.20 Delete Static MAC Address (D9/01 06)

This attribute adds one or more static MAC addresses from the forwarding table for the port in context.

Table 51 - Delete Static MAC Address

Size	Description	Units	Default	Min	Max
6	MAC address 0	-	-	-	-
...	MAC address 1	-	-	-	-

9.3 Statistics

9.3.1 Rx Unicast Frames (D7/02 01)

This attribute represents RxUnicastFrames counter of one port.

Table 52 - Rx Unicast Frames

Size	Description	Units	Default	Min	Max
8	RxUnicastFrames counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.2 Tx Unicast Frames (D7/02 02)

This attribute represents TxUnicastFrames counter of one port.

Table 53 - Tx Unicast Frames

Size	Description	Units	Default	Min	Max
8	TxUnicastFrames counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.3 Rx Frame Too Short (D7/02 03)

This attribute represents RxFrameTooShort counter of one port.

Table 54 - Rx Frame Too Short

Size	Description	Units	Default	Min	Max
8	RxFrameTooShort counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.4 Rx Frame 64 (D7/02 04)

This attribute represents RxFrame64 counter of one port.

Table 55 - Rx Frame

Size	Description	Units	Default	Min	Max
8	RxFrame64 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.5 Rx Frame 65_127 (D7/02 05)

This attribute represents RxFrame65_127 counter of one port.

Table 56 - Rx Frame 65_127

Size	Description	Units	Default	Min	Max
8	RxFrame65_127 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.6 Rx Frame 128_255 (D7/02 06)

This attribute represents RxFrame128_255 counter of one port.

Table 57 - Rx Frame 128_255

Size	Description	Units	Default	Min	Max
8	RxFrame128_255 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.7 Rx Frame 256_511 (D7/02 07)

This attribute represents RxFrame256_511 counter of one port.

Table 58 - Rx Frame 256_511

Size	Description	Units	Default	Min	Max
8	RxFrame256_511 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.8 Rx Frame 512_1023 (D7/02 08)

This attribute represents RxFrame512_1023 counter of one port.

Table 59 - Rx Frame 512_1023

Size	Description	Units	Default	Min	Max
8	RxFrame512_1023 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.9 Rx Frame 1024_1518 (D7/02 09)

This attribute represents RxFrame1024_1518 counter of one port.

Table 60 - Rx Frame 1024_1518

Size	Description	Units	Default	Min	Max
8	RxFrame1024_1518 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.10 Rx Frame 1519 Plus (D7/02 0A)

This attribute represents RxFrame1519Plus counter of one port.

Table 61 - Rx Frame 1519 Plus

Size	Description	Units	Default	Min	Max
8	RxFrame1519Plus counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.11 Tx Frame 64 (D7/02 0B)

This attribute represents TxFrame64 counter of one port.

Table 62 - Tx Frame 64

Size	Description	Units	Default	Min	Max
8	TxFrame64 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.12 Tx Frame 65_127 (D7/02 0C)

This attribute represents TxFrame65_127 counter of one port.

Table 63 - Tx Frame 65_127

Size	Description	Units	Default	Min	Max
8	TxFrame65_127 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.13 Tx Frame 128_255 (D7/02 0D)

This attribute represents TxFrame128_255 counter of one port.

Table 64 - Tx Frame 128_255

Size	Description	Units	Default	Min	Max
8	TxFrame128_255 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.14 Tx Frame 256_511 (D7/02 0E)

This attribute represents TxFrame256_511 counter of one port.

Table 65 - Tx Frame 256_511

Size	Description	Units	Default	Min	Max
8	TxFrame256_511 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.15 Tx Frame 512_1023 (D7/02 0F)

This attribute represents TxFrame512_1023 counter of one port.

Table 66 - Tx Frame 512_1023

Size	Description	Units	Default	Min	Max
8	TxFrame512_1023 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.16 Tx Frame 1024_1518 (D7/02 10)

This attribute represents TxFrame1024_1518 counter of one port.

Table 67 - Tx Frame 1024_1518

Size	Description	Units	Default	Min	Max
8	TxFrame1024_1518 counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.17 Tx Frame 1519 Plus (D7/02 11)

This attribute represents TxFrame1519Plus counter of one port.

Table 68 - Tx Frame 1519 Plus

Size	Description	Units	Default	Min	Max
8	TxFrame1519Plus counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.18 Tx Delay Threshold (D7/02 12)

This attribute represents Threshold for Delay that causes Bytes Delayed counter to increment of one port.

Table 69 - Tx Delay Threshold

Size	Description	Units	Default	Min	Max
1	TxDelayThreshold of one port	100us	0x1E	0	0xFF

9.3.19 Tx Delay (D7/02 13)

This attribute represents Maximum Frame Delay experienced since statistic reset of one port.

Table 70 - Tx Delay

Size	Description	Units	Default	Min	Max
8	TxDelay of one port	100us	-	0	FFFF FFFF FFFF FFFF

9.3.20 Tx Frames Dropped (D7/02 14)

This attribute represents the Upstream frames dropped due to queue overflow counter of one port.

Table 71 - Tx Frames Dropped

Size	Description	Units	Default	Min	Max
8	TxFramesDropped counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.21 Tx Bytes Dropped (D7/02 15)

This attribute represents the Upstream bytes dropped due to queue overflow counter of one port.

Table 72 - Tx Bytes Dropped

Size	Description	Units	Default	Min	Max
8	TxBytesDropped counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.22 Tx Bytes Delayed (D7/02 16)

This attribute represents the bytes in frames delayed more than TxDelayThreshold of one port.

Table 73 - Tx Bytes Delayed

Size	Description	Units	Default	Min	Max
8	TxBytesDelayed counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.23 Tx Bytes Unused (D7/02 17)

This attribute represents the bytes granted to the LLID but not filled with transmitted data of one port.

Table 74 - Tx Bytes Unused

Size	Description	Units	Default	Min	Max
8	TxBytesUnused counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.24 Rx Delay Threshold (D7/02 18)

This attribute represents the Threshold for delay that causes Bytes Delayed counter to increment of one port.

Table 75 - Rx Delay Threshold

Size	Description	Units	Default	Min	Max
1	RxDelayThreshold counter of one port	100us	0x1E	0	0xFF

9.3.25 Rx Delay (D7/02 19)

This attribute represents the Maximum frame delay experienced since statistic reset of one port.

Table 76 - Rx Delay

Size	Description	Units	Default	Min	Max
8	RxDelay counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.26 Rx Frames Dropped (D7/02 1A)

This attribute represents the Downstream Frames dropped due to queue overflow of one port.

Table 77 - Rx Frames Dropped

Size	Description	Units	Default	Min	Max
8	RxFramesDropped counter of one port	Frames	-	0	FFFF FFFF FFFF FFFF

9.3.27 Rx Bytes Dropped (D7/02 1B)

This attribute represents the downstream bytes dropped due to queue overflow of one port.

Table 78 - Rx Bytes Dropped

Size	Description	Units	Default	Min	Max
8	RxBytesDropped counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.28 Rx Bytes Delayed (D7/02 1C)

This attribute represents the Bytes in downstream frames delayed more than RxDelayThreshold of one port.

Table 79 - Rx Bytes Delayed

Size	Description	Units	Default	Min	Max
8	RxBytesDelayed counter of one port	bytes	-	0	FFFF FFFF FFFF FFFF

9.3.29 Optical Mon Temperature (D7/02 1D)

This attribute represents the current optical module temperature.

Table 80 - Optical Mon Temperature

Size	Description	Units	Default	Min	Max
8	Current temperature	1/256 C	1	0	0xFFFF

9.3.30 Optical Mon Vcc (D7/02 1E)

This attribute represents the current optical module Vcc.

Table 81 - Optical Mon Vcc

Size	Description	Units	Default	Min	Max
8	Current Vcc	100 uV	-	0	0xFFFF

9.3.31 Optical Mon Tx Bias Current (D7/02 1F)

This attribute represents the current optical module Tx bias current.

Table 82 - Optical Mon Tx Bias Current

Size	Description	Units	Default	Min	Max
8	Current Tx bias	2 uA	-	0	0xFFFF

9.3.32 Optical Mon Tx Power (D7/02 20)

This attribute represents the current optical module Tx power.

Table 83 - Optical Mon Tx Power

Size	Description	Units	Default	Min	Max
8	Current Tx power	mW	-	0	0xFFFF

9.3.33 Optical Mon Rx Power (D7/02 21)

This attribute represents the current optical module Rx power.

Table 84 - Optical Mon Rx Power

Size	Description	Units	Default	Min	Max
8	Current Rx power	mW	-	0	0xFFFF

9.3.34 Clear Status (D9/02 01)

This action clears all statistics for the DPoE ONU.

9.4 Alarms

Alarms are indicated by the DPoE ONU to the DPoE System using DPoE Event Notification TLVs in an [802.3] Clause 57 Event Notification PDU.

9.4.1 Port Stat Threshold (D7/03 01)

This attribute allows the OAM client to specify an alarm to be generated when a port statistics counter exceeds a certain value at the end of a 1-second sampling period. A rising threshold and a falling threshold (high-water mark and low-water mark) are provided to allow hysteresis. The alarm condition will occur when the statistic is greater than or equal to the rising threshold. The alarm condition will be cleared when the statistic is less than or equal to the falling threshold. A value of 0 for the rising threshold means that the alarm is disabled.

Table 85 - Port Stat Threshold

Size	Description	Units	Default	Min	Max
3	Statistic Attribute branch/leaf	-	-	0	FF-FFFF
4	Rising Threshold (to set alarm; 0 disables the alarm)	As stat	-	0	FFFF FFFF
4	Falling Threshold (to clear alarm)	As stat	-	0	FFFF FFFF

9.4.2 Link Stat Threshold (D7/03 02)

This attribute allows the OAM client to specify an alarm to be generated when a LLID statistics counter exceeds a certain value at the end of a 1-second sampling period. A rising threshold and a falling threshold (high-water mark and low-water mark) are provided to allow hysteresis. The alarm condition will occur when the statistic is greater than or equal to the rising threshold. The alarm condition will be cleared when the statistic is less than or equal to the falling threshold. A value of 0 for the rising threshold means that the alarm is disabled.

Table 86 - Link Stat Threshold

Size	Description	Units	Default	Min	Max
3	Statistic Attribute Branch/Leaf)	-	-	0	FF FFFF
4	Rising Threshold (to set alarm; 0 disables the alarm)	As stat	-	0	FFFF FFFF
4	Falling Threshold (to clear alarm)	As stat	-	0	FFFF FFFF

9.5 Security

Security attributes control encryption on the EPON. Details of encryption methods and their use can be found in [DPoE-SP-SECv1.0].

9.5.1 Encryption Key Expiry Time (D7/04 01)

This attribute represents the timeout value for encryption keys. A new key will be generated and exchanged periodically, as this timer expires. A timeout value of 0 is used to disable security (i.e., encryption). The minimum non-zero value should be at least 10 seconds.

Table 87 - Encryption Key Expiry Time

Size	Description	Units	Default	Min	Max
2	Timeout value	sec	0	0/10	FFFF

9.5.2 Encryption Mode (D7/04 02)

This attribute sets the encryption method to be used on a particular logical link. Details of encryption methods are defined in [DPoE-SP-SECv1.0].

Table 88 - Encryption Mode

Size	Description	Units	Default	Min	Max
1	Encryption Method 0: None 1: 1Down 2: 10Down 3: 10Bi	enum	0	0	3

9.6 Frame Processing

9.6.1 Port Ingress Rule (D7/05 01)

This attribute represents a rule in the ingress table of the current port. A single rule, which can be complex and larger than the 128-byte contents of a single TLV, is represented in an OAM frame as a series of TLVs with this attribute code. The first byte of the attribute is always a subtype indicator, which indicates the structure of the rest of the TLV contents.

A single rule is represented by a sequential series of Port Ingress Rule TLVs, which must start with one Header subtype, then one or more Clause subtype TLVs, then one or more Result subtype TLVs, and finally end with a Terminator subtype. For each rule, DPoE System MUST include one Header subtype, one or more Clause subtypes, one or more Result subtypes, and end with the Terminator subtype. Similarly, for each rule, DPoE ONU MUST include one Header subtype, one or more Clause subtypes, one or more Result subtypes, and end with the Terminator subtype.

