Ethernet in the First Mile over Point-to-Point Fiber – A Tutorial

Overview

Ethernet, which has been with us since 1980, has been the dominant enterprise LAN protocol for the last decade. Several popular Ethernet standards, including 10BASE-T and 100BASE-T for copper, and 1000BASE-T and 1000BASE-LX for fiber, have enabled deployment to grow to roughly half a billion ports worldwide.

In the last few years, Ethernet has been called upon to solve the bandwidth bottleneck in aggregation networks and is the technology best suited to provide access to customers—the so called first mile of broadband access. It is now poised to be the single technology to deliver universal broadband access for high-end user applications, and enable a true end-to-end, seamless technology for communications.

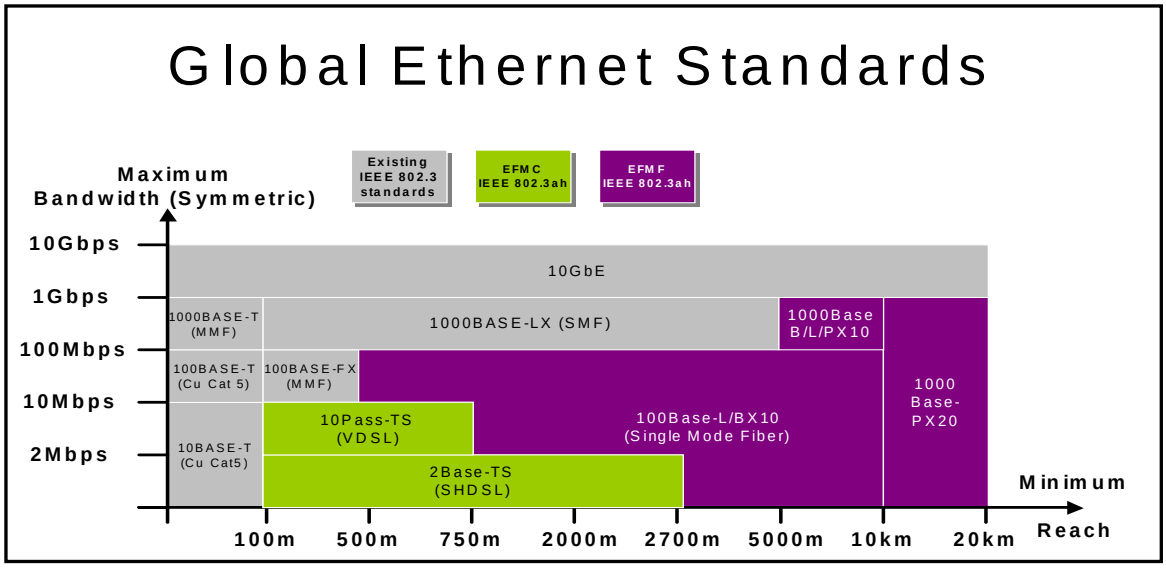
New standards are being developed by the EFM task force of the IEEE (P802.3ah) to make this happen. The EFM over Fiber (EFMF) is aimed at the physical layer for point-to-point fiber with Ethernet at speeds of 100 Mbps and 1 Gbps, and spanning lengths of at least 10 km over single-mode fiber. This will allow a broad range of applications.

The following chart shows global Ethernet standards for all the main physical media in use today, as well as the new ones for copper and fiber to support Ethernet in the First Mile. [1]

Based on the existing 802.3 fiber optic standards, the EFMF adds support for both single fiber and dual fiber, as well as support for an extended temperature range, from –40 to +85 degrees C—making it suitable for outside deployments that need to withstand a variety of environmental conditions.

As Figure 1 and 2 show, the 100 Mbps option is targeted at residential or small office access. This option is likely to see success because of its inherent lower cost (in terms of processor speed, memory and buffers). Tis will allow an easier way into the market for cautious operators, whereas the gigabit Ethernet options will be more appropriate to small and medium enterprises

[1] For tutorials on Ethernet in the First Mile over Copper (EFMC) and Ethernet in the First Mile over Passive Optical Networks (EPON), see the relevant links on the Metro Ethernet Forum web site (www.metroethernetforum.org)



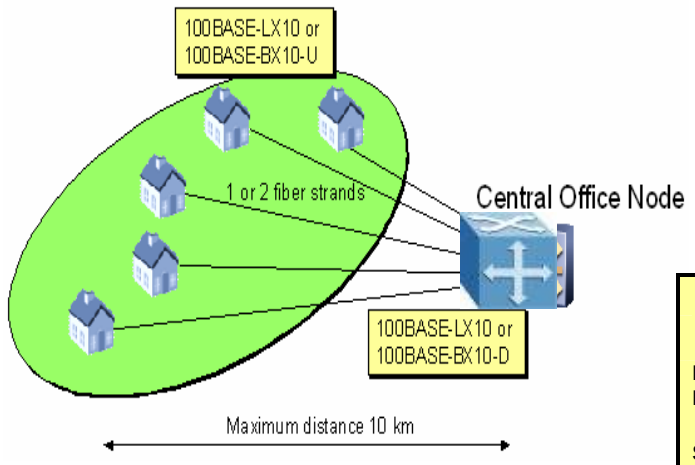


Figure 1: Home or Small Office Application

For small and medium enterprises as well as residential access in multi-tenant units, there will likely be an aggregation link between the access or aggregation node and the CO

