

# Next-Generation 50 $\mu\text{m}$ Fiber Enhances 10 Gigabit Ethernet Performance

## White Paper



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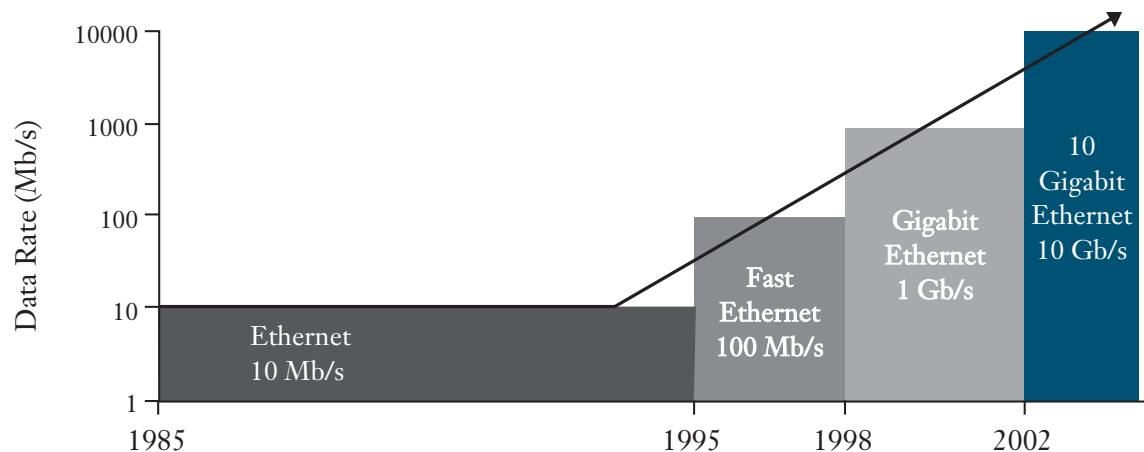
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### Evolution of Ethernet

Ethernet has withstood the test of time in the enterprise segment and has emerged stronger than ever (Figure 1). Ethernet was first invented in Xerox's Palo Alto Research center in 1973 to interconnect the lab's early personal computers. It was primarily designed as a low-cost but high-speed (10 Mb/s!) solution to ensure compatibility and provide equal access to all the nodes connected to the network. The success of the protocol led Xerox to join with DEC and Intel to form the DIX 10 Mb/s Ethernet standards, which formed the basis for IEEE 802.3, standardized in 1985.

### Evolution of Ethernet

Figure 1



As more and more LANs became 10 Mb/s capable, newer installations required higher bandwidth capability. This need for higher bandwidth led IEEE to begin development of Fast Ethernet (IEEE 802.3u), which became the industry standard in 1995. Fast Ethernet increased the data rates by a factor of 10 to 100 Mb/s by using different coding schemes such as 4B/5B or 8B/6T (as opposed to Manchester encoding used by Ethernet) and higher clock speeds. The commonly used source of optical transmission at this time was the low cost but highly inefficient LEDs. The maximum data rate achievable from an LED is only 622 Mb/s.

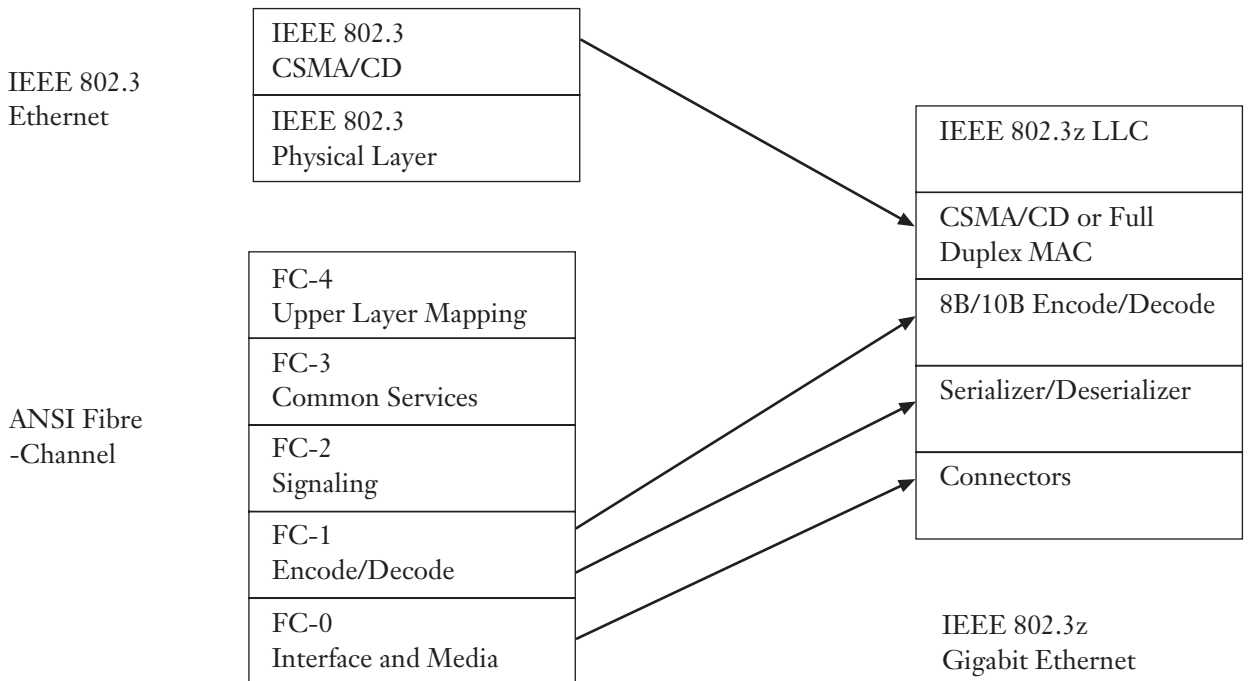
Unlike LEDs, lasers have a more concentrated power distribution, which reduces the loss in the system and allows for higher data rates to be transmitted. Around 1996, the market saw the commercialization of low cost Vertical Cavity Surface Emitting Lasers (VCSELs) that were capable of being directly modulated up to 1 Gb/s. The VCSELs offered both technical and manufacturing advantages. In manufacturing, VCSELs lend themselves to mass production as they can be tested in wafer state before any kind of packaging is done. Technically, the circular output of VCSELs also enables better coupling with fiber than the edge emitting lasers, which have an elliptical output.

