Fiber Optic Gigabit Transmission and Field Testing Issues

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Today's fiber optic installations are fast increasing in number and in bandwidth to alleviate the throughput bottlenecks on the backbone networks where traffic from multiple workstations aggregates. This article examines the latest developments in high speed Ethernet transmission over fiber optic media and discusses the new field testing issues associated with these emerging standards.

Background – the need for more speed

The two-year old IEEE (Institute of Electrical and Electronics Engineers) gigabit Ethernet standard [1] for LAN backbone signaling is no longer sufficient to satisfy the exploding demands for bandwidth. The number of LAN users is increasing so fast that the backbones are once again ready for a ten-fold boost in throughput and, as a result, in March of this year the IEEE has officially approved the development of the 10 gigabit Ethernet standard for backbone communications. The new IEEE working group responsible for the 10 gigabit Ethernet specification is 802.3ae. Figure 1 shows the hierarchy of Ethernet physical layer (PHY) standards including the 10 Gb/s specification under development.

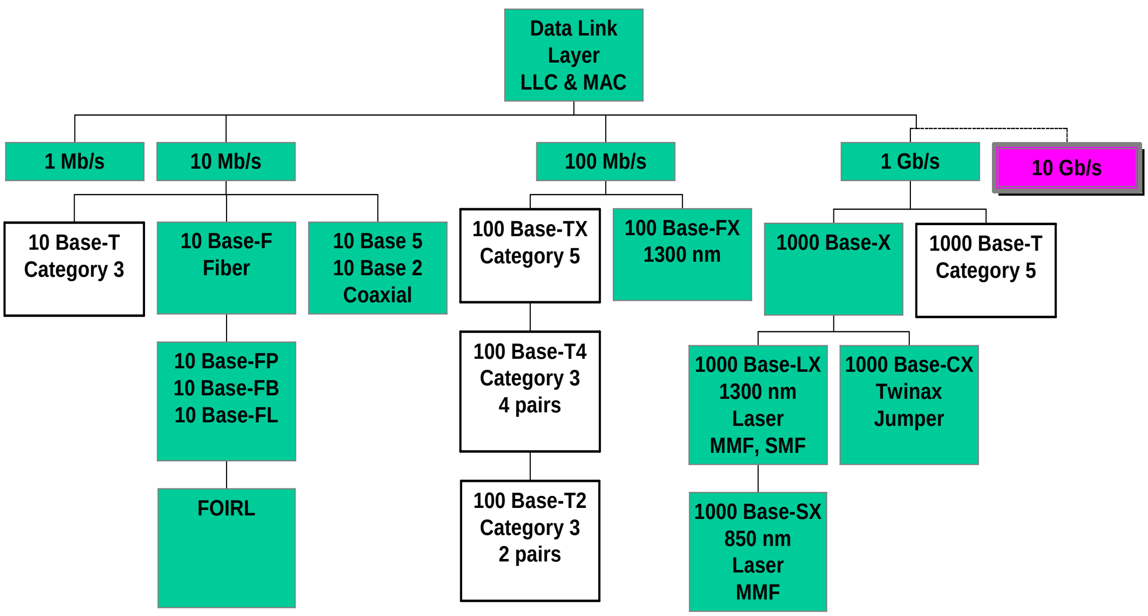

Figure 1: Chart of Ethernet physical layer standards. Shaded boxes represent fiber optic physical layers and clear boxes represent twisted pair physical layers. 10 Gb/s Ethernet is the new specification for fiber optic backbone signaling.

Ethernet data rates have traditionally been a power of 10 increasing exponentially from one generation of products to the next. The 10 Gb/s Ethernet standard is the latest and the fastest generation of the Ethernet family. With the release of this new standard, the LAN backbone data rates will increase from 1 Gb/s to 10 Gb/s (figure 2).

