Will Your Fiber Optic Cable Plant Support Gigabit Ethernet?

GBE, as the name says, is Ethernet scaled up to gigabit speeds, providing a migration path from Ethernet at 10 MB/s to Fast Ethernet at 100 MB/s and then on to gigabit speeds for network backbones. Few users will use GBE to the desktop; it will be mainly a backbone network, and only that for “power users.”

Since the majority of network backbones now use multimode optical fiber, GBE migration using the installed cable plant is highly desirable. While standards are being developed for UTP cabling, GBE will stretch the limits of copper cable capability. In fact, it begins to push multimode fiber bandwidth limits.

GBE has a data rate of 1 gigabit per second (GB/s, a billion bits per second) and a baud rate of 1.250 GB/s including the data encoding. These speeds require laser transmitters, since LEDs run out of steam at a few hundred MB/s (millions of bits/second).

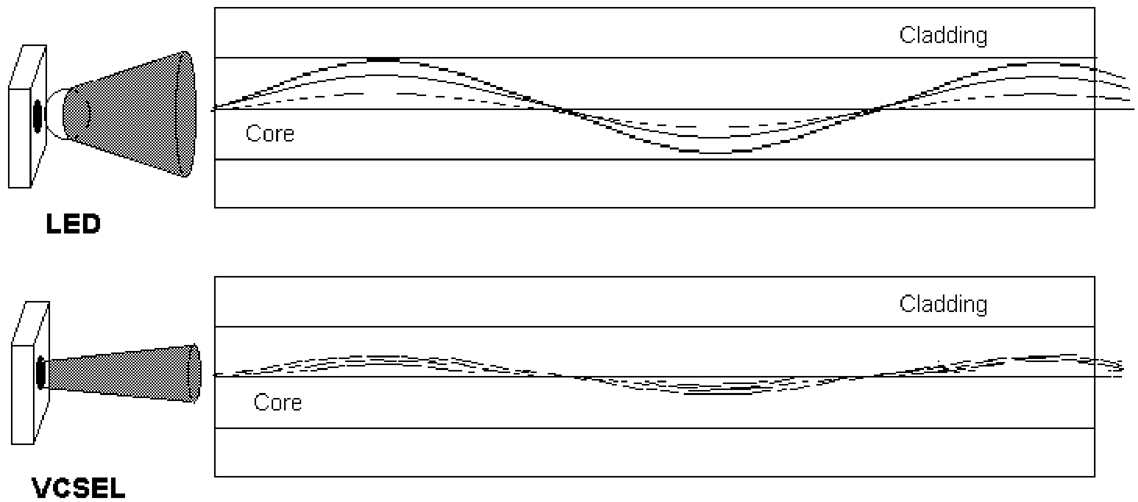
Two fiber optic standards are approved: 1000BASE-SX for short wavelength lasers over multimode fiber and 1000BASE-LX for long wavelength lasers over multimode or singlemode fiber. The short wavelength standard will typically be met with a 850 nm VCSEL (vertical cavity surface emitting laser), a new type of device that offers high performance and very low cost. A CD laser may also be used. Long wavelength lasers will be standard 1300 nm singlemode transmitters.

Fiber Does NOT Have Infinite Bandwidth

But the desire to run GBE over installed multimode fiber cable plants in premises applications, not singlemode fiber like the telco and CATV networks, creates a problem. Multimode fiber works well with LEDs, but somewhat unpredictably with coherent laser sources. Coherent sources emit light in phase, and interaction of various modes in multimode fiber can create modal noise, causing bit error rate problems.

Furthermore, LEDs have a wide angle of light output which must be focused into the fiber, while lasers have a much narrower beam that is more easily coupled to the fiber. The LED will fill the higher order modes in the fiber (higher modes = wider angles), lasers will concentrate the light in the center of the fiber, especially the long wavelength lasers with singlemode pigtails.