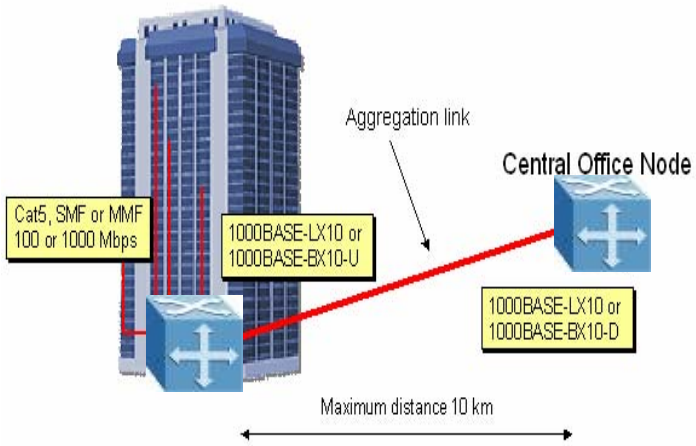


Figure 2: Small/Medium Enterprise or multi-residential access, P2P GbE Aggregation

Within the building, the network would reach the desktop or the individual subscriber on each floor with either Cat 5 cable or other copper cabling.

Physical Media Dependent (PMD) Sublayer

Table 1 shows where EFMF fits in terms of the existing fast Ethernet and gigabit Ethernet standards.

	100 Mbps SMF	1000Mbps SMF
Dual Fiber	1000BASE-LX10, 10km	1000BASE-LX, 5km 1000BASE-LX10, 10km, extended temp
Single Fiber	100BASE-BX10-D, 10km 100BASE-BX 10-U, 10km	1000BASE-BX10-D, 10km 1000BASE10-U, 10km

Table 1: Standards State for EFM Fiber

Essentially, EFMF completes the dual fiber standards suite. EFMF also adds a new set of standards to the 802.3 standards suite by introducing support for a lone single-mode fiber. Most importantly, for a subscriber access technology, EFMF allows extended temperature and reach capabilities for both fast and gigabit Ethernet.

EFMF supports symmetrical, high bandwidth and full duplex point-to-point links. Both the 100 Mbps options and the GbE option are implemented through single-mode fiber. These options are implemented by multiplexing the laser signal into different wavelengths. A 10 km span will be supported with standard single-mode fiber.

There are high-volume MAC chip-sets available for both the 100 Mbps and the 1 Gbps options, and early EFMF rollouts will take advantage of this.

EFMF implements a new Physical Media Dependent (PMD) layer as shown in Figure 3. The PMD specifies the quality and type of hardware needed including cables, connectors, transmitters, receivers, and optical bypass devices.

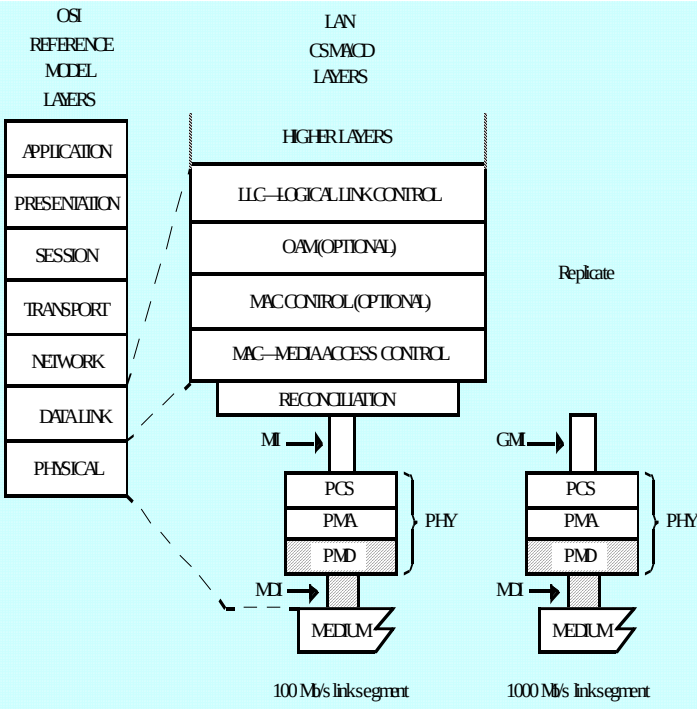


Figure 3: The PMD Sublayer of the PHY

Features of the PMD are discussed in the following table.

