Super speeds on the horizon: What will skew do?

by Tony Irujo and David Mazzarese

The IEEE is working to weigh all factors affecting delay skew in 40- and 100-Gbits/sec transmission before a standard is finalized.

The IEEE 802.3ba Task Force is well underway in developing the next higher speed transmission rates for Ethernet network communications. On the heels of 10 Gigabit Ethernet, it is remarkable to think that within two years we'll be seeing network gear and cabling infrastructure capable of supporting 40 and 100 Gbits/sec (40G and 100G).

What are the drivers behind the need for more bandwidth and higher speeds? This article will address that question, as well provide an overview of the approach the IEEE 802.3ba Task Force is taking to develop the standards. With a focus primarily on enterprise or premises applications, such as data centers that utilize mostly multimode fiber, we will also discuss the technical issue of delay skew and whether it will impact high-speed cable.

Super-speed factors

Higher network speeds are required because of the explosion in bandwidth demand and consequent need for high-capacity, high-performance computing. But specifically, here are the major factors that are driving this demand:

- Bandwidth-intensive applications, such as video over the Internet (e.g., YouTube);
- Rapid advancement in R&D and super computer activities;
- Migration of LANs from 100 Mbits/sec to 1 Gbit/sec throughput to the desktop;
- Greater bandwidth demand in the data center, where all the information is aggregated and stored.

Specific application areas requiring either 40G or 100G are different, which is why the IEEE 802.3ba Task Force is developing standards for both speeds simultaneously. 40G will soon be needed in the server market, including server traffic aggregation and storage applications (SANs and NAS), which are seeing significant growth today in 10G connectivity. In fact, some high profile Internet companies and large financial firms are already struggling with the difficulties associated with aggregating multi-ple 10G links.

The need for 100G capability is expected in the not-too-distant-future for network aggregation, core networking applications (switching and routing), high-performance computing environments, and service provider and Internet exchange peering points.

To balance cost with performance, the 802.3ba Task Force will leverage existing technology, media, and network management practices that have already been proven. In fact, they may relax component performance specifications in some cases to help reduce overall cost. An example is the VCSEL light sources for shorter reach applications using multimode fiber. Proposals within 802.3ba aim to relax the spectral width of these sources from 0.45 nm (current 10-GbE requirement) to 0.65 nm. This limits the distance of such a link due to chromatic dispersion effects, even though the same performance grade of fiber (e.g., OM3 laser-optimized 50 μm) will continue to be specified.

As in previous Ethernet standards, 40G and 100G will define several different Physical Layer (PHY) implementations for transmitting information over various distances, and media types that will include multimode and singlemode fiber-optic cabling, as well as some form of copper cabling. Addition-ally, various transceiver types will be defined, distinguished by which media they are intended for and how far they transmit.

The adjacent table lists the currently proposed Physical Medium Dependent (PMD) devices that are being considered for adoption by the IEEE 802.3ba Task Force, along with the irmedia type and minimum expected reach.

PMD nomenclature	Media type	Wavelength window	Minimum reach objective
40GBase-LR4	Singlemode fiber (G.652/021)	1310 nm	10 kms
40GBase-SR4	Multimode fiber (OM3)	850 nm	100 m
40GBase-CR4	Copper cable		10 m
40GBase-	Backplane		1 m
100GBase-ER4	Singlemode fiber (G.652/021)	1310 nm	40 km
100GBase-LR4	Singlemode fiber (G.652/021)	1310 nm	10 km
100GBase-SR10	Multimode fiber (OM3)	850 nm	100 m
100GBase-CR10	Copper cable		10 m

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For the PMDs involving singlemode fiber, the Task Force is leaning towards using some form of Wavelength Division Multiplexing (WDM) technology, where multiple wavelengths are transmitted over a single fiber. For example, 40 Gbits/sec can be achieved by multiplexing (combining) four wavelengths that are each carrying 10 Gbits/sec. Similarly, 100 Gbits/sec can be obtained by combining four wavelengths operating at 25 Gbits/sec each.

There have been some proposals to use serial transmission for 40G (single wavelength over a single fiber), but this would require further development work and the consensus appears to be that it would be a more costly option.

