TECHNICAL REPORT

TR-200
Using EPON in the Context of TR-101

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Issue History

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Executive Summary

Broadband Forum Technical Reports provide an Ethernet-based architecture that has become the global standard for triple-play DSL deployments for residential and business customers. A large part of the specifications of this architecture are technology-agnostic and are used widely today in conjunction with other broadband-access technologies, especially FTTx / PON.

TR-200 strengthens the TR-101 requirements as applied to EPON by providing more detailed and specific requirements. In order to reduce operational complexity and maximize equipment interoperability, a subset of EPON's flexible configuration arrangements are specified here to facilitate the implementation of TR-101's VLAN architecture options. TR-200 contains requirements systems based on IEEE 802.3 EPON, which describes both 1G-EPON (developed in P802.3ah and approved in June 2004) and 10G-EPON (developed in P802.3av and approved in September 2009). Accordingly, throughout TR-200, the terms "shared-media Ethernet access system" and "EPON" are used interchangeably. In addition to specifications facilitating the implementation of TR-101's VLAN architecture, other specifications included herein cover multicast, QoS, OAM, and EMS functionality.

1. Purpose and Scope

1.1 Purpose

Service providers deploying or planning to deploy EPON systems are eager to use elements of the architecture and requirements provided by the Broadband Forum; however, they find there are some aspects of current EPON systems which require definition and could benefit from standardization. This is especially true for service providers planning both EPON and DSL deployments, or who have already deployed DSL and intend to add EPON. Similarly, equipment vendors of particular network elements and management systems are interested in determining the requirements and approach for developing EPON equipment that fits into a consistent broadband-access architecture, with minimal variations among the deployments of individual service providers.

TR-200 is intended to provide the architectural basis and technical requirements needed to successfully deploy EPON equipment within the Broadband Forum architecture, either independently or together with other access technologies.

1.2 Scope

TR-200 outlines an Ethernet-based access system in the context of the existing Broadband Forum Technical Reports. TR-200 focuses on access systems comprising EPON OLT and ONU components. It builds on the architectural/topological models of the Ethernet-based aggregation network and deployment scenarios defined in earlier Broadband Forum Technical Reports, and in doing so it describes how to design and deploy EPON access nodes as well as hybrid access nodes that support combinations of EPON and DSL.

TR-200 specifies the use of EPON both as an access and an aggregation technology. When used as an access technology, it addresses a single subscriber ONT (either residential or business) which may have more than one subscriber-side port. When used as an aggregation technology (e.g., using EPON to feed DSLAMs or multiple-subscriber Ethernet switches), the EPON aggregates traffic from a much larger number of subscribers. Figure 1 shows the position of the EPON system within the end-to-end network for the two cases.

Specifically TR-200:

- is limited to the services and architecture defined by TR-101;
- Describes the ADSL2+, VDSL2, and Ethernet protocols at any **U** reference point that supports connection to the EPON, including defining relationships between the RG and ONT;
- Takes into account the interface requirements at **R/S** and **S/R** reference points;
- Describes various ONT and RG topologies required for EPON deployments;
- Documents extensions to currently defined network-management interactions between Broadband Network Gateways (BNGs) and EPON Access Nodes (ANs).

Specifically TR-200 does not cover:

- ATM and RF Video interfaces on the EPON system.

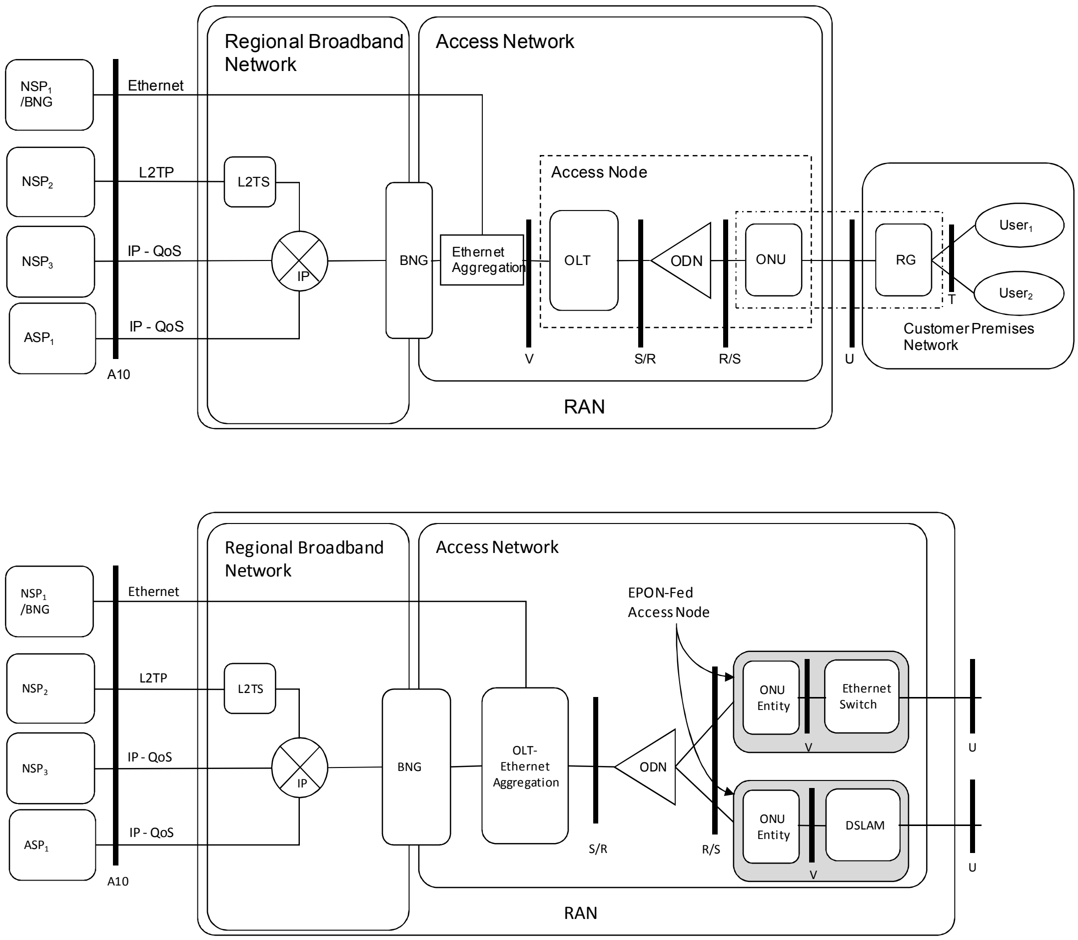


Figure 1 Network architecture in the case of EPON access (top panel) and EPON aggregation (bottom panel).

TR-200 encompasses the OLT and ONT elements and the specific behavior of the elements at the various Reference Points.

Multiple-customer EPON ONUs provide multiple-user access and in some aspects have specific requirements that differ from single-customer ONTs. Multiple-customer ONU requirements are described in Section 6. Unless explicitly indicated otherwise, all ONU Requirements apply to both single-customer and multiple-customer ONUs. In TR-200, the term ONT indicates single-customer units.

This Technical Report covers both 1G-EPON and 10G-EPON, which are described in IEEE Std 802.3-2008 [4] and IEEE Std 802.3av-2009 [5], respectively. 1G-EPON operates at an effective data-rate of 1 Gb/s in both the upstream and downstream directions, while 10G-EPON has two modes of operation, 10G/1G-EPON and 10G/10G-EPON. 10/1G-EPON is an asymmetric system, where the downstream and upstream channels support effective data rates of 10 Gb/s and 1 Gb/s, respectively. 10/10G-EPON is a symmetric system, where the downstream and upstream channels both support an effective data rate of 10 Gb/s. In this specification 10G/1G-EPON and 10G/10G-EPON will be referred to collectively as 10G-EPON. Similarly, 1G-EPON and 10G-EPON will be referred to collectively as EPON.

2. References and Terminology

2.1 Conventions

In this Technical Report several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be in RFC 2119.

MUST	This word, or the term "REQUIRED", means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the adjective "RECOMMENDED", means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the adjective "OPTIONAL", means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication the editions indicated were valid. All references are subject to revision; users of this Technical Report are encouraged therefore to investigate the possibility of applying the most recent edition of the references listed below.

A list of the currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IETF	1997
[2]	TR-101	*Migration to Ethernet-Based DSL Aggregation*	Broadband Forum	2006
[3]	TR-142	*Framework for TR-069 enabled PON devices*	Broadband Forum	2006
[4]	Std 802.3-2008	*Carrier Sense Multiple Access with Collision Detection. (CSMA/CD) access method and Physical Layer specifications*	IEEE	2008
[5]	Std 802.3av-2009	*Carrier Sense Multiple Access with Collision Detection. (CSMA/CD) access method and Physical Layer specifications: Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks*	IEEE	2009
[6]	RFC 3376	*Internet Group Management Protocol, Version 3*	IETF	
[7]	Y.1541	*Network Performance Objectives of IP-Based Services*	ITU-T	2006
[8]	Y.1731	*OAM functions and mechanisms for Ethernet based networks*	ITU-T	2006

2.3 Definitions

DBA

Dynamic Bandwidth Allocation: A process by which the Optical Line Terminal (OLT) distributes the upstream bandwidth among the Optical Network Units (ONUs) attached to a specific OLT PON interface based upon the dynamic indication of their traffic status and their configured bandwidth contracts.

EPON Data Path

An EPON Data Path is a traffic bearing object within an EPON system that represents a data or control flow connection. An EPON Data

	Path is used to ensure per-service and/or per-service-class QoS. A multiple-service ONU typically has one EPON Data Path per service. EPON Data Paths may be either bidirectional unicast, or downstream-only multicast, including broadcast. An EPON Data Path exists only within the EPON; one end is terminated by the OLT PON line card and the other end is terminated by the ONU .
EPON Interface	The interface at reference points S/R and R/S, as defined in 4.3 of this Technical Report. This is a PON-specific interface that supports all of the protocol elements necessary to allow transmission between OLT and ONUs.
EPON Network	An OLT connected to one or more ONUs using an ODN. An EPON network is a subset of the Access Network.
LOID	Logical Identification: the LOID is composed of a series of characters and is used for the identification of an ONU. LOID typically is provisioned by operators.
OAM	Operations, Administration, and Maintenance (OAM): A sublayer providing mechanisms for managing link operation, including ONU authentication, ONU configuration, ONU software-image management, event notification, and performance monitoring.
ODN	Optical Distribution Network: The physical medium that connects an OLT to its subtended ONUs. The ODN is comprised of various passive components, including the optical fiber, splitter or splitters, and optical connectors.
OLT	Optical Line Terminal (OLT): A device that terminates the common (root) endpoint of an ODN, implements a PON protocol, such as that defined by IEEE 802.3, and adapts PON PDUs for uplink communications over the provider service interface. The OLT provides management and maintenance functions for the subtended ODN and ONUs.

ONT	Optical Network Terminal (ONT): A physical, single-subscriber device that terminates any one of the distributed (leaf) endpoints of an ODN, implements a PON protocol, and adapts PON PDUs to subscriber service interfaces. An ONT is a special case of an ONU.
ONU	Optical Network Unit (ONU): A generic term denoting a functional element that terminates any one of the distributed (leaf) endpoints of an ODN, implements a PON protocol, and adapts PON PDUs to subscriber service interfaces. In some contexts an ONU supports interfaces for multiple subscribers.
ONU entity	The EPON ONU function that is associated with an EPON-fed Ethernet access node. This function may be contained in a physically distinct device external to the access node or integrated into the TR-101 access node entity.
PON	Passive Optical Network. A PON includes the OLT, ONU, and Optical Distribution Network (ODN).
Subscriber	A billable entity.
Traffic Flow	A sequence of frames or packets traversing a particular reference point within a network that share a specific frame/packet header pattern. For example, an Ethernet traffic flow can be identified by any combination of specific source MAC address, destination MAC address, VLAN ID, 802.1p bits, etc.
Traffic Classes	A Traffic Class (TC) is a set of upstream and downstream flows whose members are forwarded with the same behavior by a network element.
U interface	U interface is a short form for describing one or more of the interfaces defined in this Technical Report at the U reference point. Functionally it is equivalent to a subscriber-facing interface at the access node.
V interface	V interface is a short form for describing one or more of the interfaces defined in this Technical

	Report at the V reference point. Functionally it is equivalent to a network-facing interface at the access node.
1G-EPON	1 Gb/s EPON, as specified by IEEE 802.3-2008.
10G-EPON	10 Gb/s EPON, as specified by IEEE 802.3av-2009.
10/1G-EPON	Asymmetric data-rate 10G-EPON, as specified by IEEE 802.3av-2009, where the downstream and upstream channels support effective data rates of 10 Gb/s and 1 Gb/s, respectively.
10/10G-EPON	Symmetric data-rate 10G-EPON, as specified by IEEE 802.3av-2009, where the downstream and upstream channels both support an effective data rate of 10 Gb/s.

2.4 Abbreviations

ACS	Auto-Configuration Server
ADSL	Asymmetric Digital Subscriber Line
AN	Access Node
ATM	Asynchronous Transfer Mode
BTS	Base Transceiver Station
CFM	Connectivity Fault Management
CO	Central Office
CPE	Customer Premises Equipment
CPN	Customer Premises Network
DSL	Digital Subscriber Line
EDP	EPON Data Path
EMS	Element Management System
EPON	Ethernet Passive Optical Network
EVC	Ethernet Virtual Circuit
FE	Fast Ethernet (100Mb/s)
FITH	Fiber Into The Home

FTTC	Fiber To The Curb
FTTH	Fiber To The Home
FTTO	Fiber To The Office
FTTP	Fiber To The Premises, including buildings
GbE	Gigabit Ethernet (1000 Mb/s)
GPON	Gigabit-capable Passive Optical Network
ID	Identification
L2	Layer 2
MAC	Media Access Control
MD	Maintenance Domain
MDU	Multi-Dwelling Unit
ME	Maintenance Entity
MEG	ME Group
MEP	MEG End Point
MIP	MEG Intermediate Point
MPCP	Multi-Point Control Protocol
MTU	Multi-Tenant Unit – or Maximum Transmission Unit
NSP	Network Service Provider
OAM	Operations, Administration, and Maintenance
ODN	Optical Distribution Network – as defined in IEEE 802.3
OLT	Optical Line Terminal – as defined in IEEE 802.3
ONT	Optical Network Terminal
ONU	Optical Network Unit – as defined in IEEE 802.3
PON	Passive Optical Network
POTS	Plain Old Telephone Service
PW	PassWord
RAN	Regional Access Network
RBN	Regional Broadband Network
RG	Residential Gateway
RGU	Residential Gateway Unit
SBU	Single-Business Unit
SCB	Single-Copy Broadcast
SFU	Single Family Unit – a type of residence

STB	Set-Top Box
TC	Traffic Class
TDM	Time-Division Multiplexing
TDMA	Time-Division Multiplexed Access
TE	Terminal Equipment
TLS	Transparent LAN Service – a synonym for Business Ethernet Services
TR	Technical Report
VBES	VLANs for Business Ethernet Service
VDSL	Very high speed Digital Subscriber Line
WDM	Wavelength Division Multiplexing
xDSL	Any variety of DSL

2.5 Keywords

access, architecture, BBF, broadband, context, Ethernet, forum, IEEE 802.3, EPON, 10G-EPON, MDU, migration, MTU, ODN, OLT, ONT, ONU, optical, QoS, RGU, SBU, SFU, TR-058, TR-059, TR-101, TR-102, TR-156, TR-167, triple-play.

3. Technical Report Impact

3.1 Energy Efficiency

TR-200 has no impact on energy efficiency.

3.2 IPv6

TR-200 has no impact on IPv6.

3.3 Security

TR-200 has no impact on Security.

4. Architecture and Services

This section describes requirements that differ from TR-101. There are no changes to the requirements for the BNG and Aggregation Node, nor changes to the protocols at the V reference point. The Access Node, as described in TR-101, is distributed between the OLT and ONU. The OLT and ONU share the responsibility for Access Node requirements as specified in TR-101. The ONU faces the user with the **U** reference point and the OLT provides aggregation and meets the **V** reference point. TR-200 describes the functionalities that derive from the use of EPON between the OLT and ONU. In the following text ODN, OLT, ONU and ONT will be used to describe the physical entities. The general term Access Node will be used when describing a function that does not depend on the physical locations but rather on the black-box behavior of the combination of OLT and ONU.

The exception to this is the configuration wherein the ONT also contains the RG functionality. In this configuration the combined element (RGU) must satisfy both ONU and RG requirements.

4.1 ONU Deployment Options

TR-200 describes five types of EPON ONUs:

- SFU: An EPON ONT, designed for residential services, typically serving a single subscriber. An SFU may be deployed with an external RG in some scenarios;
- RGU: A single piece of CPE that combines the EPON ONT and RG functions;
- SBU: An EPON ONT, designed for business services, serving a single customer. The customer interfaces are either Ethernet or TDM (via circuit emulation). TR-200 specifies only the customer Ethernet **U** interface; any TDM adaptation functions are out-of-scope of this document;
- MDU: An EPON ONU with multiple subscriber-facing interfaces (either Ethernet, ADSL2+, or VDSL2), designed for residential services;
- MTU: An EPON ONU with multiple subscriber-facing interfaces, either Ethernet or TDM (via TDM/Ethernet emulation), designed for business services. TR-200 specifies only the customer Ethernet **U** interface; any TDM adaptation functions are out-of-scope of this document.

