# DOCSIS® Provisioning of GPON Specifications
# DPoGv1.0

# DPoG Physical Layer Specification

# DPoG-SP-PHYv1.0-C01-160830

## CLOSED

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# Document Status Sheet

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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 generally public document that has undergone Member and Technology Supplier review, cross-vendor interoperability, and is for Certification testing if applicable. Issued Specifications are subject to the Engineering Change Process. |
| **Closed** | A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs. |

## Trademarks

# Contents



# Figures



# Tables

# 1 INTRODUCTION

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

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

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

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

## 1.1 Scope

This specification identifies requirements for the GPON PHY for the adaptation or additions to DOCSIS specifications that are required to support DOCSIS Provisioning of GPON.

This specification:

- Specifies interoperable implementations for various DPoG vendors; and
- Specifies additional requirements for GPON PHY layer as used in cable networks which are outside the scope of [G.984.2] specifications.

## 1.2 Goals

The DPoG PHY specification accomplishes the following objectives:

- Identify and document the requirements for Forward Error Correction.
- Define requirements for optical monitoring and power control.

## 1.3 Requirements

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

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

## 1.4 DPoG Version 1.0 Specifications

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

***Table 1 - DPoGv1.0 Series of Specifications***

| Designation | Title |
|---|---|
| DPoG-SP-ARCHv1.0 | DPoG Architecture Specification |
| DPoG-SP-OAMv1.0 | DPoG OAM Extensions Specification |
| DPoG-SP-PHYv1.0 | DPoG Physical Layer Specification |
| DPoG-SP-SECv1.0 | DPoG Security and Certificate Specification |
| DPoG-SP-MULPIv1.0 | DPoG MAC and Upper Layer Protocols Interface Specification |
| DPoG-SP-OSSIv1.0 | DPoG Operations and Support System Interface Specification |

