

## Ethernet Passive Optical Network (EPON) A Tutorial

### Overview

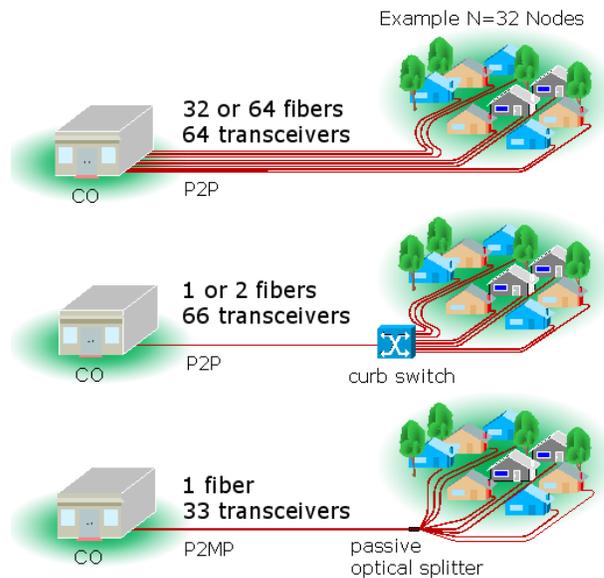
A Passive Optical Network (PON) is a single, shared optical fiber that uses inexpensive optical splitters to divide the single fiber into separate strands feeding individual subscribers. PONs are called "passive" because, other than at the CO and subscriber endpoints, there are no active electronics within the access network.

Using these techniques to create a passive optical infrastructure, Ethernet in the First Mile PON (EFMP) builds a point-to-multi-point fiber topology that supports a speed of 1 Gbps for up to 20 km. While subscribers are connected via dedicated distribution fibers to the site, they share the Optical Distribution Network (ODN) trunk fiber back to the Central Office.

Eliminating the need for electrical equipment in the first mile network is a key facet of the EFMP topology. Another advantage is that much less fiber is required than in point-to-point topologies.

To visualize the lower fiber requirements, it is useful to look at the topologies of point to point Ethernet and "curb switched" Ethernet along with EPON. Figure 1 illustrates all of these options.

EPON is based on the Ethernet standard, unlike other PON technologies, which are based on the ATM standard. This lets you utilize the economies-of-scale of Ethernet, and provides simple, easy-to-manage connectivity to Ethernet-based, IP equipment, both at the customer premises and at the central office. As with other Gigabit Ethernet media, it is well-suited to carry packetized traffic, which is dominant at the access layer, as well as time-sensitive voice and video traffic.



**Figure 1: Point to Point Ethernet, Curb-Switched Ethernet, and EPON**

Point-to-point Ethernet might use either  $N$  or  $2N$  fibers, and thus has  $2N$  optical transceivers. Curb-switched Ethernet uses one trunk fiber and thus saves fiber and space in the Central Office (CO). But it uses  $2N+2$  optical transceivers and needs electrical power in the field.

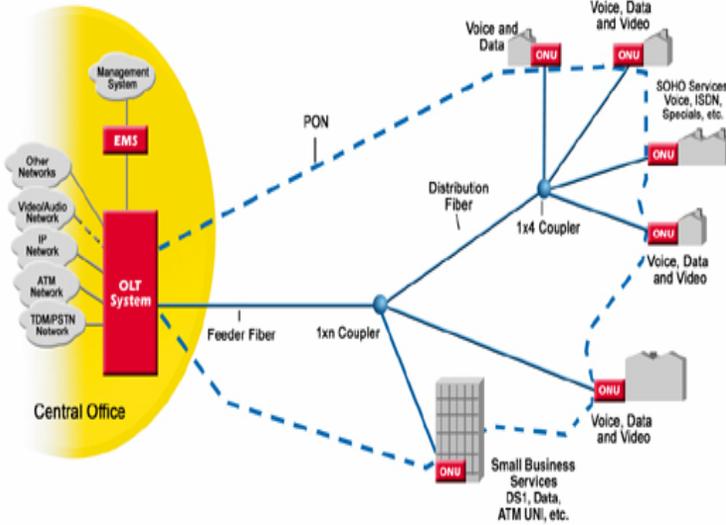
EPON also uses only one trunk fiber and thus minimizes fibers and space in the CO, and also only uses  $N+1$  optical transceivers. It requires no electrical power in the field. The drop throughput can be up to the line rate on the trunk link. EPON can support downstream broadcast such as video.