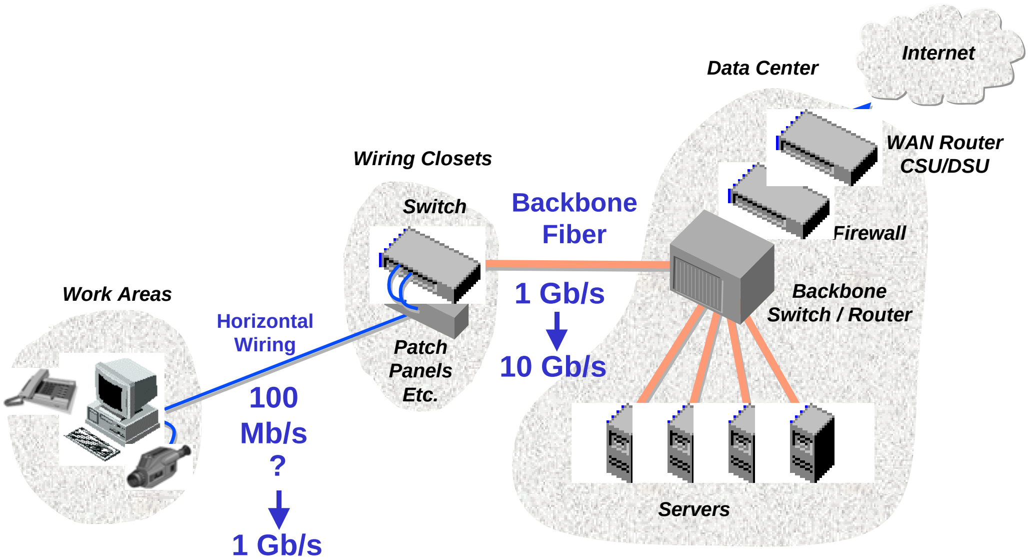

Figure 2: Typical LAN. Backbone connections will be migrating from 1 to 10 Gb/s Ethernet. It is not clear whether work area connections need to be upgraded above 100 Mb/s at this time.

The bandwidth shortage is even more acute in the WAN (Wide Area Network) environment than on the LAN backbones as more and more web traffic flows outside the LAN and over the Internet. For this reason the IEEE is planning to develop a 10 Gb/s Ethernet PHY that can operate either in the LAN or in the WAN mode. Let's take a look at the work done so far on the 802.3ae 10 Gb/s Ethernet standard.

The emerging IEEE 10 Gigabit Ethernet standard

The IEEE 802.3ae working group is in the process of narrowing down the numerous proposals for 10 Gb/s signaling schemes. The committee's official objectives are as follows:

♦ Provide physical layer specifications that support link distances of:
- At least 100 meters over installed MMF
- At least 300 meters over new high bandwidth MMF
- At least 2 km over SMF
- At least 10 km over SMF
- At least 40 km over SMF

♦ Support fiber media selected from the second edition of ISO/IEC 11801

♦ Define two families of PHYs:
- A LAN PHY operating at a data rate of 10 Gb/s
- A WAN PHY operating at the OC-192 data rate of 9.95328 Gb/s

The target cost of a 10 Gb/s Ethernet PHY is 3 times the cost of a 1 Gb/s 1000Base-X PHY with the ten-fold increase in the data rate. Expected completion date of the standard is March 2002.

To meet the distance objectives several variations of PHYs may be standardized – some of these PHYs may be optimized for MMF operation and some may be optimized for long distance SMF transmission. The most promising proposals are as follows.

- ♦ 1310 nm WWDM (Wide Wavelength Division Multiplexing)
- Supports 300 m over installed 62.5 µm and 50 µm fiber
- Supports at least 10 km over SMF
- Requires the use of an offset patch cord just like 1000Base-LX [1]

- ♦ 850 nm VCSEL (Vertical Cavity Surface Emitting Laser)
- Supports 300 m over new 2200 MHz-km 50 µm fiber but less than 100 m over installed 62.5 µm fiber
- No SMF support

- ♦ 1310 nm DFB (distributed feedback) laser
- Cooled version supports 40 km
- Uncooled version supports 10 km
- Candidate for supporting dual data rate communications – 10 Gb/s for the LAN environment and OC-192 data rates for the WAN environment

At least one of the PHY schemes is expected to support both LAN and WAN data rates. This LAN/WAN PHY will be able to operate either at exactly 10 Mb/s on an Ethernet LAN or at a multiple of 51.84 Mb/s OC-1 (Optical Carrier 1) data rate of 9.95328 Gb/s[1] over a WAN. The most likely candidate for the dual data rate PHY is the 1310 nm DFB laser proposal.

The 802.3ae committee is also considering a proposal for an 850 nm VCSEL requiring the use of the new high bandwidth 50 µm fiber. This new 2200 MH•km fiber is optimized for 850 nm operation but offers the same 500 MHz•km performance at 1310 nm as the installed 62.5 and 50 µm fiber. The specification for the new 50 µm fiber is expected to be incorporated into the draft ISO 11801 2nd edition [2], the cabling specification that will be referenced by 802.3ae.