Media and their reach

As shown in the table, for both 40G and 100G, the minimum reach objective for short-reach applications on multi mode fiber is 100 meters, requiring use of OM3 fiber. Studies have shown that 100 meters should be long enough for the majority of links in data centers; however, there are instances where longer reach is necessary. To address these, an ad hoc committee was formed within 802.3ba to study and propose the best way to support greater distances on multimode fiber. Upwards of 200 or more meters is being considered likely requiring use of an OM3+ (or OM4) extended-reach grade of laser-optimized fiber in combination with narrow spectral width VCSELs. The final decision will be a com-promise between cost and performance, and will be greatly dependent on how the physical layer is specified.

As an aside, both the Telecommunications Industry Association (TIA) and the International Electrotechnical Commission (IEC) are working to standardize an OM4 multimode fiber having significantly higher bandwidth than the minimum 2000 MHz•km effective modal bandwidth of OM3 fiber. The TIA and IEC will likely settle on a minimum4700 MHz•km effective modal bandwidth for OM4 fiber, which currently supports 550 meters at 10 Gbits/secover Ethernet. OM4 is expected to provide 150-metercapability for 16GFC (Fiber Channel), and something greater than 100 meters for 40G and 100G Ethernet.

To achieve 40 and 100 Gbits/sec transmission on OM3 multimode fiber, and continue taking advantage of current low-cost VCSEL technology, the IEEE task force is expected to agree on a PMD solution based on a parallel optics tech-nology that has already been proven in the marketplace (like that used for InfiniBand, for instance). This will entail simultaneous transmission of one 10 Gbits/sec signal on each of four or 10 fibers (for 40G and 100G, respectively). Each 10-Gbits/secsignal will be combined in an arrayed transceiver containing four of 10 VCSELs and detectors.

Aggregating these parallel signals may sound complex; however, from a user perspective, it is the same approach that has been used for years for copper-based systems. The array of VCSELs and the array of detectors will be built onto a single chip that will be connected to the optical fibers with one MPO connector. The MPO connector connects 12 optical fibers as a unit, simplifying the interconnection of both 40G and 100G parallel solutions proposed for multimode fiber. The result is that, for a given link, all detectors will be connected to all the transmitters with a single optical cable.

Using parallel optics with multimode fiber is less complex and, hence, less expensive than doing Wavelength Division Multiplexing (WDM—multiple wavelengths) over one singlemode fiber. Furthermore, the technology for VCSELarrays is already mature, while higher-speed WDM over singlemode is still being developed.

Weighing delay skew

The move from serial to parallel transmission will put new requirements on optical cables. For parallel transmission, a parameter known as delay skew comes into play and is being discussed within the IEEE 802.3ba task group. Delay skew can be defined as the difference in the time it takes the signals traveling down one "lane" (or fiber) compared to that in the other lanes. The transceiver needs to wait until all signals from each fiber are collected before combining them together and sending them on their way.

Delay skew can be affected by several factors, including:

- Differences in the lengths of each fiber within the cable;
- Differences in speed that the light signal travels down one fiber compared to other fibers in that cable;
- Any timing differences between the optical transmitters.

The fiber/cable-based properties (lengths and signal speed) are well understood. One conservative estimate of worst-case skew due to fiber strand length differences is 25 ps/m. On the fiberside, signal speed or propagation time is related to variations in a fiber's Group Refractive Index and Numerical Aperture (NA). Maximum skew due to extreme variations in these properties (within industry-standard fiber specs) is 16 ps/m. With additional smaller contributions from DMD, group delay, and possible stress affects, the total maximum amount of skew encountered is 45 ps/m.

Good control of fiber length differences in a cable requires a good cable manufacturing process. Ribbon cables have the potential to offer the best skew performance because the fibers are closely packaged side-by-side and have virtually the same length. But tight buffer and loose tube cable designs, which are much easier to handle and route through the building, should not be counted out by any means; most leading cable manufacturers can produce tight buffer and loose tube cables on par with the performance of ribbon cable.

Similarly, good control of fiber properties is necessary to minimize differences in signal propagation time that lead to delay skew. This control is made possible by a high-quality fiber manufacturing process, such as used for producing high-performance OM3 and OM4 multimode fibers.

Skew under control

Any delay skew from the factors discussed here will be compensated for in the transceiver circuitry. Techniques are already well established for copper twisted-pair cabling, and in other parallel optics applications, such as InfiniBand. The IEEE 802.3ba Task Force will ensure that all factors that affect delay skew are taken into account and that skew compensation will be accomplished in a cost-effective way.

Delay skew is an important parameter, but with adequate skew compensation built into the electronics, and with high-quality fiber and cabling, multimode systems are expected to be able to support 40G and 100G transmission well over 100+ meters and at substantial savings over more complex single-mode systems using WDM technology.

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