Fast Ethernet	Gigabit Ethernet
100BASE-LX10	1000BASE-LX10
Dual fiber	Dual fiber
Extended temperature and reach	Extended temperature and reach
100BASE-BX10-D/U	1000BASE-BX10-D/U
Single single-mode fiber	Single single-mode fiber
Downstream and Upstream Wavelengths	Downstream and Upstream wavelengths
Extended temperature	Extended temperature

Table 2: PMD Features for EFMF

The dual fiber options transmit in the send and receive directions on separate fibers; the single fiber options have a multiplexer to split the send and receive signals into two wavelengths and consolidate fiber usage accordingly.

Dual Fiber Standards

The dual fiber options are 100BASE-LX10 and 1000BASE-LX10. These standards use separate fibers for sending and receiving Ethernet frames.

100BASE-LX10

The 100BASE-LX10 support is for single-mode, dual fiber connections at a signaling speed of 125 Mbd. 100BASE-LX10 has a reach of over 10 km. The optical output power of the laser (Pout) is –15 dBm with a sensitivity of –25dBm. 100BASE-LX10 uses 4B/5B NRZI encoding.

The wavelength plan makes it possible to use existing STM-1/OC-3 optical TRx. The encoding scheme makes it possible to use existing 100BASE-X chip-sets.

1000BASE-LX10

The gigabit option (1000BASE-LX10) supports a signaling speed of 1250 Mbd, operating on single mode, dual fiber at lengths of greater than 10 km. The optical power (Pout) is –9.5 dBm with a sensitivity of –20 dBm. The transmit wavelength 1260-1360 nm.

Gigabit EFMF can also be run on multimode dual fibers, at a span of greater than 550 meters. The Pout for this option is -11 dBm with a sensitivity of –20 dBm. The transmit wavelength is 1310 nm.

8B/10B encoding is used, to leverage on existing GbE standards. 1000BASE-LX10 standardizes the vast amount of pre-standard GbE TRx deployed today.

Figure 4 illustrates the dual fiber support for GbE EFMF.

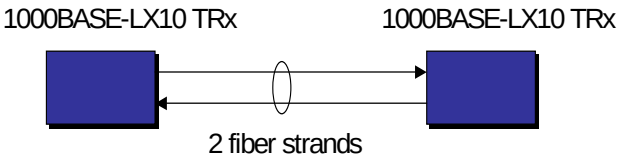


Figure 4: Dual Fiber Option for Gigabit EFMF

Single Fiber Standards

The single fiber options, described in the following sections, depend on the use of a special multiplexer (Figure 5) placed in front of the laser. The signal is split into transmit and receive wavelengths.

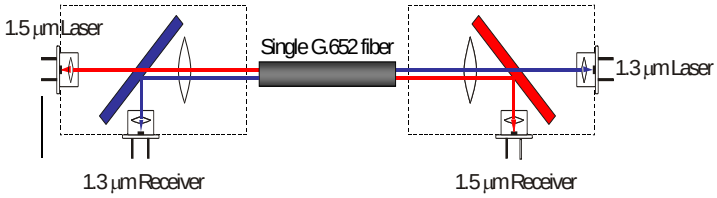


Figure 5: A two-wavelength device (one possible solution).

The laser and receiver are in the same package where the optical light path is split into a second and third window by the WDM filter. This filter has a typical insertion loss less than one decibel.

100BASE-BX10

100BASE-BX10 supports single-mode, single fiber and a signaling speed of 125 Mbd. It also supports greater than a 10 km span. The optical output is -14 dBm with a sensitivity of -29.2 dBm.

The single fiber support is made possible because the uplink TRx and downlink TRx are transmitting on different wavelengths:

- Downlink at 1480 – 1580 nm
- Uplink at 1260 – 1360 nm

The downlink PMD is called 100BASE-BX10-D and would typically be located in the central office or similar POP presence, whereas the uplink 100BASE-BX10-U PMD is typically located at subscriber premises.

This new PMD for single fiber access is illustrated in Figure 6.

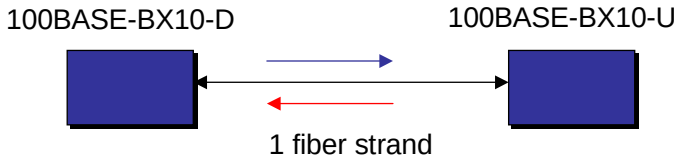


Figure 6: PMD for Single Fiber 100Mb/s EFMF

Since the send and receive directions are on different wavelengths, only a single fiber is needed.

