White Paper

GPON - EPON Comparison

CommScope Solutions Marketing

October 2013

Contents

Passive Optical Networking (PON) technology has been available since the mid-1990s. Significant development activities occurred during the early 2000s to develop Gigabit rate solutions designed to deliver Ethernet and IP services. Two very different solutions were developed by the IEEE and ITU-T—EPON and GPON, respectively. While the general concepts (PON operation, ODN framework, wavelength plan, and application) are the same for both EPON and GPON, their operation is very different, as are the features and services supported by each. EPON is a native Ethernet solution that leverages the features, compatibility and performance of the Ethernet protocol, while GPON leverages the techniques of SONET/SDH and Generic Framing Protocol (GFP) to transport Ethernet.

Introduction

PON standardization activities have been ongoing for the past fifteen years within the ITU-T and IEEE standards bodies. EPON and 10G-EPON are the latest ratified IEEE standards and GPON is the latest ratified ITU-T standard. Figure 1 shows some of the key historical milestones:

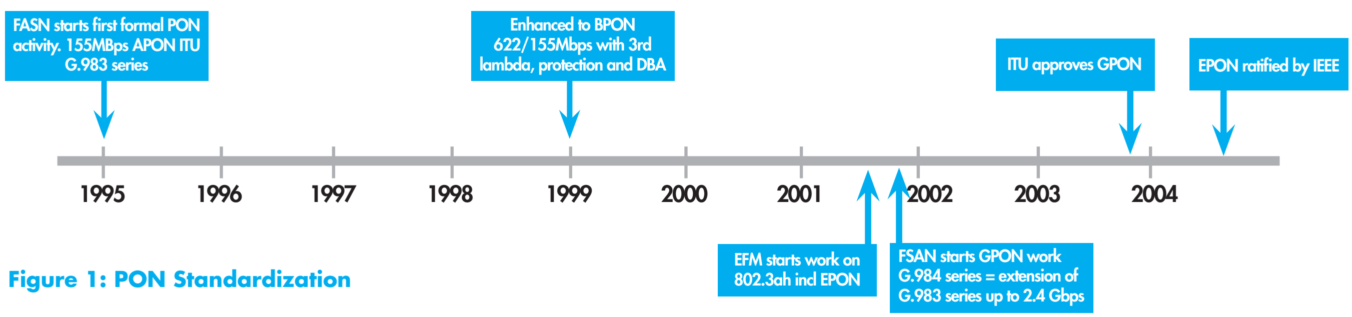

Figure 1: PON Standardization

Initial PON offerings in the early and mid-1990s were based on ATM framing (APON, BPON). With the explosion of Internet- and intranet-based traffic in the years following, ATM-based BPON systems proved to be very inefficient, as the vast majority of traffic through the access network consisted of variable-length IP traffic. This became the catalyst for the development of a purely Ethernet-based PON (EPON), taking advantage of emerging QOS-aware Gigabit Ethernet (GbE) switch silicon, evolving Ethernet standards (VLANs, prioritization, OAM), and cost-effective integration with other Ethernet equipment.

Development of the Gigabit-capable Passive Optical Network (GPON) standard started after proposals by FSAN members (Quantum Bridge et al) for a dual Gigabit speed ATM/Ethernet PON solution were not able to gain support within the IEEE 802.3ah work groups and decided to continue this work within the ITU.

EPON and GPON both draw heavily from G.983, the BPON standard for their general concepts (PON operation, ODN framework, wavelength plan, and application). Also, both were designed to better accommodate variable-length IP frames at Gigabit line rates. There are, however, significant differences in the approaches used by each.

Protocol fundamentals

EPON is based upon IEEE 802.3 Ethernet that was modified to support point-to-multipoint (P2MP) connectivity. Ethernet traffic is transported natively and all Ethernet features are fully supported. GPON, on the other hand, is fundamentally a transport protocol, wherein Ethernet services are adapted at the OLT and ONT Ethernet interfaces and carried over an agnostic synchronous framing structure from end to end.

Framing/service adaption

The GPON Transmission Convergence (GTC) layer is responsible for mapping service-specific interfaces (e.g. Ethernet) into a common service-agnostic framework.