Table 89 - Rule Attribute Subtypes

Field Value	Name	Description
0	Terminator	Indicates end of one individual rule
1	Header	Information which pertains to the entire rule
2	Clause	One single clause of the rule condition; all clauses are ANDed together to form the condition that determines whether the rule matches
3	Result	One single result that occurs if the rule condition is true

9.6.1.1 Rule Attribute – Terminator Subtype

The terminator subtype indicates the end of a single rule. There are no further contents in the body of this subtype.

9.6.1.2 Rule Attribute – Header Subtype

All rules begin with a Rule attribute of the Header subtype.

Table 90 - Rule Attribute Header Subtype

Size	Name	Description
1	Subtype	Header (01)
1	Precedence	Precedence of the rule (00..0F)

9.6.1.3 Rule Attribute – Clause Subtype[8]

Rule clauses define the condition that must evaluate to true for the rule to match a frame. All clauses of a rule are evaluated and the individual results ANDed together to determine the match condition. An individual clause is a binary operation which relates a field in the frame with a constant match value via a binary operator.

Table 91 - Rule Attribute Clause Subtype

Size	Name	Description
1	Subtype	Clause (02)
1	Field Code	Code representing the field of the frame for this clause; see Table 92.
1	Field Instance	Which instance of a field identified by code (if there is more than one)
1	MSB Mask	Bits to ignore on the most significant side of the field
1	LSB Mask	Bits to ignore on the least significant side of the field
1	Operator	Binary operator for this rule
1	Match Value Length	Number of bytes of Match Value to follow
varies	Match Value	Constant value combined with field value via the binary operator for this clause

Some fields, such as VLAN tags, occur in multiple instances in some frames. To distinguish two such fields, a Field Instance is used in conjunction with the Field Code. Instances of such fields are numbered starting from 0 in the order in which they are transmitted in the frame. So, for example, C-VLAN Tag 0 would be the outermost tag in a frame, immediately after the addresses, with two C-VLAN tags, with C-VLAN Tag 1 being the inner tag, closer to the payload of the frame.

The most-significant- and least-significant-bits masks are used to reduce the number of field codes and provide flexibility for frame processing rules. A VLAN tag, for instance, is coded as one field. Commonly, however, rules might be interested in just the Tag Protocol Identifier (TPID), just the Class of Service (CoS), or just the VID portions of this field. A rule can compare these subfields by using the MSB and LSB masks to isolate the sub-field of interest. Similarly, the IPv4 TOS field is 8 bits wide, but the same bits are interpreted as IP Precedence (upper three bits) or DSCP. Any of these interpretations can be accommodated with the single IPv4 TOS field and the proper masks.

The match value is a variable-length field, always an integral number of octets wide. Values are right-aligned in this field, occupying the least significant bits.

Since IPv4 and IPv6 headers have similar semantics, and a single frame can only be one or the other, but not both, of these types, some field codes are re-used for the IP equivalents like the addresses or priority fields. Rule sets that need to treat the same field differently based on protocol should use the EtherType field to distinguish IPv4 from IPv6.

[8]Revised per OAMv1.0-N-12.0016-2 on 3/30/12 by JB.

Table 9 - Field Codes

Value (hex)	Description	Multiple?
00	LLID Index	N
01	L2 Destination MAC address	N
02	L2 Source MAC address	N
03	L2 Type/Len	N
04	B-DA ([802.1ah])	N
05	B-SA ([802.1ah])	N
06	I-Tag ([802.1ah])	N
e	S-VLAN Tag	Y
08	C-VLAN Tag	Y
09	MPLS	Y
0A	IPv4 TOS/IPv6 Traffic Class	N
0B	IPv4 TTL/IPv6 Hop Limit	N
0C	IPv4/IPv6 Protocol Type	N
0D	IPv4 Source Address	N
0E	IPv6 Source Address	N
0F	IPv4 Destination Address	N
10	IPv6 Destination Address	N
11	IPv6 Next Header	Y* (Note 1)
12	IPv6 Flow Label	N
13	TCP/UDP source port	N
14	TCP/UDP destination port	N
e	Reserved	-
e	Reserved	-
17	Reserved	-
18	Custom field 0	N
19	Custom field 1	N
1A	Custom field 2	N
1B	Custom field 3	N
1C	Custom field 4	N
1D	Custom field 5	N
1E	Custom field 6	N
1F	Custom field 7	N

Table Notes:

Note 1 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.

Note 2 LLID Index represents the local index of the logical link instantiated on the DPoE ONU. For example, for a DPoE ONU supporting 8 LLIDs, the value of LLID Index would range from 0 to 7. In this way, the LLID Index has only local, DPoE ONU specific meaning. The LLID Index matches the LLID in order of the link MAC address. That is, LLID Index 0 on a particular DPoE ONU is the LLID with the numerically lowest MAC address on that DPoE ONU; LLID Index 1 is the next higher MAC address, and so on.

Table 93 Rule Operator

Field Value	Symbol	Description
0	F	Never match
1	==	Field equal to value
2	!=	Field not equal to value
3	<=	Field less than or equal to value
4	>=	Field greater than or equal to value
5	exists	True if field exists (value ignored)
6	!exist	True if field does not exist (value ignored)
7	T	Always match

9.6.1.4 Rule Attribute – Result Subtype

Rule results represent the processing performed on a frame when the frame matches the rule condition.

Table 94 - Rule Attribute Result Subtype

Size	Name	Description
1	Subtype	Result (03)
1	Rule Result	Rule Result (see Table 95)
varies	Result Parameters	Rule Result Parameters, as defined for each result

Table 95 - Rule Results

Code (hex)	Name	Description	Parameter Len	Parameter
00	NOP	No operation	0	
01	Discard	Set Discard Flag for Frame	0	
02	Forward	Clear Discard Flag for Frame (Forward Frame)	0	
03	Queue	Set destination queue for frame	3	{port type, port instance, link, queue}
04	Set	Set output field	2 + n	Field code to set; n bytes of value
05	Copy	Copy output field	2	Field Code to set from field used in last clause of rule
06	Delete	Delete field	2	Field Code to remove from frame
07	Insert	Insert field	2	Field Code to insert into frame
08	Replace	Delete field and Insert current output field	2	Field Code to replace
09	Clear Delete	Do not delete field (override other Delete result)	2	Field Code not to delete
0A	Clear Insert	Do not insert field (override other Insert result)	2	Field Code not to insert

9.6.1.4.1 NOP

The NOP result has no net effect, and does not affect the state of the frame. It can be useful as a placeholder result.

9.6.1.4.2 Discard

Frames are considered to be associated with a "discard" flag. If the discard flag is true after all rule processing, the frame will be discarded. This result sets the discard flag to true.

9.6.1.4.3 Forward

The Forward result sets the discard flag for a frame to false. The frame will be forwarded. (See the Queue result, 9.6.1.4.4.)

9.6.1.4.4 Queue

The Queue result sets the destination queue for a frame. A queue specified as a { port type, port instance, link, queue } tuple. Only TU interface ports have logical links; the logical link field of the tuple for other types of port is ignored and SHOULD be set to zero. The port type indicates whether the port is a Network Port or User Port, and uses the same values as the Object Context.

9.6.1.4.5 Set

The Set result sets the value of an output field for the frame. The result takes as parameters the field code and instance to set, followed by the value for that field. Values for fields less than one octet wide are right-justified. Specified values less than the actual width of the field are padded with zeros on the left (most significant) bits.

Table 96 - Set Result

Size	Name	Description
1	Field Code	Field code to set
1	Field Instance	Field Instance to set
varies	Value	New value for output field

9.6.1.4.6 Copy

The Copy result copies the value of some field into the specified output field. The source field is the field used in the last clause of the rule condition. Typically this result is used to copy priority fields, such as IP TOS to [802.1p] CoS bits, or to copy an inner VLAN tag to an outer one.

9.6.1.4.7 Delete

This result marks a field of a frame to be deleted. If the Delete flag is set after all rules have been processed, the deleted field will not be present in a forwarded frame. This result is commonly used to remove VLAN tags or other encapsulation from a frame.

9.6.1.4.8 Insert

The Insert result adds a field to a frame. If the Insert flag is set after all rules have been processed, the output field will be added to the frame. The value of the field should be Set by some rule. The default value for a field that did not exist in the frame is all zeroes. This result is commonly used to add VLAN tags or other encapsulation to a frame.

9.6.1.4.9 Replace

Replace combines the Insert and Delete results into a single operation for convenience, resulting in overwriting a field of a frame with a new value. This result is commonly used to translate priority values or VLAN tag values.

9.6.1.4.10 Clear Delete

This result clears the Delete flag for a field, reversing the decision of a lower precedence rule to delete the given field.

9.6.1.4.11 Clear Insert

This result clears the Insert flag for a field, reversing the decision of a lower precedence rule to delete the given field.

9.6.2 Custom Field (D7/05 02)

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

Each DPoE ONU port contains a table of ingress rules that are applied to the frames received on the port. Each field is programmed with a "field code". The code describes the field parsed from the frame in terms of protocol layer, 32-bit word offset in the frame, bit start, and bit width.

Table 97 - Custom Field

Size	Description		Units	Default	Min	Max
1	Field Code (see Table 97)		enum	-	18	1F
1		Layer select	See Table 98	-	0	8
1		32-bit word offset	32-bit words	-	0	8
1		Least significant bit (bit offset)	Bits	-	0	31
1		Bit width	Bits	-	1	32
1		Reference Count	Number of clauses	-	0	255

The Reference Count indicates the number of clauses in rules that are currently using this field. If the field is currently unused, the Reference Count will be zero. When this is the case, the Layer Select, 32-bit word offset, Least significant bit, and Bit width fields will contain the maximum possible values.

Fields with a non-zero Reference Count cannot be reprogrammed with the Set PDU. All rules using a given field must be deleted, reducing the reference count to zero, before the meaning of that field is changed.

The Reference Count field is ignored in Set messages, and SHOULD be set to zero by the transmitter.

Table 98 - Custom Field Layer Values

Layer Value	Name	Description
0	Preamble/L2	LLID, DA, SA, SNAP headers (if present)
1	Preamble/[802.1ah]	LLID, B-DA, B-SA, I-Tag
2	EtherType	L2 protocol type of remainder of the frame
3	S-VLAN Tags	All S-VLAN tags in the frame
4	C-VLAN Tags	All C-VLAN tags in the frame
5	MPLS Tags	The MPLS stack, if any, in the frame
6	IPv4	Frames with EtherType 0800
7	IPv6	Frames with EtherType 86DD
8	Generic L3	Payload of a frame that is not IPv4 or IPv6, according to the EtherType
9	TCP/UDP	IPv4 or IPv6 frames containing UDP or TCP (according to the IP protocol type field)
A	Generic L4	Payload of IP frames that is not TCP or UDP

9.6.2.1 Preamble/L2 Header[9]

The preamble/L2 layer consists of the LLID and L2 Ethernet header fields of the received frame. This layer also contains the SNAP headers if they are present. Figure 6 shows the offsets within this layer when the frame does not have SNAP encapsulation.

[9] Revised per OAMv1.0-N-12.0016-2 on 3/30/12 by JB.

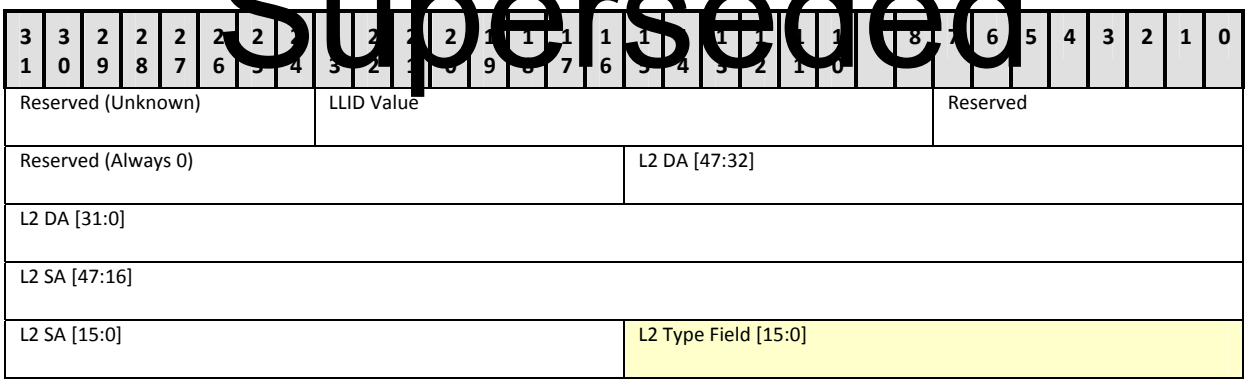

Figure 6 - Preamble/L2 without SNAP

Figure 7 shows the offsets into this layer when the frame has SNAP encapsulation.