The Gigabit Ethernet standard (IEEE 802.3z), ratified in 1998, was a technological response by the standards organization to enable the higher bandwidth (1000 Mb/s) now made available through VCSELs. The quick turnaround time in standardizing the Gigabit Ethernet was enabled by combining the high-speed capability of already existing Fibre Channel (an interconnection technology for connecting workstations, storage devices and peripherals) and Ethernet.

The Open System Interconnection (OSI) model is a seven-layer model, which describes the communication process between two systems. The actual transmitting medium is the lowest layer, and the topmost layer is the application layer, which deals with the various protocols for the user to interact with the system. The Gigabit Ethernet combines the two layers, the interface and the 8B/10B encoding scheme from Fibre Channel and the collision detection mechanism of Ethernet, therefore providing backward compatibility with Ethernet and Fast Ethernet (Figure 2).

### IEEE 802.3z Gigabit

Figure 2



Not surprisingly, the thirst for bandwidth is unquenchable, and with the rapid development in 10 Gb/s VCSEL technology, IEEE commissioned the 802.3ae working group in March 2000 with the task of completing a 10 Gigabit Ethernet standard by June 2002.

## 10 Gigabit Ethernet

Besides increasing the data rate, the 10 Gigabit Ethernet standard was also proposed to expand Ethernet to include the Wide Area Network (WAN) application space. This is significant in that it marks the transition of Ethernet from a purely Local Area Network (LAN) technology into a major player in the Metropolitan Area Network (MAN), WAN and access application space, therefore acting as a single cost-effective solution to bridge these spaces.

Unlike its predecessors, 10 Gigabit Ethernet is a full-duplex only and optical-media only technology. The half-duplex operation of the 10, 100 and 1000 Mb/s Ethernet is a means to avoid collision of data transmitted by different stations or nodes. Carrier Sense Multiple Access/Collision Detection (CSMA/CD) protocol is used to reduce collisions that occur in the network. When a station attempts to transmit data, it checks to see if any other station is transmitting (carrier sense), when there is no transmission the station begins to transmit its data. This process provides equal access for all the stations to transmit data when no signal is sensed on the network (multiple access). Two stations transmitting data at the same time result in a collision, and once a collision is detected by the transmitting station, it waits for a random period of time before retransmission. This process of collision detection is inefficient, as there is a higher chance of collision when the number of stations on the network increases.

CSMA/CD protocol is a half-duplex operation as only one station can transmit at any given time. This reduces the data-carrying capacity of the network by almost half versus a full-duplex system, which permits two stations to transmit and receive data at the same time. In a copper transmission medium, full-duplex operation is not possible and is achieved by using separate lines for transmit and receive. The physical medium of 10 Mb/s Ethernet is coax, Unshielded Twisted Pair (UTP) and fiber; Fast Ethernet uses CAT3, UTP and fiber and the physical media used by Gigabit Ethernet are CAT5 and fiber. Copper is distance limited at high data rates of 10 Gb/s and was not considered a viable solution. Being a fiber-only solution helped the 10 Gigabit Ethernet standards to eliminate the half-duplex operation and significantly improve the speed of operation.

The IEEE 802.3ae draft standards identified four different Physical Media Dependents (PMDs) to achieve various link distances on both single and multimode fiber:

- 1310 nm Wide Wavelength Division Multiplexing (WWDM) PMD, and
- The 850 nm, 1310 nm and 1550 serial PMD.