The IEEE 802.3ah EPON specification defines Multi-Point Control Protocol (MPCP), Point-to-Point Emulation (P2PE), and two 1490/1310 nm PMDs for 10 and 20 km, required to build an EPON system.

Typical EPON-based systems may include extra features above the IEEE 802.3ah standard, including security, authentication and dynamic bandwidth allocation.

## EPON Topologies

As Figure 2 shows, EPON is typically deployed as a tree or tree-and-branch topology, using passive 1:N optical splitters.



**Figure 2: EPON System Architecture**

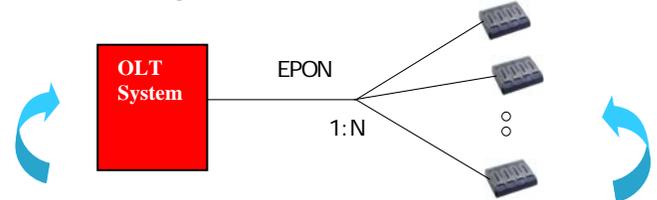
## EPON Network

An EPON network includes an *optical line terminal* (OLT) and an *optical network unit* (ONU).

The OLT resides in the CO (POP or local exchange). This would typically be an Ethernet switch or Media Converter platform.

The ONU resides at or near the customer premise. It can be located at the subscriber residence, in a building, or on the curb outside. The ONU typically has an 802.3ah WAN interface, and an 802.3 subscriber interface.

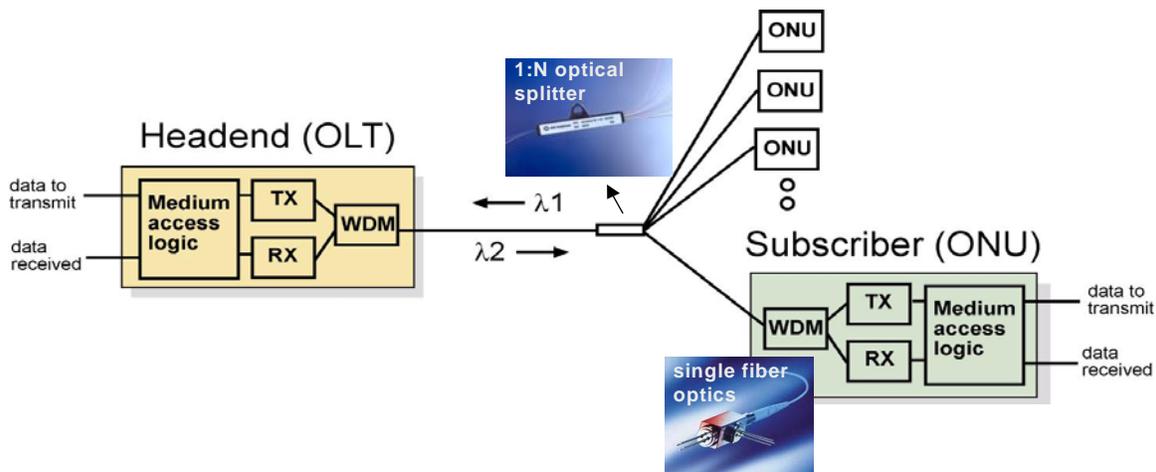
In Figure 3, the OLT is on the left and several ONUs are shown on the right