These ONUs and ONTs can be categorized as follows:

Single-Customer ONTs

- Single Family Unit (SFU),
- Residential Gateway Unit (RGU),

- Single Business Unit (SBU).

Multiple-Customer ONUs

- Multi-Dwelling Unit (MDU),
- Multi-Tenant Unit (MTU).

4.2 U Reference Point Interfaces

All of the interfaces and protocol stacks described in TR-101 at the **U** reference point (U interfaces) are still supported. (See Section 2.2/TR-101 and Figure 4/TR-101.) Additionally, the protocol stacks depicted in Figure 2 are added to support Ethernet physical layer interfaces.

Figure 2, option **a** represents an Ethernet access network using an IP-over-Ethernet stack. Option **b** represents the same for a PPPoE access stack. Finally, option **c** represents a stack that can be used to provide a business Ethernet service, commonly referred to as a Transparent LAN Service (TLS). All of these options also may include 802.1Q and option **c** also may include 802.1ad headers to carry VLAN tags and P-bits.

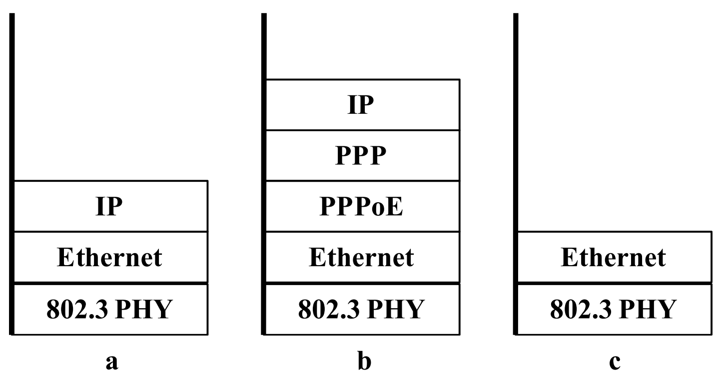
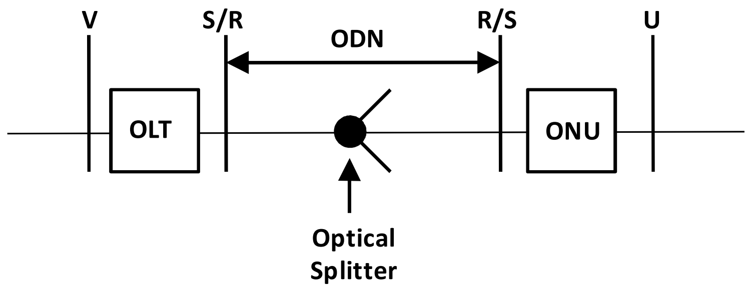


Figure 2 New Protocol Stacks for Interfaces at the U Reference Point.

Note: It is not a requirement that all RGs support all of the above. When an ONU integrates the RG function and the interface at **U** is not externally accessible, there might not be a physical 802.3 PHY. However, there is still an Ethernet layer at this point and the externally visible functionality is no different from that of an ONT where the **U** interface is a physical and external interface.

4.3 R/S and S/R Reference Points

The **R/S** and **S/R** reference points, as shown in Figure 3, apply only to PONs and contain all the protocol elements necessary to allow communication between an OLT and one or more ONUs/ONTs over an Optical Distribution Network (ODN).



S = Point on the optical fiber just after the OLT (Downstream)/ONU (Upstream) optical connection point (i.e., optical connector or optical splice)
R = Point on the optical fiber just before the ONU (Downstream)/OLT (Upstream) optical connection point (i.e., optical connector or optical splice)

Figure 3 Reference configuration for EPON.

R-1 The OLT and ONU MUST prevent direct L2 connectivity between users by default configuration. However, if L2 connectivity between users is supported, this behavior MUST be configurable per S-VID.

R-2 The ONU and OLT MUST support frame sizes of 2000 bytes as per IEEE 802.3as.

4.4 ONU Requirements and Deployment Scenarios

This section describes requirements and typical deployment scenarios for the various ONU types.

4.4.1 Single Family Unit (SFU)

Figure 4 depicts a typical deployment scenario for the SFU. This ONT is deployed on the user's premises and may connect to the RG across the **U** interface using a single FE/GE Ethernet link. This ONT provides mapping of tagged Ethernet frames to the EPON-specific scheduling and traffic management mechanisms in the upstream direction and extraction of the relevant traffic from the

EPON interface in the downstream direction. The RG performs standard RG functionality but with an Ethernet uplink (e.g., 100-BaseT, 1000-BaseX, etc.) instead of an xDSL uplink, at **U**. This specification covers only the EPON functionality inside the ONT, as well as the Ethernet protocol specification, at **U**.

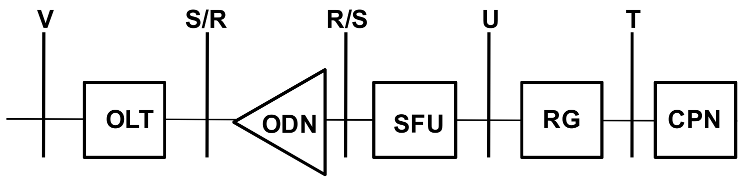


Figure 4 SFU deployment scenario.

4.4.2 Residential Gateway Unit (RGU)

Figure 5 depicts a typical deployment scenario for the RGU. This scenario is similar to the SFU architecture, but differs in that the ONT and RG functionality are combined in a single device. In this scenario the **U** reference is located inside the device and may not be physically present or accessible. The RGU typically provides the same kinds of interfaces (e.g. VoIP ATA, 802.11, Ethernet – managed through TR-069) to the home network as those provided by a typical xDSL RG device. As in the previous model, the RG functionality (and hence the protocols and functions at the **T** reference point) is unchanged and is not described in this specification. Note that the EPON functionality in this configuration and the previous configuration are identical.

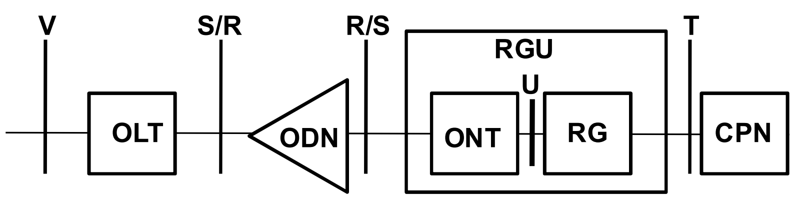


Figure 5 RGU deployment scenario.

4.4.3 Single Business Unit (SBU)

Figure 6 depicts a typical deployment scenario for the SBU, which is the business variation of the SFU/RGU architecture. The SBU provides one or more FE/GbE/10GbE interfaces and one or more TDM interfaces (via TDM/Ethernet emulation) for a single business customer. TR-200 specifies only the customer Ethernet **U** interface; any TDM adaptation functions are out-of-scope of TR-200. In this scenario it is assumed the Enterprise RG is capable of supporting the sending and receiving the following frame types at the U interface: untagged frames, priority-tagged frames, VLAN-tagged and double-tagged (802.1ad) Ethernet frames.

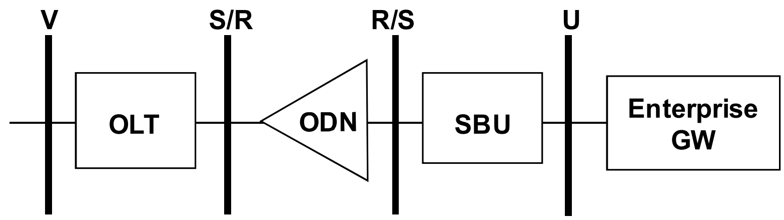


Figure 6 SBU deployment scenario.

4.4.4 Multi-Dwelling Unit (MDU)

Figure 7 depicts a typical deployment scenario for the MDU, which is deployed near or on the premises of a multiple-dwelling building, typically in a wiring closet or other infrastructure area. Alternatively, the MDU can be deployed at the curb or at another outside location that serves multiple single-family or multi-family dwellings. This ONU provides either Ethernet or xDSL physical-layer access. The MDU supports the same EPON functionality as described in previous options, but adapts multiple subscriber interfaces in a single physical device. These interfaces can be Ethernet, ADSL2+, or VDSL2. In simple versions of this configuration the MDU only needs to perform the subscriber-line-to-EPON adaptation functions and does not perform Ethernet switching or learning bridge functions. More sophisticated versions of this configuration which do perform higher-layer functionality are described in Section 6. It should be noted that hybrid options may exist.

For example, it is possible to have both xDSL and native Ethernet interfaces at the U reference point on the same PON, including the case where they are on the same MDU.

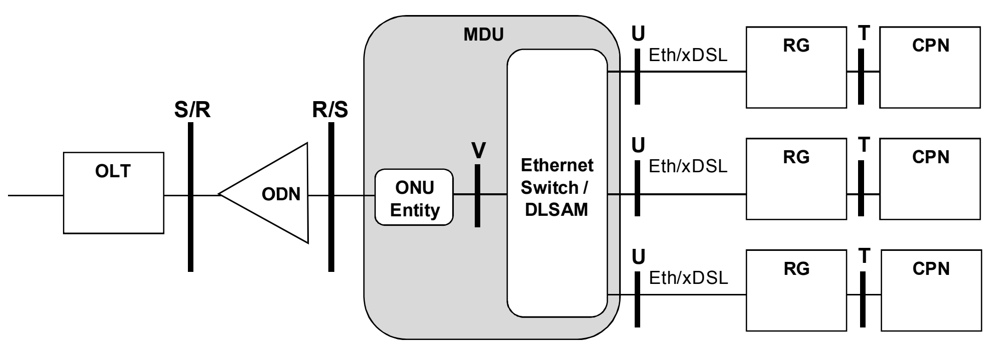


Figure 7 MDU deployment scenario.

4.4.5 Multi-Tenant Unit (MTU)

Figure 8 depicts a typical deployment scenario for the MTU, which is the business variation of the MDU architecture. The MTU is deployed on a customer's premises or at a curb or other common outside location in order to serve multiple businesses.

The MTU provides either Ethernet or TDM (via TDM/Ethernet emulation) physical-layer access. This option uses the same EPON functionality as described in the previous options but adapts multiple subscriber interfaces in a single physical device. These interfaces can be Ethernet, ADSL2+, or VDSL2. In simple versions of this configuration the ONU only needs to perform the subscriber-line-to-EPON adaptation functions and does not perform Ethernet switching or learning bridge functions. More sophisticated versions of this configuration, which do perform higher-layer functionality, are described in Section 6. TR-200 specifies only the customer Ethernet **U** interface; any TDM adaptation functions are out-of-scope of TR-200.

It should be noted that hybrid options may exist. For example, it is possible to have both xDSL and native Ethernet interfaces at **U** on the same PON, including the case where they are on the same MTU.

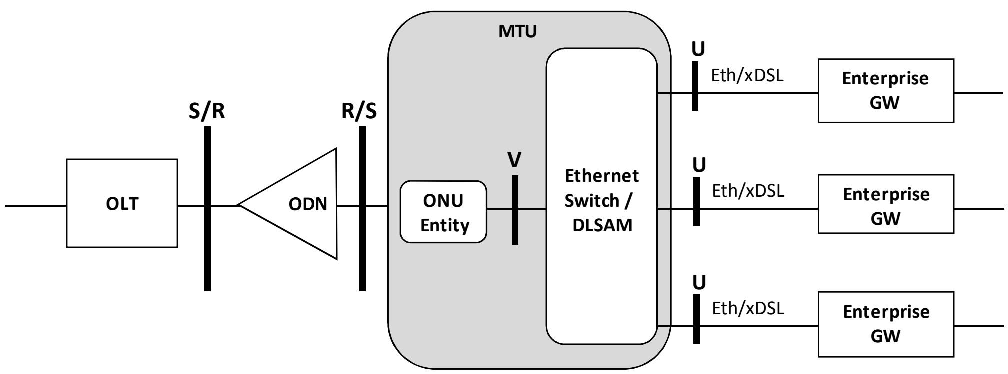


Figure 8 MTU deployment scenario.

4.4.6 EPON with Mixed ONU Types

Figure 9 shows an EPON with more than one ONU type. All ONU types MUST meet all of the pertinent requirements listed in TR-200 whether they are deployed on EPONs with only one type of ONU or on EPONs with a mixture of ONU types.

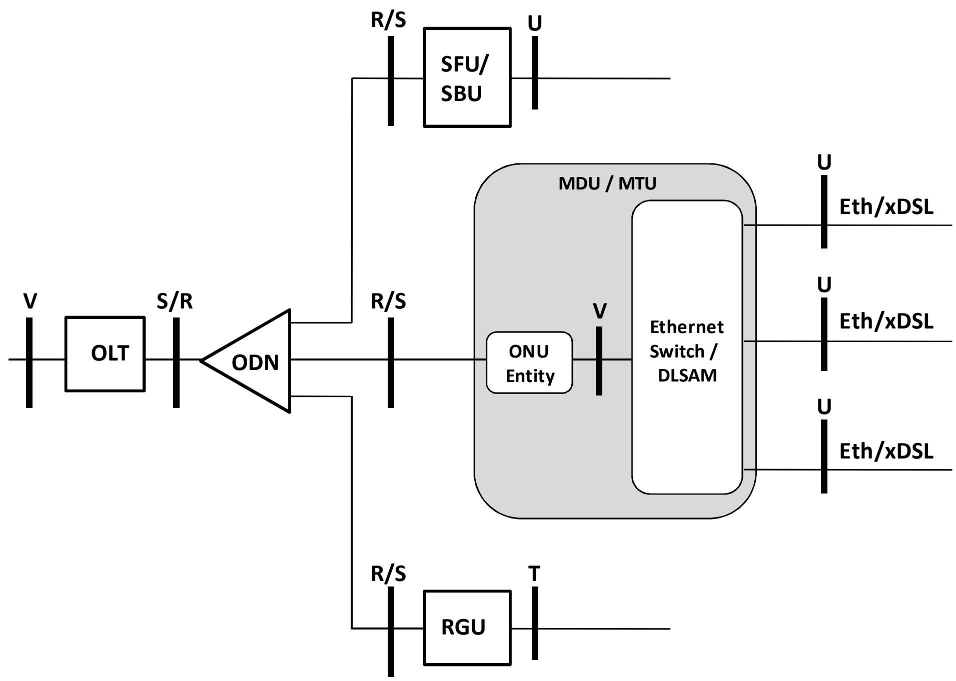


Figure 9 EPON with mixed ONU types.

Note: For the SFU, SBU, and RGU, the V reference point is to the left of the OLT. For the MTU and MDU the V reference point is between the ONU Entity and the Ethernet Switch / DSLAM.

R-3 The OLT MUST support the deployment of mixtures of ONU types on the same ODN.

5. EPON Access Architecture

This Section describes the VLAN, QoS, multicast, security, filtering, port-management, and coexistence requirements for single-customer ONUs/ONTs and for simple, multiple-customer ONUs/ONTs designed to support a small number of subscribers. Any additional or differing requirements in these areas pertaining to larger, more complex, multiple-customer ONUs are described in Section 6.

5.1 VLANs

The OLT and ONU share the responsibility for Access Node VLAN requirements as specified in TR-101. TR-101 identifies two VLAN topologies (N:1 and 1:1) and these, along with specific port configurations to support ASP, NSP, and Business Ethernet services (TLS), still apply when there is an EPON-based Access Node. These various VLAN and port configurations are supported simultaneously on the same EPON in this Technical Report.

The ONU supports equivalent functionality for the U interfaces of an Access Node as that specified in TR-101. The ONU assumes the responsibility of ingress traffic classification for the U interface. Similarly, the OLT supports equivalent functionality for the V interfaces of an Access Node as that specified in TR-101. The OLT assumes the responsibility of ingress traffic classification for the V interface. Between the ONU and OLT is the ODN, and Ethernet is native transport mechanism.

5.1.1 N:1 VLANs

In the upstream direction, for N:1 VLANs it is the responsibility of the ONU to add an S-VID tag or translate an incoming S-VID tag, so that there always is an S-VID tag at the R/S interface. The OLT passes through upstream frames without modifying the S-VIDs.

The downstream essentially performs the opposite operation. The S-VLAN and MAC address are learned from frames in the upstream direction. The ONU removes or translates the tag and then forwards frames to the appropriate **U** interface based on MAC address.

5.1.2 1:1 VLANs

In a 1:1 VLAN architecture the ONU maps each 1:1 VLAN into a unique U interface. One or more VLANs can be mapped into each U interface. In this model there are two variations on tag assignment at **V**. In the first variation the 1:1 VLANs are double-tagged and in the second they are single-tagged.

For 1:1 VLANs in the upstream direction, the ONU always adds a tag to untagged frames or translates an incoming Q-Tag.

- For single-tagged VLANs at **V**, the ONU is provisioned to add an S-VID tag or translate an incoming tag into an S-VID tag. The OLT passes-through the tag transparently or translates it to a new S-VLAN tag;
- For the case where the VLAN is double-tagged at **V**, the ONU is provisioned to assign a C-VID tag or translate the incoming tag into a C-VID tag and the OLT adds the S-VID.

The downstream essentially performs the opposite operation. For a single-tagged VLAN at the **V** interface, the OLT passes-through or translates the S-VLAN tag to a C-VLAN tag. For a double-tagged VLAN at the **V** interface, the OLT removes the outer tag and also may translate the S-VLAN tag to a C-VLAN tag. The ONU removes or translates the tag and forwards the frame to the appropriate user port.