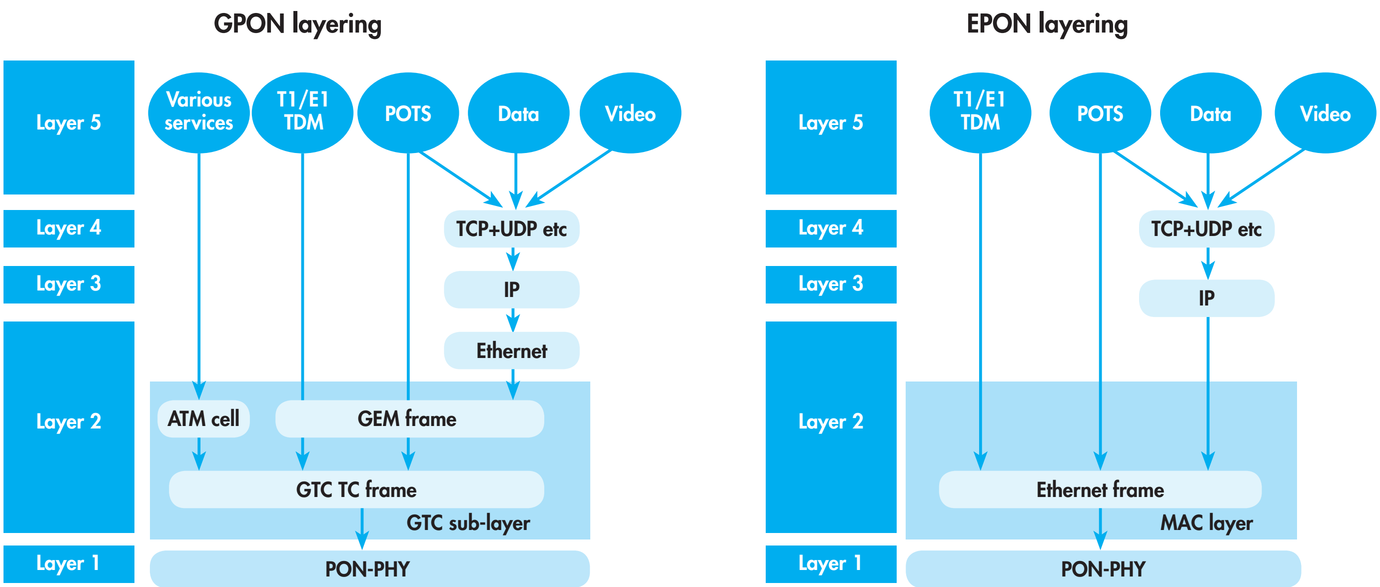

Figure 2: GPON vs. EPON Protocol

Ethernet frames are encapsulated into GTC Encapsulation Method (GEM) frames, which have a GFP-like format (derived from Generic Frame Procedure ITU G.7401). GEM frames are, in turn, encapsulated into a SONET/SDH-like GTC frame (in both upstream and downstream directions) that is transported synchronously every 125 μsec over the PON.

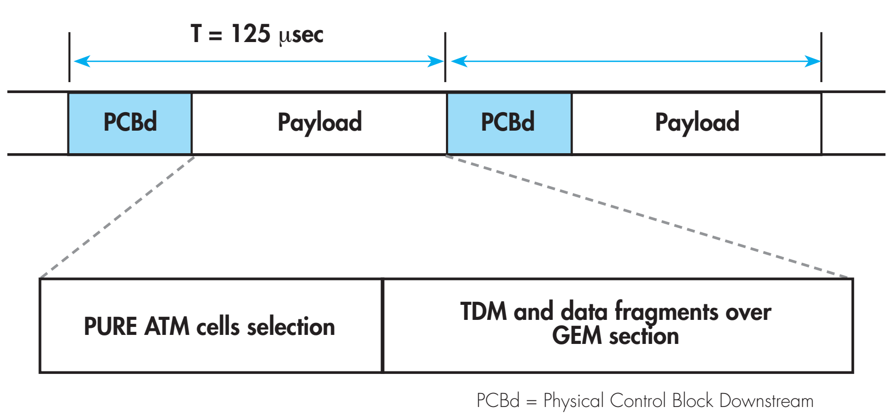

Figure 3: Downstream GTC Frames

In contrast, EPON carries Ethernet frames natively on the PON with no changes or modifications. There is no need for extra adaption and encapsulation.