## 1.5 Reference Architecture

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

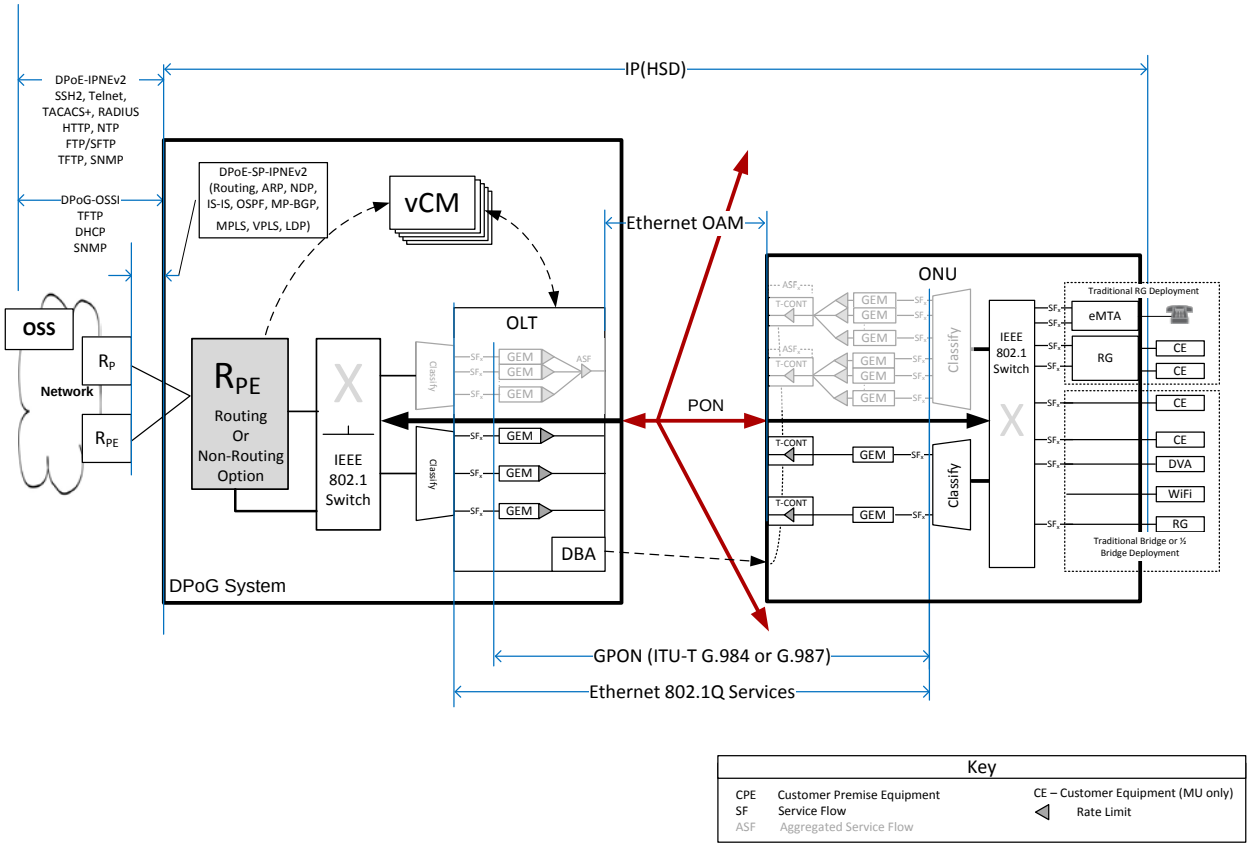


***Figure 1 - DPoGv1.0 Reference Architecture***

## 1.6 DPoG Interfaces and Reference Points

The DPoG interfaces and reference points shown in Figure 2 provide a basis for the description and enumeration of DPoG specifications for the DPoG architecture. Refer to [DPoG-ARCH] for a discussion of these interfaces and reference points.