5.1.3 VLANs for Business Ethernet Services (VBES)

In a VLAN for Business Ethernet Services (VBES) architecture, traffic at the U interface can be untagged, tagged, double-tagged or priority-tagged. For TLS, the required implementation is for the ONU to always add an S-Tag or translate an incoming S-Tag to a new S-Tag, on upstream traffic.

It should be noted that the option to receive double-tagged traffic was not specified in TR-101 and reflects new business requirements resulting from the maturation of transparent LAN services since TR-101 was developed.

In the TLS VLAN architecture the ONU maps each U interface into one or more unique S-VLANs. In this model there are two mutually exclusive methods of subscriber tag assignment.

The first method is for subscriber packets that are single-tagged, priority-tagged or untagged. In this method an S-Tag is added at the ONU for upstream traffic and is passed through at the OLT. In the downstream direction, the OLT passes the packet through again, and the S-Tag is removed at the ONU before forwarding traffic to the U interface. For this method, the subscriber can identify optional non-TLS VLANs with specific Q-Tags.

The second method is for subscriber packets that are double-tagged. Frames with valid S-Tags are accepted and may be translated to new values at the ONU. Frames with invalid S-Tags are silently discarded. In both directions the frames are passed through the OLT. Downstream, the S-Tag may be translated back to the original value at the ONU before being forwarded to the U interface.

5.1.4 VLAN Requirements

To support the TR-101 VLAN paradigm, the combination of an OLT and ONU must support the N:1, 1:1, and TLS VLAN paradigms.

R-4 The ONU and OLT MUST support all VID values in the range 1-4094, as specified in IEEE 802.1Q, on all ports.

R-5 The ONU MUST support setting the VID for untagged and priority-tagged frames in the upstream direction based on EtherType, except for VLANs used for Business Ethernet Services.

Note: For more details, see R-26/TR-101 and R-27/TR-101.

R-6 The OLT MUST support forwarding Ethernet frames received on an EDP to a network facing interface based on S-VID and destination MAC address.

R-7 The OLT MUST support forwarding frames received at a network facing interface to EDPs on the PON based on any combination of destination MAC address, S-VID, and P bits.

R-8 The ONU MUST support forwarding downstream Ethernet frames to a given downstream interface based on S-VID and destination MAC address.

N:1 VLANs

In this configuration the upstream traffic can be received at the U interface in either a Multi-VC ATM, VLAN-tagged Ethernet, or Untagged/Priority-tagged Ethernet format. In order to provide simplicity within the EPON interface, the ONU is required to tag the untagged traffic or map a specified Q-Tag into a separately specified S-Tag.

The following requirements apply to N:1 VLANs:

R-9 The ONU MUST support adding an S-Tag to upstream untagged traffic received at the **U** interface.

R-10 The ONU MUST support removing an S-Tag from downstream traffic received from the OLT.

R-11 In the upstream the ONU MUST support unique translation of Q-Tag VIDs into S-Tag VIDs.

R-12 In the downstream the ONU MUST support unique translation of the S-Tag VIDs into the Q-Tag VIDs.

R-13 The unique symmetric translation among tag VIDs MUST be done by means of a single provisioned table per **U** interface.

R-14 The OLT MUST support passing without modification an S-Tag in the upstream direction.

R-15 The OLT MUST support passing without modification an S-Tag in the downstream direction.

R-16 The OLT MUST be able to prevent forwarding traffic between user ports (user isolation). If user isolation is provisionable, this behavior MUST be configurable per S-VID.

1:1 VLANs

In this configuration the upstream traffic can be received either in a Multi-VC ATM Architecture, VLAN-tagged **U**, or Untagged/Priority-tagged **U**. Thus, in order to provide simplicity within the EPON interface, the ONU is required to tag the untagged traffic or map a Q-Tag into a new C-Tag or S-Tag.

The following requirements apply to 1:1 VLANs:

R-17 The ONU MUST support adding a C-Tag or S-Tag to upstream untagged traffic.

R-18 The ONU MUST support removing a VLAN tag from downstream traffic.

R-19 The ONU MUST support VID translation of the Q-Tag received from the **U** interface into a C-Tag or S-Tag for upstream traffic.

R-20 The ONU MUST support VID translation of the tag used in the downstream into the Q-Tag sent to the **U** interface.

R-21 The OLT MUST support adding an S-Tag in the upstream direction for C-tagged traffic.

R-22 The OLT MUST support passing without modification an S-Tag in the upstream direction.

R-23 The OLT MUST support passing without modification an S-Tag in the downstream direction.

R-24 The OLT MUST support the forwarding of traffic to the **V** interface (i.e. upstream direction) based on S-VID.

R-25 The OLT SHOULD support the forwarding of traffic to the **V** interface (i.e. , in the upstream direction) based on the S-VID and C-VID.

R-26 The OLT MUST support the removal of an S-Tag in the downstream direction when traffic is double-tagged.

R-27 The OLT MUST support deactivating MAC learning, for 1:1 VLANs.

R-28 The Access Node MUST configure 1:1 VLANs so that the C-Tags are unique across the **U** interfaces on the PON and across the entries in the 1:1 VLAN membership list. This is necessary because multiple 1:1 VLANs present at the same **U** interface cannot be distinguished at the OLT without a unique identifier imposed at the ONU.

VLANs for Business Ethernet Services

In this configuration the upstream traffic can be received on a tagged, untagged, double-tagged or priority-tagged **U** interface. The ONU is required to always add an S-Tag to frames that are not already S-tagged.

The following requirements apply to TLS VLANs:

R-29 The ONU MUST support adding an S-Tag in the upstream direction for Q-tagged, untagged, and priority-tagged frames.

R-30 The ONU MUST support validating and translating an S-Tag in the upstream direction for S-tagged frames.

R-31 The ONU MUST support removing an S-Tag in the downstream direction.

R-32 The OLT MUST support the forwarding of traffic to the **V** interface (i.e., in the upstream direction) based on the S-Tag.

R-33 The OLT MUST support passing an S-Tag in the upstream direction.

R-34 The OLT MUST support passing an S-Tag in the downstream direction.

R-35 The ONU MUST support VID translation of the S-Tag received from the **U** interface into a new S-Tag for upstream double-tagged traffic.

R-36 The ONU MUST support VID translation of the S-Tag received from the EPON interface into a new S-Tag for downstream double-tagged traffic sent to the **U** interface.

5.2 QoS

5.2.1 QoS Architecture

In general the goals for QoS remain those defined in TR-101. The high level goals for the QoS architecture include the following:

- Efficient use of bandwidth resources;
- Statistical multiplexing gain;
- Provision of a forwarding class that supports low-latency flows;
- QoS mechanisms that allow the utilization of available bandwidth by eligible traffic classes.

In the distributed EPON Access Node, the network **U** and **V** interfaces are Ethernet-based[1]. This Section provides a mapping of the Ethernet QoS behaviors defined in TR-101 to the EPON QoS mechanisms.

The general requirement for an EPON system is to provide QoS mechanisms that can support the Ethernet QoS requirements of TR-101. By doing this, the set of Access Node QoS requirements defined by Section 3.3/TR-101 still applies in the Ethernet domain of the EPON distributed access-node. In order to provide QoS, two principal mechanisms are described: the classification of traffic

[1] Ethernet-based is used broadly to include the case where an Ethernet layer exists over ATM framing on a DSL physical layer at the **U** interface.

and the forwarding of the resulting traffic classes into EDPs configured to support the desired QoS behaviors.

EPON ONTs potentially may terminate multiple services and have different types of **U** interfaces. An ONT may support an Ethernet data service on a **U** interface using Ethernet or DSL technology at the physical layer, and also support POTS, T1/E1, or other services on other interfaces via emulation.

As illustrated in Figure 10, in the downstream direction the traffic multiplexing functionality is centralized. The OLT multiplexes traffic (data or control flows) into the transmission medium using different Logical Links and various flow features (like QoS or other fields in the L2/L3 header), the combination of which are denoted as EDPs. Thereafter, downstream traffic may be mapped into either unidirectional (downstream-only) multicast EDPs or bi-directional unicast EDPs. Each ONU filters the downstream traffic based on the Logical Link assignments and processes only the traffic that belongs to that ONU.

In the upstream direction, the traffic multiplexing functionality is distributed. The OLT grants upstream transmission opportunities to the subtending ONTs. The ONT classifies upstream traffic into EDPs with various Ethernet priorities and QoS requirements based on a number of criteria: physical port, VID, VLAN P-bits, EtherType and/or DSCP, other fields in the frame, or some combination of these criteria. All upstream traffic, including control messages associated with downstream flows carried by multicast EDPs, is mapped into bi-directional unicast EDPs.

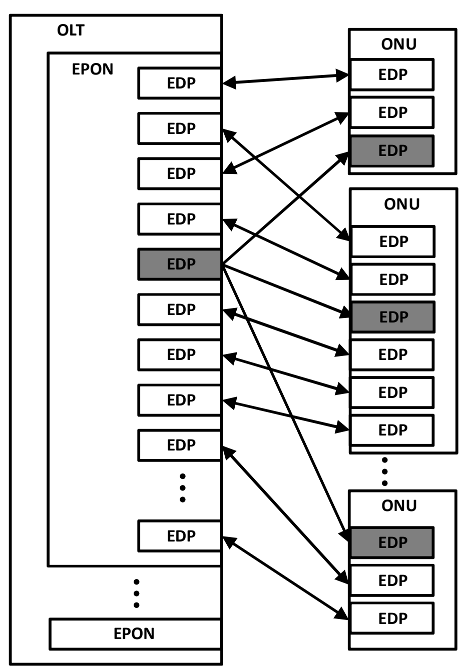


Figure 10 EPON multiplexing.

Note: Shaded EDPs indicate unidirectional (downstream only) multicast EDPs and un-shaded EDPs indicate bi-directional unicast EDPs.

Normally, unicast EDPs for an ONU are carried by one Logical Link, as specified in IEEE 802.3 [2]. Figure 11 illustrates one possible mapping of unicast EDPs onto the underlying Logical Link for this case. Another possible mapping is shown in Appendix A (Figure 31).

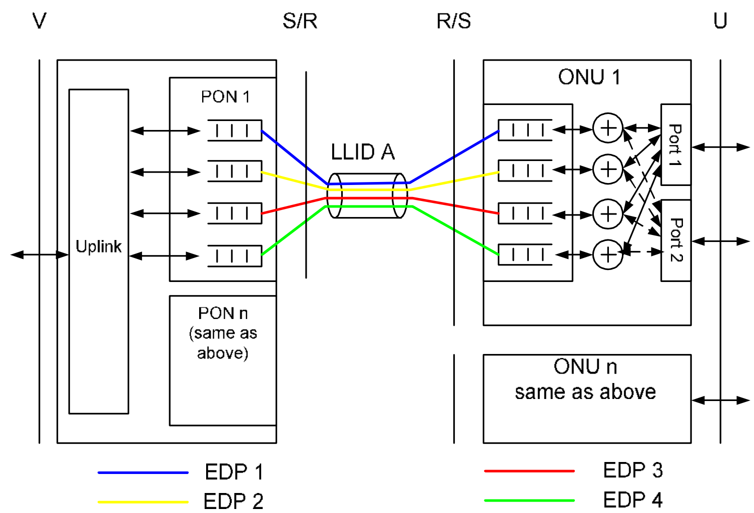


Figure 11 Mapping unicast EDPs onto a single Logical Link.

Multicast EDPs are carried by the Broadcast Logical Link as specified in IEEE 802.3 [2]. Figure 12 illustrates the mapping of the multicast EDP onto the underlying broadcast Logical Link.

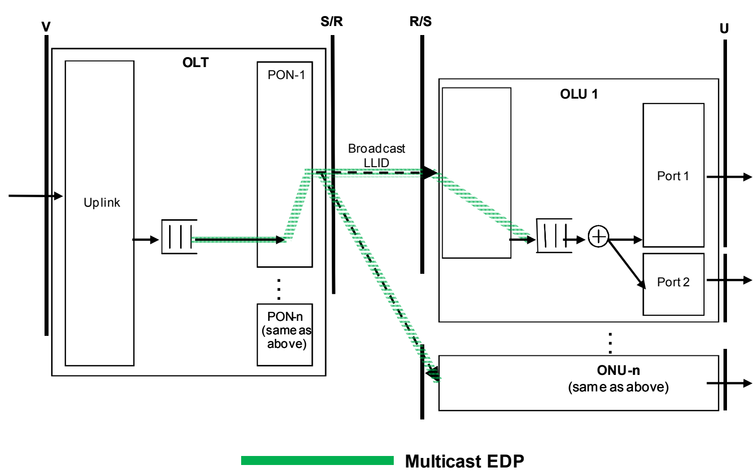


Figure 12 Mapping the multicast EDP onto the broadcast Logical Link.

While emulation-based services and interfaces require a broad range of QoS characteristics, the scope of this specification covers only Ethernet data services. In this context the QoS requirements are specified independently of the existence of other emulation-based services on the ONT and

EPON network. This allows simplifying the requirements and keeping the specification consistent with TR-101. The following sections detail service-class requirements.

5.2.2 Upstream Traffic Management

Upstream Traffic Management Description

Figure 13 depicts an exemplary model of upstream traffic management. This model shows four EDPs on the same PON interface, each carrying a specific TC. Upstream traffic received from U interfaces is mapped to the EDPs based on the TCs. Other upstream traffic received by other ONTs is mapped to other sets of EDPs. At the OLT the traffic is extracted from the EDPs and mapped into the appropriate queues. A scheduler is used to distribute upstream bandwidth among the queues towards the network facing port. Note that the particular architecture shown in Figure 13 with a one-to-one correspondence between OLT queues and EDPs and a one-to-one correspondence between EDPs and ONU queues, is illustrative only; other options, such as multiple queues (OLT or ONU) corresponding to a single EDP, also are possible.

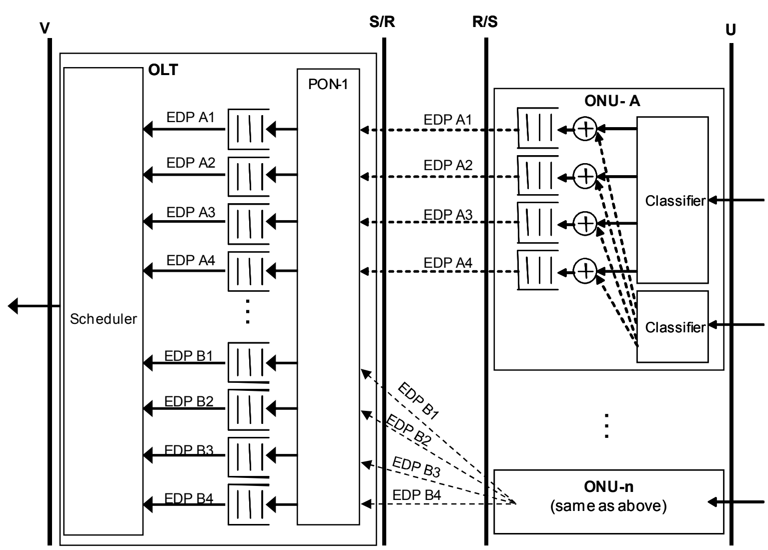


Figure 13 Upstream queuing and scheduling example.

5.2.3 Downstream Traffic Management

The downstream forwarding of traffic is performed similarly to that performed by point-to-point links. EDPs are bidirectional (except for multicast) and are used in the downstream as well as the upstream. At the OLT a classifier places downstream traffic into the appropriate EDPs for downstream scheduling. Once the traffic has been released by the scheduler and transmitted across the PON, the ONU extracts the traffic from the EDPs and maps it into the appropriate output queues

Figure 14 depicts an exemplary model of downstream traffic management. Traffic received from the network-facing port of the OLT is mapped into EDPs and transmitted downstream to the PON interface by a scheduler. At the ONU, the traffic is placed into appropriate queues for each U interface according to its EDP. A scheduler is used per **U** interface to transmit frames that egress the system. Note that the particular architecture shown in Figure 14, with a one-to-one correspondence between OLT queues and EDPs and a one-to-one correspondence between EDPs and ONU queues, is illustrative only; other options, such as multiple queues (OLT or ONU) corresponding to a single EDP, also are possible.

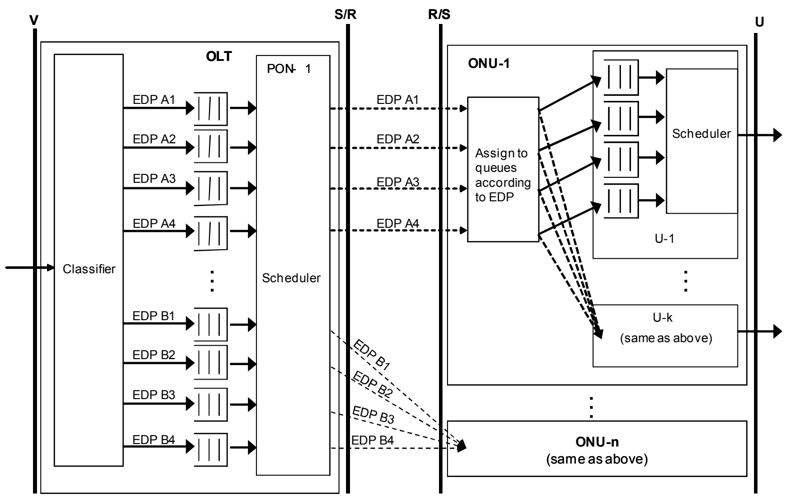


Figure 14 Downstream queuing and scheduling example.