The most broadly applicable proposal is the 1310 nm WWDM proposal. This scheme is similar to the 1000Base-LX flavor of the currently deployed gigabit Ethernet in that it supports both MMF and SMF and requires an offset patch cord for MMF operation. The WWDM PHY supports at least 300 meters over all types of multimode fiber and 10 km over singlemode fiber.

Selecting the signaling schemes – the tradeoffs

The key factor influencing the decision on the signaling schemes is the distance that would be supported by the selected schemes over different types of fiber optic cables and the complexity of implementation. The types of fiber to be supported are listed in table 1.

Table 1: Fiber types to be supported by 10 Gb/s Ethernet

	Bandwidth	
	At 850 nm	**At 1300 nm**
MMF 62.5 µm	160 MHz•km	500 MHz•km
MMF 62.5 µm	200 MHz•km	500 MHz•km
MMF 50 µm	500 MHz•km	500 MHz•km
MMF 50 µm	2200 MHz•km	500 MHz•km
SMF		

[1] OC-192 data rate is equal to OC-1 data rate multiplied by 192, or 51.84 Mb/s * 192 = 9.95328 Gb/s.

The 850 nm VCSEL proposal is best suited for localized server-farm-type environments where the new 50 µm fiber can be installed. One disadvantage of the 850 nm VCSEL scheme is that it supports less than 100 m over the currently installed MMF and does not support SMF at all. The best candidate for general purpose LAN backbone deployment may be the 1310 WWDM proposal that supports both MMF and SMF with the distances of 300 m and 10 km respectively.

While it may be too early to speculate on what PHY proposals will be selected for the final 802.3ae standard, it is clear that several schemes, optimized for different types of environments, may be standardized. All of this translates into increased complexity when it comes to field-testing.

Existing and emerging fiber field testing standards

The IEEE typically references ISO and TIA cabling standards for field testing requirements. However, while these specifications cover field measurement methodology, the IEEE still specifies the loss and length limits for each application.

TIA 568B.3 [3] and ISO 11801 [2] specifications include generic loss limits based on wavelength and fiber type. Tables 2 and 3 show the loss limits for fiber cables, connectors and splices currently specified in draft TIA 568B.3 document being developed by the TIA TR42.8 committee.

Table 2: TIA 568B.3 Fiber optic cable loss limits

Optical fiber cable type	Wavelength (nm)	Maximum attenuation (dB/km)
50/125 µm	850	3.5
	1300	1.5
62.5/125 µm	850	3.5
	1300	1.5
Singlemode inside plant cable	1310	1.0
	1550	1.0
Singlemode outside plant cable	1310	0.5
	1550	0.5

Table 3: TIA-568B.3 Connector and splice loss limits

	Attenuation (dB)
Splice	0.3
Connection, TIA	0.75
Connection, ISO	0.5

A field tester can evaluate the measured fiber losses against the generic limits shown in tables 2 and 3 provided the test technician specifies the length of fiber and the number of connectors or splices[2]. However, testing to these generic limits does not guarantee that the applications would work. It is important to select a field tester that can automatically produce pass/fail limits for different networks.

Already, we have 7 different sets of length and loss limits specified by IEEE for the existing variants of gigabit Ethernet (table 4).

Table 4: Maximum length and attenuation specifications for different versions of gigabit Ethernet over various types of fiber optic media

Gigabit Ethernet Specification	Type of Fiber	Wave-length (nm)	Fiber Core Size (microns)	Modal Bandwidth (MHz • km)	Maximum Distance (m)	Attenuation (dB)
1000Base-SX	MMF	850	50	400	500	3.37
				500	550	3.56
			62.5	160	220	2.38
				200	275	2.60
1000Base-LX	MMF	1310	50	400,500	550	2.35
			62.5	500	550	2.35
	SMF	1310	10		5,000	4.57

The new 802.3ae 10 Gb/s Ethernet standard will likely require at least as many different sets of limits which will considerably add to field testing complexity. With so many different limits, it becomes virtually impossible to certify fiber optic installation with old-fashioned loss meters and still guarantee that all the backbone technologies will work over a given installation.

The loss and length limits for different networks are a function of cable type and transceiver operating wavelength. Because of the vast number of different applications and in many cases several different sets of limits for each application, the field tester should automatically keep track of the application test limits (figure 3). The test report should document the pass/fail result for each network and the pass/fail result with respect to generic TIA or ISO limits (figure 4).