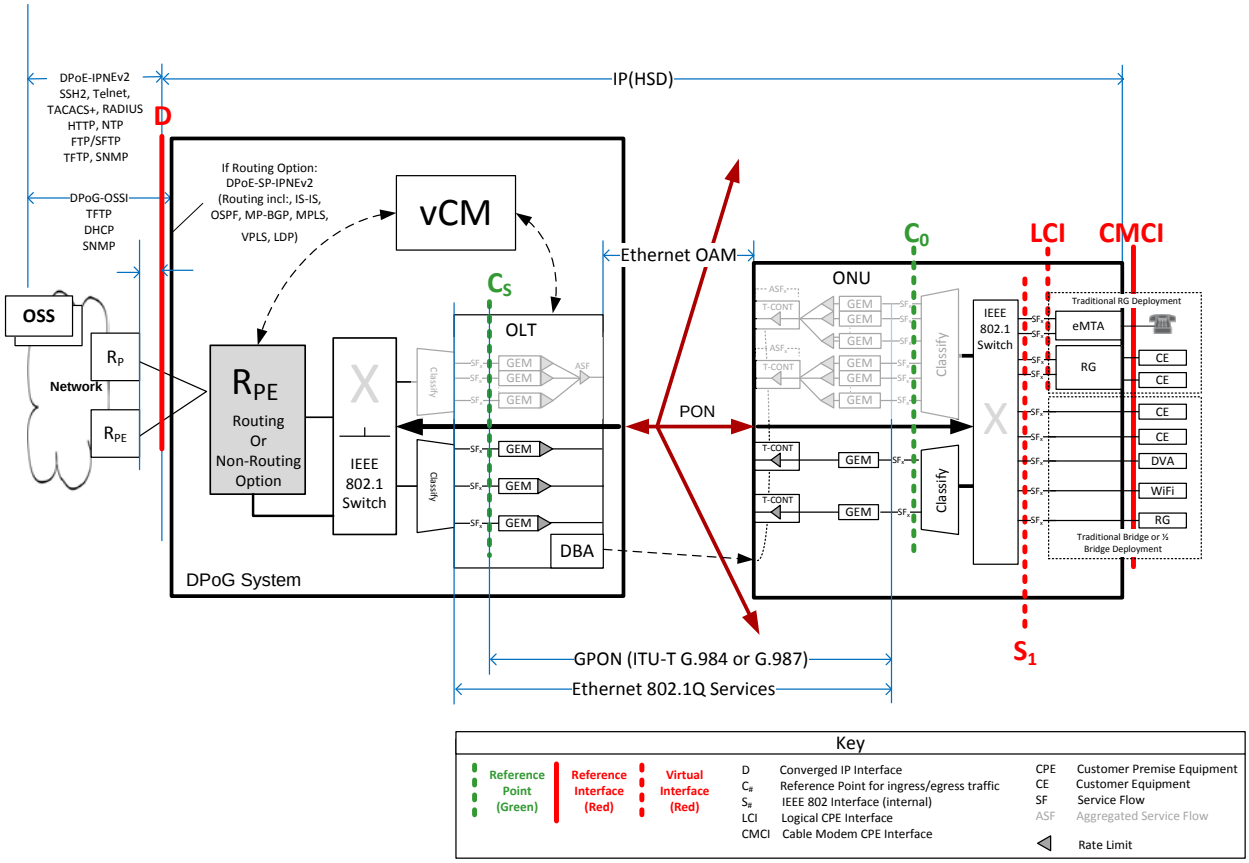


***Figure 2 - DPoGv1.0 Interfaces and Reference Points***

# 2 REFERENCES

## 2.1 Normative References

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

| | |
|---|---|
| [802.1] | IEEE Std 802.1, Refers to entire suite of IEEE 802.1 standards unless otherwise specified. |
| [802.3] | IEEE Std 802.3™-2012, IEEE Standard for Ethernet, December 2012. |
| [G.984.2] | ITU-T Recommendation G.984.2, Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification, Amendment 2. |
| [G.984.3] | ITU-T Recommendation G.984.3, Gigabit-capable Passive Optical Networks (G-PON): Transmission Convergence Layer Specification. |
| [G.984.5] | ITU-T Recommendation G.984.5, Gigabit-capable Passive Optical Networks (G-PON): Enhancement band. |
| [G.987.2] | ITU-T Recommendation G.987.2, 10-Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification. |
| [G.987.3] | ITU-T Recommendation G.987.3, 10-Gigabit-capable passive optical networks (XG-PON): Transmission Convergence Layer Specification. |
| [SFF-8472] | SFF-8472 Specification for Diagnostic Monitoring Interface for Optical Transceivers, Revision 12.1, released September 2014. |
| [SFP MSA] | INF 8074i Rev 1.0, SFP (Small Form-factor Pluggable) Transreceiver, released 12 May 2001. |

## 2.2 Informative References

This specification uses the following informative references.

| | |
|---|---|
| [802.1Q] | IEEE Std. 802.1Q-2011, IEEE Standard for Local and Metropolitan Area Networks-Virtual Bridged Local Area Networks, August 2011. |
| [DPoE-OAMv2.0] | DOCSIS Provisioning of EPON, DPoE OAM Extensions Specification, DPoE-SP-OAMv2.0, Cable Television Laboratories, Inc. |
| [DPoG-ARCH] | DOCSIS Provisioning of GPON, DPoG Architecture Specification, DPoG-SP-ARCHv1.0, Cable Television Laboratories, Inc. |
| [DPoG-OAM] | DOCSIS Provisioning of GPON, DPoG OAM Extensions Specification, DPoG-SP-OAM-v1.0, Cable Television Laboratories, Inc. |
| [DOCSIS] | Refers to entire suite of DOCSIS 3.0 specifications unless otherwise specified. |
| [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. |

## 2.3 Reference Acquisition

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- Institute of Electrical and Electronics Engineers (IEEE), +1 800 422 4633 (USA and Canada);
  http://www.ieee.org
- 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
- ITU-T Recommendations: http://www.itu.int/ITU-T/publications/recs.html
- Small Form Factor Committee (SFF), http://www.sffcommittee.com
- 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/

# 3 TERMS AND DEFINITIONS

This specification uses the following terms and definitions.