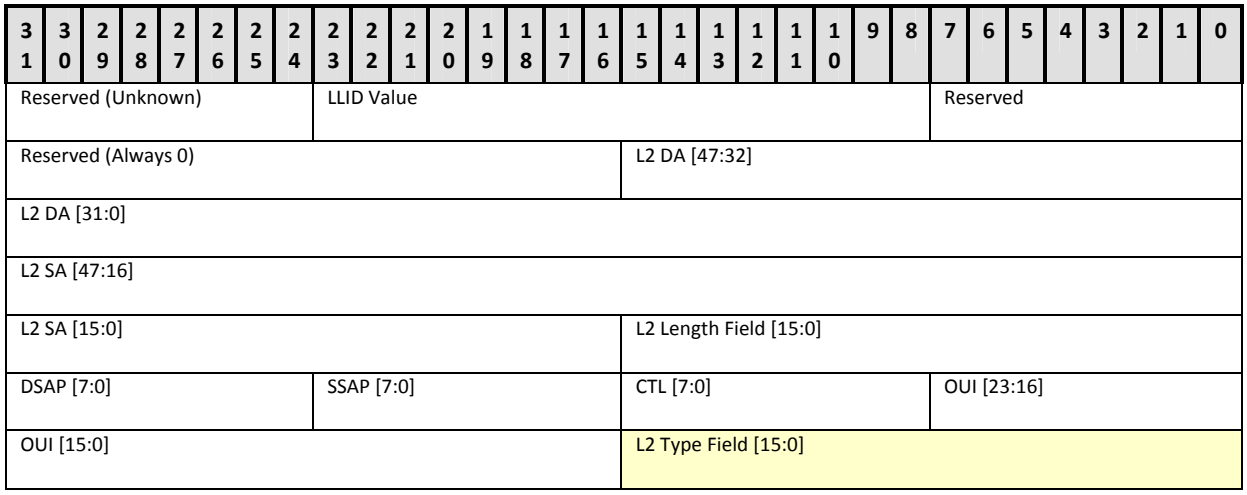

Figure 7 - Preamble/L2 with SNAP

9.6.2.2 [802.1ah][10]

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).

[10] Revised per OAMv1.0-N-12.0016-2 on 3/30/12 by JB.

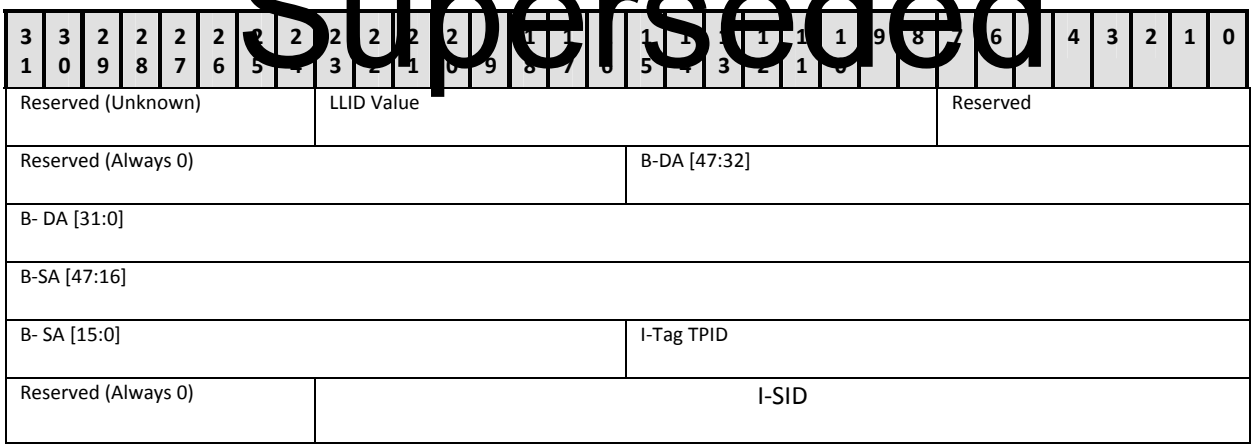

Figure 8 - [802.1ah] Layer

9.6.2.3 EtherType

The EtherType layer consists only of the 16-bit EtherType value, wherever it may be located in the source frame. Note that a Length value in an [802.3] format frame is not considered an EtherType value. Ethernet II versus [802.3] format can be tested by testing the existence of the EtherType.

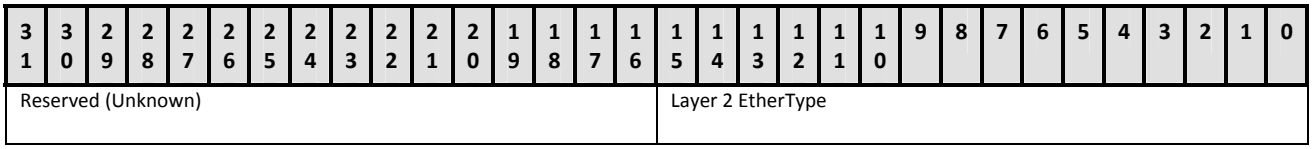

Figure 9 - EtherType Layer

9.6.2.4 S-VLAN Tags

The S-VLAN tag layers consist of all S-VLAN tags identified in the frame. An S-VLAN tag is defined by the TPID seen by the parser, which includes the [802.1ad] value 0x88A8 as well as the additional S-VLAN TPID value, if that value has been defined.

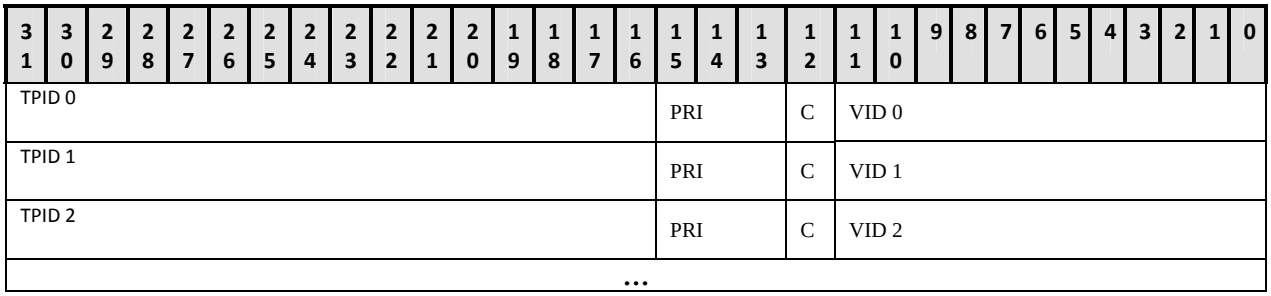

Figure 10 - S-VLAN Layer

9.6.2.5 C-VLAN Tags

The C-VLAN tag layers consist of all C-VLAN tags identified in the frame. A "C-VLAN tag" is defined by the TPID seen by the parser, which includes the [802.1q] value 0x8100, as well as the Additional C-VLAN TPID value, if that value has been defined.

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
TPID 0																PRI			C	VID 0											
TPID 1																PRI			C	VID 1											
TPID 2																PRI			C	VID 2											
…																															

Figure 11 - C-VLAN Layer

9.6.2.6 MPLS Tags

The MPLS Tags layer consists of all MPLS labels identified in the frame.

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
Label 0																				Exp 0		S	TTL 0								
Label 1																				Exp 1		S	TTL 1								
Label 2																				Exp 2		S	TTL 2								
…																															

Figure 12 - MPLS Layer

9.6.2.7 IPv4

The IPv4 layer only exists in frames with EtherType 0x0800, and consists of the 40 bytes of standard IPv4 header, followed by any IPv4 options. Note the bit ordering in this layer is consistent with the other layers in this specification, but is the reverse of IETF documentation.

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
Version				Hdr Len				Type of Service								Length of datagram															
Identification																Flags			Fragment Offset											
Time to Live								Protocol								Header Checksum															
Source IP Address																															
Destination IP Address																															
IP Options (if any) …																															

Figure 13 - IPv4 Layer

9.6.2.8 IPv6

The IPv6 layer only exists in frames with EtherType 0x86DD, and consists of the 40 bytes of base IPv6 header, followed by extension headers. Note the bit ordering in this layer is consistent with the other layers in this specification, but is the reverse of IETF documentation.

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
Version				Traffic Class								Flow Label																			
Payload Length																Next Header								Hop Limit							
Source Address																															
Source Address																															
Source Address																															
Source Address																															
Destination Address																															
Destination Address																															
Destination Address																															
Destination Address																															

Figure 14 - IPv6 Layer

9.6.2.9 Generic L3

The Generic L3 layer consists of all bytes after the VLAN or MPLS layers in frames that are not IP frames; that is, those frames with EtherType other than 0x0800 or 0x86DD. Rules that match custom fields in the Generic L3 layer likely need also to match the EtherType to ensure that the frame contains the expected protocol.

9.6.2.10 TCP/UDP

The TCP/UDP layer consists of the bytes of the standard TCP or UDP header, if the frame is an IP frame (v4 or v6), and if the IP Protocol type indicates UDP or TCP.

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
Source Port																Destination Port															

Figure 15 - Layer TCP/UDP

9.6.2.11 Generic L4

The Generic L4 layer consists of all bytes after the IP header (v4 or v6) if the IP protocol type is not UDP and not TCP. Rules that match custom fields in the Generic L4 layer likely need also to match the IP protocol type field to ensure that the frame contains the expected protocol.

9.6.3 C-VLAN TPID (D7/05 03)

This attribute represents an alternate EtherType value that is used to identify a C-VLAN tag in a frame, in addition to the standard IEEE value of 0x8100. ONUs with an alternate C-VLAN TPID will accept either the alternate value or 0x8100 as indicating a C-VLAN tag. C-VLAN tags added by a DPoE ONU are always added with the standard value of 0x8100 by default. If the "Insert This TPID" field is set to TRUE (1), then this alternate TPID will be used for all tags inserted by the ONU instead.

Table 99 - C-VLAN TPID

Size	Description	Units	Default	Min	Max
2	Alternate C-VLAN TPID	-	0x8100	0	0xFFFF
1	Insert This TPID	Boolean	0	0	1

9.6.4 S-VLAN TPID (D7/05 04)

This attribute represents an alternate EtherType value that is used to identify an S-VLAN tag in a frame, in addition to the standard IEEE value of 0x88A8. ONUs with an alternate S-VLAN TPID will accept either the alternate value or 0x88A8 as indicating an S-VLAN tag. VLAN tags added by a DPoE ONU are always added with the standard value of 0x88A8 by default. If the "Insert This TPID" field is set to TRUE (1), then this alternate TPID will be used for all tags inserted by the ONU instead.

Table 100 - S-VLAN TPID

Size	Description	Units	Default	Min	Max
2	Alternate S-VLAN TPID		0x88A8	0	0xFFFF
1	Insert This TPID	Boolean	0	0	1

9.6.5 Clear Port Ingress Rules (D9/05 01)

This action deletes all ingress frame processing rules of the current port.

9.6.6 Add Port Ingress Rule (D9/05 02)

This action adds the Port Ingress Rule, which preceded this TLV to the port in context.

9.6.7 Delete Port Ingress Rule (D9/05 03)

This action deletes the Port Ingress Rule, which preceded this TLV to the port in context.

9.7 Service Level Agreements

9.7.1 Broadcast Rate Limit (D7/06 01)

This attribute represents a limit on the number of broadcast frames that can be received through the Ethernet interface. The rates refer to packet counts in a second. Once the count is exceeded, the discard result will be set for the packet at precedence 1. ONU rules can override the discard with a forward result at higher precedence. These registers reset to their maximum value which disables broadcast rate filtering.

Table 101 - Broadcast Rate Limit

Size	Description	Units	Default	Min	Max
4	The maximum number of broadcast packets allowed from Ethernet port 1 in 1 second.	packets	20 0000	0	20 0000

9.7.2 Egress Shaping (D7/06 02)

This attribute is used to control the output rate of logical links and UNI ports at the DPoE ONU. The TU interface egress rate is controlled by specifying rate constraints on each logical link configured through the TU interface port. Thus, the TU interface egress rate is the sum of individual link rates. The UNI port rate is applied on a per-port basis.