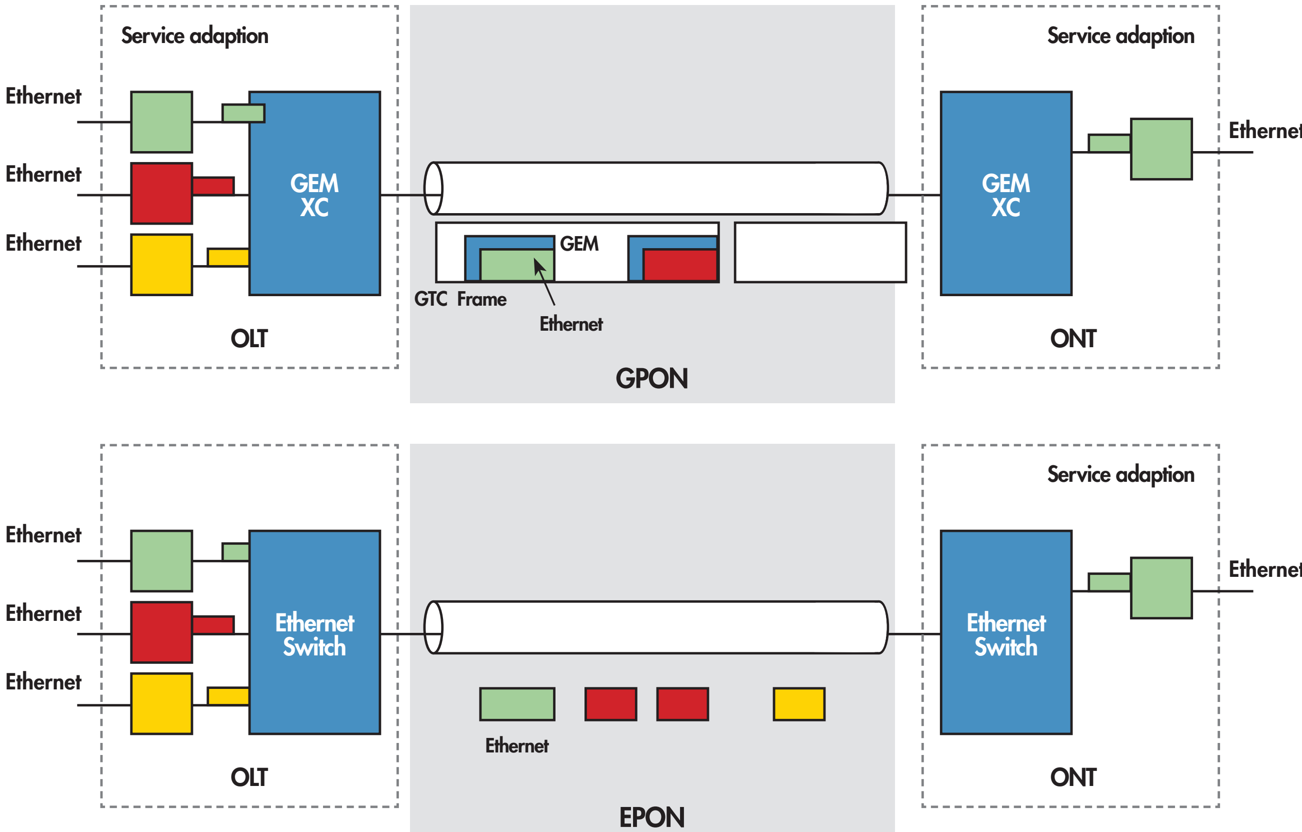

Figure 4: Framing in GPON and EPON

Basic operation

As shown above, EPON is an IEEE Ethernet architecture. Its downstream media access control (MAC) works in the same manner as a standard GbE MAC, where all Ethernet traffic is broadcast. Optical splitters are used to passively divide the same downstream signal among each of the ONT end points.

Downstream broadcast

All data goes to all ONUs and the ONU address controls the downstream data.