**Figure 3: ONU and OLT**

## EPON Systems

EPON is configured in full duplex mode (no CSMA/CD) in a single fiber point-to-multipoint (P2MP) topology. Subscribers, or ONUs, see traffic only from the headend; each subscriber cannot see traffic transmitted by other subscribers, and peer-to-peer communication is done through the headend, or OLT. As Figure 4 shows, the headend allows only one subscriber at a time to transmit using a Time Division Multiplex Access (TDMA) protocol



**Figure 4: EPON Configuration**

EPON systems use an optical splitter architecture, multiplexing signals with different wavelengths for downstream and upstream as such:

- 1490 nm downstream
- 1310 nm upstream

Though configured as point to multipoint, Ethernet PON can be deployed in an Ethernet access platform, with both point-to-point and point-to-multipoint access cards, as shown in Figure 5.

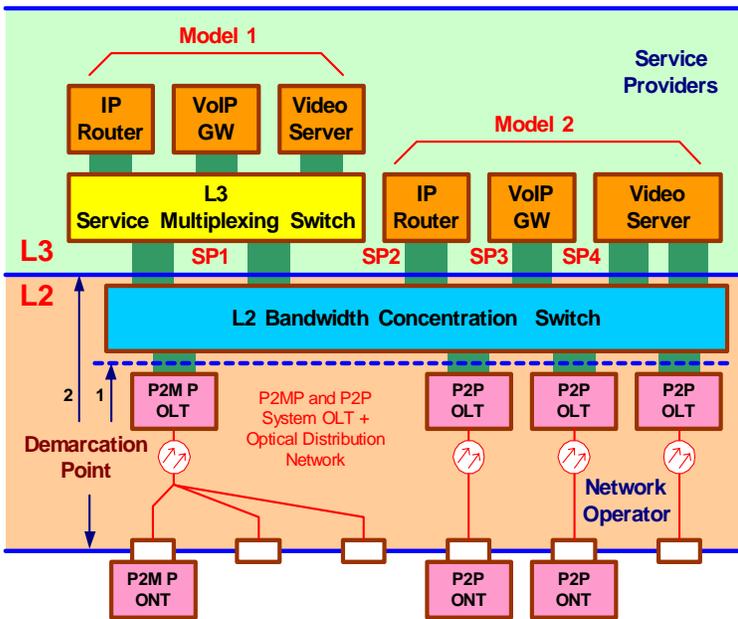


Figure 5: EPON in the Ethernet Access Model

## EPON Protocol

To control the P2MP fiber network, EPON uses the Multi-Point Control Protocol (MPCP).

MPCP performs bandwidth assignment, bandwidth polling, auto-discovery, and ranging. It is implemented in the MAC Layer, introducing new 64-byte control messages:

- GATE and REPORT are used to assign and request bandwidth
- REGISTER is used to control the auto-discovery process

MPCP provides hooks for network resource optimization. Ranging is performed to reduce slack, and bandwidth reporting satisfies requirements by ONUs for DBA. Optical parameters are negotiated to optimize performance.

## ONU and OLT Operation

The ONU performs an auto-discovery process which includes ranging and the assignment of both Logical Link IDs and bandwidth. Using timestamps on the downstream GATE MAC Control Message, the ONU synchronizes to the OLT timing. It receives the GATE message and transmits within the permitted time period.

The OLT generates time stamped messages to be used as global time reference. It generates discovery windows for new ONUs, and controls the registration process. The OLT also assigns bandwidth and performs ranging operations.

## EPON Downstream

Downstream, EPON handles the physical broadcast of 802.3 frames. As Figure 6 shows, broadcast frames are extracted by the logical link ID in the preamble. 64-byte GATE messages are sent downstream to assign upstream bandwidth.

