The EPON Advantage

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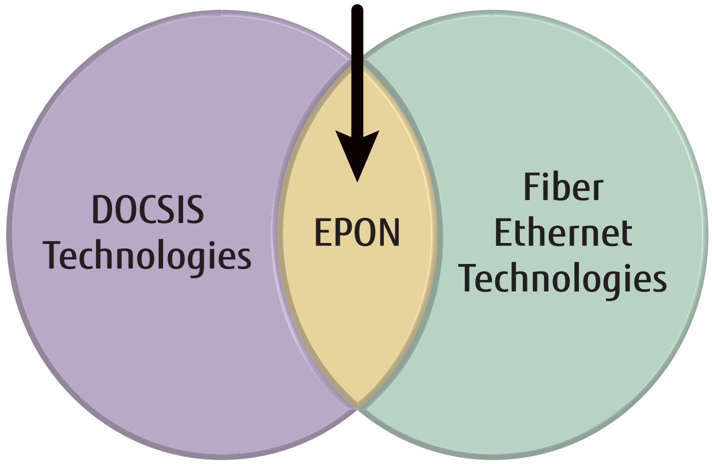
The Technology of Choice for Next Generation Service Delivery

Within North America, data services at 100 megabit plus symmetrical rates have traditionally only been available to large enterprise customers because of the high costs of fiber construction and enterprise data equipment. Small-to-medium enterprise customers have been relegated to lower performance cable modem or DSL technologies that have proven unable to deliver high symmetrical bandwidth economically.

Now that small-to-medium enterprise customers are adopting bandwidth-intensive applications such as cloud services, demand for dedicated fiber Ethernet performance at a DSL or cable modem price point is increasing rapidly. This, in turn, is motivating operators to investigate technologies that can allow them to profitably meet the service demands of this highly lucrative market. Existing dedicated enterprise Ethernet solutions, while capable of meeting the technology requirements, are too expensive to effectively support the price expectations of the small-to-medium business customer. Passive Optical Networking (PON) offers promising possibilities in terms of both service quality and price point. Operators have two valid technology choices to serve this market: EPON and GPON. Although GPON is currently in wide deployment in North America, it is set to be superseded by EPON, which is a superior technology investment for delivering residential and small-to-medium enterprise Ethernet services. This paper examines the reasons why EPON is the technology of choice for delivering large-enterprise quality Ethernet services to small or medium enterprises and residential customers at a price they are willing to pay.

Overcoming the Limitations of the DOCSIS® Infrastructure

Cable operators have long been serving small-to-medium enterprise customers using DOCSIS devices. However, they are finding it operationally and financially impractical to perform the radical changes to existing DOCSIS infrastructure necessary to keep up with customer demand for higher speed symmetrical service offerings. Delivering symmetrical bandwidth using DOCSIS has always been a challenge due to the limited number of available upstream channels as defined in the original DOCSIS standard. This limitation has resulted in cable modem services evolving to favor large downstream bandwidth, often in excess of 100 Mbs, while the upstream capabilities of most operators' products have been limited to 10 Mbs or below. It is true that the DOCSIS 3.0 standard defines additional RF channels that allow expansion of upstream capacity, but removing filters from existing cable infrastructure to support the new frequency ranges is a capital intensive exercise that most cable operators are not enthusiastic to undertake. To improve network performance while lowering the cost of delivering higher speeds and symmetrical bandwidth, cable operators are seeking solutions that combine the performance of dedicated Ethernet with the low capital and operational costs of DOCSIS devices. PON is emerging as an appealing alternative because of its use of low-cost equipment to deliver symmetrical gigabit speeds, its support for multiple service offerings, and its immunity to radio frequency impairments that can disrupt customer quality of experience and inflate operational costs.



Rival Standards: EPON versus GPON

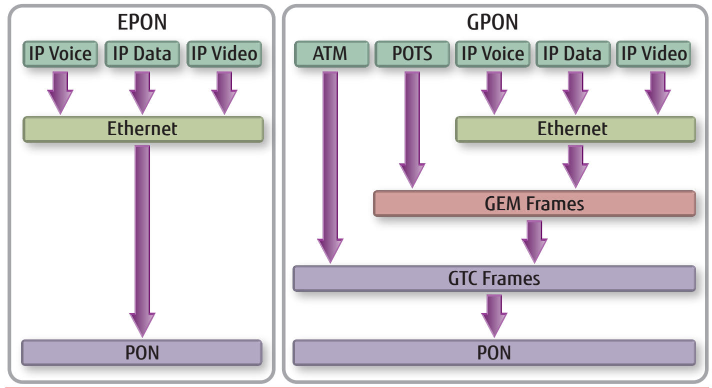
Mainstream use of PON for subscriber services is relatively new in the United States, with Verizon first offering its FiOS service beginning in 2005 and the Kansas City Google Fiber offerings in 2012. Conversely, as of the time of writing, Asia has more than thirty million EPON ports deployed. Initially standardized as ATM-based PON, or APON, by the ITU in the late 1990s, PON has evolved into what are now two competing International standards implementations from the ITU (GPON) and the IEEE (EPON). The GPON standard has an advantage of market timing in North America; the ITU-T G.984.x series standards were ratified in 2003, while the IEEE did not ratify the 802.3ah standard until 2004, one year later. The timing of the ratification of the GPON standard, as well as its ability to carry native TDM services, were likely contributing factors to its selection as a platform for Verizon's FiOS deployments, which explain why GPON currently accounts for the bulk of the FTTH deployments in North America.