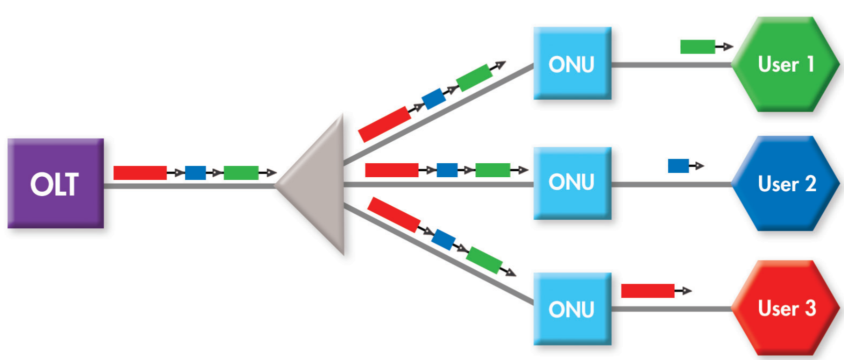

Figure 5: EPON Downstream

Upstream, the Ethernet MAC has been modified by the IEEE to support time division multiple access (TDMA) scheduling. The upstream Ethernet bandwidth (before 8B/10B coding) is scheduled for use by each of the ONT end points using a TDMA algorithm controlled by the OLT. The full bandwidth is available to each endpoint for the duration of its scheduled time. Dynamic Bandwidth Allocation (DBA) algorithms are implemented by vendors to dynamically change the allocation for each ONU based on the amount of traffic it has queued to send.

Upstream TDMA operation

ONUs send information to the OLT in a specific time window.

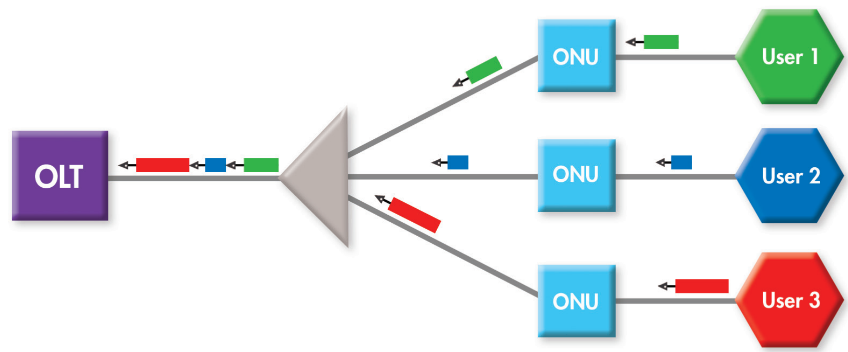

Figure 6: EPON Upstream

As shown in Figure 7, GPON is a synchronous transport network architecture. Its downstream MAC is derived from GFP-framed SONET, whereby it operates on a fixed time base of 125 μsecs and time division multiplexing (TDM) is used to divide the bandwidth to the 32 ONTs. Because it is synchronous in nature, idle characters are inserted whenever no asynchronous Ethernet traffic is available. Optical splitters passively split the same downstream signal to each of the 32 ONU end points.

Upstream, TDMA scheduling is used and incoming Ethernet traffic is again encapsulated and mapped into a 1.2 Gbps synchronous framed signal in a similar manner to the downstream.