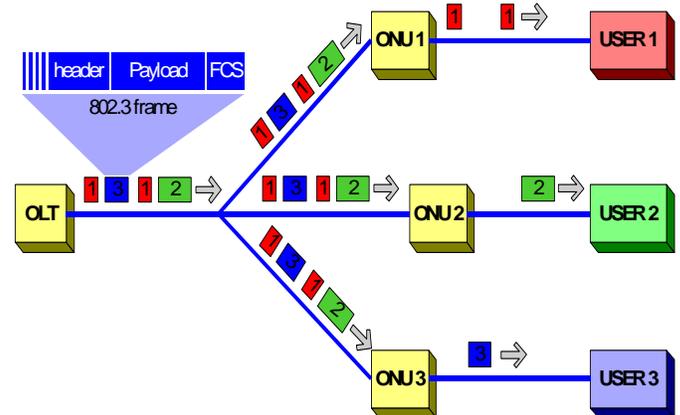


Figure 6: Downstream EPON Operation

More detail on the 64-byte GATE message is shown in Figure 7.

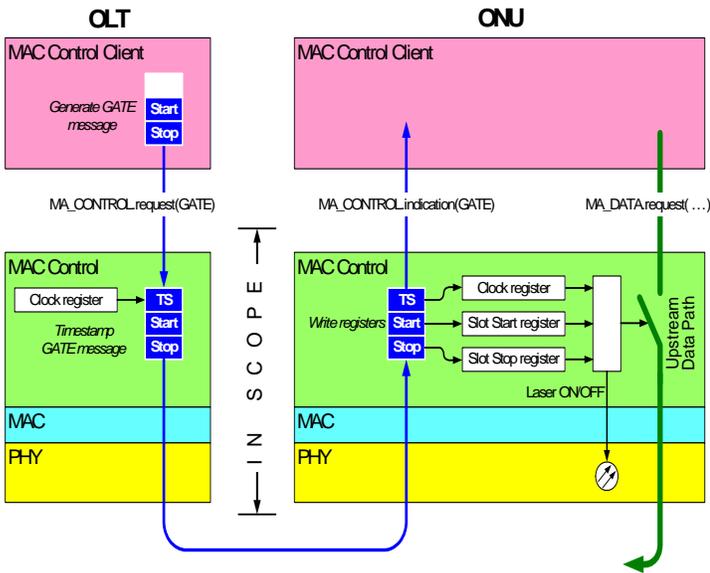


Figure 7: Path of GATE Message from OLT to ONU

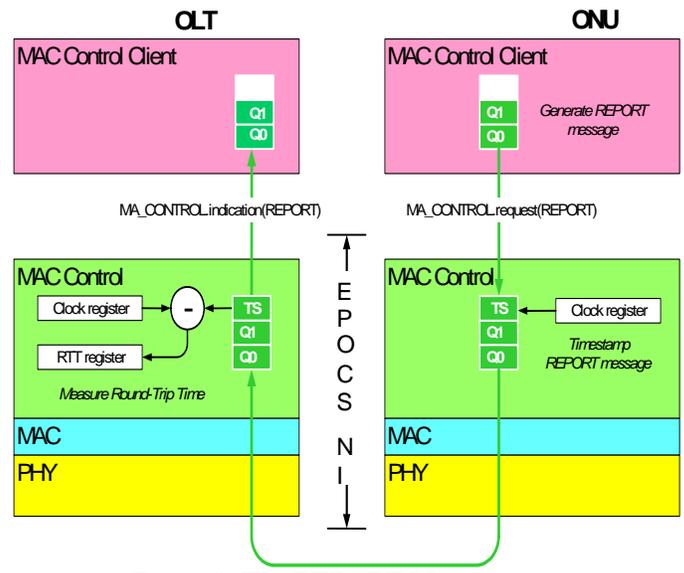


Figure 9: The REPORT Message

### EPON Upstream

Figure 8 outlines the upstream control; the MPCP uses time slots containing multiple 802.3 frames, where each ONU sends a 64-byte REPORT message, with ONU state information to the OLT. There are no collisions and no packet fragmentation in this architecture.