5.2.4 Traffic Management Requirements

The following requirements describe the behavior of the EDPs, queues, classifiers, and schedulers that support multiple TCs, support drop precedence, and otherwise manage traffic.

R-37 The ONU MUST support deriving P-bit markings and mapping traffic into EDPs in the upstream direction based on an arbitrary combination of: user port, VID, received P-bit markings, and EtherType.

R-38 The ONU SHOULD support deriving the P-bit markings and mapping traffic into EDPs in the upstream direction based on an arbitrary combination of: user port, VID, and received DSCP value.

R-39 The ONU MUST perform any necessary VID and P-bit manipulations before performing the mapping into EDPs.

R-40 The ONU MUST support mapping traffic into EDPs based on arbitrary combination of user port, VID and P-bit values in the upstream direction[2].

[2] Note that user ports include both physical ports as well as PVCs on ports that have an ATM layer, like ADSL. For more information, see Section 2.5.1.1/TR-101.

R-41 The OLT and ONU MUST support configuration of the classification rules, with the ability to set the precedence of classification actions in the case where multiple rules have been configured.

R-42 The OLT and ONU MUST NOT prevent multiple P-bit values from being used in the same VLAN.

R-43 The OLT and ONU MUST NOT prevent multiple VLANs from using the same P-bits.

R-44 The OLT and ONU MUST support drop precedence within at least 2 traffic classes and MUST support configurable mapping to these classes and drop precedence from the 8 possible values of the Ethernet P-bits.

R-45 The OLT and ONU MUST support drop precedence within all of the supported traffic classes based on the DEI bit value of the 802.1ad header.

R-46 In the downstream direction, the ONU MUST support at least 4 queues per user port, i.e., at least one queue per traffic class.

R-47 In the upstream direction, the ONU MUST support at least 4 queues, i.e., at least one queue per traffic class.

R-48 In the downstream direction, the OLT MUST support at least 4 queues per PON, i.e., at least one queue per traffic class.

R-49 In the downstream direction, the ONU SHOULD support at least 6 queues per user port, i.e., at least one queue per traffic class.

R-50 In the upstream direction, the ONU SHOULD support at least 6 queues, i.e., at least one queue per traffic class.

R-51 In the downstream direction, the OLT SHOULD support at least 6 queues per PON, i.e., at least one queue per traffic class.

R-52 The OLT and ONU MUST support scheduling of downstream queues according to strict priority among at least 4 TCs.

R-53 The OLT and ONU MUST support assigning an individual TC to a downstream queue.

R-54 The OLT and ONU SHOULD support assigning multiple downstream queues to the same priority. If multiple downstream queues are assigned to the same priority, queues assigned to the same priority MUST be scheduled according to a weighted algorithm (like WFQ) with weights assigned through provisioning. This mechanism provides support for mapping DiffServ PHBs (e.g. EF, AF, BE, LE) to the Ethernet queues.

R-55 In the upstream direction, the OLT MUST support at least 4 queues per network facing port, i.e., at least one queue per traffic class.

R-56 The ONU MUST support at least 4 bidirectional EDPs, i.e., at least one per traffic class.

R-57 In the upstream direction, the OLT SHOULD support at least 6 queues per network facing port, i.e., at least one queue per traffic class.

R-58 In the upstream direction, the ONU SHOULD support at least 6 EDPs, i.e., at least one per traffic class.

R-59 The OLT MUST support strict priority scheduling of upstream queues among at least 4 priorities.

R-60 The OLT MUST support assigning a TC to an upstream queue.

R-61 The OLT SHOULD support assigning multiple upstream queues to the same priority. If multiple upstream queues are assigned to the same priority, queues assigned to the same priority MUST be scheduled according to a weighted algorithm (like WFQ) with weights assigned through provisioning. This mechanism provides support for mapping DiffServ PHBs (e.g. EF, AF, BE, LE) to the Ethernet queues.

R-62 The OLT MUST and ONU SHOULD support setting the maximum depth of all queues.

R-63 The OLT and the EPON ONU entity MUST support at least four traffic classes for Ethernet frames, and MUST support configurable mapping to these classes based on an arbitrary combination of ingress interface, S-VID and P-bit value.

R-64 The OLT and the EPON ONU entity SHOULD support at least six traffic classes for Ethernet frames, and MUST support configurable mapping to these classes based on an arbitrary combination of ingress interface, S-VID and P-bit value.

R-65 The EPON ONU entity MUST support one queue (traffic class) per EDP.

5.3 Multicast Support

5.3.1 IGMP Controlled Multicast

5.3.1.1 Introduction

In EPON, a Single Copy Broadcast (SCB) mechanism is used for the distribution of multicast data from the OLT to all of its subtended ONUs. IGMP agents exist within the OLT and ONUs to support multicast optimization by controlling the flooding of Ethernet multicast frames.

There are a few unique considerations for deploying multicast services over an EPON network:

- **Point to multi-point topology** – an EPON optical distribution network is a physical point to multi-point network. This means that downstream data sent from the OLT is broadcast at the optical layer and will be received by all ONUs, however upstream traffic sent by any ONU is received only by the OLT. This characteristic is exploited for downstream multicast. In the upstream direction, however, multicast control traffic must make use of a unicast channel;
- **Replication hierarchy** – the hierarchy of multicast replication may be deeper in the physical network, first due to the OLT-ONU replication, and second due to the opportunity to replicate again in an ONU;
- **Scale** – a single EPON OLT may support thousands of ONUs and tens of thousands of hosts (STBs) attached to the ONUs. This highlights the need for scalability in the EPON-based access network.

5.3.1.2 EPON-Specific Multicast Requirements

This section includes multicast configuration requirements that are specific to EPON and describes OLT and ONU responsibilities. Figure 15 illustrates the multicast service architecture. The detailed structure of the EPON stack is not shown for simplicity.

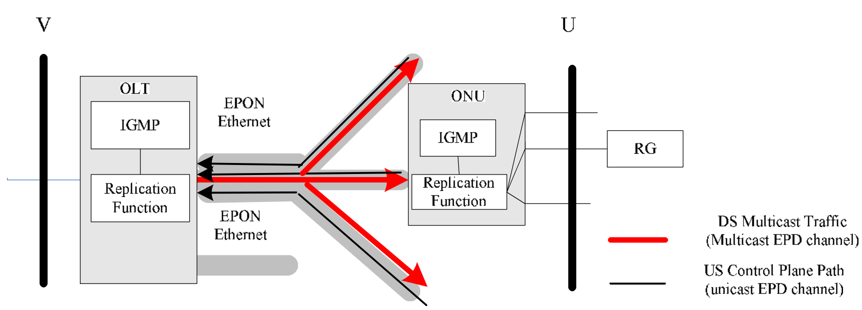


Figure 15 Downstream and upstream multicast data paths in EPON.

5.3.1.3 Data Plane

In EPON the downstream multicast traffic, consisting of a set of multicast groups and downstream IGMP messages, is forwarded using one or more multicast VLANs. A multicast VLAN may be used for carrying only multicast traffic, or it may be used for carrying both unicast and multicast traffic. In some service models the multicast content may be divided into multiple VLANs.

To support multicast optimization in the Access Node, both the OLT and the ONU use IGMP transparent snooping, IGMP snooping with proxy reporting or an IGMP proxy to control the flooding of Ethernet multicast frames. To take full advantage of the point-to-multi-point topology of the EPON network, a multicast EDP typically is used to transport the multicast traffic required by the various multicast groups.

R-66 The OLT MUST support at least one multicast VLAN.

R-67 The OLT and ONU MUST support at least one downstream-only multicast EDP for the purpose of transporting multicast traffic.

R-68 The OLT and ONU entity MUST be able to forward all multicast-VLAN traffic using a single downstream multicast EDP.

R-69 The OLT and ONU MUST allow the configuration of the IP multicast groups that are acceptable per user port based on:
• Source-address matching,
• Group-address matching,
• VLAN membership.

R-70 The OLT MUST allow the configuration of the IP multicast groups that are associated with a multicast VLAN based on:
• Source-address matching,
• Group-address matching.

R-71 The OLT MUST allow configuration of the IP multicast groups described in R-69 and R-70 using ranges based on:
• Source-address matching,
• Group-address matching.

5.3.1.4 Control Plane

All downstream IGMP messages may be transported within an associated multicast VLAN (typical) or transported as untagged VLAN frames. In the case where a multicast bridge is used in the ONU, the IGMP message is flooded selectively towards user ports configured to belong to the same multicast VLAN.

The OLT and ONUs process upstream IGMP messages via IGMP transparent-snooping, IGMP snooping-with-proxy-reporting, or IGMP proxy. To support multiple, multicast VLANs, additional classification functions are required to map multicast groups to multicast VLANs.

EPON naturally separates downstream multicast traffic from upstream multicast control traffic due to the unidirectional nature of the downstream-only multicast EDP. An upstream IGMP message received from any user port is mapped to a bi-directional unicast EDP assigned to the user port sourcing the IGMP message. All the control plane enhancements established in TR-101 apply in this case. The EPON uses unicast EDPs for the transport of upstream IGMP messages, and an EDP may be shared by multiple VLANs on the same **U** interface.

R-72 The OLT SHOULD send downstream multicast IGMP messages (e.g. Global Query messages) using the same EDP (multicast EDP) that is used to carry the multicast content.

R-73 The ONU MUST support receiving downstream multicast IGMP messages (e.g. Global Query messages) on either a unicast EDP or the downstream-only multicast EDP that is used to carry multicast content.

R-74 The ONU and OLT MUST support the identification and processing of upstream IGMP messages. When this function is disabled on a port and/or VLAN, these messages MUST be forwarded transparently.

R-75 The ONU MUST support the configurable, silent-discarding of all IGMP messages received on an ONU user port and/or VLAN.

R-76 The OLT and ONU MUST support the matching of groups indicated by IGMP messages from a user port to the list of groups (R-69) associated with this port. When there is no match, the IGMP message MUST be discarded silently. When there is a match, the IGMP message SHOULD be forwarded and processed by the IGMP snooping function.

Note: IGMPv3 report messages may carry membership information for multiple multicast groups. Therefore, a single IGMP report message may carry membership information on groups 'matching' a multicast VLAN as well as on groups 'not matching' a multicast VLAN.

R-77 The ONU MUST be able to prevent user ports from injecting multicast traffic into the aggregation network. This behavior MUST be configurable on a per-ONU-user-port and/or per-VLAN basis.

R-78 The ONU MUST be able to discard IGMP messages received from user-facing ports on a multicast VLAN.

R-79 The ONU MUST be able to rate-limit IGMP messages received from user-facing ports on a multicast VLAN.

R-80 The OLT MUST be able to rate-limit IGMP messages received from ONUs on a multicast VLAN.

R-81 The OLT MUST support an IGMPv3 (per RFC 3376) transparent-snooping function. This MUST be configurable on a per-VLAN basis.

R-82 The OLT MUST support IGMPv3 (per RFC 3376) snooping-with-proxy-reporting, configurable on a per-VLAN basis.

R-83 The OLT MUST allow selection between IGMP transparent-snooping and IGMP snooping-with-proxy-reporting on a per-VLAN basis.

R-84 The ONU MUST support an IGMPv3 (per RFC 3376) transparent-snooping function. This MUST be configurable on a per-VLAN basis.

Note 1: IGMPv3 includes support of earlier versions of IGMP. Specifically, this function is responsible for configuring multicast filters such that frame replication is restricted to those user ports that requested receipt.

Note 2: Since multicast forwarding is performed at L2, users of TR-200 should coordinate IP group address assignment to avoid multiple IP source and destination addresses mapping to the same MAC group address. Similarly, the ONU and OLT are not required to support the 'exclude multicast source' feature of IGMPv3.

R-85 The ONU and OLT IGMPv3 transparent-snooping function MUST be able to dynamically create and delete MAC-level group-filter entries, enabling in turn, selective multicast forwarding from network-facing VLANs to downstream ports.

R-86 The ONU MUST support both the IGMP immediate-leave and non-immediate-leave modes as part of the IGMP transparent-snooping function. The ONU must allow selection between immediate-leave and non-immediate-leave modes.

R-87 Upon detecting topology changes, the OLT MUST be able to issue an IGMP proxy query solicitation, i.e. an IGMP group leave with group address 0.0.0.0. This indicates to the BNG that it needs to immediately send group-specific queries, which will populate the L2 multicast filters in the OLT, in order to speed up network convergence. For reference see RFC 4541.

R-88 For security purposes, the ONU SHOULD and OLT MUST discard silently any user-initiated IGMP Leave messages for group '0.0.0.0.'

R-89 In the upstream direction, the ONU MUST support marking user-initiated IGMP messages with Ethernet P-bits.

R-90 The OLT MUST provide the following statistics:
Per-VLAN, per-multicast-group:
1. Total number of currently active hosts.

Per-multicast-VLAN:
1. Current number of active groups (dynamic reading, not a counter),
2. Total number of Joins sent
3. Total number of Joins received,
4. Total number of successful Joins,
5. Total number of unsuccessful Joins,
6. Total number of Leave messages,
7. Total number of General Queries sent,
8. Total number of General Queries received,
9. Total number of Specific Queries sent,
10. Total number of specific queries received,
11. Total number of invalid IGMP messages received.

Per-downstream interface, per-multicast-VLAN:

1. Total number of successful Joins,
2. Total number of unsuccessful Joins,
3. Total number of Leave messages,
4. Total number of General Queries sent to users,
5. Total number of Specific Queries sent to users,
6. Total number of invalid IGMP messages received.

R-91 The ONU MUST support configuring which user ports are members of a given multicast VLAN.

R-92 The ONU and OLT MUST be able to configure per **U** interface the maximum number of simultaneous multicast groups allowed.

R-93 It SHOULD be possible to configure the maximum number of simultaneous multicast groups allowed on a per-ONU basis.

R-94 The ONU MUST discard IGMPv1 messages silently.

R-95 When the OLT is in the snooping-with-proxy-reporting mode, the IGMP general/specific group query message that the OLT sends downstream MUST have a multicast VLAN tag.

R-96 The IGMP snooping-with-proxy-reporting function MUST support IGMP proxy-query functions.

R-97 When the OLT initiates a downstream IGMP message, the OLT proxy-reporting function MUST support marking IGMP messages it initiates with Ethernet (VLAN) P-bits.

Note: Part of the ONU's Immediate-Leave function requires that the ONU, upon receiving an IGMP Leave message for a particular multicast group, the ONU will stop forwarding multicast traffic from the indicated multicast group and delete the corresponding entry in the multicast forwarding table. Additionally, the ONU will transmit transparently the IGMP Leave message to the OLT.

To confirm multicast group-member status for a particular multicast group, the OLT sends a Last Member Query on the PON downstream. The OLT and ONU decide whether to stop forwarding this traffic for this multicast group or not, depending on whether any valid IGMP Report messages have been received within the specified timeout time. If valid users remain registered to the particular multicast group, the OLT and ONU will keep forwarding multicast traffic for this multicast group. If this user is the last user leaving this multicast group, the OLT and ONU will cease forwarding traffic for this multicast group.

R-98 If the OLT is operating in the IGMP Snooping with Proxy Reporting mode, upon receipt of an IGMP Leave Message related to a multicast group, the OLT MUST send a Last Member Query related to that multicast group.

R-99 After a Last-Member Query relative to a multicast group is sent, the OLT and ONU MUST NOT stop forwarding the multicast traffic related to that multicast group before a configurable Query response timeout expires.

R-100 When the Query response timeout expires after a Last Member Query related to a multicast group is sent, meaning no IGMP Report message was received related to that multicast group since the Last Member Query was sent, the OLT and ONU MUST stop forwarding the multicast traffic related to that Group.

The control list as defined in R-67 specifies the behavior ("policy") of the ONU upon receipt of IGMP messages from a user port. If a multicast group in the list and marked "permitted," the ONU forwards the IGMP Report message to the OLT and configures local multicast filtering entries. If a multicast group in the list and marked "prohibited," the ONU discards the IGMP Report message. This function is called multicast control and is configurable for each user port.

R-101 The ONU and OLT MUST discard, process, or forward IGMP Report messages based on the multicast control lists described in R-69 and R-70.

In some deployments IGMP processing and multicast access-control are centralized in the OLT, with multicast forwarding by the ONUs controlled by the OLT. This authorization-based IGMP method is described in Appendix B.

R-102 The ONU and OLT SHOULD support the authorization-based IGMP method described in Appendix B.

R-103 If the OLT and ONU support authorization-based IGMP, the OLT MUST allow selection between IGMP transparent-snooping, IGMP snooping-with-proxy-reporting, and authorization-based IGMP on a per-VLAN basis.

5.3.2 Non-IGMP Controlled Multicast and Broadcast

5.3.2.1 Introduction

The following sections provide the requirements for the treatment of broadcast, multicast, and other flooded frames both at the ONU and the OLT.

5.3.2.2 Unknown MAC address frames at the OLT

R-104 In the downstream, it MUST be possible to configure each N:1 VLAN so that the OLT either discards silently or floods frames with MAC addresses that are not in the AN forwarding table.

R-105 For N:1 VLANs with flooding enabled, when the OLT receives a downstream tagged frame with an unknown unicast MAC address it MUST be flooded by forwarding to a multicast EDP.

5.3.2.3 Broadcast MAC address frames at the OLT

There are various filtering options that prevent the broadcast of Ethernet frames for consumer access VLANs, however it is desirable to have the capability of disabling these features so that broadcast is possible in N:1 VLANs.