Table 102 - Egress Shaping

Size	Description	Units	Default	Min	Max
1	Type of traffic to control (Bitmap) Bit 0: Broadcast Bit 1: Multicast Bit 2: [802.1d] reserved group (01:80:C2:00:00:0x) Bit 3: Unicast Bit 4: Flooded unicast Bits 5..7: Reserved for future use	Bitmap	FF	0	FF
1	Rate units (0 = Kbps, 1 = Frames/second)	Enum	0	0	1
1	Number of Shapers	Shapers	1	1	FF
1	Queue Bitmap. Queues to which shaping applies.	bitmap	0	0	0xFF
4	Maximum rate	Varies	0	0	0xFFFF FFFF
2	Burst size	Kbytes	0	0	0xFFFF

9.7.3 Ingress Policing (D7/06 03)

This attribute controls ingress traffic policing behavior at a DPoE ONU S_1 interface (port).

Table 103 - Ingress Policing

Size	Description	Units	Default	Min	Max
1	Rate units (0 = Kbps, 1 = Frames/second)	Enum	0	0	1
1	Number of Rate Levels		1	1	varies
1	Type of traffic to control (Bitmap) Bit 0: Broadcast Bit 1: Multicast Bit 2: [802.1d] reserved group (01:80:C2:00:00:0x) Bit 3: Unicast Bit 4: Flooded unicast Bits 5..7: Reserved for future use	bitmap	0	0	0XFF
4	Maximum rate	Varies	0	0	0xFFFF FFFF

9.7.4 Queue Rate Control (D7/06 04)

This attribute represents the Queue output rate control.

Table 104 - Queue Rate Control

Size	Description	Units	Default	Min	Max
1	Number of Queues (the fields below are repeated this Number of times)	Queues	0	0	FF
2	Port	-	0	0	FFFF
2	Link	-	0	0	FFFF
2	Queue	-	0	0	FFFF
2	Burst size (0 to disable shaping)	256 Bytes	0	0	FFFF
4	Queue Rate	1 Kbps	0	0	FFFF FFFF

9.7.5 FEC Mode (D7/06 05)

This attribute represents the current FEC mode.

Table 105 - FEC Mode

Size	Description	Units	Default	Min	Max
1	The ONU rx/downstream FEC 0: Off – No FEC 1: On – FEC is ON for all links 2: Per Link – FEC is settable per link (with the Per Link message)	enum	0	0	2
1	The ONU tx/upstream FEC 0: Off – No FEC 1: On – FEC is ON for all links 2: Per Link – FEC is settable per link (with the Per Link message)	enum	0	0	2

9.7.6 Enable User Traffic (D9/06 01)

Enable user data traffic for the link in context. The Disable User Traffic message stops this traffic. DPoE ONUs boot with user data traffic disabled.

9.7.7 Disable User Traffic (D9/06 02)

The Disable message causes the DPoE ONU to disable all user data traffic for the logical link in context. OAM and MPCP traffic remains intact. The Enable User Traffic message restores the user traffic. ONUs boot with user traffic disabled.

9.7.8 Loopback Enable (D9/06 03)

The DPoE Network MUST implement logical link loopback as per [802.3]. The DPoE Network MAY implement loopback at the DPoE S_1 interface using this action.

This attribute enables MAC or PHY loopback at the specified DPoE ONU S_1 interface (port). The figure below is an example of Set Loopback for a DPoE ONU S_1 interface (port). When a DPoE ONU S_1 interface (port) is in loopback, packets sent upstream to the UNI port will be dropped. Packets sent downstream are looped back upstream and transmitted out the TU interface port of the DPoE ONU. Traffic flowing to other ports will not be affected. This loopback message tests a path through the entire DPoE ONU, in contrast to the [802.3] link loopback, which occurs at the TU interface side of the DPoE ONU.

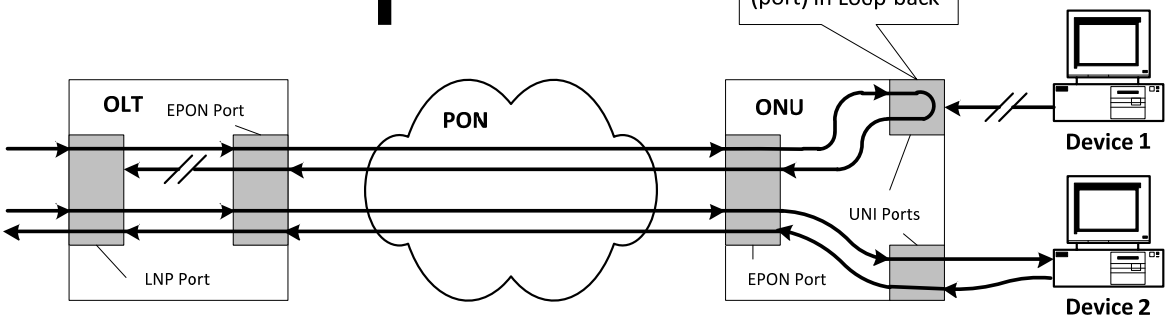

Figure 16 - Set Loopback for DPoE ONU S_1 Interface

Table 106 - Loopback Enable

Size	Description	Units	Default	Min	Max
1	Location (0 = PHY, 1 = MAC, 2 = TU interface link)		0	0	2

9.7.9 Loopback Disable (D9/06 04)

This attribute takes the specified entity out of loopback. If the given entity is not in loopback, this message is ignored.

Table 107 - Loopback Disable

Size	Description	Units	Default	Min	Max
1	Location (0 = PHY, 1 = MAC, 2 = [802.3ah] EPON link)	enum	0	0	2

The procedure for initiating a loopback is to send an Enable Loopback command with the port label of the port on which the loopback is to be established. After the loopback has been set, an autonomous loopback alarm message will be sent to the host. In accordance with [802.3] Clause 57, the DPoE System will start a countdown timer with the value from the Get Loopback Timeout Host Interface message. If the loopback is not cleared by the Host within the period specified (Scenario 1 in the figure below), the Loopback will be cleared automatically by the DPoE System (Scenario 2 in the figure below). An autonomous alarm report will then be sent to the host, indicating that the loopback has been cleared.

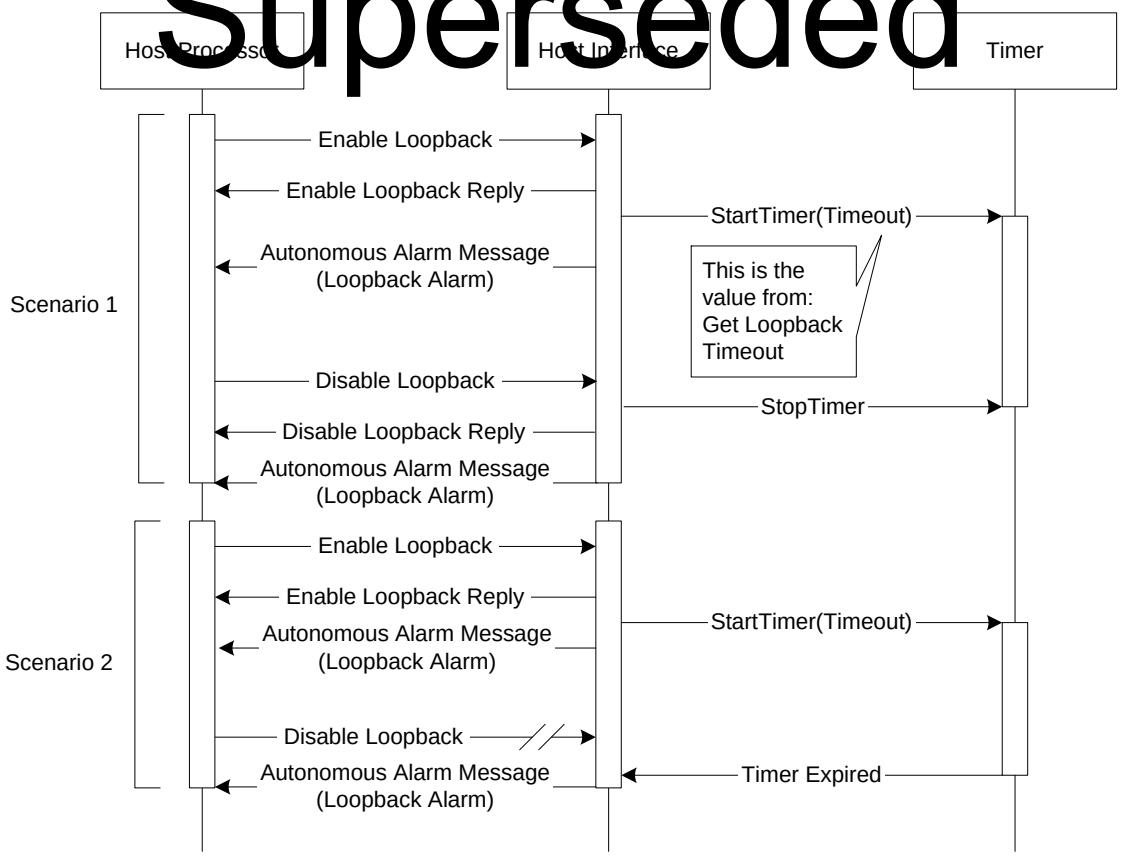

Figure 17 - Enable/Disable Loopback

9.7.10 Laser Tx Power Off (D9/06 05)

This attribute turns off the laser Tx for specified time for diagnostic purposes. Note that this message can also instruct a DPoE ONU to permanently remove itself from the network. Setting the power off time to 0 enables the laser power again, bringing an ONU back onto the network without waiting for an earlier timer to expire.

Table 108 - Laser Tx Power Off

Size	Description	Units	Default	Min	Max
2	Disable time	milliseconds	-	0 (turn laser on)	FFFF (disable permanently)

10 MULTICAST LLID REGISTRATION

DPoE Systems are capable of using additional multicast LLIDs other than just one global broadcast LLID (0x7FFF on 1G-EPON, 0x7FFE for 10G-EPON). This feature allows subdivision of the physical EPON into subsets, which can provide independent encryption and rate control for different services, providers, ISPs, and other such distinctions useful in a carrier-grade multiple-service network.

The broadcast LLID is a special case of a multicast LLID, which is automatically assigned to all DPoE ONUs on the PON. The broadcast LLID is a well-known value used by DPoE ONUs for discovery, and is the default multicast LLID associated with any newly-registered unicast LLID.

Every unicast LLID is associated with exactly one multicast LLID (possibly the broadcast LLID). A multicast LLID may be associated with more than one unicast LLID.

Multicast LLIDs carry traffic only in the downstream direction. DPoE OAM related to management of a multicast LLID is carried on one of the associated unicast LLIDs.

Multi-Point Control Protocol (MPCP) is used for auto-discovery of ONUs and registration of LLIDs. [802.3ah] and [802.3av] provide no mechanism for extending MPCP PDU formats and indeed forbid extending those PDU types; therefore, OAM messages are used for this feature instead. DPoE OAM extensions enable users to request and assign multicast LLIDs to groups of ONUs.

10.1 Multicast Request

This PDU exists to reserve the opcode for future use and for symmetry with MPCP unicast registration, but is not used in this version of the DPoE OAM Extension specification. Multicast LLIDs are assigned by DPoE System rather requested from the DPoE ONU, and carry traffic only in the downstream direction

10.2 Multicast Registration

The multicast registration message associates a multicast LLID with a unicast LLID assigned by the standard MPCP registration process. The default multicast LLID for a unicast link is 0x7FFF or 0x7FFE (the standard broadcast LLID as appropriate for the downstream speed at which the DPoE ONU is registered, 1G or 10G, respectively).

Table 109 - Multicast Registration

Width (Octets)	Field	Value (hex)
1	Flags	
2	Multicast LLID value	Varies; e.g., 0x7FFF for 1G broadcast, or a value chosen by the DPoE System for a multicast LLID.
2	Unicast LLID value	As previously assigned to the ONU

Flags values are the same as for the standard REGISTER MPCPDU and REGISTER ACK MPCPDU.

Table 110 - Multicast Registration Flags

Value (hex)	Meaning
1	(Re)Register
2	Deallocate
3	Success
4	Nack

10.3 Multicast Response

The Multicast Response PDU is returned by the DPoE ONU to acknowledge receipt of the Multicast Registration PDU.

Table 111 - Multicast Response

Width (Octets)	Field	Value (hex)
1	Flags	
2	Multicast LLID value	Varies; e.g., 7FFF for broadcast or a value chosen by the DPoE System for a multicast LLID.
2	Unicast LLID value	As previous assigned to the ONU

11 SECURITY

See the [DPoE-SP-SECv1.0] document for details of encryption, key exchange, authentication, and other requirements related to security and authentication.