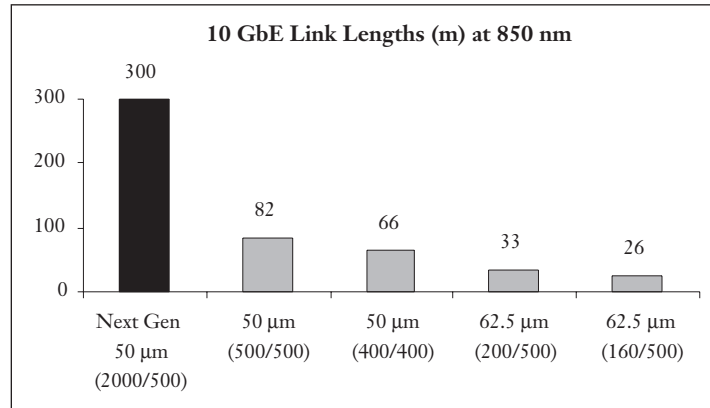
The LAN and the WAN Physical Layers (PHY) operate based on the above mentioned PMDs. The WAN PHY essentially differs from the LAN PHY by providing compatibility with existing WAN networks that use Synchronous Optical Networks (SONET)/Synchronous Digital Hierarchy (SDH).

While the single-mode fiber solutions are geared for regional and long-haul applications with distances ranging from 2-10 km at 1310 nm and up to 40 kms at 1550 nm, the multimode fiber solution provides the premises networks with a quick and easy upgrade path to 10 Gb/s for distances up to 300 m.

The various 10GBASE serial 850 nm LAN PHY solutions, along with the fiber bandwidth and their length requirements, are identified in Figure 3. The 850 nm 10 Gb/s serial solution, utilizing the optimal bandwidth performance in the 850 nm window, will be discussed further in the following section as the primary choice for premises backbone and riser applications for its performance as well as its economic value.

## 10 GbE Link Lengths at 850 nm

Figure 3:



## 10 Gb/s Multimode Fiber for Premises Networks

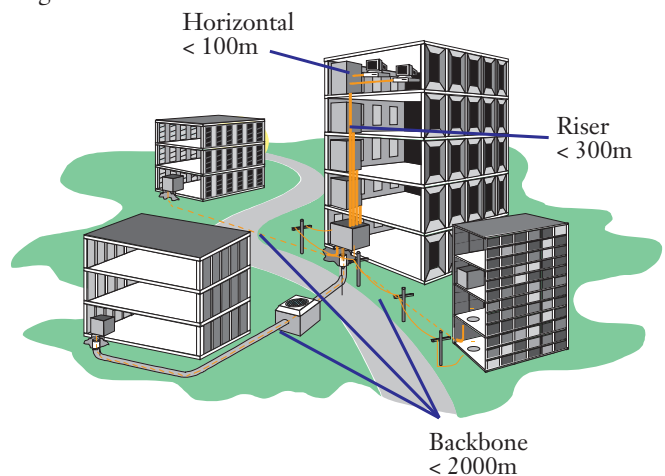
The 10 Gb/s serial solution using the next generation 50 μm multimode fiber (MMF) is ideally the best solution for new builds in a premises network. A premises or enterprise network is an interconnection of LANs and typically consists of three segments as shown in Figure 4. In figure 4, the physical medium connecting the two buildings is known as the 'backbone'. The 'riser' connects the cables across the different levels in the building, and the 'horizontal' connects the various systems/computers on the same level and is typically less than 100 m.

With the increase in bandwidth consuming applications such as multimedia, streaming audio/video and peer-to-peer networking, the 'riser' sees a higher aggregation of data. Next-generation MMF provides much needed capacity in terms of bandwidth and performance. This PMD is on par with single-mode fiber, only at a significantly lower cost since it makes use of inexpensive 10 Gb/s Vertical Cavity Surface Emitting Laser (VCSEL) sources and lower installation costs. The 850 nm electronics, besides being *2-3 times* less expensive than the single-mode electronics, also lower costs due to lower power consumption and less stringent maintenance requirements.

The increased performance in next-generation MMF is guaranteed by an Effective Modal Bandwidth (EMB) of 2000 MHz·km. EMB is the actual system bandwidth that is obtained from the fiber and laser interaction. Fiber performance is measured using FOTP 220, which uses Differential Modal Delay (DMD) measurement methodologies to indicate 2000 EMB. In a multimode fiber, the different modes travel at different speeds and the delay between subsequent modes is defined as DMD.

### A Premises Network

Figure 4:



## Corning® InfiniCor® SX+ Fiber

Corning introduced the InfiniCor® family of multimode fibers in 1998. InfiniCor fiber is the first *laser-optimized fiber*<sup>™</sup> designed for high-bandwidth laser-based performance. InfiniCor® SX+ fiber is a 50 µm next-generation multimode fiber. It is optimized for 850 nm performance, and is guaranteed for 2000 MHz·km EMB, as measured by DMD measurement method. In standards-compliant links, EMB enables the fiber to transmit data at 300 m at 10 Gb/s in the 850 nm window, while maintaining compatibility with legacy LAN systems. InfiniCor SX+ fiber provides single-mode speeds with multimode economics, which empowers premises networks to conquer the high bandwidth requirements of today while allowing an easy upgrade path for future network requirements.

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