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Is Your Network Ready for 100G?

Next-generation requirements and solutions for the data center.

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It wasn't so long ago that network managers were wondering if 10 gigabit Ethernet transmission would have any practical application in enterprise networks. Yet today, 10 gigabits per second (Gb/s) is installed in many data centers, enterprise local area networks (LANs) and central offices around the country. Still our insatiable appetite for bandwidth continues to grow; so much so that the industry is developing standards for speeds up to 100 Gb/s. This article examines the requirements of 100 Gb/s applications and the optical fiber-based solutions that address those needs.

It's clear that the initial enterprise market for 40 and 100 gigabit Ethernet will be in data centers. Enterprise LAN speeds are expected to maintain 1 to10 Gb/s links to the workstation, with 10 Gb/s speeds in the backbone. However, increasing processor speed and server utilization in the data center are driving a need for 40 Gb/s server links to the access switch. In turn, these high-speed server links create a need for 100 Gb/s uplinks from the access switch to the distribution and core switches in the data center.

Standards Now Under Development

Optical fiber has become the medium of choice to connect data center and storage area network (SAN) equipment. The IEEE 10 gigabit Ethernet standard (IEEE 802.3ae) issued in 2002 defined multimode and singlemode optical fiber transceiver links that support various link distances. The IEEE802.3ba task force is currently working to define similar links for 40 and 100 gigabit Ethernet and expects to complete the task in 2010.

Different application spaces will benefit from different transmission speeds. For this reason, the IEEE 802.3ba task force is currently working to develop the 40G and 100G standards simultaneously. 40 Gb/s will support an immediate need in the server market, while 100 Gb/s speeds are needed for core switching and routing applications, network aggregation and high performance computing. As in the past, the IEEE task force will leverage existing media and technology to balance cost and performance.

10, 40, & 100 Gb/s Tansceiver Designation	Wavelength Source	62.5 um (OM1)	50 um (OM2)	LO 50 um (OM3)	LO 50 um (OM4)	SM (SM1)
10G Base-SR (10 Gb/s)	850nm Serial VCSEL	33	82	300	550	NA
40G Base-SR4 (draft) (40 Gb/s)	Parallel VCSEL Array	NA	NA	100	125	NA
100G Base-SR4 (draft) (100 Gb/s)	Parallel VCSEL Array	NA	NA	100	125	NA
100G Base-LR4 (draft) (100 Gb/s)	1300nm CWDM	NA	NA	NA	NA	10,000
100G Base-ER4 (draft) (100 Gb/s)	1300nm CWDM	NA	NA	NA	NA	40,000

Table 1: Ethernet PMD Interfaces and Link Distances by Fiber Type

IEEE 802.3ba has set different reach objectives (link distances) for singlemode and multimode optical fiber. Multimode optical fiber will support both 40 and 100 Gb/s speeds over link lengths up to 125 meters (m [410 feet (ft)]). Singlemode fiber will support 100 Gb/s link lengths of 10 and 40 kilometers (km [6.2 and 25 miles (mi)]) and a 40 Gb/s link length of 10 km (25 mi).

Singlemode applications use coarse wavelength division multiplexing (CWDM) to support these longer link distances. However, singlemode optoelectronics remain significantly more expensive than those used with multimode optical fiber due to the much higher level of complexity and the tighter tolerance associated with singlemode optical fiber. Therefore, singlemode links will be limited to use in longer campus applications, metropolitan area backbone networks and a small percentage of extremely long data center links.

For short-reach applications on multimode optical fiber, the 802.3ba task force has defined a physical medium dependent (PMD) solution involving already-proven parallel optics technology. This will help preserve the low-cost advantage of today's vertical cavity surface emitting laser (VCSEL) light sources. These parallel systems will transmit one 10 Gb/s signal on each of 4 or 10 fibers (for 40G and 100G, respectively). Each 10 Gb/s signal will be aggregated in an arrayed transceiver containing 4 or 10 VCSELs and detectors. These short-reach links are typically found in data centers and some high-speed LAN applications.

Bandwidth, Reach and Cost Demands Determine Optical Fiber Choice

Multimode optical fiber is the conventional choice for supporting short distance, high bandwidth links in central offices, LANs and data centers. The main advantage of a multimode optical fiber system is its much lower cost when compared to a single-mode system.