R-106 It MUST be possible to configure each VLAN so that it silently discards upstream broadcast frames.

R-107 For N:1 VLANs, when the OLT receives a downstream broadcast frame, and if it is not otherwise filtered, then it MUST be forwarded using a multicast EDP.

5.3.2.4 Multicast EDP at the ONU

R-108 If the ONU receives a tagged frame on a multicast EDP, it MUST forward it to all U interfaces that are members of that VLAN.

5.4 Security

In scenarios where the Operator cannot rely on security functions provided by the CPE, the network may be exposed to various attacks (spoofing attacks, DoS attacks, etc.). The following Requirements address this situation.

R-109 The ONU SHOULD be able to provide services to users with duplicate MAC addresses.

R-110 The ONU SHOULD be able to deny service to users with duplicate MAC addresses.

R-111 The ONU SHOULD inspect upstream and downstream DHCP packets in order to discover the mapping of IP address to MAC address and populate an ARP table associating these addresses with their respective U-interface and VLAN.

R-112 The ONU SHOULD ensure that downstream broadcast ARP requests are not sent on U-interfaces that do not have the requested IP address.

R-113 The ONU SHOULD provide mechanisms to prevent user IP address spoofing, by discarding upstream IP packets received from U-interfaces that do not match the configured or DHCP discovered source IP address.

R-114 The ONU SHOULD be configurable with a list of IP address associated with user port and VLAN, to be used for users having static IP configuration.

R-115 In order to prevent source MAC flooding attacks, the ONU SHOULD be able to limit the number of source MAC addresses learned and forwarded from each user port. This limit SHOULD be configurable per user port.

R-116 The OLT SHOULD be able to provide services to users with duplicate MAC addresses (aligns with R-89/TR-101).

R-117 The OLT SHOULD be able to deny service to users with duplicate MAC addresses.

R-118 The OLT SHOULD provide a mechanism to prevent Broadband Network Gateway MAC address spoofing.

R-119 The OLT SHOULD inspect upstream and downstream DHCP packets in order to discover the mapping of IP address to MAC address and populate an ARP table associating these addresses with the appropriate ONU and VLAN.

R-120 The OLT SHOULD ensure that downstream broadcast ARP requests are not forwarded to ONUs that do not have the requested IP address.

R-121 The OLT SHOULD provide mechanisms to prevent user IP address spoofing, by discarding upstream IP packets received from ONUs that do not match the configured or DHCP-discovered source IP address.

R-122 The OLT SHOULD be configurable with a list of IP addresses associated with ONUs and VLANs, to be used for subscribers with static IP configurations.

R-123 In order to prevent source MAC flooding attacks, the OLT SHOULD be able to limit the number of source MAC addresses learned and forwarded from each ONU. This limit MUST be configurable per ONU.

5.5 Filtering

R-124 The OLT and ONU SHOULD allow configuring and applying the following filters. The OLT MUST apply any configured filters in the downstream direction, and the ONU MUST apply any configured filters in the upstream direction.

1. Source MAC address filter. This filter MAY be used in one of the following ways:
    - i. Allowing access from a specific MAC address,
    - ii. Denying access from a specific MAC address.

2. Destination MAC address filter. This filter MAY be used in one of the following ways:
    - i. Allowing access to specific destinations,
    - ii. Denying access to specific destinations.

R-125 The ONU SHOULD allow configuration of an EtherType filter, and applying it per U-interface in the upstream direction. This filter MAY be used in one of the following ways:
i. Allowing a specific EtherType frame access (e.g. IPoE, PPPoE),
ii. Denying a specific EtherType frame access (e.g. IPoE, PPPoE).

R-126 The OLT and ONU SHOULD be able to filter reserved group MAC destination addresses (in the 01:80:C2 range – See R-95/TR-101).

5.6 Port Identification and Characterization

The configurable syntax of TR-101 line identifiers is retained for EPON, however a new identifier, 'ONU_Descriptor,' is added to the flexible syntax list as a static identifier for the ONU. The ONU_Descriptor may be obtained in several ways, however it is only the identifier's characteristics, and not the method by which it is derived, that is described here.

Description of the variable	Possible name for the variable	Type of variable and max length	Range of values for the variable
Logical name of the Access Node.	Access_Node_ID	Variable. Note that total length of the overall agent-circuit-id MUST NOT exceed 63 bytes	
Chassis number in the access node	Chassis	Char(2)	"0".. "99"
ONU descriptor in a PON (Port)	ONU_Descriptor	Char(24)	
Rack number in the access node	Rack	Char(2)	"0".. "99"
Frame number in the rack	Frame	Char(2)	"0".. "99"
Slot number in the chassis or rack or frame	Slot	Char(2)	"0".. "99"
Sub-slot number	Sub-slot	Char(2)	"0".. "99"
Port number in the slot	Port	Char(3)	"0".. "999"
VPI on U interface in case of ATM over DSL	VPI	Char(4)	"0".. "4095"
VCI on U interface in case of ATM over DSL	VCI	Char(5)	"0".. "65535"
VLAN ID on U interface (when applicable)	Q-VID	Char(4)	"0".. "4095"
Ethernet Priority bits on V interface	Ethernet Priority	Char(1)	"0".. "7"

Table 1 – Port Identification String Elements

R-127 The OLT MUST create the Agent Circuit ID and Remote ID as described in TR-101.

R-128 The OLT MUST use a static identifier, ONU_Descriptor, for each ONU device on a PON interface. This identifier MUST remain constant following re-initialization, software and firmware updates, adds, moves, or any other network change that does not involve the ONU.

The OLT and ONU use the same syntax to generate the Agent Circuit ID field and populate the fields separately. For single-customer ONUs identifying the ONU's subscriber-facing port is not necessary, however for multiple-customer ONUs it is necessary to provide ONU's subscriber-facing port information.

R-129 The OLT MUST use the following syntax to automatically generate the Agent Circuit ID field, identifying the access loop logical ports as follows:

Access-Node-Identifier atm Slot/ Port/ONU_Descriptor/Slot/Port:VPI.VCI
(when ATM/DSL is used),

Access-Node-Identifier eth Slot/Port/ONU_Descriptor/Slot/Port[:VLAN-ID]
(when Ethernet[/DSL] is used).

R-130 The OLT MUST populate the ONU_Descriptor and fields preceeding the ONU_Descriptor. The L2 type(atm, eth) MUST be set by the OLT if the ONU doesn't set the Agent Circuit ID field.

R-131 The multiple-subscriber ONU MUST use the syntax of R-129 to generate the value for the Agent Circuit ID field, identify the access loop logical ports, set the L2 type(atm, eth) field and fields following the ONU_Descriptor, while filling the remaining fields with "0", as follows:

0 atm 0/0/0/Slot/Port:VPI.VCI (when ATM/DSL is used),

0 eth 0/0/0/Slot/Port[:VLAN-ID] (when Ethernet[/DSL] is used).

If a variable does not exist or is meaningless, the corresponding field SHOULD be filled with '0'.

In this syntax, the Access-Node-Identifier MUST be a unique ASCII string (with no character spaces). The Access-Node-Identifier, L2 type (atm, eth) field and the slot/port fields are separated using a single space character. The Slot identifier MUST NOT exceed 6 characters in length and the Port identifier MUST NOT exceed 3 characters in length, using a '/' character as a delimiter. The VPI, VCI, and VLAN-ID fields (when applicable) are related to a given access loop (U interface).

R-132 The OLT and the multiple-subscriber ONU MUST be able to perform the L2 DHCP Relay Agent function, as specified in Section 3.9.1/TR-101.

R-133 The OLT and the multiple-subscriber ONU MUST be able to perform the PPPoE Intermediate Agent function, as specified in Section 3.9.2/TR-101.

5.7 Requirements for Coexistence

Figure 16 shows the scheme for the coexistence of 1G-EPON and 10G-EPON (both 10/10G-EPON and 10/1G-EPON) on the same ODN, where three types[3] of ONUs are connected to a single OLT PON port. Coexistence in the downstream channel is enabled through Wavelength Division Multiplexing (WDM). Coexistence in the upstream channel is enabled through the Time Division Multiple Access (TDMA).

10G-EPON is compatible with the fiber infrastructure and equipment deployed for 1G-EPON. This facilitates an economical migration from 1G-EPON to 10G-EPON, with a minimum of required changes on the CO side.

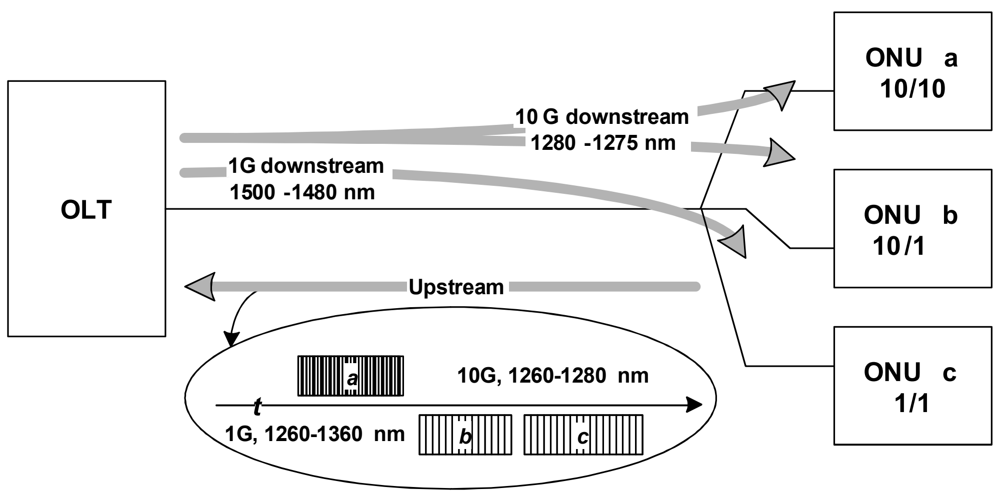


Figure 16 Coexistence of 1G-EPON and 10G EPON on the same ODN.

To support the coexistence of 1G-EPON and 10G-EPON ONUs on the same ODN, the OLT must have dual-rate capabilities in the downstream and upstream channels. The dual–rate mode, discovery and registration processes are defined in IEEE 802.3.

[3] In this chapter, ONU types are distinguished according to the data rate, as defined in Section 2.3.

Three ONU types are defined, namely a 1G-EPON ONU, 10/1G-EPON ONU or 10/10G-EPON ONU. In a generic case, the term ‘ONU type’ refers to all possible ONU versions collectively.

5.7.1 Deployment Scenarios

Figure 17 depicts a deployment scenario with different ONU types. Three types of ONUs are connected to a single OLT PON port.

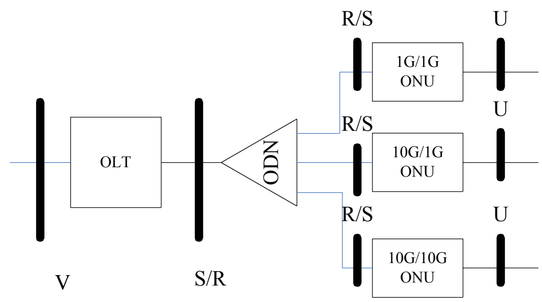


Figure 17 EPON deployment scenario with different ONU types.

R-134 The 10G-EPON OLT SHOULD support coexistence of 1G EPON ONUs and 10G-EPON ONUs (both 10/10G-EPON and 10/1G-EPON) on a common ODN.

5.7.2 QoS

When 1G-EPON and 10G-EPON ONUs coexist on the same ODN, the OLT places downstream traffic into two queue groups, one for 1G-EPON ONUs and another for 10G-EPON ONUs. Data destined for different ONU types is mapped into their respective, associated queues.

For certain services, it may be necessary for the OLT supporting coexisting 1G-EPON and 10G-EPON ONUs to replicate incoming data at the data plane, assuring that both customers served with 1G-EPON and 10G-EPON receive the transmitted frames. Examples of such services include multicast services.

Figure 18 depicts a model of downstream traffic management. Traffic from the network facing port at the OLT is distributed to different queue groups and then assigned to queues, depending on the target ONU type. The classifier decides which queue and EDP downstream data is assigned to.

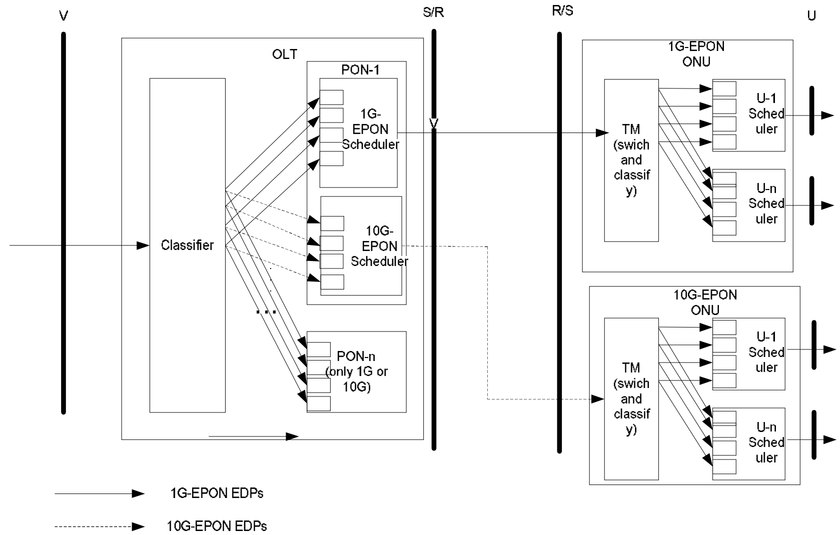


Figure 18 Example of a downstream queuing and scheduling model.

The queue groups are independent. Requirements for each queue group are identical with the requirements specified in Section 5.2.

5.7.3 Multicast

Section 5.3 specifies that multicast traffic and downstream IGMP messages are distributed through multicast EDPs. Figure 19 depicts different ONU types coexisting on the same ODN and connected to the same OLT.

In the case of a 1G-EPON interface and a 10G-EPON interface coexisting on the same PON port, traffic for a given multicast group is copied to interfaces which have members of that multicast group connected. The OLT keeps track of ONUs joining individual multicast groups on each interface and distributes multicast content to the ONUs using the appropriate EDPs, depending on the target ONU types and their supported data rates. Upstream IGMP messages are forwarded to the OLT using bidirectional unicast EDPs, as specified in section 5.3. Downstream IGMP messages are carried over the multicast EDPs used to carry the multicast content.

Figure 19 illustrates the delivery mechanism for multicast traffic on an EPON composed of different ONU types.

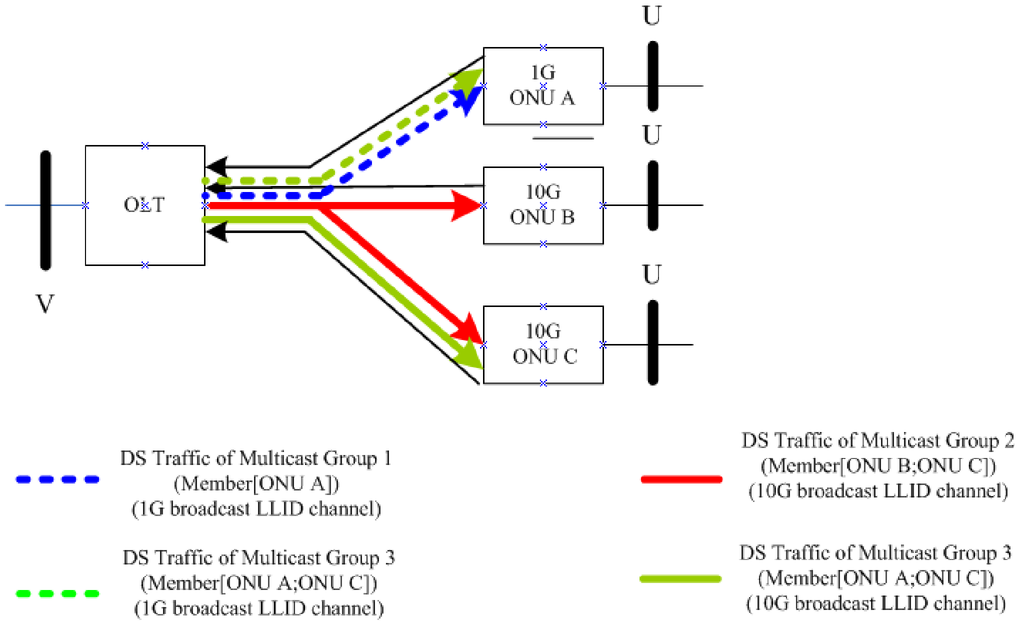


Figure 19 Delivery of multicast contents in coexisting1G-EPON and 10G-EPON.

R-135 For a 10G-EPON OLT PON interface, if all users with membership in a given multicast group are connected to the same ONU type, the OLT MUST forward downstream traffic and IGMP messages for this multicast group using a single multicast EDP associated with the given ONU type.

R-136 For a 10G-EPON OLT PON interface, if some users with membership in a given multicast group are connected to 1G-EPON ONUs and some other users with membership in the same multicast group are connected to 10G-EPON ONUs, the OLT MUST forward downstream traffic and IGMP messages related to that group in both the 10G-EPON multicast EDP and 1G-EPON multicast EDP.

6. EPON-Fed Access Nodes

This Section describes the VLAN, QoS, multicast, security, filtering, port-management, and coexistence requirements for multiple-customer ONUs designed to support a large number of subscribers. Any Requirements in these areas that differ from or are additional to those described in Section 5 are described in this Section.