Originally, GPON had a technical market advantage in that its transmission convergence layer natively accommodated not only encapsulation of native Ethernet frames, but also of ATM cells and TDM services. This capability made it an ideal choice for carriers wishing to deliver simultaneous voice and data services to their customers. As telephony services have migrated from traditional TDM to IP, this technical advantage of GPON over EPON has now lost most of its relevance.

The Relative Economic and Technical Merits of EPON and GPON

The costs of the optical distribution equipment (fiber type, splitters, connectors, and so on) are similar for both GPON and EPON. The primary technical and therefore, cost variation between the two standards is to be found in the OLT and the ONU. The primary component differences in the OLT and ONU for GPON and EPON are the ASIC/FPGA and optical modules. The majority of GPON products available on the market are FPGA-based, while EPON products predominantly utilize lower-cost ASICs. While it is significantly more expensive to tool up to build an ASIC, once this up-front investment has been made, the production costs are much lower than for FPGA chipsets and costs are further driven down proportionally with the volume of chips produced. High demand for EPON in Asia, where tens of millions of units have been deployed to-date, allowed manufacturers to amortize the initial ASIC investment while continuing to lower the cost of the components as demand, and therefore volume, grew. The better economies of scale at higher volumes for ASIC manufacturers suggests that it is unlikely GPON products will decline as rapidly in price as EPON chipsets have done thus far (and will continue to do as demand increases). Furthermore, the optical modules for GPON are also more expensive than EPON due to the faster on-off laser modulation and the multiple laser power leveling required by the ITU-T standard. Additionally, the 2.4 Gbps rate used by many GPON manufacturers is non-standard to the optical industry which limits the volume of demand necessary to drive down manufacturing costs for those devices. It is very doubtful that the cost of GPON equipment can ever be as low as that for EPON in the long term.

EPON has a distinct technical advantage in a network where services are defined as Ethernet or IP over Ethernet, in that Ethernet frames are carried natively on the passive optical network. GPON requires two layers of encapsulation to carry the same traffic. In GPON, Ethernet data and TDM frames must first be encapsulated into GEM frames which are then further encapsulated along with ATM frames into GTC frames for transport on the PON. While this approach worked well where the need to carry native TDM and ATM traffic was required, in an all-Ethernet network the inclusion of GEM and GTC encapsulation adds unnecessary complexity and serves no real benefit in transporting pure Ethernet frames.

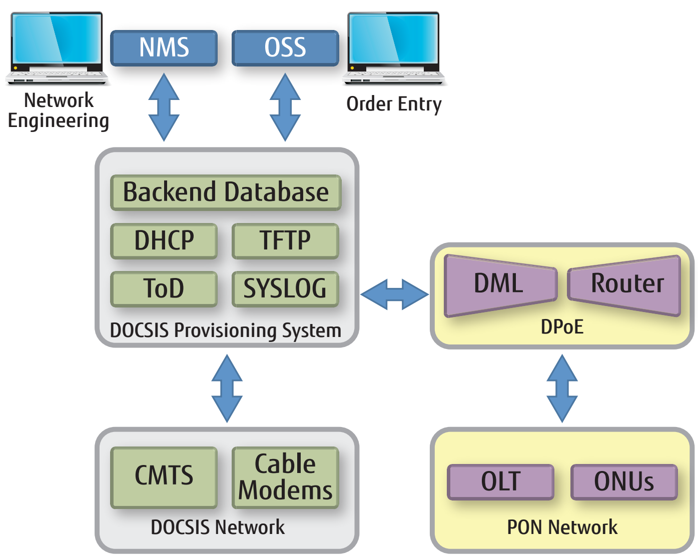


EPON vs GPON Encapsulation

GPON is architected specifically to support point-to-point connections; thus, where Ethernet bridging or LAN/VLAN support is required, this must be done upstream of the OLT with overlay equipment. Conversely, delivery of MEF-defined services are standard capabilities of EPON systems.