[2] TIA 568B.3 [3] document references TIA-526-14 for field measurement methodology over multi-mode fiber and it references TIA-256-7 for measurement over singlemode fiber.

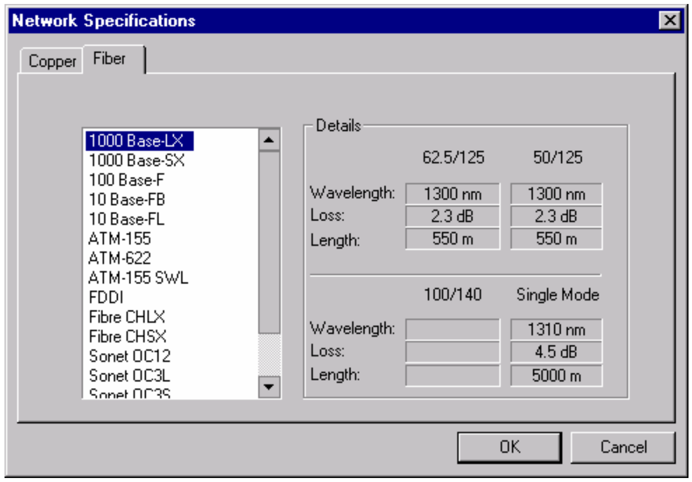

Figure 3: An example of fiber optic network test limits programmed into a field tester.

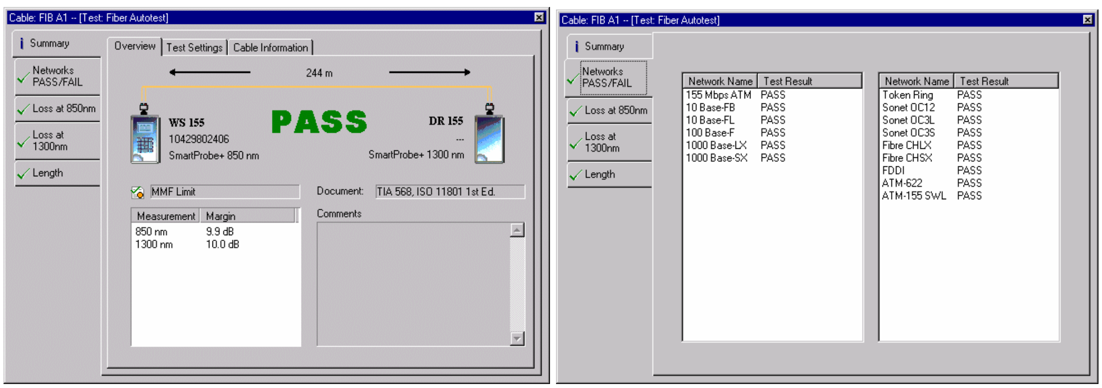

Figure 4: A sample test report displaying application-specific pass/fail results for each fiber optic network in addition to the generic TIA and ISO pass/fail results.

Summary

The emerging IEEE 802.3ae 10 Gb/s Ethernet will add considerable complexity to field testing. This specification is expected to support several different transceivers operating over five different types of fiber. Today, we already have 7 different sets of test limits for IEEE 802.3z gigabit Ethernet. The new 10 Gb/s Ethernet is expected to at least double this number of field test limits.

Given the increasing complexity of field testing, it is more important than ever to use a tester able to automate the pass/fail determination for different networks.

References

[1] **802.3, 1998 Edition** Information technology--Telecommunications and information exchange between systems--Local and metropolitan area networks--Specific requirements--Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications
This edition includes all contents of the 8802-3:1996 Edition, plus IEEE Std 802.3aa-1998, IEEE Std 802.3r-1996, IEEE Std 802.3u-1995, IEEE Std 802.3x&y-1997, and IEEE802.3z-1998.

[2] ISO 11801 2nd edition, draft document N 568, October 6, 1999, "Customer Premises Cabling"

[3] TIA 568B.3 draft SP-3894, August 22, 1999, "Optical Fiber Cabling Components Standard"

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Fanny Mlinarsky has been developing networking and network testing products for 17 years. At Agilent Technologies, she manages the Engineering group responsible for the development of hand-held test tools for LAN installation and certification. Mlinarsky has been actively participating in the development of networking and cabling standards at IEEE, ANSI, ISO/IEC and TIA.