11.1 Key Exchange

DPoE OAM extensions include a key exchange protocol. This can be used to synchronize keys between the DPoE System and DPoE ONU.

Table 112 - AES 128 CFB

Width (Octets)	Field	Value (hex)
1	Key Number	0..1; indicates key phase
1	Key Length	Number of bytes of key data (16 for 128-bit AES)
Varies	Key	Random data equal to Length bytes

12 FILE TRANSFER

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

This protocol is a simplified form of TFTP. It has been modified to operate over the [802.3] OAM channel instead of IP. This protocol differs from TFTP in the following ways:

- It includes support for only one data encoding option (binary).
- It supports variable sized frames, to suit the negotiated length of the Ethernet OAM frame and take advantage of the longer MTU.
- It acknowledges next block to receive rather than last block received, to avoid the Sorcerer's Apprentice problem without extra timers.
- It replaces the file pathname string with a numeric file type identifier.

To maximize interoperability, the contents of DPoE ONU files are considered to be opaque to the DPoE System and management system. There is intentionally no standardized header that all DPoE ONU models must support. An EMS might well add headers to binary files for DPoE ONUs for its own purposes of storage and tracking, but these headers would be removed before sending the data to the DPoE ONU. Conversely, any information which a particular DPoE ONU needs for its own purposes for storage and validation MUST be included in the DPoE ONU file; the exact format of this data is up to the DPoE ONU vendor so long as the file format meets the requirements of this section. The DPoE System does not parse into the contents of files for the DPoE ONU, but only acts as a gateway to transfer the files.

12.1 File Transfer PDU Header

File Transfer PDUs have a common header, shown below.

Table 113 - File Transfer PDU Header

Width (Octets)	Field	Value (hex)
6	Ethernet DA	0180C2000002 ([802.3] OAM multicast address)
6	Ethernet SA	As per sending MAC
2	Ethernet Type	8809 (Ethernet Slow Protocol)
1	Subtype	03 ([802.3] OAM)
2	Flags	As per [802.3ah]
1	Opcode	FE (Vendor extended)
3	OUI	0x001000 (DPoE EPON)
1	DPoE Opcode	09 (File Transfer)
1	File Transfer Opcode	See Table 114
varies	File Transfer PDU body	As per each PDU type, defined below

Table 114 - File Transfer PDU Opcodes

File Transfer PDU Opcode	Value (hex)
Reserved	0
Write Request	1
File Transfer Data	2
File Transfer Ack	3

12.1.1 File Transfer Write Request

The File Transfer Write Request OAM PDUs indicates a request to initiate a file transfer from the DPoE System to the DPoE ONU. The recipient prepares to receive a file.

The response to a File Transfer Request is a File Transfer Ack message. The error code of the Ack is either zero (Ok), allowing the transfer to proceed, or non-zero, indicating the reason that the transfer cannot take place.

12.1.2 File Transfer Data

File Transfer Data PDUs contain the data for the current file. Each PDU carries a sequence number and size field, specifying the number of file data bytes to follow. Data PDUs are sent one block at a time in sequential order. Each block is acknowledged by the recipient before the next block is sent. (This is a "stop and wait" protocol). The first block of a file has sequence number 0.

The response to a Transfer Request is a File Transfer Ack message. The error code of the Ack is either zero (Ok), allowing the transfer to proceed, or non-zero, indicating the reason that the transfer was aborted. The Ack also contains the block number of the next block the recipient expects to receive.

Once the file transfer begins, at least one Data PDU must be sent every second. If the recipient fails to receive a Data PDU every second, a timeout is counted and the recipient sends a File Transfer Ack. This message contains the timeout error code and the sequence number indicating the desired block. Three successive timeouts will abort the file transfer process. In this case, the file on the recipient is unchanged.

A Data PDU may be sent with a size of zero. This resets the block reception timer on the recipient to prevent a timeout. It does not advance the block sequence number or the state of the received file. This feature can be used to keep a transfer alive in the event of an unanticipated delay at the sender.

Table 115 - File Transfer Data

Width (Octets)	Field	Value (hex)
2	Block Number	Increments
2	Block Width (Octets)	Varies
(Size)	File data	Varies

12.1.3 File Transfer Ack

The Acknowledgement PDUs contain a sequence number and an error code. The sequence number is the number of the next block expected by the recipient. The error code indicates the status of the transfer. A non-zero error code aborts the file transfer and leaves the files on the recipient unchanged.

To signal the end of a file transfer, the sender sends an Ack PDU. This PDU contains sequence number 0 and a code indicating the status of the transfer. (The transfer status indicated is assessed by the sender, not the recipient.) A zero status instructs the recipient to commit the file to permanent storage. A non-zero status instructs the recipient to discard the file, even if the transfer appears successful to the recipient. This Ack is the only Ack sent by the sender in this protocol.

The final Ack from the sender is acknowledged by a final Ack from the recipient. The recipient sends the Ack after it has committed the file or discarded it. Committing a file to flash requires more time than processing a single data frame. Therefore, the timeout for the final Ack response from the recipient should be at least 15 seconds.

Table 116 - File Transfer Ack

Width (Octets)	Field	Value (hex)
2	Block Number	Increments
1	Response Code	As per File Acknowledgement Response Code table, below

Table 11.7 - File Acknowledgment Response Codes[11]

Ack Response Code	Meaning	Value (hex)
OK	No errors	0
Undefined	Unknown error, or one not covered elsewhere	1
Not Found	Read requested file that is not available	2
No Access	Access permissions do not allow the requested read/write	3
Full	Storage is full, and cannot hold the written file	4
Illegal Operation	Cannot perform requested operation in current state	5
Unknown ID	Requested file ID is not supported by this device	6
Bad Block	Block received in error	7
Timeout	No block received before timer expiration	8
Busy	Cannot perform requested action due to other activity	9
Incompatible File	Received file is incompatible with this device. File incompatibility is determined by the device vendor.	A
Corrupted File	File was received corrupted and is unusable by this device. File integrity is determined by the device vendor.	B

[11] Table updated per OAMv1.0-N-12.0019-1 on 5/25/12 by PO.

Appendix I Branch/Leaf Code Reference (Informative)

I.1 [802.3] Clause 30 Attributes (Branch 07)

The following table lists attributes as defined in [802.3] Clause 30. They are repeated here for ease of reference. These attributes can also appear in DPoE OAM PDUs to avoid the need to send separate PDUs to query both [802.3] and DPoE attributes.

Table 118 - [802.3] Clause 30 Attributes (Branch 07)

Leaf (HEX)	Attribute	Read/ Write	Description
MAC			
00 01	MAC ID	R	ID for this MAC in this device
00 02	Frames Tx OK	R	Frames transmitted
00 03	Single Collision Frames	R	Frames suffering a single collision
00 04	Multiple Collision Frames	R	Frames suffering multiple collisions
00 05	Frames Rx OK	R	Frames received with no errors
00 06	FCS Err	R	Frames received with FCS errors
00 07	Alignment Error	R	Alignment errors
00 08	Octets Tx OK	R	Octets transmitted in frames with no errors
00 09	Frames Deferred	R	Deferred due to collisions
00 0A	Late Collisions	R	Collisions after frame in progress
00 0B	Excessive Collisions	R	Frames dropped due to too many collisions
00 0C	Lost MAC Tx Err	R	Frames lost due to MAC transmission error
00 0E	Octets Rx OK	R	Octets received in good frames
00 0F	Frames Lost MAC Rx Error	R	Frames lost due to MAC receive error
00 12	Multicast Frames Tx	R	Frames transmitted with a multicast address
00 13	Broadcast Frames Tx	R	Frames transmitted with a broadcast address
00 14	Frames Excessive Deferral	R	Frames dropped due to too many backoff retries
00 15	Multicast Frames Rx	R	Frames received with multicast address
00 16	Broadcast Frames Rx	R	Frames received with broadcast address
00 17	In Range Length Error	R	[802.3] format frames received with actual length not equal to length field
00 18	Out of Range Length Error	R	Frames received out of allowed length (short or long)
00 19	Frame Too Long	R	Frames received longer than the maximum permitted
00 1A	MAC Enable Status	R/W	Port enabled or disabled
00 1D	MAC Address	R	MAC Address of the port
00 1E	MAC Collision Frames	R	Number of collisions detected by MAC
PHY			
00 20	PHY Type	R	Type of PHY for this port
00 23	PHY Symbol Err During Carrier	R	Transmission errors detected
00 25	PHY Admin State	R/W	PHY enabled or disabled
MAU			
00 47	MAU Media Available	R	

Leaf (HEX)	Attribute	Read/ Write	Description
Auto-negotiation			
00 4E	Auto Neg ID	R	
00 4F	Auto Neg Admin State	R/W	
00 50	Auto Neg Remote Signal	R	
00 51	Auto Neg Config	R	
00 52	Auto Neg Local Tech	R/W	
00 53	Auto Neg Advertised Tech	R/W	
00 54	Auto Neg Rx Tech	R	
00 55	Auto Neg Local Select	R	
00 56	Auto Neg Advert Select	R	
00 57	Auto Neg Rx Select	R	
MAC			
00 5A	Duplex Status	R/W	
MAC Control			
00 5D	MAC Ctrl Functions Supported	R	
00 5E	MAC Ctrl Frames Tx	R	
00 5F	MAC Ctrl Frames Rx	R	
00 60	MAC Ctrl Unsupported Op Rx	R	
00 61	MAC Ctrl Pause Delay	R	
00 62	MAC Ctrl Pause Tx	R	
00 63	MAC Ctrl Pause Rx	R	
OMP Emulation			
01 18	MPCP Frames Tx	R	
01 19	MPCP Frames Rx	R	
01 20	MPCP Tx Discovery	R	
01 22	MPCP Disc Timeout	R	
FEC			
01 24	FEC Corrected Blocks	R	
01 25	FEC Uncorrectable Blocks	R	
01 39	FEC Ability	R/W	
01 3A	FEC Mode	R/W	
OMP Emulation			
01 3B	MPCP Tx Gate	R	
01 3C	MPCP Tx Reg Ack	R	
01 3D	MPCP Tx Register	R	
01 3E	MPCP Tx Reg Req	R	
01 3F	MPCP Tx Report	R	
01 40	MPCP Rx Gate	R	
01 41	MPCP Rx Reg Ack	R	
01 42	MPCP Rx Register	R	

Leaf (HEX)	Attribute	Read/ Write	Description
01 43	MPCP Rx Reg Req	R	
01 44	MPCP Rx Report	R	

I.2 DPoE Attributes (Branch D7)

The table below lists attributes defined for managing extended features with DPoE OAM. See Section 9 for Branch D7 attribute details.

I.3 [802.3] Clause 30 Actions (Branch 09) (Informative)

These actions are defined in [802.3] Clause 30, and are repeated here for ease of reference.

Table 119 - [802.3] Clause 30 Actions (Branch 09)

Leaf (HEX)	Attribute	Description
00 05	PHY Admin Control	Enable/disable PHY
00 0B	Auto Neg Renegotiate	Force renegotiation
00 0C	Auto Neg Admin Ctrl	Auto Neg enable/disable

I.4 DPoE Actions (Branch D9)

An action is identified by a Variable Container. Action parameters, if any, are included in the data portion of the container in the Set Request OAM PDU. Actions with no parameters have a zero length Container (Width code 0x80).

Responses to an action in the Set Response OAM PDU similarly have a list of Containers. Typically the response is just the result code (0x80, No Error, or a failure code). A response could return a result in the data portion of the container.

See Sections 9.7.6 through 9.7.10 for DPoE OAM PDUs for Branch D9.

Appendix II Example PDUs (Informative)

This informative-only appendix shows examples of DPoE OAM PDUs to illustrate the format and usage of these messages.

II.1 Get and Get Response

This example shows the use of the Object ID in a complex Get message that requests attributes from several objects. The Get message received from the DPoE System is shown on the left, with the corresponding ONU response on the right. The frame begins with some attribute TLVs (branch 7, D7), both standard and DPoE, without an object context. These attributes by definition refer to the default object, which is the EPON port and logical link on which the message was received. The ONU responds to an Object ID simply by echoing the TLV back in the Get Response. For each Variable Descriptor in the Get message, the ONU creates a matching Variable Container. Note that there is one response indicating an error code. All errors designate a length of 0 bytes, so there is no data field. As in the [802.3] standard, a branch value of zero terminates the list of TLVs. This null terminator is always in the message; it is not padding.