In Section 5 the OLT is regarded as an Access Node. This Section describes the requirements of EPON-fed TR-101 Access Nodes, where the OLT and its subtending ONUs are treated as part of the aggregation network, as well as describing any higher-layer requirements that are needed but have not been specified elsewhere. Multiple-customer ONUs occur in two varieties: (1) simple units, typically with low-customer counts, are described in Section 5, and (2) sophisticated units, which typically serve a large number of subscribers. This Section describes requirements for the latter class.

In this Section, the ONU provides an interface at the V reference point for a TR-101 Access Node, collocated with the ONU deep in the access plant. In most cases the ONU is built into the Access Node and exists only as a logical construct ("ONU entity"), hence in this Section the terms "ONU" and "ONU entity" are used interchangeably. Regardless of whether the ONU is a physically separate unit or is built into the Access Node, the functional requirements are identical. The ONU entity in an EPON-fed Access Node is managed by the OLT using IEEE 802.3 OAM/extended OAM, while the TR-101 Access Node is managed in the same manner as an Access Node which is fed by a point-to-point Ethernet connection at the V reference point. Any device that meets the TR-101 Access Node V reference point requirements can be connected on the downstream side of the EPON system.

In TR-101, the interface between the access node and the aggregation network is designated a V reference point. In an EPON-fed access node, as shown in bottom panel of Figure 1, the EPON ONU entity transports Ethernet frames on the PON, while a TR-101 Access Node is responsible for switching them to subscriber ports and, if necessary, converting to ATM. An ONU entity providing the V reference point may coexist on the same ODN as an ONU providing a U reference point (described in Section 5). In this case, the aggregation-node and access-node functions coexist in the OLT.

Figure 20 and Figure 21 illustrate the functions of the TR-101 Access Node and those of the ONU entity. Their respective domains are separated by the V reference point, which may be physical or virtual. The EPON ONU entity can also provide a stage of aggregation when there is more than one V reference point on the ONU entity.

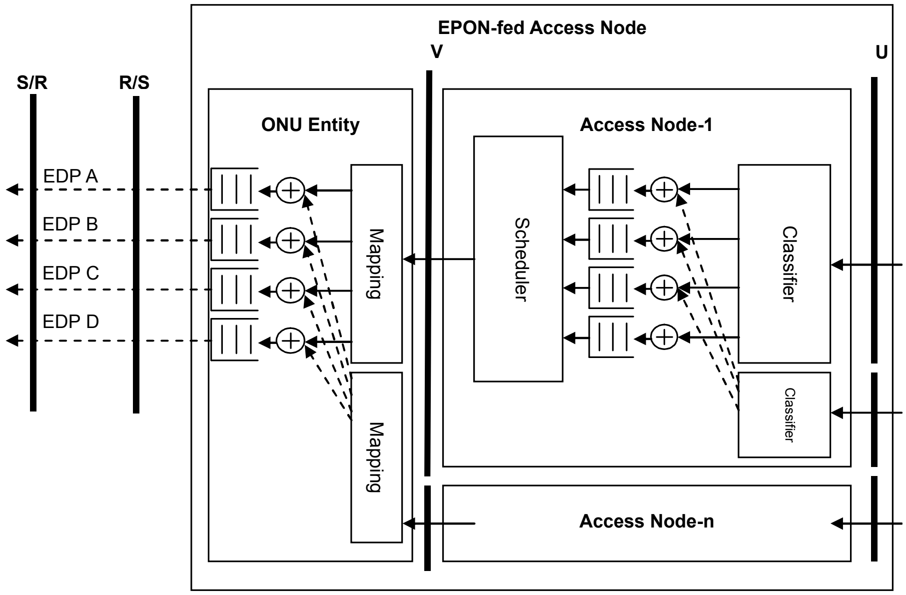


Figure 20 Separation of functions at the V reference point: upstream.

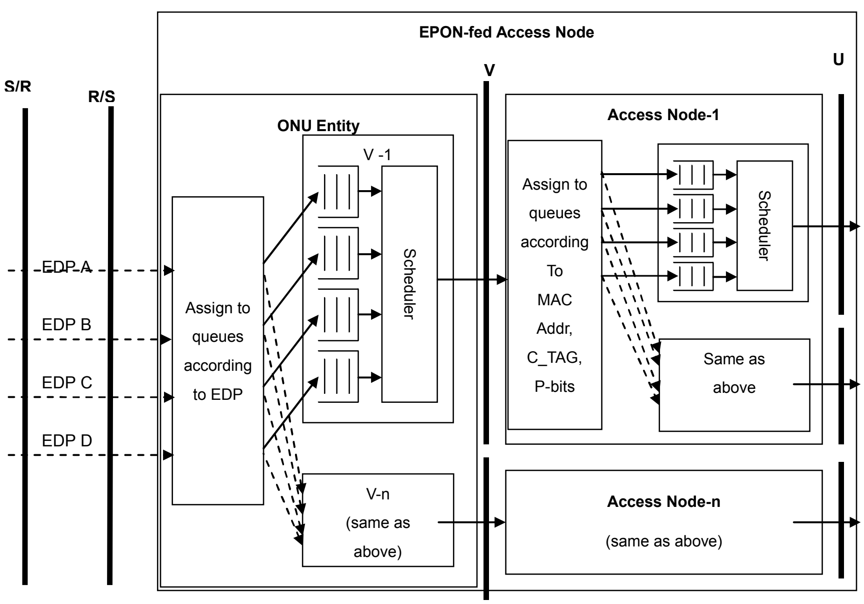


Figure 21 Separation of functions at the V reference point: downstream.

6.1 VLANs and QoS

6.1.1 EPON-fed Access Node VLAN Scope and QoS

The TR-101 Access Node entity in an EPON-fed Access Node adheres to all TR-101 Access Node VLAN and QoS requirements. In the Access Node, both C-Tags and S-Tags are in scope and scheduling is performed at the V interface. In the ONU entity, only S-Tags are in scope and mapping to EDPs is performed based upon S-Tag values (including p-bits) and other frame markings, as described in Section 5.

6.1.2 ONU entity VLAN and QoS

As shown in Figure 22, the EPON ONU entity receives frames that have been classified and marked (tagged) by the TR-101 Access Node.

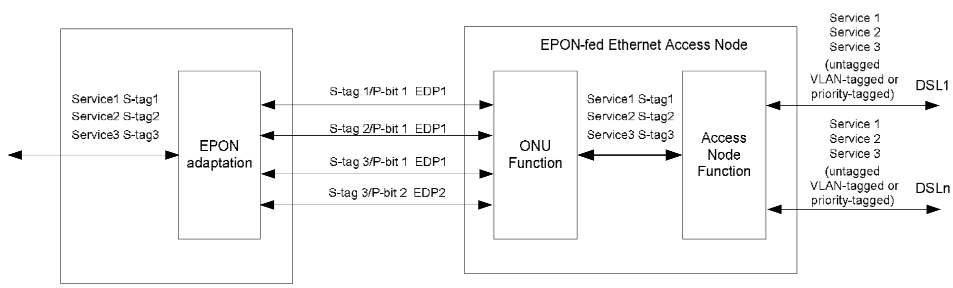


Figure 22 Frame mapping for an EPON-fed Ethernet Access Node.

6.1.2.1 Upstream Frame Handling

Frame mapping by an EPON-fed Access Node is depicted in Figure 22. The TR-101 Access Node classifies upstream frames and passes them to the ONU entity. The ONU entity then maps the frames to EDPs based on the V interface and any combination of the S-VIDs and P bits.

6.1.2.2 Downstream Frame Handling

The OLT maps downstream frames to EDPs based on any combination of the MAC addresses, S-VIDs, and P bits. The EPON ONU entity maps downstream frames from EDPs to V reference point interfaces – assuming there is more than one – based on any combination of the S-VIDs and destination MAC addresses.

6.1.3 VLAN and QoS requirements

This section describes aggregation node requirements from TR-101 and how they are mapped to an EPON system used as an Ethernet aggregation node.

All of the VLAN and QoS Requirements of Sections 4 and 5 apply to EPON-fed Access Nodes. R-137 is an additional Requirement specific to EPON-fed Access Nodes.

R-137 The ONU entity MUST support setting the maximum depth of all queues.

6.2 Multicast

In an EPON system, downstream frames are visible to all ONU entities on the PON. Therefore, an EPON ONU entity must filter multicast frames arriving on the PON, accepting only multicast traffic that has been joined by that ONU entity's subscribers, as well as possible static (always-on) multicast groups. This means that the EPON ONU entity in an EPON-fed Access Node must perform transparent IGMP snooping to maintain the multicast filtering tables associated with the PON interface.

An OLT used as an Ethernet aggregation node may have hundreds of ports serving access nodes. Regardless of whether these are Ethernet ports or EPON ports, each constitutes a possible branch for multicast frames. As with any large multicast branching point, the OLT is required to offer a snooping with proxy reporting service to limit IGMP traffic toward the multicast source. The TR-101 Access Node entity in a EPON-fed Access Node adheres to all TR-101 Access Node multicast requirements. The TR-101 Access Node entity replicates the multicast group to subscriber ports that have joined it, and necessarily must support an IGMP snooping function. The TR-101 Access Node entity supports snooping with proxy reporting. As defined in Section 5.3, multicast EDPs are used to transmit multicast streams from the OLT to EPON-fed access nodes. All of the multicast Requirements of Section 5 apply to EPON-fed Access Nodes.

6.3 Forwarding Information and Loop-Detection (Spanning Tree)

6.3.1 EPON Forwarding Information and Loop Avoidance/Removal

An Access Node can be used to subtend other Access Nodes via subtending V interfaces. A ring topology may be used for connecting an arbitrary number of Access Nodes using two V interfaces of the ONU entity. Therefore, a loop avoidance capability is required from the ONU on the Access Node facing ports and from the OLT on the EDPs serving such rings of Access Nodes.

An OLT serving as an Ethernet aggregation node may contain numerous ports that exchange Ethernet frames with the service provider network. Since the interconnecting networks between the service provider and these ports may be complex, loop avoidance capability is required on network facing ports of the OLT.

In an ONU entity, upstream frames arriving from the V interfaces can be forwarded only toward the PON. Conversely, frames arriving from the PON can be forwarded only toward the V interfaces.

6.3.2 Forwarding Information and Loop Detection Requirements

The following requirements apply to the OLT and to ONUs having multiple Access-Node facing interfaces.

R-138 The OLT and the multiple-interface ONU entity MUST support a minimum of two instances of multiple spanning tree, as per IEEE 802.1Q (2005).

R-139 The OLT and the multiple-interface ONU entity MUST forward frames according to 802.1ad. This includes the per VLAN ability to disable MAC address learning and to tunnel customer BPDUs.

R-140 The OLT and the multiple-interface ONU entity MUST support interworking with the Common Spanning Tree according to IEEE 802.1Q (2003).

R-141 The OLT and the multiple-interface ONU entity MUST support Rapid Spanning Tree as per IEEE 802.1w.

R-142 The OLT and the multiple-interface ONU entity MUST support link aggregation on its network facing ports as specified by IEEE 802.3ad to allow link resilience.

R-143 The OLT and the multiple-interface ONU entity MUST support load balancing over IEEE 802.3ad aggregated links.

R-144 The OLT and the multiple-interface ONU entity MUST be able to prioritize BPDUs in the data plane (by providing dedicated queues) and in the control plane (by providing dedicated CPU queues for BPDUs).

R-145 The OLT and the multiple-interface ONU entity MUST be able to drop BPDUs if those BPDUs have a root bridge identifier that is lower (better) than the current spanning tree root. This function MUST be configurable on a per port basis.

R-146 The OLT MUST be able to drop BPDUs regardless of the BPDU content. This function MUST be configurable on a per Ethernet port basis.

R-147 The OLT MUST support the disabling of MAC learning on a per VLAN basis. This MUST NOT prevent IGMP snooping from installing bridge table entries.

6.4 Port Identification and Characterization

Section 5 describes the construction of the Agent Circuit ID by the OLT in the SFU case and by the OLT and ONU, acting together, in the MDU case.

For EPON-fed Access Nodes, as specified in Section 6, the Agent Circuit ID is generated by the Access Node, per TR-101. R-124 of TR-101 specifies the syntax that an Access Node must support when it generates port identification and characterization information. R-123 of TR-101 specifies that Access Nodes must also support explicit configuration of the Agent Circuit ID. This allows EPON-fed Access Nodes and OLTs to populate the constituent fields of the Agent Circuit ID using a common syntax.

7. OAM

This section describes OAM requirements consistent with the VLAN requirements of Section 5.1. At the network layer, IEEE 802.1ag OAM is used in all shared media access systems, including EPON. At the physical layer, IEEE 802.3 OAM is used for EPON.

7.1 IEEE 802.1ag OAM in an Access-Node Architecture

Ethernet OAM, defined in IEEE 802.1ag, provides a simple method for maintaining a uniform, L2, end-to-end OAM capability. The mechanisms and requirements described in TR-101 use four distinct Maintenance Domains (MDs) with corresponding Maintenance-Entity-Group End Point / Maintenance-Entity-Group Intermediate Point (MEP/MIP) placements to support various OAM capabilities. TR-200 maintains these four MDs and adds one new MD for an EPON AN. In contrast with TR-101, here the AN is composed of multiple, distinct devices, namely the OLT, the subtending ONUs, and the ODN, hence the need for the intra-AN MD described below. These requirements will be used in conjunction with the requirements of TR-101, Section 7.3[4].

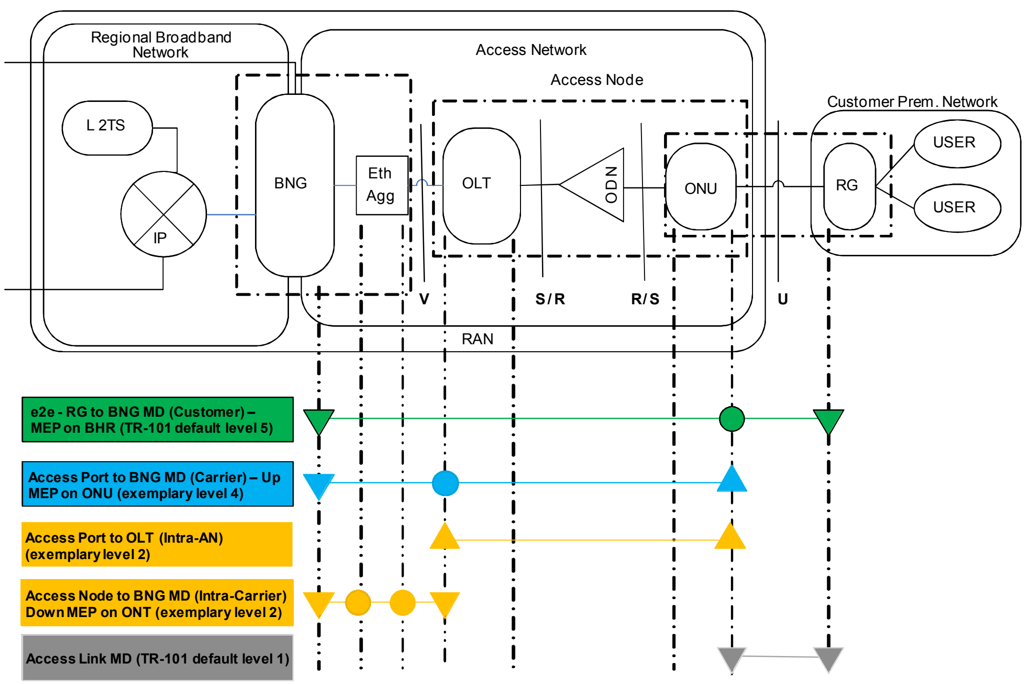


Figure 23 Ethernet OAM Requirements for the EPON Maintenance Domains.

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[4] Note that the Metro Ethernet Forum (MEF) has defined a "Test" Maintenance Entity Group to allow a carrier to test connectivity to the customer (e.g., to send Loopbacks to the subscriber location), and uses level 5 for that purpose. If a service is also a MEF-compliant service, then ME level 6 or 7 should be used for the Customer level.

R-148 For an AN-to-BNG MD (intra-carrier), a Down MEP in the AN MUST be created on the OLT at the interface facing the BNG.

R-149 For an access-port-to BNG carrier MD, an Up MEP in the AN MUST be created on the user port of the ONU.

R-150 For an access-port-to-BNG Carrier MD, a MIP MUST be created on the OLT at the interface facing the BNG.

R-151 For end-to-end RG-to-BNG Customer MD, a MIP MUST be created on the ONU interface facing the user.

R-152 For an AN-to-BNG MD, access-port-to-BNG carrier MD, and the end-to-end RG-to-BNG Customer MD, the BNG MUST support MEP functionality at all 3 levels at the same time.

Note: The new "Intra-AN" MA is introduced here to enhance the Ethernet OAM capability between the OLT and ONU.

R-153 For an Intra-AN MA, an Up MEP in the AN MUST be created on the network port on the OLT.

R-154 For an Intra-AN MA, an Up MEP in the AN MUST be created on the user port on the ONU.

Note: for MEPs created in an ONU or RG, carriers may specify a limited set of OAM capabilities in the associated OAM domains optimized for specific service requirements.

Since the VLAN tags for an Ethernet Virtual Circuit (EVC) differ depending upon device location in the network, Ethernet OAM frames are affected as well. In other words, EVC VLAN tags are set according to the MD and VLAN modes.