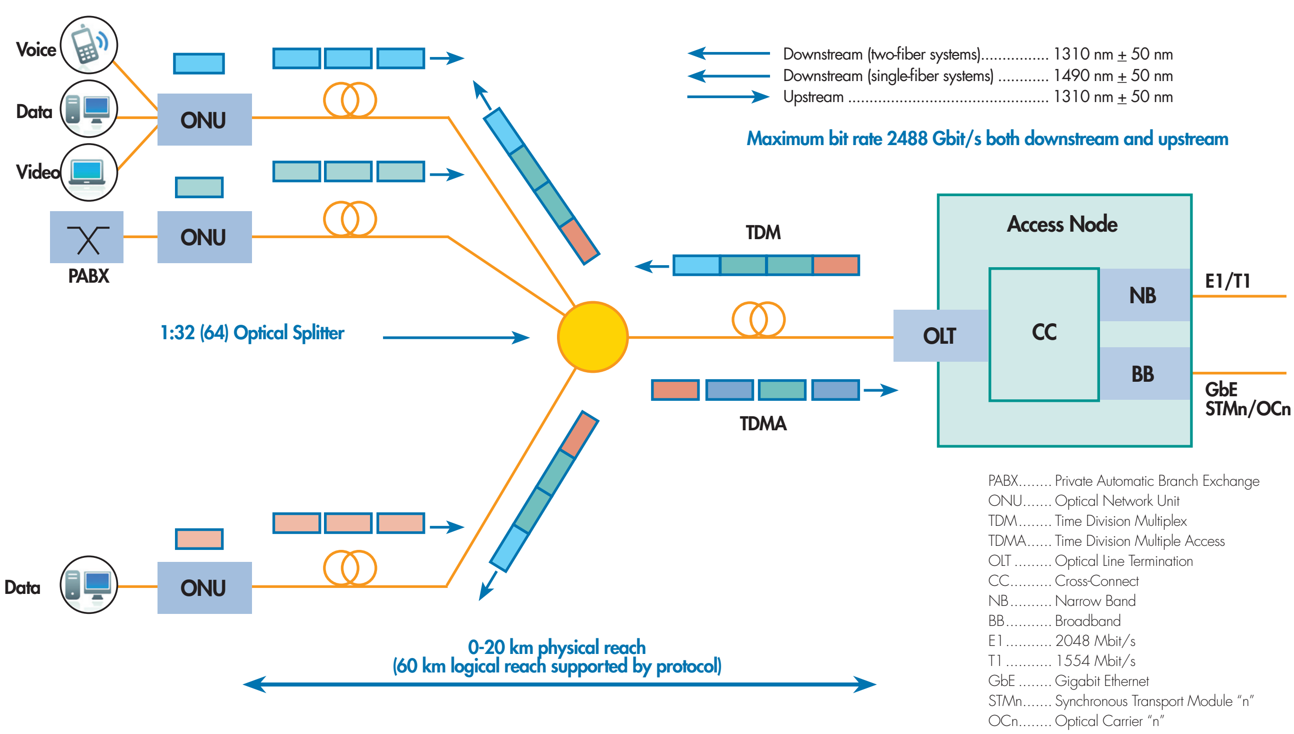

Figure 7: GPON Upstream & Downstream

Service hierarchy

Since PON is P2MP in nature, the OLT must be able to uniquely identify and communicate with each ONT. EPON uses a Logical Link ID (LLID) to uniquely address an ONT. In addition, VLAN_IDs are used for further addressing in order to deliver VLAN-based services. In the downstream direction, the OLT attaches the LLID to the preamble of the frame to identify the destination ONT.

In GPON, one or more Traffic Containers (T-CONT) are created between the OLT and an ONT. This T-CONT allows for the emulation of a point-to-point virtual connection between the OLT and ONT and the subsequent TDM multiplexing of the downstream bandwidth between T-CONTs. Within each T-CONT there can exist multiple Port IDs to identify individual ONT ports within a single ONT.