## 3.1 DPoG Network Elements

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

## 3.2 Other Terms and Definitions

| | |
|---|---|
| **Address Resolution Protocol** | A protocol of the IETF for converting network addresses to 48-bit Ethernet addresses. |
| **Byte** | A contiguous sequence of eight bits. An octet. |
| **Burst** | A single, continuous transmission in the upstream direction originating from a single ONU, where queued customer data is transmitted towards the DPoG System at the full data rate supported by the transmission channel. Between bursts, ONUs do not transmit any data. |
| **Cable Modem CPE Interface** | The interface defined in DOCSIS between a CM and CPE. |
| **Classifier** | A set of criteria used for packet matching according to TCP, UDP, IP, LLC, [802.1Q] packet fields. A classifier maps each packet to a Service Flow. A Downstream classifier is used by the DPoG System to assign packets to downstream service flows. An Upstream classifier is used by The D-ONU to assign packets to upstream service flows. |
| **Codeword** | An element of an error-correcting code used to detect and correct transmission errors. |
| **Customer Premise Equipment (CPE)** | Customer Premise Equipment as defined in [DOCSIS]. |
| **Data Link Layer** | Layer 2 in the Open System Interconnection (OSI) architecture; the layer that provides services to transfer data over the transmission link between open systems (here, equal to GPON). |
| **Data Rate** | Rate Throughput, data transmitted in units of time usually in bits per second (bps). Various multipliers are used in this document, ranging from kbit/s (thousand bits per second) to Gbps (billion bits per second). |
| **DPoG Operations and Maintenance Messaging (OAM)** | DPoG OAM messaging as defined in [DPoG-OAM] and [DPoE-OAMv2.0]. |
| **Frame** | Basic data organizational unit. Here, disambiguated per [G.984.3], section 5.6. |
| **GPON** | Gigabit-capable Passive Optical Networks (2.488 Gb/s downstream, 1.244 Gb/s upstream) as defined by G.984. |

| | |
|---|---|
| **Logical CPE Interface** | LCI as defined in [eDOCSIS]. |
| **Network Interface Device (NID)** | A DEMARC device in DPoG specifications. |
| **Upstream** | The direction of transmission from the customer to the head-end. |
| **XG-PON** | An XG-PON (10 Gb/s downstream, 2.4 Gb/s upstream) as defined by G.987 |

# 4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations:

| | |
|---|---|
| **BER** | Bit error ratio |
| **CMCI** | Cable Modem CPE Interface |
| **CoS** | Class of Service |
| **CPE** | Customer Premise Equipment |
| **DEMARC** | Demarcation Device |
| **D-ONU** | DPoG Optical Network Unit |
| **DoS** | Denial of Service |
| **DPoE** | DOCSIS Provisioning and operations of EPON |
| **eCM** | embedded Cable Modem |
| **eDVA** | embedded Digital Voice Adapter |
| **EPON** | Ethernet Passive Optical Network |
| **EVC** | Ethernet Virtual Connection |
| **FEC** | Forward error correction |
| **GPoN** | Gigabit-capable Passive Optical Networks |
| **IP** | Internet Protocol |
| **L2VPN** | Layer 2 Virtual Private Network |
| **LCI** | Logical CPE Interface |
| **MEF** | Metro Ethernet Forum |
| **MI** | MEF INNI Interface at a customer premise |
| **MU** | MEF UNI Interface |
| **NID** | Network Interface Device |
| **NNI** | Network to Network Interface |
| **NSI** | Network Systems Interface |
| **OAM** | EPON Operations Administration and Maintenance |
| **ODN** | Optical distribution network |
| **OLT** | Optical Line Termination |
| **ONU** | Optical Network Unit |
| **OSC** | Optical Splitter Combiner |
| **PCS** | Physical Coding Sublayer |
| **PDU** | Protocol Data Units |
| **PHY** | Physical Layer |
| **PMA** | Physical Medium Attachment |
| **PMD** | Physical Media Dependent (Sublayer) |
| **PON** | Passive optical network |
| **R** | IP Router |
| **SFP** | Small Form-factor Pluggable |
| **SFP+** | Small Form-factor Pluggable Plus (+) |
| **UNI** | User Network Interface |

| | |
|---|---|
| **VFI** | Virtual Forwarding Instance |
| **VSI** | Virtual Switch Instance |
| **X** | IEEE Ethernet Switch (Generic) |
| **XFP** | X Form-factor Pluggable |
| **XG-PON** | 10-Gigabit-capable Passive Optical Networks |