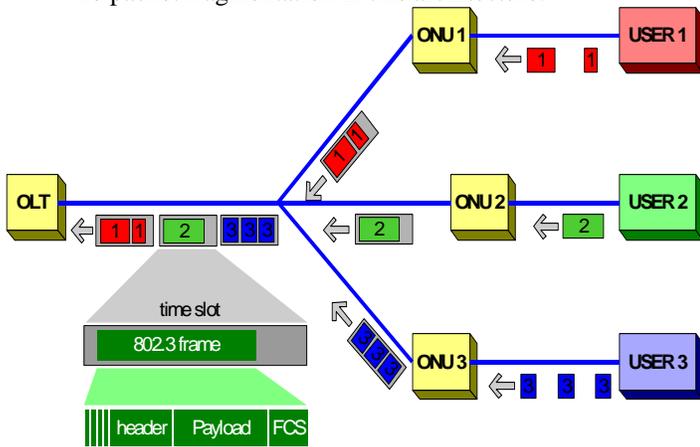


Figure 8: EPON Upstream Control

Figure 9 describes the REPORT message.

### Round Trip Time Measurement

The calculation of round trip time is as follows:

1. OLT sends GATE at T1
2. ONU receives GATE at T1
3. ONU sends REPORT at T2
4. OLT receives REPORT at T3
5. OLT calculates RTT = T3 - T2

The following figure illustrates this.

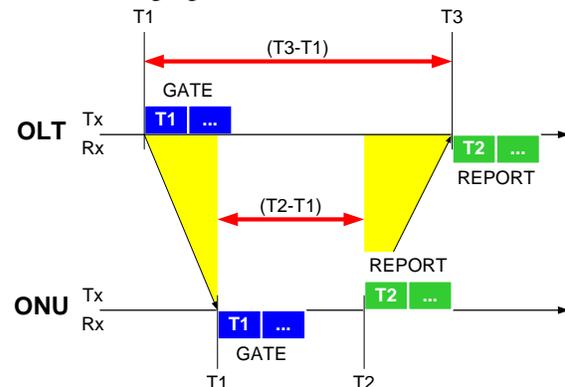


Figure 10: Calculation of Round Trip Time Measurement

The bottom line is that:

$$RTT = (T3 - T1) - (T2 - T1) = T3 - T2$$

## EPON Standards within P802.3ah Objectives

To see where EPON fits among MEF standards, consider the following table, which lists all of the P802.3ah objectives by technology.

| Subscriber Access Technology                | Physical Layer Specifications  |
|---|--|
| Point to point on optical fiber (EFMF)      | 1000BASE-LX extended temperature range optics<br>1000BASE-X $\geq$ 10km over single SM fiber<br>100BASE-X $\geq$ 10km over SM fiber  |
| Point to multipoint on optical fiber (EPON) | PHY for PON, $\geq$ 10km, 1000Mbps, single SM fiber, $\geq$ 1:16<br>PHY for PON, $\geq$ 20km, 1000Mbps, single SM fiber, $\geq$ 1:16 |
| Point to point on copper                    | PHY for single pair non-loaded voice grade copper, distance $\geq$ 750m and speed $\geq$ 10Mbps full duplex                          |

**Table 1: P8023ah Objectives**

## Summary

EPON is suitable for Fiber-to-the-Home/Building/Business applications, including voice, data and video services.

EPON is one type of fiber-based Ethernet access, using a passive optical 1:N infrastructure. An EPON network is a shared network, analogous to hybrid-fiber-coax networks, but with much greater bandwidth (1 Gbps).

EPON systems are a highly attractive access solution because of cost and performance advantage, resulting from their nature as all-passive networks, point-to-multipoint architecture, and native Ethernet protocol.