Because EPON is built upon the IEEE 802.3 Ethernet standards, it inherits the standard Ethernet MIBs which are well supported by the OSS systems already deployed to manage carrier networks. Additionally, the CableLabs® DPoE™ specification support now being built into EPON equipment allows the use of existing standardized APIs to easily provision, manage and maintain EPON installations. DPoE has been designed to mediate between an operator's existing DOCSIS provisioning and management systems to cause the OLT and ONU devices within the PON network to appear as though they are a DOCSIS CMTS and cable modem. It is important to note that DPoE encourages equipment manufacturers to build capabilities into their systems so that they support an industry standardized set of APIs to provision services. This not only allows cable operators to automate the provisioning of Ethernet services in a repeatable and efficient manner using their existing back office, but also provides a built-in standardized provisioning and maintenance mechanism for all telecommunications companies to use. This benefit is not available in GPON products.

While this standardized provisioning framework is just beginning to be adopted by cable providers, the ability to use a well understood provisioning and installation process regardless of who manufactured the equipment will continue to fuel increased uptake of EPON deployments in North America. This is because network operations is "where the rubber meets the road" in the sense that it is one of the most important contributing factors in controlling costs and improving efficiency and productivity. Most existing OSS systems are written to address specific types of hardware, rather than the hardware being designed to conform to a set of industry-standard APIs. Adoption of common software standards, rather than the current dominance of proprietary OSS interfaces, will facilitate interoperability and smooth the processes of provisioning and delivering services. Ultimately, standardized OSS APIs will improve operator market choice, enabling them to select equipment based on economic and technical merit rather than being locked into a single vendor as is common in most operators' networks. The potential benefits of this development are plain to see.



DPoE Overview

GPON has some marginal advantages over EPON that should be noted in the interest of fairness. One advantage is GPON's use of NRZ line coding versus EPON's use of 8B10B line coding, which provides for some marginal bandwidth efficiency. This is why EPON has a line rate of 1.2 Gbps but a maximum capacity of 1 Gbps while GPON's maximum capacity is the 1.2 or 2.4 Gbps line rate. Since both systems now support a 10 Gbps alternative, this advantage has become largely irrelevant. Additionally, the GPON standard defines protection switching, dynamic bandwidth allocation, and an ONU power leveling mechanism. All of these are either optional or undefined in the EPON standard and any implementations of them will be vendor-specific and may not interoperate across multivendor OLT/ONU instances.

Current standards development work on EPON will only further broaden its appeal, especially for cable operators. The first of these is the EPoC standard development, currently being undertaken by the IEEE. This allows the use of existing coaxial cable infrastructure as a physical medium for EPON, thereby eliminating the requirement to build last-mile fiber to every customer. Because of the clear cost benefit involved, this development will certainly have widespread market impact as cable operators leverage it to expand both business services and residential deployments of EPON. The second development is the addition of WDM to PON. WDM PON will give operators the ability to devote wavelengths to specific customers, eliminating concern regarding EPON as a shared medium. WDM PON will make EPON a viable solution for both cellular backhaul and large enterprise installations where oversubscription of a shared medium is not desirable.

EPON's Total Cost of Ownership Advantage

In the late 1990s when ATM and SONET dominated carrier transport networks, few would have envisioned the dominance that Carrier Ethernet holds today. In the 40 years since its introduction, Ethernet has gained its current position as the dominant transport technology due to its flexibility, simplicity, and economies of scale that have naturally driven down its cost compared to alternatives in the marketplace. These same technical capabilities and market dynamics will continue to give EPON a total cost of ownership advantage over GPON. Clearly, EPON is quickly gaining both technical and economic advantages that will further encourage operators to choose it over GPON. Just as Ethernet transport has won over SONET and ATM, as EPON gains momentum in the North American market, its costs to manufacture will continue to drop exponentially over time much like Ethernet transport has done in metro networks. Ultimately, products that provide better features and lower costs dominate in the marketplace and EPON is clearly well positioned to become the dominant last-mile fiber delivery mechanism.

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Acronyms

API	Application Programming Interface
APON	ATM PON
ASIC	Application-Specific Integrated Circuit
ATM	Asynchronous Transfer Mode
CMTS	Cable Modem Termination System
DOCSIS	Data Over Cable Service Interface Specification
DPoE	DOCSIS Provisioning of EPON
EPoC	EPON over Coax
EPON	Ethernet Passive Optical Network
FPGA	Field-Programmable Gate Array
FTTH	Fiber to the Home
GEM	GPON Encapsulation Method
GTC	GPON Transmission Convergence
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
ITU	International Telecommunications Union
LAN	Local Area Network
LTE	Long-Term Evolution
MIB	Management Information Base
NRZ	Non-Return to Zero
OLT	Optical Line Terminator
ONU	Optical Network Unit
OSS	Operations Support System
PON	Passive Optical Network
SONET	Synchronous Optical Network
TDM	Time-Division Multiplexing
VLAN	Virtual Local Area Network
WDM	Wavelength-Division Multiplexing

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