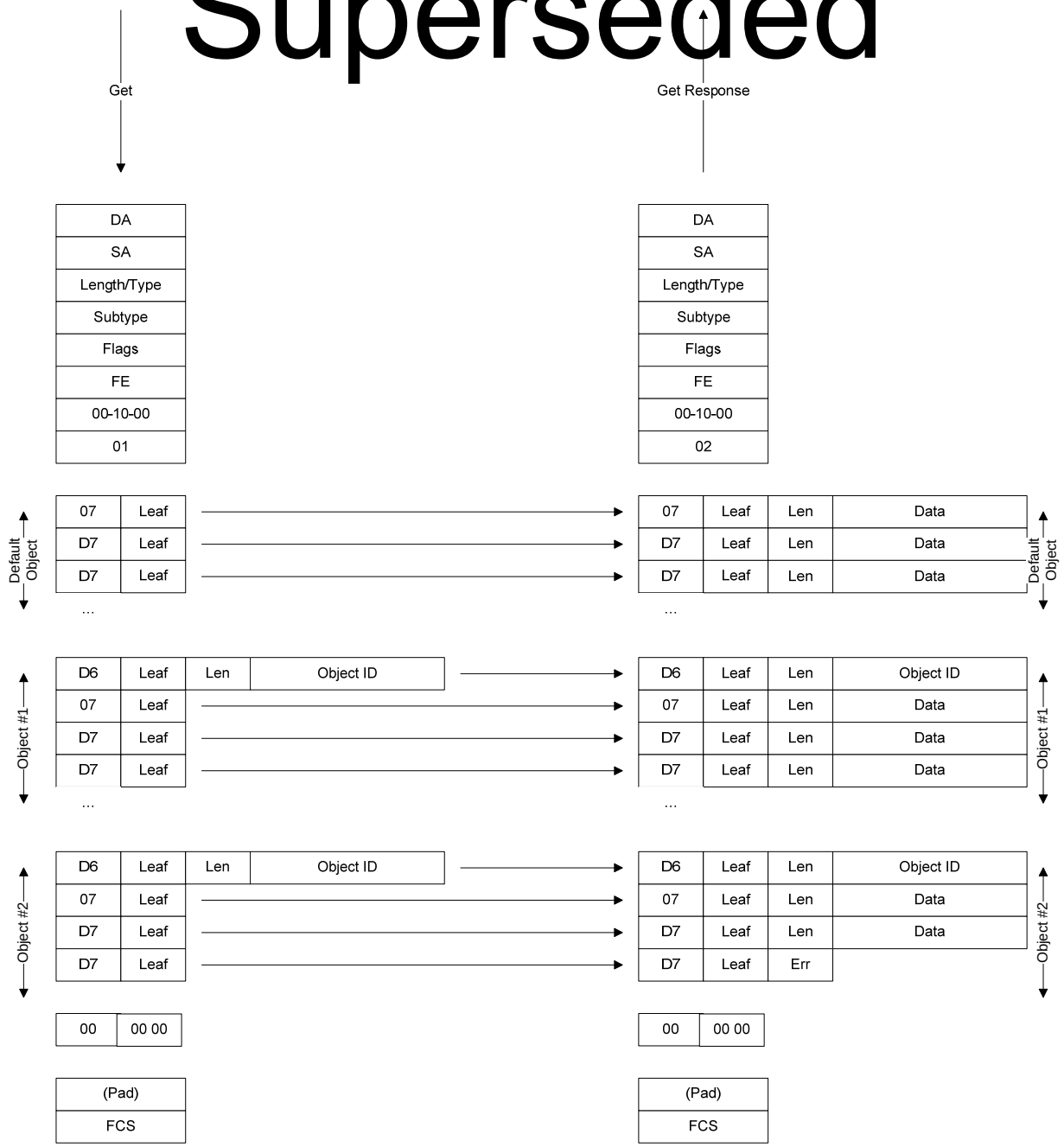

Figure 18 - Get and Get Response

II.2 Set and Set Response

This example shows a Set message, including a change in Object ID. Note that both standard and extended attributes can be set in a single message. Set messages have Variable Containers rather than Descriptors in the Get, because to set an attribute, you must specify both the attribute and its new value. The response to a Set is a TLV with a return code (usually RcOk, but perhaps an error) indicating zero data. Actions (branch codes 9, D9) can also be included in a set message. Actions often have parameters (ex: Add MAC address (M1)), so they are also Variable Containers. For consistency in parsing, even actions with no parameters, such as ONU Reset, use the Variable Container format with a length of zero.

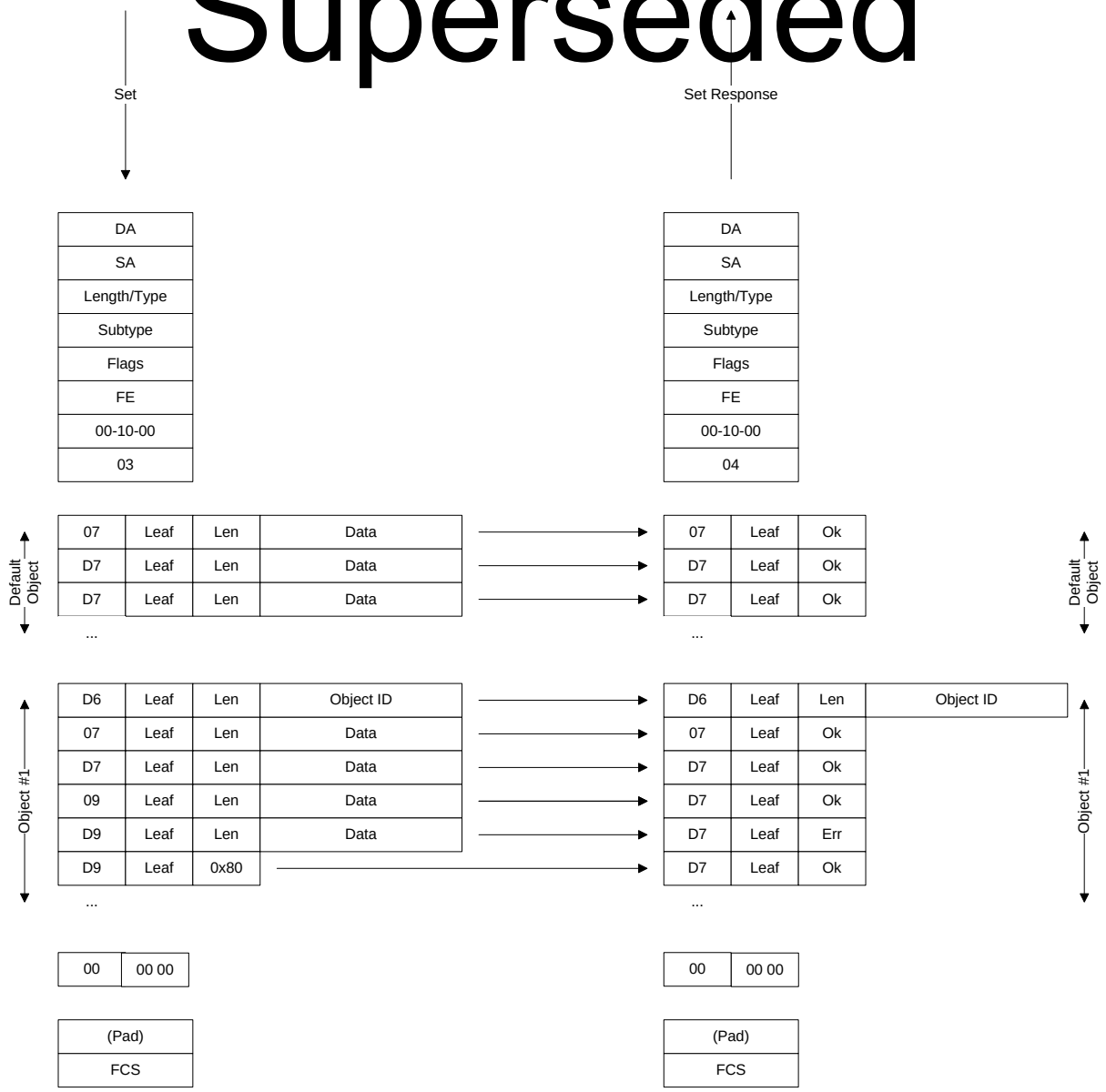

Figure 19 - Set and Set Response

II.3 Large Attribute Values

This example illustrates the format for a large return value, in this case the MAC address table for a particular UNI port. The Get Request PDU contains a single attribute, but the reply is larger than 128 bytes, and so requires several containers for the response.

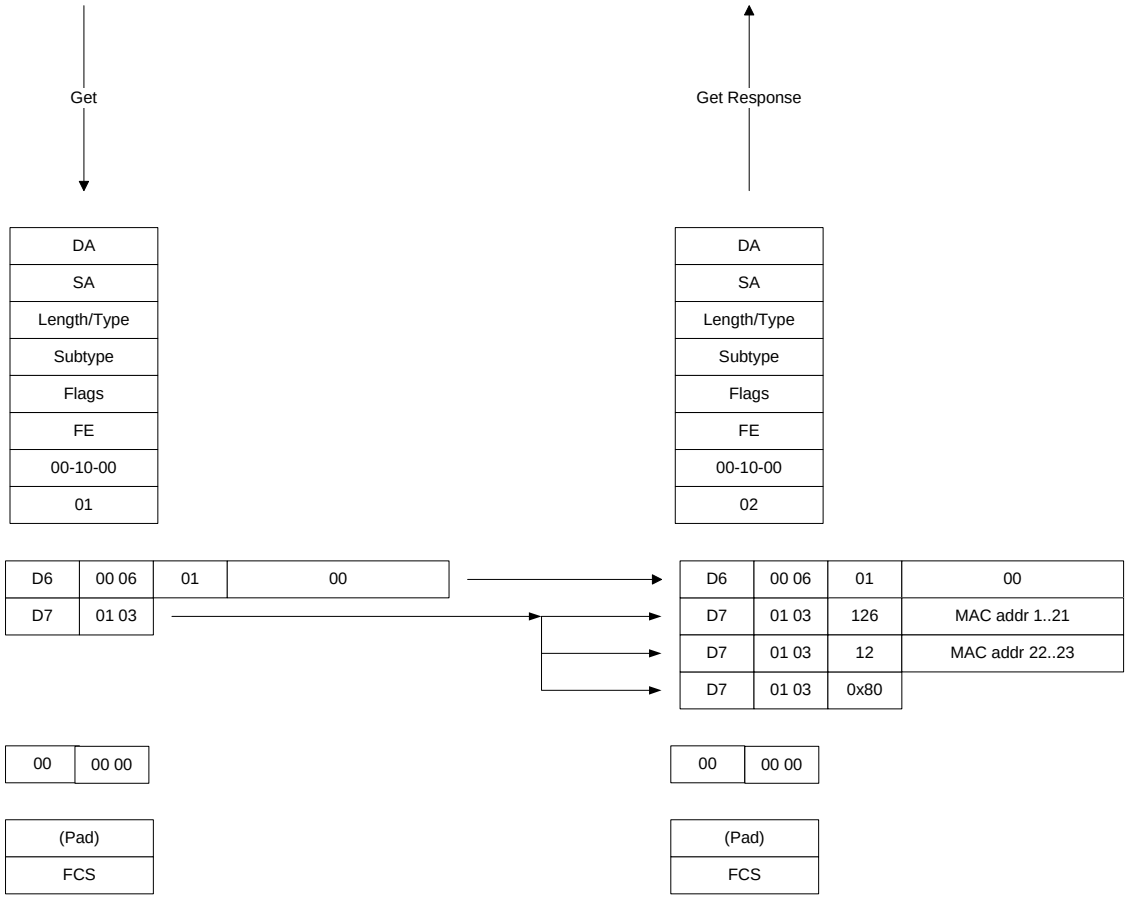

Figure 20 - Large Attribute Values

II.4 Multi-Part Replies

The following diagram illustrates the use of the sequence number attribute in a two-part reply to a single Get PDU. For the sake of example, the reply is assumed to be a single attribute, an extremely large MAC address table, as in the previous example. A multi-part reply also might be generated in response to a long list of small attributes.

Note that the large attribute is not terminated in the first frame as it is not yet complete, but is terminated only in the second frame.