# 5 GPON PHY

The specifications for the GPON PHY are in [G.984.2] and [G.984.5]. These documents and their associated amendments contain specifications for optical module wavelengths, receiver sensitivity and other parameters defining the GPON physical layer used in DPoG Networks. Details of wavelength planning, supported optical budgets, and split ratios for particular deployments are outside the scope of this specification.

## 5.1 DPoG Additional PHY Requirements

A DPoG System MUST support the 2.488 Gb/s downstream rate and associated optical interface parameters defined in [G.984.2]. A DPoG System MUST support the 1.244 Gb/s upstream rate and associated optical interface parameters defined in [G.984.2].

A D-ONU MUST support the 2.488 Gb/s downstream rate and associated optical interface parameters defined in [G.984.2]. A D-ONU MUST support the 1.244 Gb/s upstream rate and associated optical interface parameters defined in [G.984.2].

A DPoG System MUST support the optical wavelength and filtering parameters defined in [G.984.5]. A D-ONU MUST support the optical wavelength and filtering parameters defined in [G.984.5]. The D-ONU S/X protection against next generation wavelengths, as shown in Figure 5 of [G.984.5], MUST extend to λ6 = 1625 nm (not λ6 = 1580 nm).

A DPoG System MUST support the Class B+ optical power budget parameters defined in Appendix III of [G.984.2]. A D-ONU MUST support the Class B+ optical power budget parameters defined in Appendix III of [G.984.2].

A DPoG System MUST support the Class C+ optical power budget parameters defined in Appendix V of [G.984.2] for single-sided extension.

A DPoG System MUST support the XG-PON physical medium dependent layer parameters defined in [G.987.2]. A D-ONU MUST support the XG-PON physical medium dependent layer parameters defined in [G.987.2].

An XG-PON DPoG System MUST support the N1 optical power budget parameters defined in [G.987.2]. An XG-PON D-ONU MUST support the N1 optical power budget parameters defined in [G.987.2].

An XG-PON DPoG System MUST support the N2a optical power budget parameters defined in [G.987.2]. An XG-PON D-ONU MUST support the N2a optical power budget parameters defined in [G.987.2].

### 5.1.1 Forward Error Correction

A GPON DPoG System MUST support the Forward Error Correction (FEC) methods defined in [G.984.3], with the additional capabilities as defined in this section. A GPON D-ONU MUST support the Forward Error Correction (FEC) methods defined in [G.984.3], with the additional capabilities defined in this section.

An XG-PON DPoG System MUST support the FEC methods defined in [G.987.3]. An XG-PON D-ONU MUST support the FEC methods defined in [G.987.3].

### 5.1.2 FEC

The DPoG System MUST support enabling downstream FEC on a per-PON basis. The DPoG System MUST support enabling upstream FEC on a per-D-ONU basis.

The DPoG System MUST be able to enable or disable FEC encoding according to operator provisioning.

#### *5.1.2.1 GPON FEC*

A GPON DPoG System MUST support FEC as defined in [G.984.3]. A GPON D-ONU MUST support FEC as defined in [G.984.3].

A GPON DPoG System MUST support different FEC states (enabled / disabled) in the upstream and downstream directions. Correspondingly, a GPON D-ONU MUST support different FEC states (enabled / disabled) in the upstream and downstream directions.

#### *5.1.2.2 XG-PON FEC*

An XG-PON DPoG System MUST support FEC as defined in [G.987.3]. An XG-PON D-ONU MUST support FEC as defined in G.987.3.