- In the case of 1:1 VLANs, the EVC is presumed to use double tags, per IEEE 802.1ad. The usage of double tags is described below and illustrated in Figure 24:
  - The EVC frames between the RG and ONU are untagged, priority-tagged, or single-tagged;
  - The EVC frames between the ONU and OLT are single-tagged frames (C-Tag);
  - The EVC frames between the OLT and BNG are double-tagged frames (S-Tag and C-Tag).

- In the case of N:1 VLANs, the EVC is presumed to use an S-Tag:
  - The EVC frames between the RG and ONU are untagged, priority-tagged, or single-tagged (Q-Tag);
  - The EVC frames between the BNG and ONU are single-tagged frames (S-Tag);
  - At the Customer MD level, the untagged OAM frames from the RG are mapped into S-tagged frames at the ONU, and the tags are stripped off in the opposite direction;
  - All Ethernet OAM frames for the N:1 EVC also use the same S-Tags for the intra-carrier, carrier, intra-AN, and Customer MDs between the BNG and the ONU.

- In the case of a TLS, the EVC may receive tagged or untagged frames from the customer (or a mixture). There are two cases for consideration:
  - The EVC frames between the RG and ONU are untagged, priority-tagged, or single-tagged, and the ONU prepends an S-Tag. If the customer's frame is tagged, then the additional S-Tag creates a double tag and renders any customer-initiated OAM frames invisible to the network. However, if the customer's frame is untagged, the addition of an S-Tag does not hide the customer's OAM frame, and it is visible to the network;
  - The EVC frames between the RG and ONU are S-tagged only in the special case where the CPE attaches an S-Tag on behalf of the ONU. Functionally, this case works identically to the first case. It does not change the MEP point for the access-port-to-carrier-edge MD, nor does it change the MIP for the end-to-end RG-to-far-endpoint (Customer) MD, however this MIP now is accessible using the S-Tag at level 5.

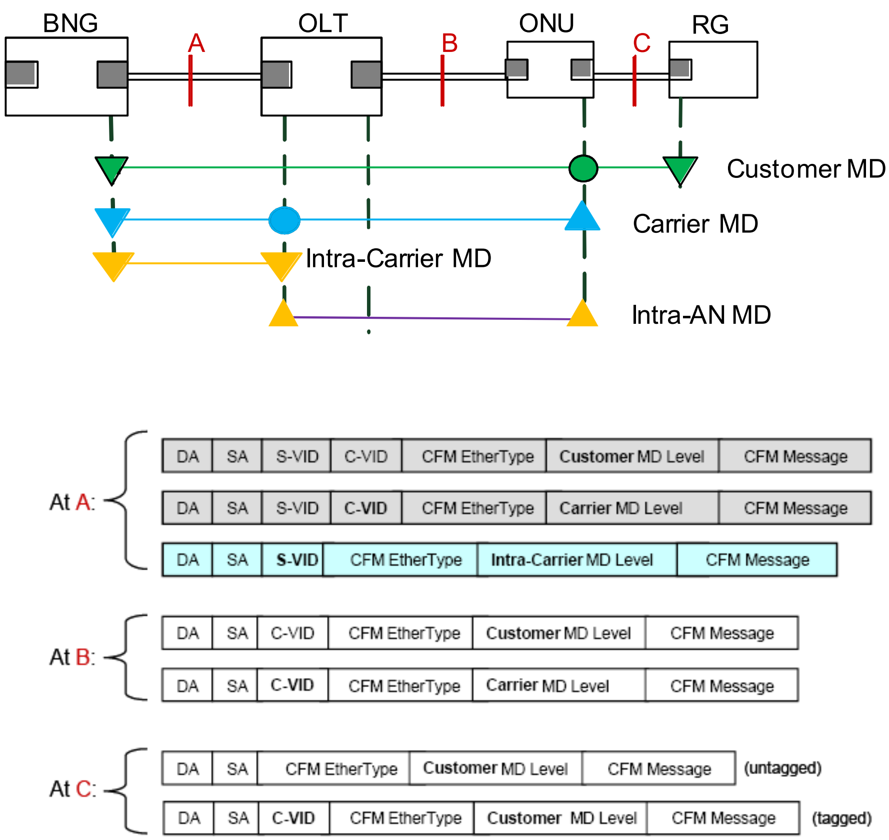

Figure 24 One Example of CFM Frame Formats at Different Points for 1:1 VLANs.

7.2 IEEE 802.1ag OAM in an Aggregation Node Architecture

7.2.1 Access Node OAM

The TR-101 access node entity in an EPON-fed Ethernet access node adheres to the TR-101 defined access node OAM requirements (Section 7.3.2/ TR-101). Figure 25 and Figure 26 illustrate the intra-carrier and wholesale management scenarios and follow the IEEE convention of using the direction of MEP triangle objects to indicate if a MEP is an UP or Down MEP.

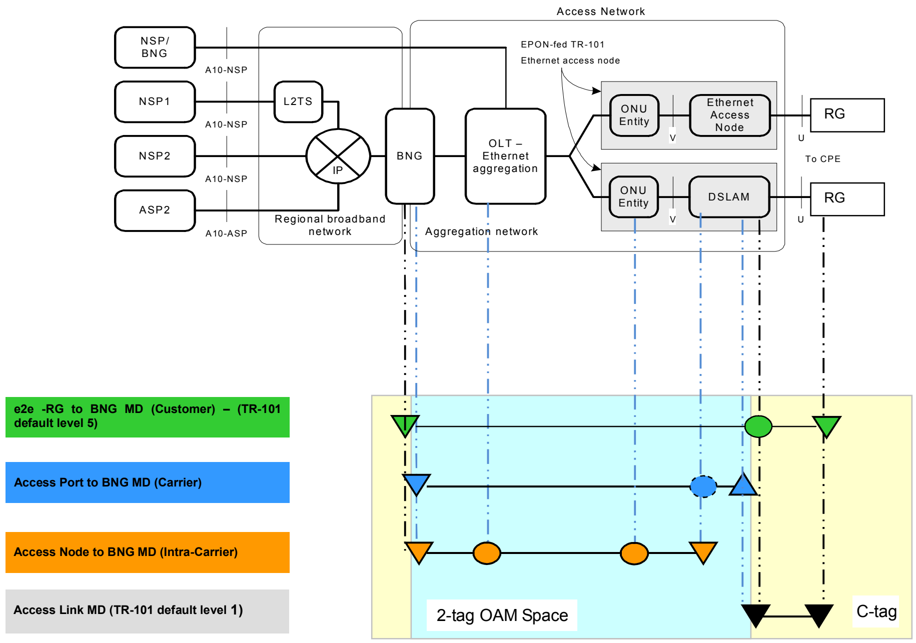

Figure 25 – Ethernet OAM model.

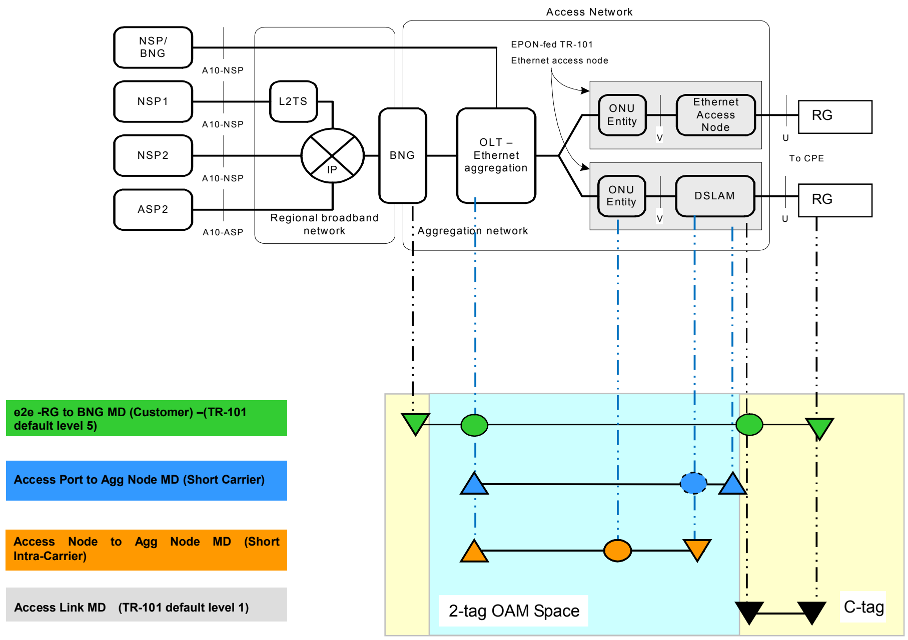

Figure 26 – Wholesale Ethernet OAM model.

7.2.2 EPON OAM Requirements

The aggregation node can have maintenance points (MPs) at the intra-carrier and carrier levels.

R-155 An EPON ONU entity MUST support rate limiting of received CFM Ethernet OAM messages on all supported maintenance levels in the upstream direction.

7.2.2.1 Intra-Carrier Maintenance Level

R-156 The OLT and the EPON ONU entity MUST support a maintenance association intermediate point (MIP) on a per-Ethernet port and per S-VLAN basis.

R-157 The OLT and EPON ONU entity MUST support a link trace reply (LTR) function for each MIP.

R-158 The OLT and the EPON ONU entity MUST support a loopback reply (LBR) function for each MIP.

R-159 The OLT and EPON ONU entity SHOULD support receiving AIS messages from an inferior maintenance level MEP(s), if present, and send out an AIS message at the appropriate MD level.

R-160 The OLT and EPON ONU entity SHOULD be able to support the use of a server MEP function (defined in Section 5.3.1/ITU-T Y.1731) to report failure of the affected server layer and send out an AIS message at the next superior maintenance level.

R-161 The OLT SHOULD trigger the appropriate alarms for loss of continuity.

7.2.2.2 Short Intra-Carrier Maintenance Level (Wholesale Model)

R-308/TR-101 requires that the aggregation node support an inward-facing maintenance association end point (MEP) on a per-network facing port and per S-VLAN basis. 802.1ag does not define or describe the term inward-facing. In TR-101 it is defined as the MEP facing toward the bridge, which in this context is an Up MEP.

R-162 The OLT MUST support an Up maintenance association end point (MEP) on a per-network facing port and per S-VLAN basis.

R-163 The OLT MUST support the function of initiating a loopback message (LBM) towards its peer MEPs and receiving the associated loopback reply (LBR), for the Up MEP on the network facing port.

R-164 The OLT MUST support the function of receiving a loopback message (LBM) from its peer MEPs and initiating the associated loopback reply (LBR) for the Up MEP on the network facing port.

R-165 The OLT MUST support the function of initiating a linktrace message (LTM) towards its peer MEPs and receiving the associated linktrace reply (LTR) for the Up MEP on the network facing port.

R-166 The OLT MUST support the function of receiving a linktrace message (LTM) from its peer MEPs and initiating the associated linktrace reply (LTR) for the Up MEP on the network facing port.

R-167 The OLT SHOULD support generating continuity check messages (CCMs) towards its peer MEPs for the Up MEP on the network facing port.

R-168 The OLT MUST support the ability to disable CCM messages for the MEP on the network facing port, while keeping the associated Up MEP active.

R-169 The OLT SHOULD support a means to determine the MAC address of a remote MEP without relying on the reception of CCMs from this remote MEP. One possible way to accomplish the above is via the multicast LBM for point-to-point segments.

R-170 The OLT MUST support receiving AIS messages on the MEP on the network facing port (at a so-called inferior maintenance level) and sending out an AIS message at the next superior maintenance level across the network facing port.

R-171 The OLT SHOULD trigger the appropriate alarms for loss of continuity.

7.2.2.3 Short Carrier Maintenance Level (Wholesale Model)

In addition to the requirements specified for the short intra-carrier maintenance level, the following requirement applies to the short carrier maintenance level.

R-172 For 1:1 VLANs the OLT node MUST support sending a multicast LBM toward its peer MEP.

8. Network Management

8.1 Remote Management of ONUs

Various methods are used for managing EPON systems, depending on the ONU type. An SFU or SBU is managed by the OLT using OAM/extended OAM. For an MDU or MTU, the ONU entity is managed by the OLT using OAM/extended OAM and the access node entity is managed using another protocol, such as SNMP. MDU/MTU management is depicted in Figure 27.

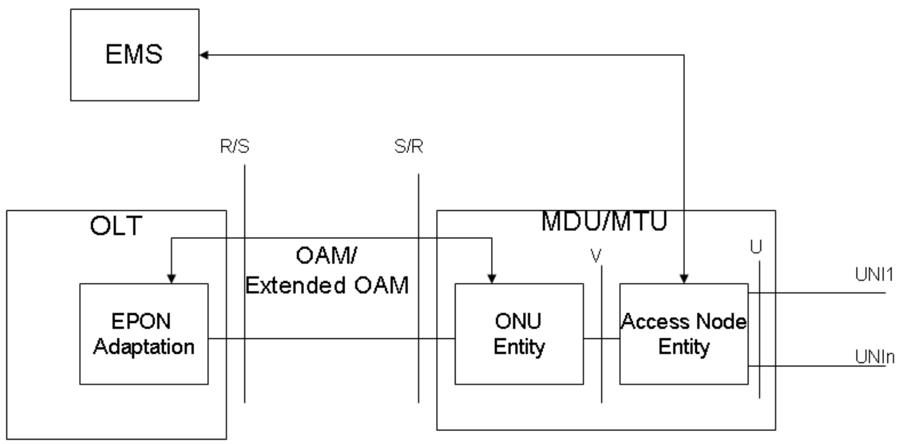

Figure 27 MDU/MTU management**.**

For an RGU, the ONU entity is managed using OAM/extended OAM, while the RG entity is managed via TR-069. RGU management is shown in Figure 28.

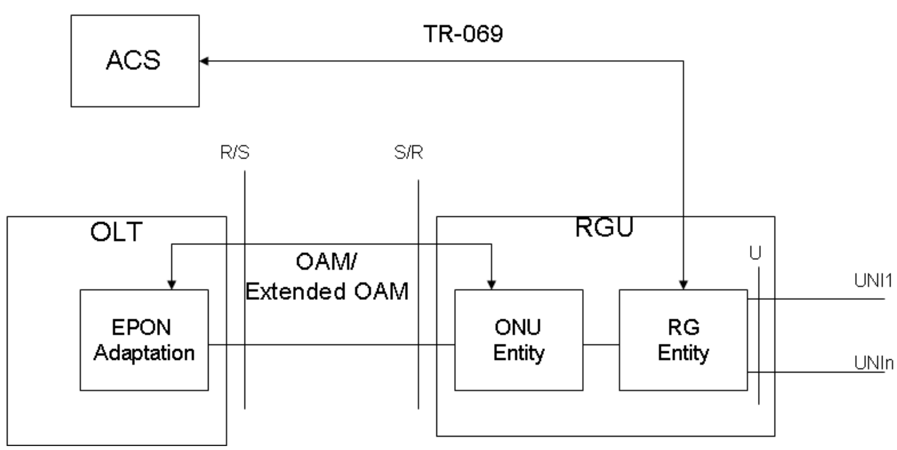

Figure 28 RGU management

R-173 All configurable features of the SFU, SBU and ONU entity in the MDU, MTU and RGU that are covered by the explicit requirements in this Technical Report MUST support being managed via the OLT using standard IEEE 802.3 OAM and extended OAM.

R-174 The ONU entity in MDU/MTU MUST allow management of the access node entity by a protocol other than OAM / extended OAM and independent of the OLT.

Extended OAM is an extension and enhancement of standard OAM using the organization-specific extension mechanism defined in IEEE 802.3.

The PDU format, message procedures, attributes and other details of extended OAM are beyond the scope of TR-200.

8.2 Initial Provisioning of ONUs

8.2.1 Introduction

Authentication for the ONUs attached to the EPON system is used by a service provider to control access to the network. Only authenticated ONUs are allowed to complete the initialization process and gain access the network.

The OLT authenticates attached ONUs using one or more of the following methods:

- Physical ID-based authentication
- Logical ID-based authentication
- Hybrid authentication

R-175 The OLT MUST support configuring the ONU authentication mode to be physical ID-based authentication, logical ID-based authentication, or hybrid authentication.

R-176 The OLT MUST prevent an illegal (authentication failed) ONU from accessing the network.

8.2.2 Physical ID-Based Authentication

If the OLT is configured for physical ID-based authentication, it uses the MAC address of an ONU as the physical ID for authentication. The MAC address of an ONU is reported to the OLT in the MPCP discovery process as defined in IEEE 802.3. In the OLT, a table of the legal MAC addresses is maintained for authentication.

R-177 The OLT MUST support MAC address-based ONU authentication.

8.2.3 Logical ID-Based Authentication

If the OLT is configured for logical ID-based authentication, the OLT authenticates the ONU based on the ONU Logical Identifier (LOID) and possibly a password (PW). The LOID/LOID+PW is a series of configurable characters in the ONU, hence logical ID-based authentication is more flexible than physical ID-based authentication.

Following successful completion of the MPCP discovery process and OAM discovery process, the OLT requests a LOID/LOID+PW from the target ONU in order to authenticate it. If the logical authentication process fails, the OLT deregisters the given ONU and denies it to access the EPON system.

Figure 29 depicts the process of successful logical ID-based authentication.