Mode Fill Variations by LED and VCSEL Sources

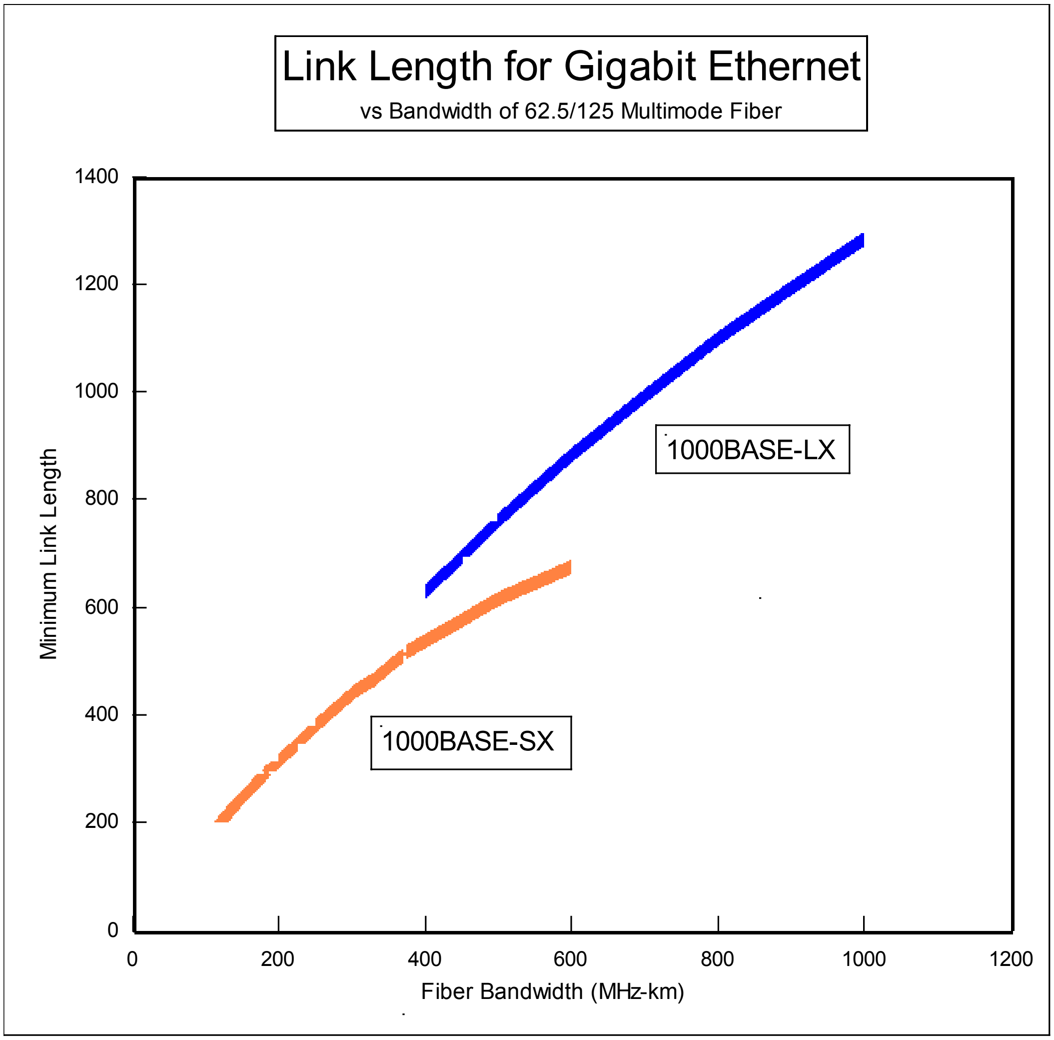


While this could theoretically allow higher fiber bandwidth to the laser, the laser can have severe problems with some fibers. To minimize the problems, transceiver manufacturers are looking at changing the source output to create offset or even "doughnut" launches to minimize modal problems.

Most "legacy" multimode fibers have their bandwidth optimized for 1300 nm, not 850 nm, adding to the problems of short wavelength lasers. Fiber manufacturers have begun making fiber with high bandwidth capability at 850 nm as well as 1300 nm. Led by Plasma in the Netherlands, SpecTran, Alcatel and Corning have announced high bandwidth 62.5/125 fiber that will support GBE to lengths much longer than currently proposed in the standard.

However, many users already have 62.5/125 fiber installed in their backbone and most of that fiber is "FDDI spec" with bandwidths of 160 MHz-km at 850 nm and 500 MHz-km at 1300 nm. The big question is how far you can go on this fiber before encountering problems.

For multimode fiber, it's a function of the fiber bandwidth and transceiver design as shown in the graph below. This is theoretical data calculated for worst case conditions by engineers working on the GBE spec and published in the addenda.



If you are planning on running on fiber already installed, but within the last 10 years, and you do not have the actual fiber performance data, you must assume the worst case lengths and/or look for modal conditioning methods to enhance the application. The adventuresome user will just try it, as successful links running more than twice the worst case lengths have been reported. It appears to be a very conservative standard.

You cannot easily test the fiber you already have installed for bandwidth. There are no portable testers for multimode fiber bandwidth and there haven't been any built in 15 years. Fiber manufacturers routinely test bandwidth, but the testers are enormous and cost hundreds of thousands of dollars.

The only hope for testing fiber for GBE is to use a link BER test. If the link is over the maximum length, you can set up two workstations and simply see if it works on all the fibers.

Cable Plant Loss

Like FDDI and ESCON, GBE link length will be limited by the bandwidth of the cable plant, not the attenuation. While these earlier LED-based networks were limited equally by modal and chromatic dispersion, GBE will be affected almost entirely by the modal dispersion, since it uses narrow spectral width lasers as sources.

Without dispersion effects, GBE VCSEL transceivers have absolute loss margins of 7.5 dB minimum to about 13 dB maximum. Worst case loss margin, with all the power penalties caused by dispersion and modal noise and other noise contributions, can be as low as about 3-4 dB, depending on the fiber performance and length.