# Appendix

## Terminology

| Term             | Definition  |
|------------------|---|
| CWDM             | Coarse Wave Division Multiplexing   |
| Ethernet         | A packet-based protocol that is used universally in local area networks and strong candidate for cost efficient deployment in access and metropolitan networks.   |
| EFMC             | Ethernet in First Mile topology for voice-grade copper.   |
| EFMF             | Ethernet in First Mile using Point-to-Point Fiber topology  |
| EFMP             | Etehrnet in First Mile using Point-to-Multipoint topology, based on Passive Optical Networks (PONs).  |
| EFMA             | Ethernet in First Mile Alliance. An alliance of companies whose goal is to focus the necessary resources to make IEEE 802.3ah a successful industry standard. In 2004, the EFMA became part of the Metro Ethernet Forum |
| FTTB             | Fiber to the building   |
| FTTC             | Fiber to the curb   |
| FTTH             | Fiber to the home   |
| First Mile       | Also called the last mile, the subscriber access network or the local loop, the first mile is the communications infrastructure of the business park or the neighborhood.   |
| IEEE             | Institute of Electrical and Electronics Engineers. A standards setting body responsible for many telecom and computing standards, including the Ethernet in the First Mile standard, IEEE 802.3ah.                      |
| MDU              | Multi-dwelling unit, such as an apartment house or hotel.   |
| MTU              | Multi-tenant units, such as an apartment house or office building.  |
| OAM              | The specification for managing EFM.   |
| Network operator | Also called service providers and local exchange carriers, they provide access network services to subscribers.   |
| PON              | Passive Optical Network. A single, shared optical fiber that has inexpensive optical splitters located near the subscribers.  |
| PMD              | Physical Media Dependent sub-layer  |
| PHY              | Physical Layer  |
| PSTN             | Public Switched Telephone Network.  |

## References and Resources

| Reference              | Description  |
|------------------------|--|
| IEEE 802.3-2002        | “CSMA/CD Access Method and Physical Layer Specifications”, <a href="http://standards.ieee.org/reading/ieee/std/lanman/restricted/802.3-2002.pdf">http://standards.ieee.org/reading/ieee/std/lanman/restricted/802.3-2002.pdf</a> |
| IEEE 802.1Q            | “Virtual Bridged Local Area Networks”, <a href="http://standards.ieee.org/reading/ieee/std/lanman/802.1Q-1998.pdf">http://standards.ieee.org/reading/ieee/std/lanman/802.1Q-1998.pdf</a>   |
| MEF 10                 | MEF Technical Specification “Ethernet Service Attributes, Phase 1”, <a href="http://www.metroethernetforum.org/PDFs/standards/MEF10.pdf">http://www.metroethernetforum.org/PDFs/standards/MEF10.pdf</a>                          |
| MEN Technical Overview | “Metro Ethernet Networks – A Technical Overview”, <a href="http://www.metroethernetforum.org/PDFs/WhitePapers/metro-ethernet-networks.pdf">http://www.metroethernetforum.org/PDFs/WhitePapers/metro-ethernet-networks.pdf</a>    |

## Disclaimer

This paper reflects ongoing work within the MEF captured in a series of technical specifications which are a work in progress. The official MEF specifications are available at [www.metroethernetforum.com/techspec](http://www.metroethernetforum.com/techspec). These represent a 75% member majority consensus as voted by members of the MEF Technical Committee at the time of their adoption.

This paper will be updated as new work emerges from the MEF Technical Committee. Updates versions are available at <http://www.metroethernetforum.org>

## About the Metro Ethernet Forum

The Metro Ethernet Forum (MEF) is a non-profit organization dedicated to accelerating the adoption of optical Ethernet as the technology of choice in metro networks worldwide.

The Forum is comprised of leading service providers, major incumbent local exchange carriers, top network equipment vendors and other prominent networking companies that share an interest in metro Ethernet. As of December 2005, the MEF had over 70 members