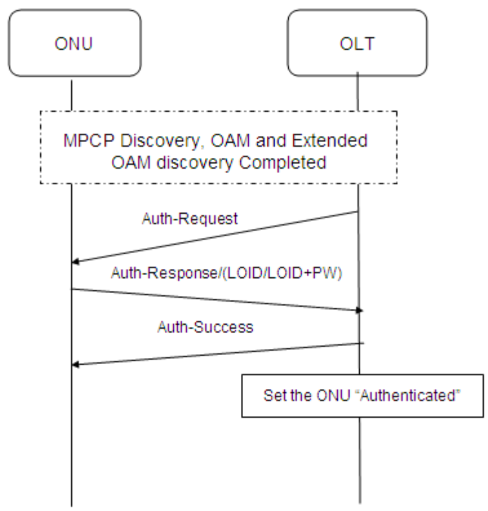

Figure 29 Successful logical ID based-authentication

Following is a brief description of the logical ID-based authentication process:

1. Once the MPCP and OAM discovery processes are completed, the OLT sends the extended OAM message 'Auth_Request' to the ONU to start the authentication process.
2. The ONU receives the message 'Auth_Request' and replies with the extended OAM message 'Auth_Response', which contains the logical ID information (LOID/LOID+PW).
3. Once the OLT receives the response from the target ONU, it verifies the ONU's LOID/LOID+PW.
4. If the verification check completes successfully, the OLT sets the state of the ONU to 'authenticated'.
5. If the verification check fails, the OLT sends the extended OAM message 'Auth_Failure' to the ONU and sets its state to 'unauthenticated'. Next, the OLT sends a MPCP DU REGISTER (with Flag = 0x02: deregister set) to deregister the ONU.

The process of unsuccessful logical ID-based authentication is shown in Figure 30.

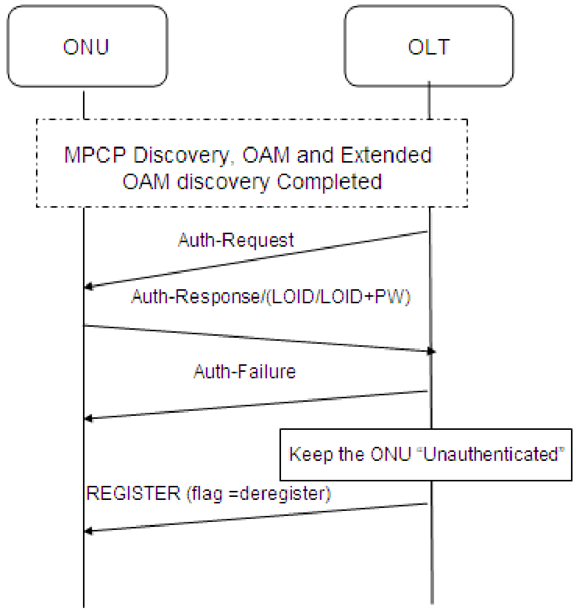

Figure 30 Unsuccessful logical ID based authentication by the OLT

R-178 The OLT MUST support ONU authentication based on LOID.

R-179 The OLT MUST support ONU authentication based on LOID+PW.

R-180 The OLT MUST support the pre-provisioning of PWs and their associated LOIDs.

R-181 The OLT MUST allow selection between LOID-based and LOID+PW-based ONU authentication.

R-182 The ONU MUST support local configuration of LOID/LOID+PW.

R-183 The ONU MUST retain the provisioned LOID/LOID+PW values indefinitely, or until the LOID/LOID+PW is re-provisioned."

If the logical ID is modified, in order to make the new logical ID effective the ONU has to go through the discovery and authentication process again.

As an example, a 24-character field can be used to hold the LOID value, and a 12-character field can be used to hold the Password value.

8.2.4 Hybrid Authentication

An OLT configured for hybrid authentication simultaneously supports both physical ID-based and logical ID-based authentication.

The OLT maintains a table of legal ONU MAC addresses. If an ONU has been successfully authenticated based on its MAC address, the OLT sets its state to 'authenticated.' Otherwise, the ONU is marked as 'unauthenticated.'

For an ONU that fails the authentication process based on its MAC address, the OLT will initiate the authentication process based on the logical ID, after finishing the MPCP discovery process and OAM discovery process.

If both the physical ID- and logical ID-based authentication processes fail, the OLT will deregister the given ONU.

R-184 The OLT MUST support hybrid authentication for the attached ONUs.

Appendix A

If a single, physical device supports multiple, fully compliant IEEE 802.3 ONUs ("Virtual ONUs"), then EDPs for the physical device can be carried by multiple Logical Links, as shown in Figure 31.

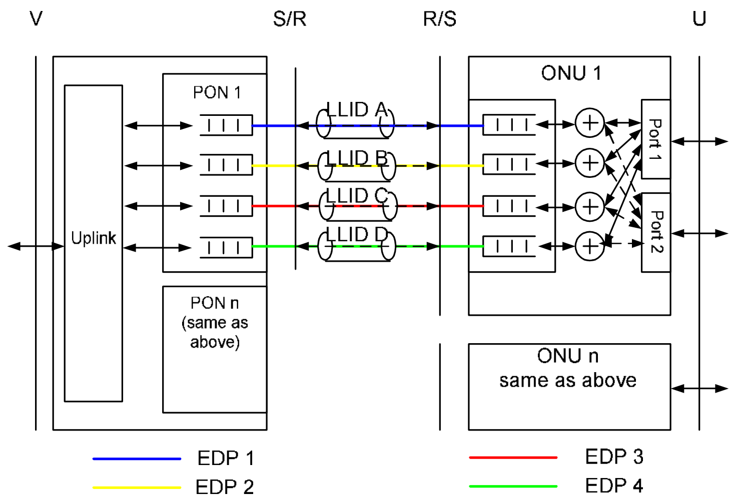

Figure 31 Mapping unicast EDPs onto multiple Logical Links.

Appendix B

Authorization-based IGMP

Authorization-based IGMP is a method by which access-control and IGMP processing are centralized in the OLT, and multicast forwarding authorizations are distributed dynamically to the ONUs by the OLT. The OLT manages a user's privileges using a multicast service authorization table and controls the multicast traffic forwarding actions of the ONU via extended multicast control OAM messages.

The multicast service authorization table maintained by the OLT contains user privileges information regarding multicast source groups. This information is maintained on a per-user-port and per-multicast-group basis. An individual user's privilege to receive a particular multicast group can have one of the following two values: "permitted" or "preview." Any multicast group not in the privilege list is prohibited.

When an IGMP REPORT message is received on a user port on an ONU, the ONU marks the IGMP Report message a unicast VLAN tag that uniquely identifies the ONU's subscriber interface and forwards the message to the OLT. The OLT parses the IGMP REPORT message and checks the table to determine whether the user is authorized to use the requested multicast service (See R-69). If the validation process is successful, the OLT takes whatever internal actions are necessary to forward the requested stream and sends the requesting ONU an IGMP authorization message instructing it to create the appropriate entry in its multicast table. Once the ONU receives this message and acts on it, multicast downstream content is forwarded to the target user port. If the privilege for the requesting user port has the value 'preview', the OLT starts a timer which determines the duration of the preview allowed the requesting subscriber. Once the timer expires, the OLT instructs the ONU via extended multicast control messages to delete the corresponding multicast forwarding entries. Alternately, if the privilege for the requesting user-port does not have a value of either "permitted" or "preview" (i.e., is not in the table), the OLT and the ONU take no further action and do not forward the requested multicast traffic.

The OLT also monitors the PON-wide membership of the various multicast groups and stops the forwarding of traffic for any multicast group that has no current members.

Figure 32, Figure 34, and Figure 33 depict the authorization-based IGMP message flow when the user privilege has the value of "permitted," "preview," or is not listed in the user's privilege table, respectively.

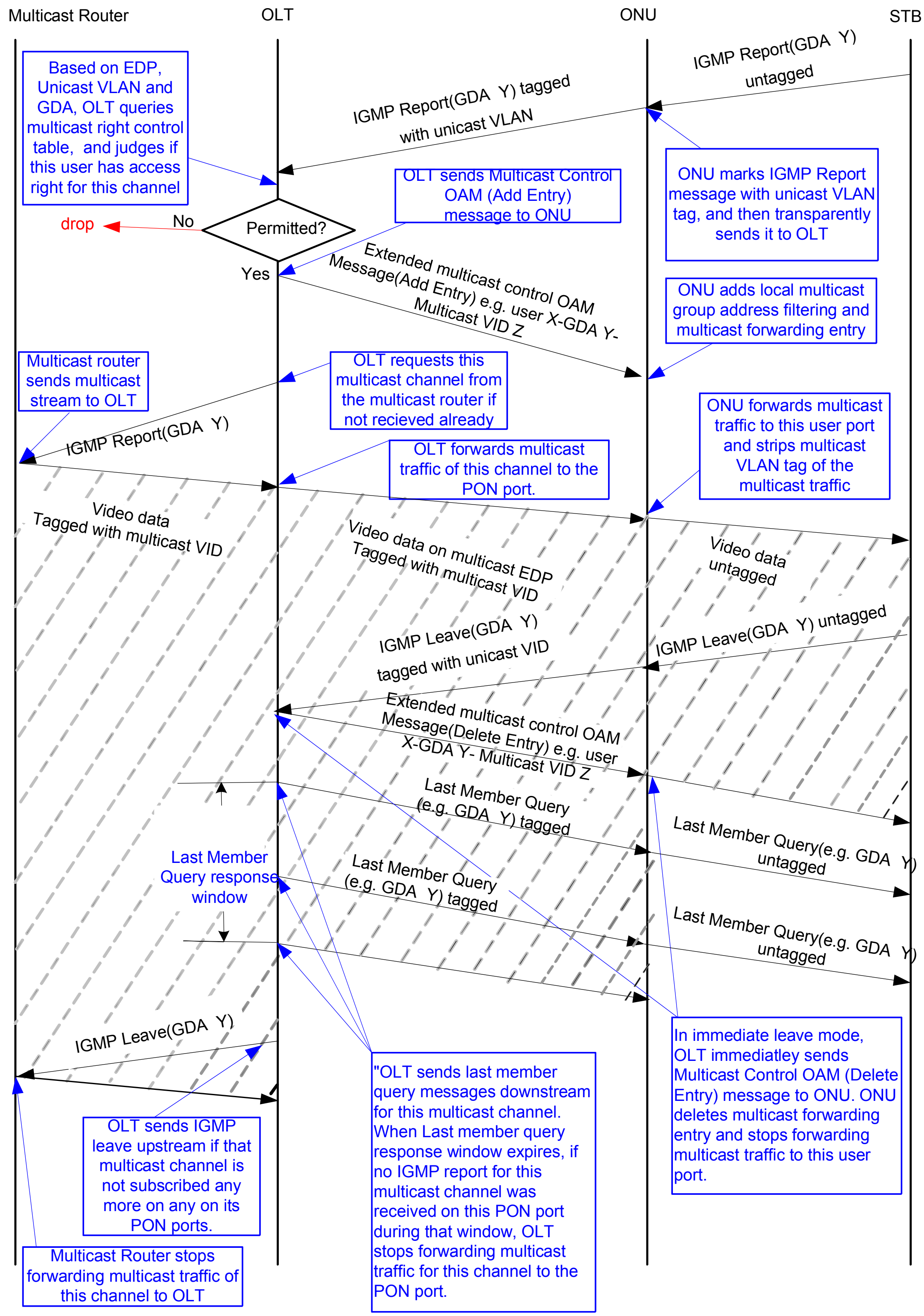

Figure 32 The authorization-based IGMP message flow when requested channel has the value "permitted" in the user's privilege table.

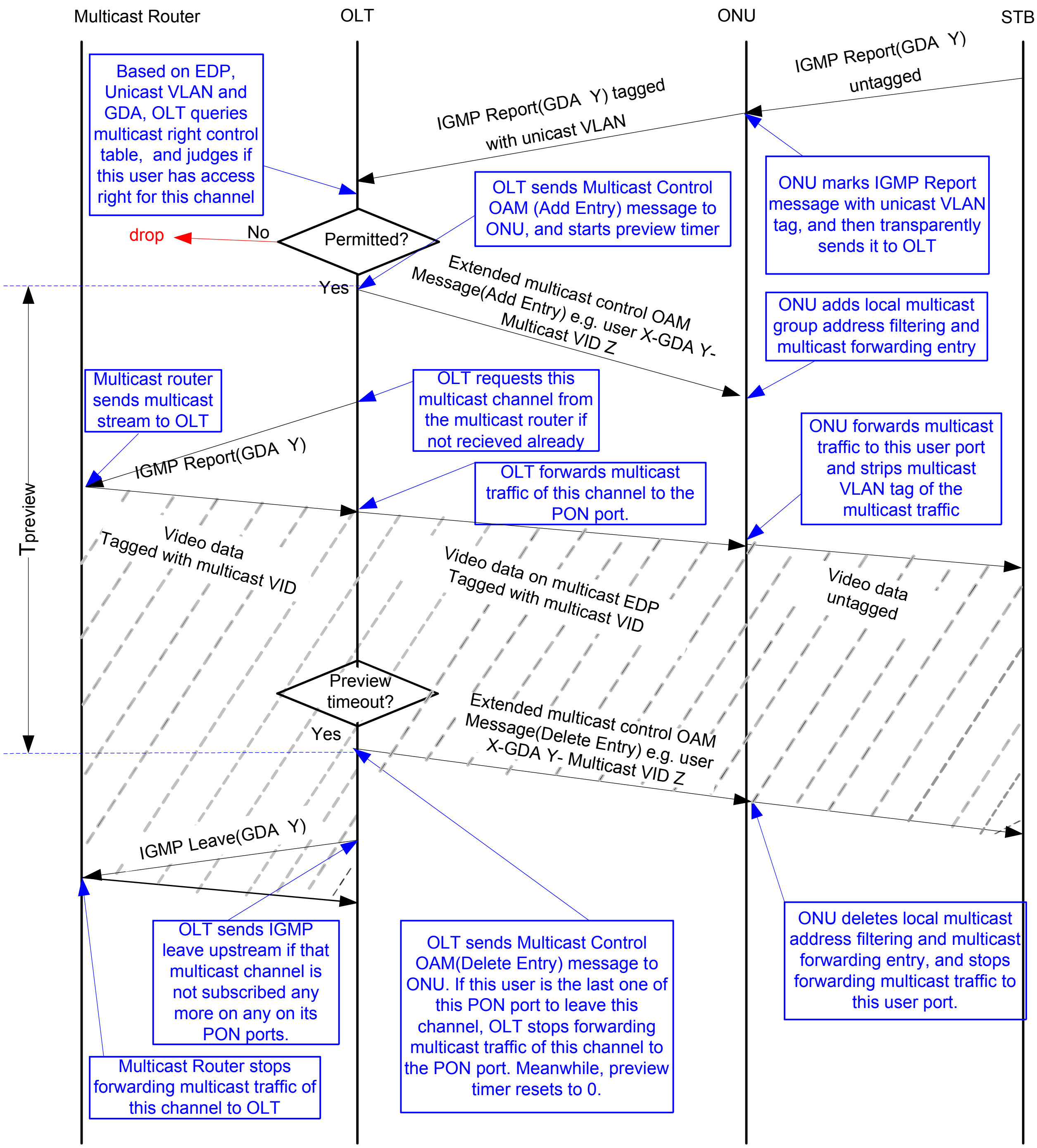

Figure 33 The authorization-based IGMP message flow when requested channel has the value "preview" in the user's privilege table.

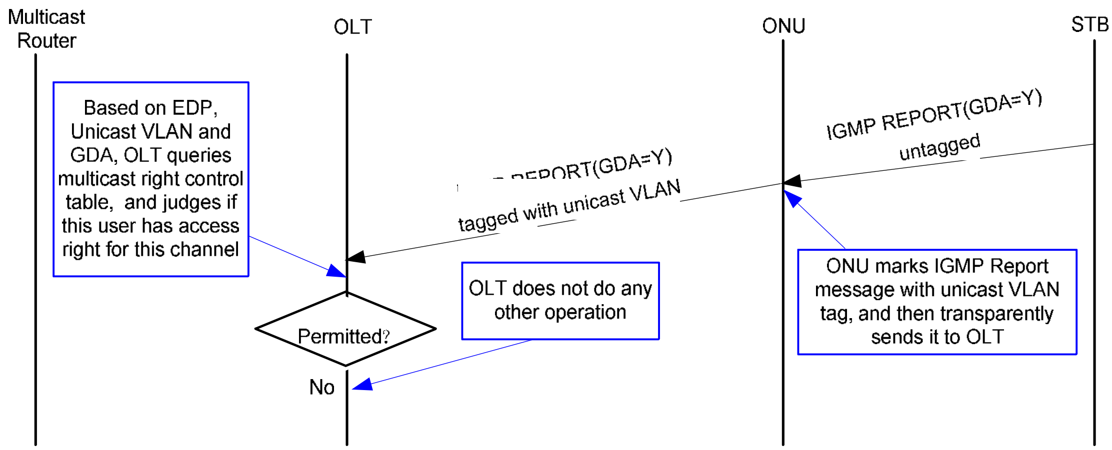

Figure 34 The authorization-based IGMP message flow when requested channel is not in the user's privilege table ("prohibited").

When the user count is very high, as is often the case for PON-fed Access Nodes (MDU), maintaining the multicast authorization table, checking user privileges, and communicating with the MDUs may impose a significant burden for the OLT. In this case the multicast authorization table is maintained on the Access Node entity and configured by an EMS. The EPON-fed Access Node, rather than the OLT, performs all of the functions described above relating to the management of subscribers' access to multicast traffic. The requirements for multicast control in this final scenario are the same as those described by TR-101.

End of Broadband Forum Technical Report TR-200