In doing research for this study, I was never able to get a manufacturer to quote a firm number for loss margins, indicating that there is not enough field experience with these systems to be comfortable with the variations in component interactions and the worst case loss of the maximum length cable plant should allow for adequate power margins. This leaves the end user with the need to make a judgment on their own as to using current fiber or installing new fiber for GBE.

At 850 nm, the losses in the maximum length cable plant should be acceptable, as long as good connectors are installed. The design of GBE was based around the specifications for fiber in EIA/TIA 568 standards, which are quite conservative.

While the EIA/TIA committee has chosen 0.75 dB as the maximum loss for a connector and 3.5 dB/km for the loss of fiber at 850 nm, these are worst case specifications in today's world.

A 500 meter link with connectors only on each end would have a loss of 3.25 dB by EIA/TIA specs. But good epoxy/polish or adhesive connectors should have losses of about 0.3 dB, and the fiber under 3 dB/km, so a good installation will have a loss of 2.1 dB, or only 2.7 dB with two intermediate patch panel connections. Therefore a link with several intermediate patch panels should have no problems supporting GBE under worst case conditions.

Cable Plant Loss With Lasers Vs. LEDs

A number of people have speculated on the differences in cable plant loss performance when used with 850 nm VCSEL laser transmitters specified in GBE vs. 850 nm LEDs used in lower speed networks and most test equipment. The lower modal fill of the lasers should make the loss of both the fiber and connectors less.

To determine the differences in loss measurements between VCSELs and LEDs when testing today's better components, I did some research myself. I did three tests, detailed below, for connector loss, longer cable loss and cable plant loss.

The test equipment used was standard production Fotec test sources with 850 nm microlensed LED and VCSEL emitters exactly as used for fiber optic transmitters. A Fotec FM310 Smart Power Meter was used at a resolution of 0.01 dB to make measurements. The same launch cable was used for all tests and cross checks were done continuously to insure minimal measurement uncertainty.

Connector Loss

Tests were performed at short (1m), medium (20 m) and long (500m) distances from the source, to see the differences for connectors near the source and at the receiver, where the modal conditions are different. We found the differences in loss to be small, but still significant.

Connector Loss

Distance from Source	Avg Conn Loss (dB) LED	Avg Conn Loss (dB) VCSEL	Difference (dB) ± Std. Deviation
1 m	0.63	0.46	0.17±0.02
20 m	0.46	0.38	0.08±0.03
500 m	0.41	0.35	0.06±0.02

Cable Loss

The loss of 6 longer length cables (10, 20 250 and 500m) was measured to see the effects of the differential mode attenuation (also called transient loss) in the fiber. All were tested with the same 1 m launch cable as the patchcords above. In the final column, we have used the average values above and subtracted the estimated connector loss. By subtracting the estimated connector losses determined in our first tests, we have only a small but consistent difference in fiber losses.

Long Cable Loss (2 directions, A & B)

	Loss (dB) (avg 2 way) LED	Loss (dB) (avg 2 way) VCSEL	Difference (dB)	Difference w/o conn
10 m	0.94	0.52	0.42	0.25
10 m	0.79	0.32	0.47	0.30
20 m	0.97	0.50	0.47	0.22
250 m	1.79	1.44	0.35	0.18
250 m	1.92	1.57	0.35	0.18
500 m	2.85	2.35	0.50	0.25

Cable plant loss per OFSTP-14

We tested a series of simulated cable plants with both sources. We used short and long cable plants typical of floor-to-floor and campus cable runs, the minimum and maximum conditions likely encountered in GBE.

Cable Plant Loss

	Loss (dB) (avg 2 way) LED	Loss (dB) (avg 2 way) VCSEL	Difference (dB)
10 m	1.07	0.49	0.58
10 m	0.91	0.37	0.54
20 m	1.27	0.85	0.42
250 m	1.93	1.24	0.69
250 m	2.01	1.35	0.66
500 m	2.93	2.30	0.63

If the installed cable plant has been tested in the past with a LED source at 850 nm, GBE VCSEL transmitters will see typical losses about 0.5-0.6 dB less. Thus, links tested with a LED with as much as 3.75 to 4 dB loss should work with GBE. If a VCSEL source is available and links are marginal in either length or loss, retesting might be advisable.

Conclusion

GBE is designed to operate over legacy fiber at distances acceptable in many backbone networks. The standard is very conservative, so some latitude can be taken with maximum distances, especially since most installed fiber was actually much better than the minimum specification. Due to the virtual impossibility of testing installed fiber for bandwidth, the only viable test is to set up an working network link and run BER tests.

If new fiber is being installed, the new high bandwidth 62.5/125 fibers should be specified and any backbone cabling should include both multimode and singlemode fibers. Terminations should be specified as low loss (about 0.3-0.5 dB), to minimize both signal loss and back reflections. The installation of singlemode fiber guarantees operation at GBE speeds and future networks operating at even higher bit rates.

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