In XG-PON, downstream FEC is always used. An XG-PON DPoG System MUST support enabling upstream FEC on a per-D-ONU basis according to operator provisioning.

## 5.2 Raman Interference Mitigation

GPON and XG-PON do not require any additional mechanisms to mitigate Raman Interference.

## 5.3 Optical Monitoring

A DPoG System MUST support all optical monitoring values as specified in [SFF-8472], including monitoring received optical power, transmit power, transmit bias current, internal voltage, and temperature. Similarly the D-ONU MUST support all optical monitoring values as specified in [SFF-8472], including monitoring received optical power, transmit power, transmit bias current, internal voltage, and temperature.

A DPoG System MUST be able to report received optical power on a per-D-ONU basis, as well as reporting received optical power during idle time on the PON upstream.

## 5.4 D-ONU Optical Power Control

One possible failure mode for a D-ONU is for the laser driver to remain in the enabled state outside of the assigned transmission slot, continually generating light into the PON, interfering with transmissions of other D-ONUs in the upstream. The procedure used to detect malfunctioning D-ONUs, and the decision whether to disable them or not, is outside the scope of this specification. Once the specific D-ONU has been identified as the source of the problem, the DPoG System MUST be able to isolate such failed D-ONUs from the PON by disabling their transmitter until the D-ONU can be replaced. The DPoG System disables a D-ONU laser by means of the Disable_Serial_Number PLOAM message.

A D-ONU that receives the Disable_Serial_Number PLOAM message MUST act as described in [G.984.3] for a GPON D-ONU or [G.987.3] for an XG-PON D-ONU.

A DPoG System MUST provide the operator the capability to turn on or off such a rogue D-ONU detection function for each PON and for an entire DPoG System.

# 6 D-ONU UNI "S" INTERFACE

The S interface in Figure 2 is the User to Network Interface (UNI). D-ONUs support two types of S interfaces: physical and logical. Although logical interfaces do not necessarily connect to the CPE, the transport of services to logical and physical interfaces is the same. Any S interface that is configured as a CMCI, MI, or MU interface is a physical interface.

## 6.1 Physical Interfaces

D-ONUs that do not comply with the [SFP MSA] MUST support standard Ethernet interfaces for the S interfaces configured as (CMCI, MI, or MU) physical interfaces, as defined in [802.3].

A D-ONU that complies with the [SFP MSA] MUST support the standard SFP interface defined in the [SFP MSA]. A D-ONU that complies with the [SFP MSA] MUST also support the digital management interface defined in [SFF-8472].

## 6.2 Logical Interfaces

In addition to a physical interface, a D-ONU MAY have a logical Ethernet [802.3] interface. This interface could be used to provide an Ethernet transport across the PON from the DPoG System to a real physical interface within the D-ONU package. It could be a sub-interface to a switch or bridge group within the D-ONU, or a sub-interface on an [802.3] interface of a real physical interface as described in Section 6.1.

# Appendix I Acknowledgments (Informative)

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

| Contributor | Company Affiliation |
|---|---|
| Richard Goodson | Adtran |
| Arkin Aydin, Rex Coldren, Michael Shaffer | Alcatel-Lucent |
| Janet Bean, Jeff Weber | ARRIS |
| Howard Abramson, Samuel Chen, Robin Grindley, Igor Ternovsky | Broadcom |
| Stephen Burroughs, Stuart Hoggan, Curtis Knittle | CableLabs |
| Jeffrey Buffum, Phil Fine, Shaun Missett, Todd Ortberg, Hal Roberts | Calix |
| Jason Combs, Saifur Rahman, Hossam Salib, Jorge Salinger, Joe Solomon, Hardik Shukla, Mehmet Toy | Comcast |
| Brian Kinnard | Commscope |
| Ony Anglade, Eugene Dai, Jeff Finkelstein | Cox |
| Mike Holmes | Finisar |
| Roy Arav, David Gaynor | Oliver Systems |