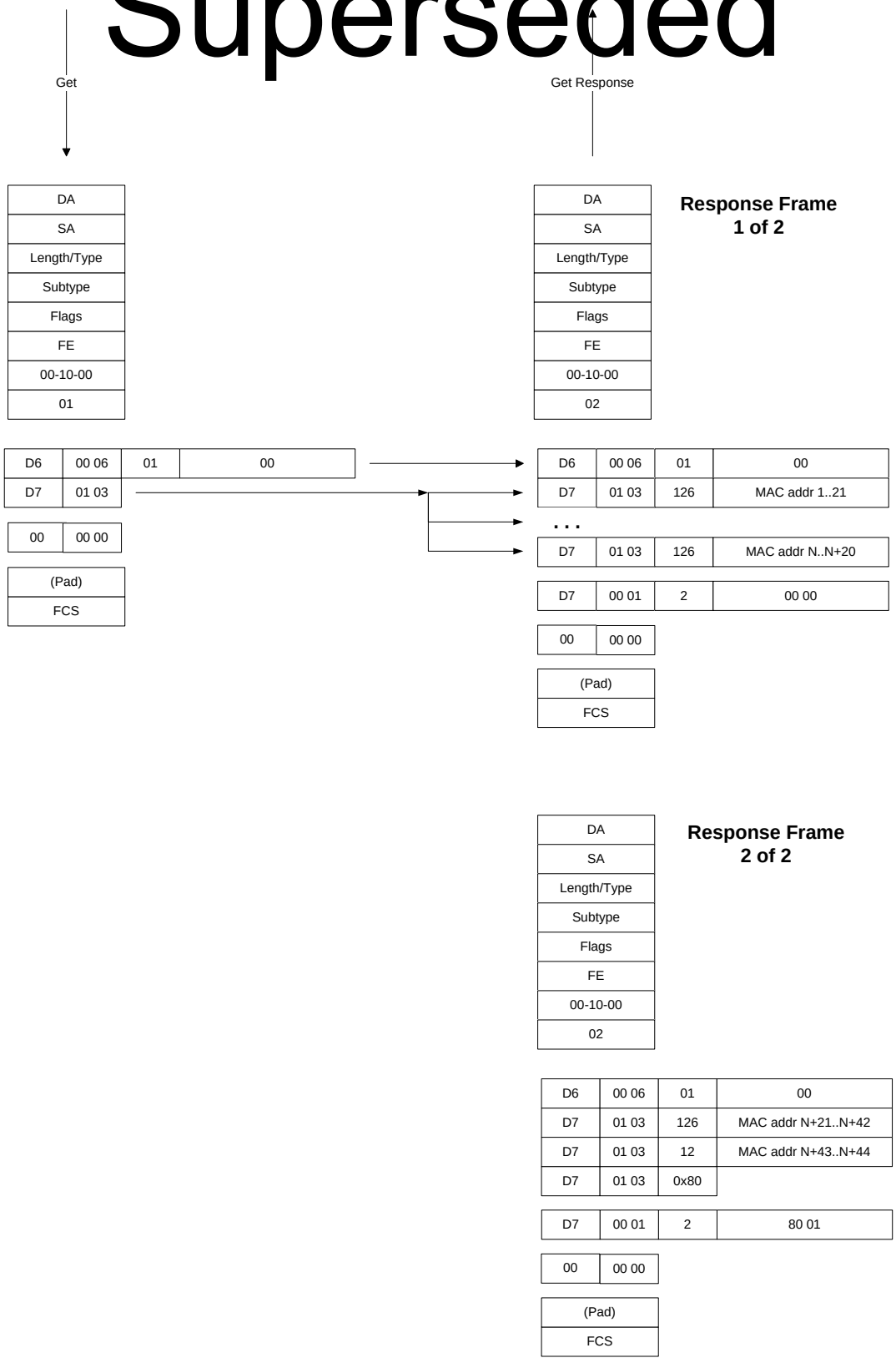

Figure 21 - Multi-Part Replies

II.5 Encryption and Key Exchange Messages

This PDU is used to set the key exchange interval on the ONU.

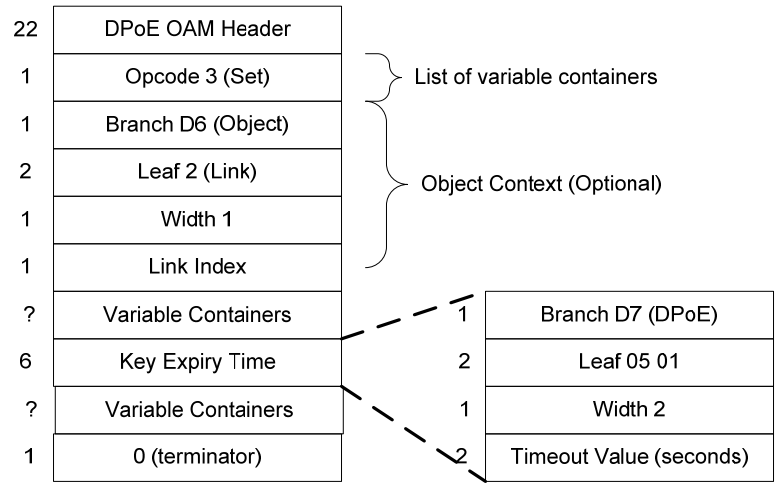

Figure 22 - Set Key Exchange Timer Request PDU

```
+ Ethernet Frame
  DA................01 80 c2 00 00 02
  SA................54 4b 37 21 00 00
  EtherType.........88 09 (Slow Protocol)
  SubType...........03 (OAM)
  + OAM PDU
    Flags...........00 10
    Code............fe (Organization Specific)
    OUI.............00 10 00 (DPoE)
    + DPoE PDU
      OpCode........03 (Set)
      + TLV
        Branch......d6 (Object Context)
        Leaf........00 02 (Link)
        Width.......02
        PortID......00 00 (Link 0)
      + TLV
        Branch......d7 (DPoE attribute)
        Leaf........05 01 (Encryption Key Expiry Time)
        Width.......02
        Value.......00 3c (60 seconds)
      + TLV
      Branch......00 (Branch null (terminator))
      Branch......00 (Leaf null (terminator))
  + PAD
  + FCS
```

II.5.1 Set Key Exchange Timer Response PDU

This PDU is returned to inform the DPoE System if the DPoE ONU was successfully configured (or not successfully configured) with the Key Exchange Timer value specified in a Set Request Message.

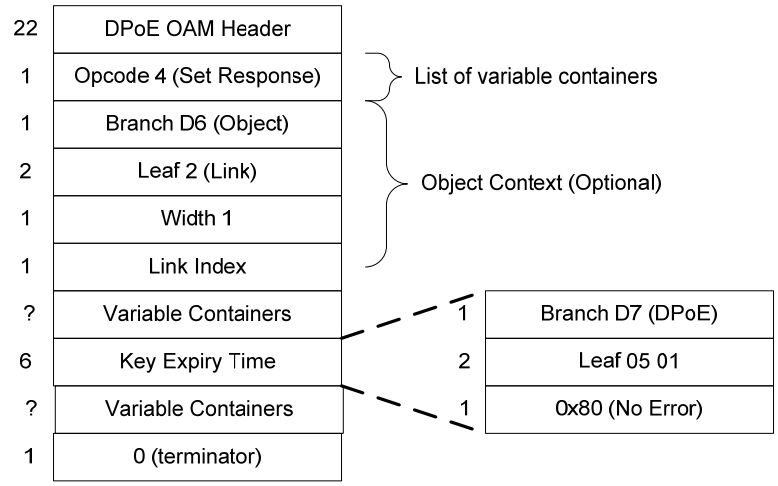

Figure 23 - Set Key Exchange Timer Response PDU

```
+ Ethernet Frame
  DA................01 80 c2 00 00 02
  SA................54 4b 37 01 00 ab
  EtherType.........88 09
  SubType...........03 (OAM)
  + OAM PDU
    Flags...........00 50
    Code............fe (Organization Specific)
    OUI.............00 10 00 (DPoE)
    + DPoE PDU
      OpCode........04(Set Response)
      + TLV
        Branch......d6 (Object)
        Leaf........00 02 (Link)
        Width.......02
        PortID......00 00 (Link 0)
      + TLV
        Branch......d7 (DPoE Attribute)
        Leaf........05 01 (Encryption Key Expiry Time)
        Width/Code..80 (No Error)
      + TLV
      Branch......00 (Branch null (terminator))
  + PAD
  + FCS
```

II.5.2 Get Key Exchange Timer PDU

This PDU may be used by the DPoE System to query the DPoE ONU to determine the currently specified Key Exchange Timer value used by one of the DPoE ONU's links.

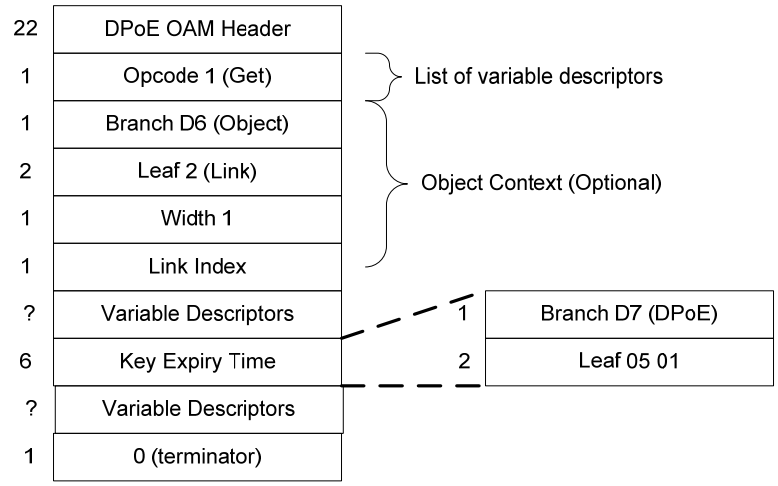

Figure 24 - Get Key Exchange Timer PDU

```
+ Ethernet Frame
  DA................01 80 c2 00 00 02
  SA................54 4b 37 21 00 00
  EtherType.........88 09 (Slow Protocol)
  SubType...........03 (OAM)
  + OAM PDU
    Flags...........00 10
    Code............fe (Organization Specific)
    OUI.............00 10 00 (DPoE)
    + DPoE PDU
      OpCode........01  (Get)
      + TLV
        Branch......d6 (Object Context)
        Leaf........00 02 (Link)
        Width.......02
        PortID......00 00 (Link 0)
      + TLV
        Branch......d7 (DPoE Attribute)
        Leaf........05 01 (Key Exchange Expiry Time)
      + TLV
        Branch......00 (Branch null (terminator))
  + PAD
  + FCS
```

II.5.3 Get Key Exchange Timer Response PDU

All DPoE ONU implementations respond either with the provisioned Key Exchange Timer Value or an appropriate error Container Value if queried by the DPoE System.