The Telecommunications Industry Association (TIA) and International Electrotechnical Commission (IEC) are in the process of completing the new OM4 multimode optical fiber standard, which will support longer link distances for 10, 40 and 100 Gb/s networks than existing OM3 multimode optical fiber. OM3 and OM4 multimode optical fibers have been specifically designed and manufactured for VCSEL transmission, and are the best choice to support today and tomorrow's high speed multi-gigabit networks. Yesterday's OM1 and OM2 grade optical fibers, which were designed for use with lower speed LED-based systems, will not support new 40 and 100 gigabit Ethernet networks.

OM3 optical fiber has an effective modal bandwidth (EMB) of 2000 MHz-km, while OM4 optical fiber will have an EMB of 4700 MHz-km. EMB is determined using either the differential mode delay (DMD) mask method or the EMB calculated (EMBc) method. Recent system testing results have shown that the DMD mask method is a more stringent method of measuring optical fiber, and that EMBc can sometimes pass optical fibers that do not meet systems requirements. Overfilled bandwidth (OFL) assists in screening out these optical fibers. OM3 and OM4 optical fibers can also support 1 Gb/s operation, and their 50 micron core size couples sufficient power from LED sources to support legacy applications like Ethernet, token ring, FDDI and fast Ethernet for virtually all in-building networks and most campus networks.

For parallel transmission, a parameter called "delay skew" has been discussed within the task group. Delay skew is the difference in signal arrival time from one lane (or optical fiber) to the next. Although skew might appear to be a critical parameter in these transmission systems, it is easily compensated for within the transceiver circuitry.

The 802.3ba task force has ensured that proper skew compensation is included in the standard, and most industry recognized cable designs (e.g. loose tube, tight buffer and ribbon cable) and standard-compliant OM3 or OM4 optical fiber can be used.

Standard OM3 grade laser-optimized optical fiber can support 10 Gb/s transmission with low cost 850 nm serial transceivers at link lengths up to 300 m (984 ft), and will support 40 and 100 Gb/s transmission up to 100 m (328 ft). For slightly longer link distances (e.g. larger data centers, riser backbones and medium-length campus backbones) and more sensitive power budget applications (e.g. data center equipment interconnects), the preferred optical fiber option is OM4 multimode optical fiber, which can support 10 Gb/s applications to 550 m (1804 ft) and 100 Gb/s applications to 125 m (410 ft).

OM4 optical fiber cannot support 40 Gb/s or 100 Gb/s over the same link distances as 10 Gb/s (550 m [1804 ft]) because VCSEL specifications have been relaxed for the higher speed links. To minimize system cost, the IEEE 802.3ba task force decided to loosen the laser spectral width requirement. This significantly improved the overall system cost, but decreased the ability to support longer distances. The 100 m (328 ft) link distance supports approximately 85 percent of data center links (depending on their size and architecture), and the 125 m (410 ft) link distance supported by OM4 optical fiber covers almost 100 percent of the reach needed, even in large data centers.

The key to OM4 performance is a manufacturing process that produces a multimode optical fiber with almost no DMD and 4700 MHz-km of EMB—more than double the IEEE requirement for 10 Gb/s 300 m (984 ft) support. See Table 1 for a complete list of Ethernet PMD interfaces and the link distances supported by different optical fiber types.

Saving on Total Systems Costs

Data center administrators may initially suspect that a parallel multimode transmission system will cost significantly more than a serial singlemode system due to the cost of the cable. While the cabling for a multimode link will cost more than a serial singlemode link, this cost is dwarfed by the significantly higher electronics costs. Based on estimates provided by optoelectronic vendors, a presentation given during an IEEE 802.3ba task force meeting showed that costs for a 40 Gb/s link are estimated to be four times higher for a two-optical fiber singlemode system than a 12-optical fiber multimode system using parallel optics technology.

The comparison is even more dramatic for a 100 Gb/s system, with costs estimated to be more than 11 times higher for a two-optical fiber singlemode system compared to a 24-optical fiber multimode system. Based on these comparisons, it can be seen that higher cabling costs for a high performance multimode multi-optical fiber link are relatively insignificant when compared to the opportunities for total system savings.

Finally, to help ensure the highest network reliability and performance, designers are encouraged to look closely at the specifications of their cabling systems. Choosing specifications that exceed the standard can provide power budget headroom, which can prove useful in improving the reliability of the network and providing the ability to use higher-loss MT-style connectors, additional interconnects or connections. In particular, designers should choose very low cable attenuation, tight optical fiber geometry tolerances and optical fiber DMD that is measured and specified to the center of the core. Optical fiber specified using the DMD mask method is the most stringent method available to help ensure error-free network operation. ■

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