1000BASE-BX10

The 1000BASE-BX10 specification provides single-mode, single fiber support at a signaling speed of 1250 Mbd for a span of greater than 10 km. The Pout is -9 dBm with a sensitivity of -20 dBm.

The uplink 1000BASE-BX10-U TRx and downlink 1000BASE-BX10-D are transmitting on different wavelengths as such:

- Downlink at 1480 – 1500 nm
- Uplink at 1260 – 1360 nm

Again, the D-option (downlink) would be located in the central office or similar point of presence, whereas the U-option (uplink) is located at subscriber premises.

The PMD for single fiber GbE is illustrated in Figure 7

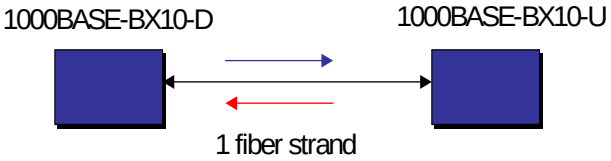


Figure 7: PMD for Single Fiber Gigabit EFMF

As with the fast Ethernet option, only a single fiber is needed when you multiplex the transmit and receive directions into different wavelengths.

Wavelength Overlays

Figure 8 illustrates the wavelength overlays for the EFM PMDs along with the Coarse Wavelength Division Multiplexing (CWDM) grid

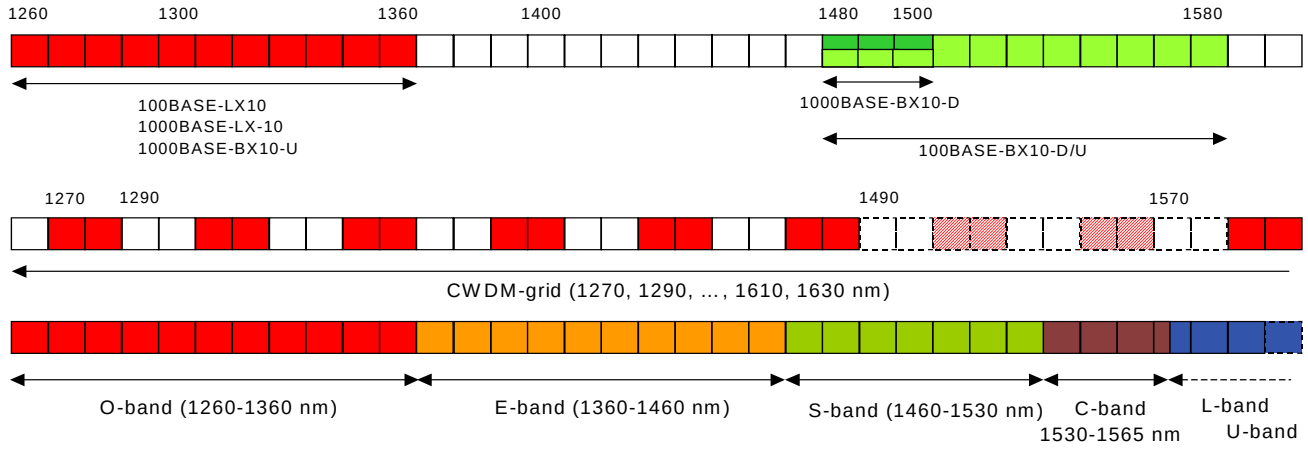


Figure 8:Wavelength Overlays and their relation to EFMF

Conclusion

The EFM point-to-point technologies are very close to existing Ethernet. The EFMF topology provides cost-effective opportunities for replacing expensive T1 and T3 links, and can also be used for fiber to the home (FTTH) applications.

This effort is also expected to lead to reduced usage of multimode fiber; at some point, single-mode fiber should be able to replace multimode fiber and allow operators to build a complete network based on this much longer-reach option.

EFMF is a proven concept; in its pre-standard form, it is already deployed today. Typical applications are fiber to the home (FTTH), fiber to the building and curb (FTTB/C), point-to-point end-to-end support for business access, and point-to-point aggregation.

Appendix

Terminology

Term	Definition
Access Node	The network side of the first mile where an operator's access equipment is located. Options exist to deploy the Access Node in a Central Office (Telephony Local Exchange) or remotely at the curbside or in a building.
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", http://standards.ieee.org/reading/ieee/std/lanman/restricted/802.3-2002.pdf
IEEE 802.1Q	"Virtual Bridged Local Area Networks", http://standards.ieee.org/reading/ieee/std/lanman/802.1Q-1998.pdf
MEF 10	MEF Technical Specification "Ethernet Service Attributes, Phase 1", http://www.metroethernetforum.org/PDFs/Standards/MEF10.pdf
MEN Technical Overview	" Metro Ethernet Networks – A Technical Overview", http://www.metroethernetforum.org/PDFs/WhitePapers/metro-ethernet-networks.pdf

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. 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
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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