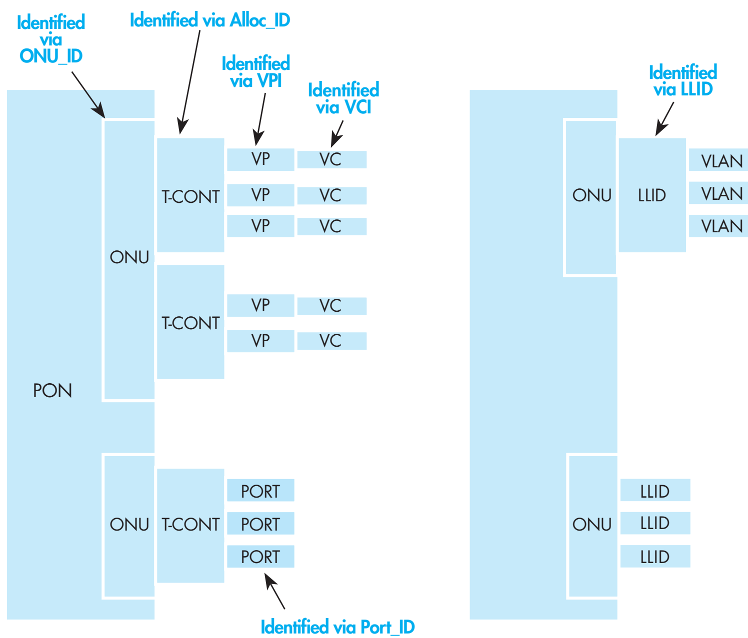

Figure 8: Service Hierarchy

Bandwidth allocation

The use of TDMA in the upstream direction requires the OLT to schedule each ONT's transmission to avoid collisions. Fundamentally, each ONT receives a grant telling it when to begin and end transmission. In GPON, grants are scheduled per T-CONT; in EPON, per LLID. In the case of GPON, grants are carried in the downstream frame header. A map field within the header specifies the specific T-CONT, start and end {Alloc-ID+Start+End} for each granted upstream window (timeslot).

In EPON, grant messages are sent per LLID, as separate MAC-Control client frames (GATEs), between regular Ethernet frames. Each grant specifies the {LLID+Start+Length}.

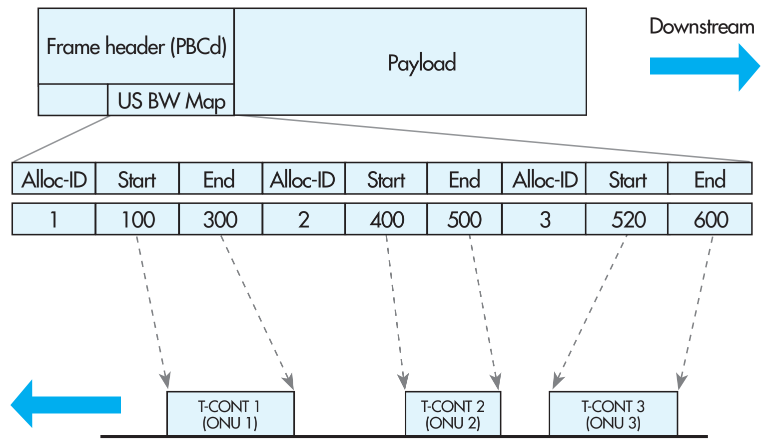

Figure 9: GPON Media Access Control

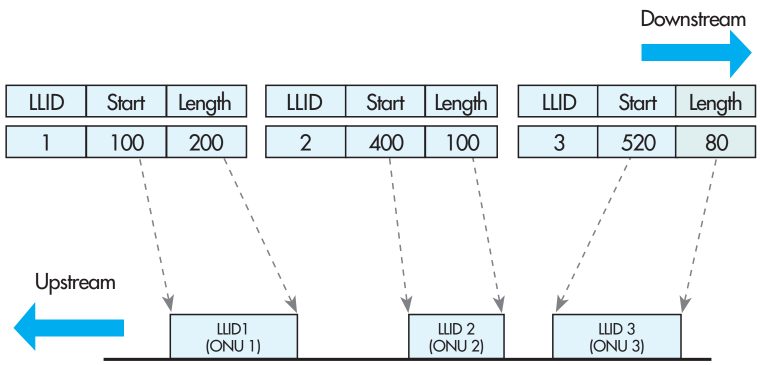

Figure 10: EPON Media Access Control

Dynamic Bandwidth Allocation (DBA)

Optionally, both GPON and EPON support DBA. This is used for real-time variation of timeslot allocation to ONTs, which increases throughput as a function of upstream demand.

	GPON DBA	GPON DBA
Granting Unit	GTC overhead	MPCP GATE frame
Control Unit	T-CONT	LLID
Identification of control unit	Alloc-ID	LLID
Reporting mechanism	Embedded OAM	Separate REPORT Frame
Negotiate Procedure	GPON OMCI	N/A

Figure 11: DBA Elements in GPON and EPON

Control messages

In GPON there are three different types of control messages: OMCI, OAM, and PLOAM. Their roles are shown in the table below.