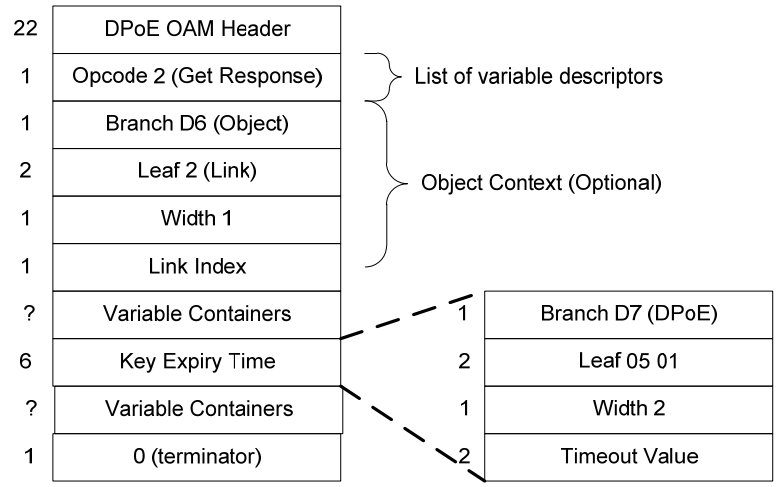

Figure 25 - Get Key Exchange Timer Response PDU

```
+ Ethernet Frame
  DA................01 80 c2 00 00 02
  SA................54 4b 37 01 00 ab
  SubType...........88 09 (Slow Protocol)
  Flags.............03 (OAM)
  + OAM PDU
    Flags...........00 50
    Code............fe (Organization Specific)
    OUI.............00 10 00 (DPoE)
    + DPoE PDU
      OpCode........02 (Get Response)
      + TLV
        Branch......d6 (Object Context)
        Leaf........00 02 (Link)
        Length......02
        PortID......00 00 (Link 0)
      + TLV
        Branch......d7 (DPoE attribute)
        Leaf........05 01 (Key Exchange Expiry Timer)
        Width.......02
        Value.......00 3c
      + TLV
        Branch......00 (Branch null (terminator))
   + PAD
   + FCS
```

II.6 Key Exchange Message

This message is example showing the key value being the DPoE ONU to DPoE System.

```
+ Ethernet Frame
  DA................01 80 c2 00 00 02
  SA................54 4b 37 01 00 ab
  EtherType.........88 09 (Slow Protocol)
  SubType...........03 (OAM)
  + OAM PDU
    Flags...........00 50
    Code............fe (Organization Specific)
    OUI.............00 10 00 (DPoE)
    + DPoE PDU
      OpCode........08 (Key Exchange)
      KeyNumber.....00
      KeySize.......10
      Key...........04 b9 98 48 04 a2 72 41
                    d1 a0 5a 36 67 db 85 66
  + PAD
  + FCS
```

II.7 Example 1Down Key Exchange Sequence

```
Set Key Exchange Timer (60 seconds)
---------------------------
01 80 c2 00 00 02 54 4b 37 21 00 00 88 09 03 00
10 fe 00 10 00 03 d7 05 01 02 00 3c 00 00 00 ...

Set Key Exchange Timer Response
------------------------------
01 80 c2 00 00 02 54 4b 37 01 00 ab 88 09 03 00
50 fe 00 10 00 04 d7 05 01 80 00 00 ...

Get Key Exchange Timer
----------------------
01 80 c2 00 00 02 54 4b 37 21 00 00 88 09 03 00
10 fe 00 10 00 01 d7 05 01 00 00 00 ...

Get Key Exchange Timer Response
------------------------------
01 80 c2 00 00 02 54 4b 37 01 00 ab 88 09 03 00
50 fe 00 10 00 02 d7 05 01 02 00 3c 00 00 ...

Key Exchange Message
--------------------
01 80 c2 00 00 02 54 4b 37 01 00 ab 88 09 03 00
50 fe 00 00 10 00 01 10 ad b5 01 ab cc a8 12 68
eb 94 35 7d ec 08 3c 65 00 00 00 ...
```

```
Key Exchange Message
--------------------
01 80 c2 00 00 02 54 4b 37 01 00 ab 88 09 03 00
50 fe 00 10 00 08 00 10 94 cb 49 59 38 d1 5b a3
d2 7d e6 ca fd 00 9f 1f 00 00 00 ...

Key Exchange Message
--------------------
01 80 c2 00 00 02 54 4b 37 01 00 ab 88 09 03 00
50 fe 00 10 00 08 01 10 80 52 4c cc 21 9d 08 ea
4e 18 f5 fb 24 48 79 d6 00 00 ...
```

Appendix III Life Cycle of a Logical Link (Informative)

The diagram below illustrates some events in the OAM sequence for a "typical" logical link. As a merely informative example, this diagram does not require a particular order of operation or set of messages. Any such requirements appear elsewhere in the DPoE specifications. Figure 26 is intended as an aid to overall comprehension only.

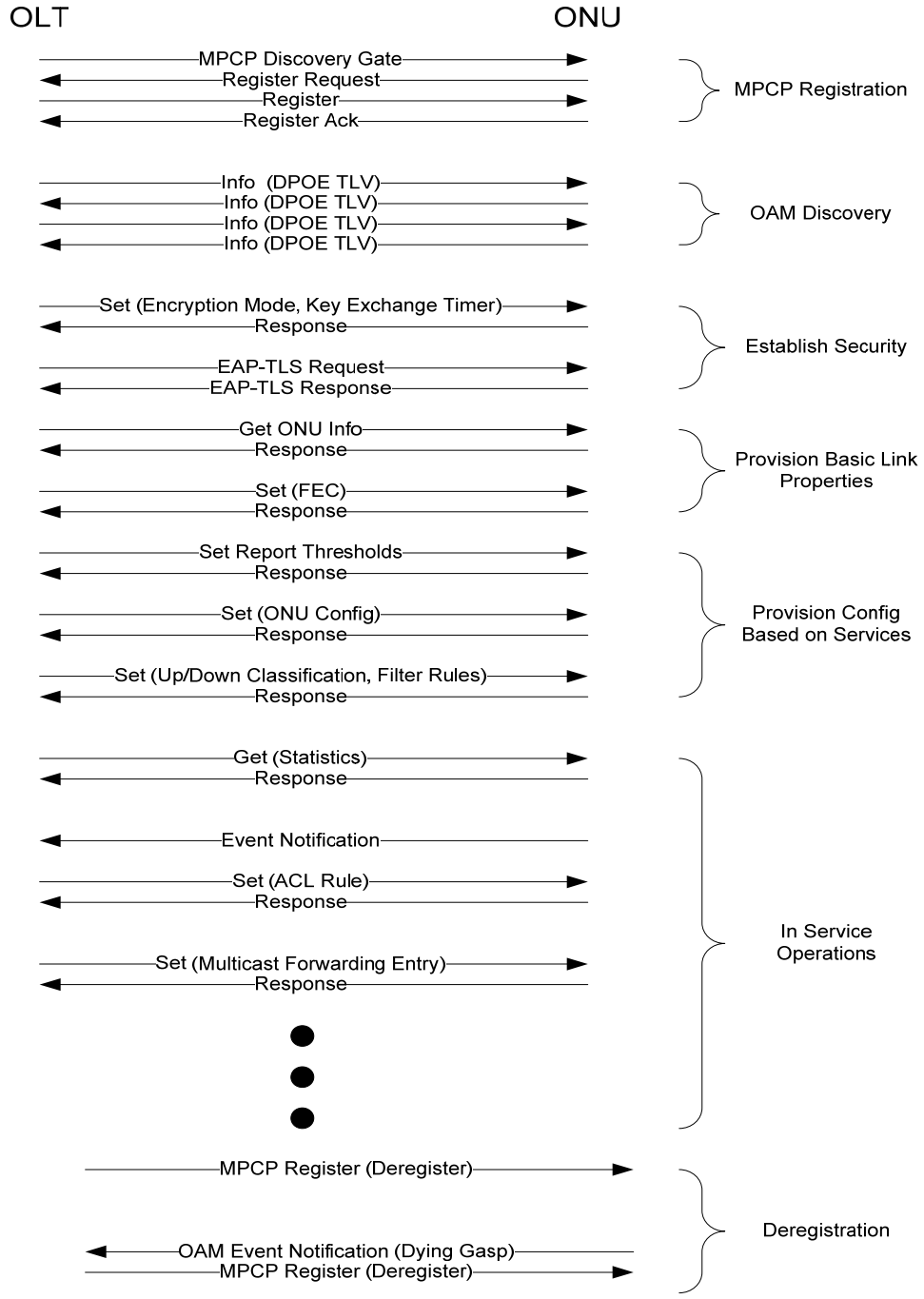

Figure 26 - Logical Link Life Cycle

III.1 MPCP Registration

Initial detection of a logical link occurs by MPCP registration as specified in [802.3] Clause 64 and [802.3av] Clause 77. Range to the DPoE ONU and MAC address of the logical link are first available at this point.

III.2 OAM Discovery

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

III.3 Establish Discovery

It is desirable to establish encryption and authenticate the newly-discovered DPoE ONU as soon as possible, and before user data traffic is allowed to pass the DPoE ONU. These processes are carried out as defined by the DPoE specifications. Other OAM should be postponed until encryption has been established and the DPoE ONU has been authenticated.

III.4 Provision Basic Link Properties

The DPoE ONU ID and capabilities for the newly-discovered link would normally be queried early in the lifetime of a link. Any basic link properties necessary to operate the link might be provisioned first. For example, FEC for the link might be enabled.

III.5 Provision Configuration Based on Services

Once the identity of the DPoE ONU has been established and the link has been configured, the DPoE System can consult its database and configure the DPoE ONU as required to support the services authorized for this user. Commands might be sent to the DPoE ONU to establish its basic configuration (number of logical links, queues, and classification scheme); MPCP report thresholds would be established as appropriate for the SLA for the logical link; filter rules for the link might be established.

The first link registered from a physical DPoE ONU is likely to see more activity than others, as the DPoE System would provision configuration global to the entire ONU on this link, but not repeat that provisioning for later links.

III.6 In Service Operations

Periodic activity can be expected on a logical link once it is in service and basic provisioning has been established. For example, statistics might be regularly polled on the DPoE ONU by periodically sending a Get PDU requesting statistics attributes of various objects of interest. Some alteration in the provisioning of the DPoE ONU may occur based on events that occur after the DPoE ONU has registered. For example, DHCP snooping might learn an IP address assigned to a user device; in response, the DPoE System provisions an anti-spoofing ACL rule on the ONU to match that particular MAC/IP combination. Systems with remote-controlled multicast forwarding (as opposed to local ONU forwarding based on IGMP or MLD snooping) might send commands to add and remove multicast forwarding entries to the DPoE ONU as required. The DPoE ONU might autonomously report events to the DPoE System, particularly indications of faults.

III.7 Link Deregistration

The logical link will typically disappear when it is deregistered by management command, for example when a user unsubscribed from a service and that logical link is no longer needed, or if the DPoE ONU is powered off.

Appendix IV Example Rules (Informative)

This section shows some example rule sets to accomplish particular actions on a frame.

IV.1 Field Masking Example

Some field codes have sub-fields that are of interest. For example, a VLAN tag has a TPID, priority, CFI/DEI, and VID fields. Rather than assign every sub-field a unique code, the rule format allows a number of bits on both the most significant ("left)" side of the field and the least significant ("right") side to be ignored for purposes of comparison. For the sake of notation, a field will be written with its mask values as {Field Code, MSB, LSB}.

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
TPID																PRI			C	VID											

To specify the TPID sub-field of a VLAN tag, the MSB mask would be 0 (ignore no bits on the left side), while the LSB mask would be 16 (ignore all bits of the VID, CFI, and PRI fields). Similarly, to select just the PRI field, a rule would ignore the 16 MSB (the TPID), and the 13 LSB (VID and CFI).

TPID 0: { VLAN 0, 0, 16}

PRI: { VLAN 0, 16, 13 }

CFI: { VLAN 0, 19, 12 }

VID: { VLAN 0, 20, 0}

IV.2 TPID Translation

Some legacy equipment uses pre-standard TPID values to indicate S-VLAN tags. For example, two tags in a frame might have TPIDs 0x9100 and 0x8100, rather than 0x88A8 and 0x8100. It can be desirable to normalize the TPID values so that core equipment only need be concerned with standard VLAN tag values.

Translating a value is a matter of matching frames to which we want to apply this translation, and then rewriting the appropriate value in the frame. Let's assume that the ONU has been instructed to treat TPID 0x9100 as a C-VLAN tag. The TPID of a VLAN tag can be found in the most significant 16 bits of the tag.

For these frames, we want to overwrite the VLAN tag with another VLAN tag with identical VID, but with a different TPID. One way to do this is to copy the input field to the output, and then overwrite the TPID.

Condition: ({C-VLAN 0, 0, 16} == 0x9100)

Result: Copy C-VLAN 0; Set (C-VLAN 0, 0, 16} 0x88A8; Replace C-VLAN 0;

Appendix V Acknowledgements

On behalf of our industry, we would like to thank the following individuals for their contributions to the development of this specification.

Contributor	Company Affiliation
John Dickinson	Bright House Networks
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Appendix VI Revision History

VI.1 Engineering Changes incorporated into DPoE-SP-OAMv1.0-I02-120607

ECN Identifier	Accepted Date	Title of EC
OAMv1.0-N-12.0007-2	3/02/2012	Starting index number error for UNI port
OAMv1.0-N-12.0009-1	3/02/2012	Parameters for Secure Software Download
OAMv1.0-N-12.0016-2	3/22/2012	Clarification changes for DPoE-SP-OAMv1.0
OAMv1.0-N-12.0019-1	4/5/2012	New File Acknowledgement Response Codes Needed to Generate OSSI Firmware Upgrade Events
OAMv1.0-N-12.0025-1	5/10/2012	Rules Parameters
OAMv1.0-N-12.0026-1	5/10/2012	Dynamic Configuration Change
OAMv1.0-N-12.0035-1	5/24/12	Reverse of OAMv1.0-N-12.0025-1