Control channel	Format	Used for
OMCI	Ethernet or ATM	Provisioning of ONT service defining layers above the GTC (e.g., via EMS)
Embedded OAM	Header overhead	BW granting, encryption key switching, and DBA
PLOAM	ATM	Auto discovery and all other PMD and GTC management info. PLOAM messages are directed to ONTs or FF for broadcasts

Figure 11: Control Messages

In contrast, EPON utilizes IEEE 802.3ah OAM messages for provisioning, fault isolation and performance monitoring in conjunction with SNMP sets and gets through IETF MIBs. Additional control messages are MPCP GATEs/REPORTs for BW granting.

ONT discovery & activation

Both EPON and GPON support automatic ONT discovery and activation mechanisms. GPON uses the Serial Number (SN) for ONT authentication. There are two methods for activating ONTs.

- Method A – The SN of the ONT is registered in advance at the OLT by the operator
- Method B – The SN of the ONT is not registered at the OLT by the operator/EMS.

Method B requires an automatic detection mechanism of the SN. If a new ONT is detected, an ONT-ID is assigned and the ONT is activated.

Traditionally, EPON does not authenticate via the SN, but, instead, uses the ONT MAC Address in order to assign an LLID. However, some vendor-specific EPON implementations optionally utilize the ONT's SN.

Encryption

Both EPON and GPON support AES-128bit encryption. For GPON, key management messages are exchanged via PLOAM cells. Upon request by the OLT, the ONT sends a new key three times. Once received, the OLT toggles a bit in the GTC header to initiate a key switch. For EPON, key management messages are either via a management VLAN or via IEEE 802.3ah OAM messagesm depending on vendor implementation.

Bandwidth and efficiency

Probably the most heralded claim of GPON vendors is that it is 2.448 Gbps in the downstream direction and 1.24416 Gbps in the upstream direction, whereas EPON is symmetrically 1.25 Gbps (1.0 Gbps prior to 8B/10B coding). Efficiency has to be considered in both directions of a PON. Each PON protocol introduces its own overhead in either direction. Overall, PON efficiency is a function of protocol encapsulation and scheduling efficiencies. In the downstream direction, protocol overhead should be negligible. In the upstream direction, the total scheduling overhead within EPON is between 2.92 percent and 9.67 percent. In other words, EPON efficiency is from 90.33 percent to 97.08 percent compared to a GbE point-to-point link. In the downstream direction, EPON efficiency reaches from 97.13 percent to 98.92 percent of the efficiency of a point-to-point 1GbE link, while GPON in GEM mode can achieve ~ 95 percent efficiency of its usable bandwidth. It should be noted that, optionally, EPON can be operated in what is typically termed 'turbo mode'. With turbo mode, the downstream EPON data rate is doubled to 2.5Gbps, thus enabling bandwidth throughput comparable to GPON.

Ethernet service support

Ethernet features

Since EPON is an IEEE Ethernet standard and utilizes Ethernet switches within its silicon, it can natively support all of the 802.1 and 802.3 features of Ethernet, including VLAN tags, prioritization, OAM, etc. All Ethernet services can be natively delivered in a manner identical to what is done with switched Ethernet today.

Since GPON only defines the transport of Ethernet frames, there is no native Ethernet functionality. Ethernet switches must be placed either in front of or within GPON OLTs and ONTs to provide any additional Ethernet capabilities. Capabilities are, thus, unique to each manufacturer's implementation.

Bridging

Since the cross-connect at the GPON OLT is not an Ethernet switch, GPON cannot support standard Ethernet bridging. Thus, in order to support standard bridging, there would be the need for an Ethernet switch upstream of the OLT cross-connect, either externally or in an aggregation point in the same chassis.

Transparent LAN Services (TLS)

TLS is achieved via VLAN tunneling on Ethernet switches. Without these in the GPON OLT chassis, one would need to use external Ethernet switches in order to achieve the same result. The GEM cross-connect cannot inspect VLANs in order to make the appropriate forwarding decisions.

Conclusion

The developers of both EPON and GPON recognized the need to evolve PON to being a Gigabit-capable solution for transporting Ethernet and IP traffic. Their implementations, while utilizing a common optical infrastructure, are very different in execution. EPON extended native Ethernet to support the PON P2MP architecture, while GPON used techniques similar to GFP-framed SONET/SDH to create an efficient Ethernet transport mechanism.

COMMSCOPE®

www.commscope.com

Visit our website or contact your local CommScope representative for more information.

WP-107286-EN (10/13)