To 10G and Beyond

SYSTIMAX® SOLUTIONS

To 10G and Beyond

Progression of Ethernet Development

1976: Paper on Ethernet published by Bob Metcalfe and David Boggs at PARC

1980: DEC, Intel and Xerox publish the 'Ethernet Blue Book' or DIX standard

1983: IEEE 802.3 Ethernet standard

1985: IEEE 802.3a Thin Ethernet standard, 10BASE-2

IEEE 802.3b Ethernet standard 10Broad36, 10 Mbps using broadband

1987: IEEE 802.3d Fiber Optic Inter-Repeater Link (FOIRL) & IEEE 802.3e 1 Mbps Ethernet over twisted pair.

1990: IEEE 802.3i Ethernet standard, 10BASE-T

1993: IEEE 802.3j Ethernet standard 10BASE-FL, Ethernet fiber links up to 2 km

1995: IEEE 802.3u Fast Ethernet standards 100BASE-TX (2 pair Cat 5), 100BASE-T4 (4 pair Cat 3), 100BASE-FX

1997: IEEE 802.3x Full duplex Ethernet standard

IEEE 802.3y Fast Ethernet standard (2 pair Cat 3), 100BASE-T2

1998: IEEE 802.3z Gigabit Ethernet over Fiber, 1000BASE-SX 1000BASE-LX 1000BASE-CX

1999: IEEE 802.3ab Gigabit Ethernet over Copper, 1000BASE-T

2002: IEEE 802.3ae 10 Gigabit Ethernet over Fiber, 10GBASE-S 10GBASE-L 10GBASE-E

2003: IEEE 802.3af Power Over Ethernet

2004: IEEE 802.3ak 10 Gigabit Ethernet over Twinax 10GBASE-CX

2006: IEEE 802.3an 10 Gigabit Ethernet over Copper 10GBASE-T

2008: Formation of IEEE 802.3ba Task Force – 40 and 100 Gigabit Ethernet

1976 1980 1990 2000

The Pervasive Internet is Here

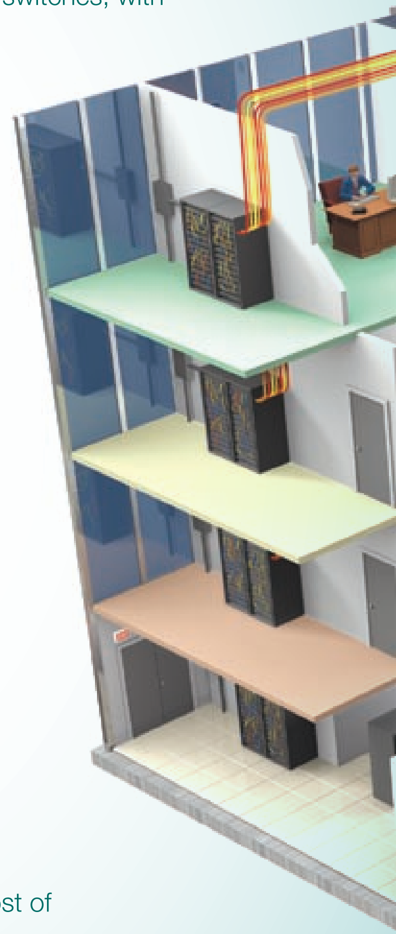
Literally billions of Internet-enabled microprocessors are extending the Internet into most aspects of our lives. Imagine any device being Internet-enabled – your home appliances, your automobile, your office coffee-pot – with all key characteristics and diagnostics available for review and adjustment on-line. The exponential growth of networked IP (Internet Protocol) devices, that are self-sensing, self-controlling and self-optimizing automatically without human intervention, will change the network landscape dramatically.

Moore's Law, Gordon Moore's 1965 prediction that the number of transistors on a chip will roughly double every 18 months, describes IT's most famous exponential growth factor. But there are many other IT exponentials, such as the growth in storage capacity as it doubles in capability annually. If this continues to hold up, then 20 years from now we will have devices with 20 petabytes of storage—20 million gigabytes sitting in our pockets and on our desktops. Someone will be able to sit at their computer and have access to every movie ever made, on their PC. And of course, we will need high resolution screens to display the images, and the dedicated bandwidth to deliver them.

With words like "everywhere" and "exponential" characterizing the future of IP networks, it is difficult to see how it could mean anything but more, more, more! The challenge is to create a flexible and evolving infrastructure that is "future-ready," revolutionary and user friendly.

Planning for IP Convergence

IP convergence is where all information (data files, voice calls, e-mails, video streams, etc.) becomes bits and bytes transported in a consistent way across the networks of the world. Information is easily created, processed, stored, understood and communicated, and accessed anywhere, at any time. VoIP (Voice over Internet Protocol), for instance, uses the local area network: cabling, router, and data switches, with an application server for all voice communications.



With the convergence of networks and devices, and wired and wireless, there are many questions on future technology trends, specifically IP, and how they will impact the cabling infrastructure both in the near term and in the longer term. The advent of IP applications, including VoIP, has created somewhat of a myth, that a key and prime benefit is a requirement for less cabling. In fact, the opposite may well be the case.

Infrastructures must not only support current needs, but must also consider future requirements. With the worldwide quest to protect the environment and conserve energy, the demand for healthy work environment, and the need to minimize TCO (Total Cost of Ownership), the merging of telephones, computers and building management controls onto one centralized IP network and cabling infrastructure is becoming a reality. If planned correctly, future applications are supported and the building's carbon footprint is reduced. The cabling infrastructure becomes the true "fourth utility" of a building.

Multimedia Applications, Bandwidth Needs, Infrastructure Decisions

Humans process visual information much faster than written information, hence the saying “a picture paints a thousand words.” Imaging and graphical applications can generate large data files and clog networks. “A video portrays a thousand pictures” means that audio and video applications can create even larger channel capacity and storage requirements.

Today, video display resolutions range from 640x480 pixels (VGA) up to 2560x2048 pixels (QSXGA). To display true photo-realistic color, data rates of up to 9Gbps are feasible for a QSXGA display. In reality, most video is transmitted compressed, but this compromises quality and latency.

This traffic would cause most networks to slow, especially with document sharing and text/image file transfer occurring on the same network. Future applications will increase the realism (and effectiveness) of the user experience by using larger, ultra-high-resolution LCD displays, and/or virtual reality or “telepresence” applications with sound and high-resolution 3-D images, with other senses engaged as well.

The potential of devices to support these streaming multimedia applications is still far from fully realized, but the upward trend is clearly evident. As a rule-of-thumb, each GIPS (billion instructions per second) handled by a device’s CPU can produce 1Gbps of LAN traffic. With predictions that CPUs operating at 100 GIPS will be widely available in the next ten years, even if such applications realize only 10% of the PC’s communication potential, makes the move towards 100Gbps links in the backbone and 10Gbps to the desktop inevitable.

Infrastructure Solutions for 10 Gigabit Ethernet Local Area Networks (LAN) and Beyond

Network planning has never been an easy process. Visions of spiraling bandwidth demand have resulted in promises of technologies capable of delivering stunning data rates. And as with most innovations, the networking industry is awash with excitement about the latest: 10, 40 and 100 Gigabit Ethernet (10G/40G/100G). But does the performance match the hype? And what are the considerations for network managers interested in planning for this technology?

WHY 10G and 100G? Growing Speed and Bandwidth

It's a simple set of equations:

high-speed LAN applications
+ increasing multimedia traffic

need for more bandwidth to transfer and stream data

high performance storage
+ powerful CPUs, interfaces

need for more speed to access and deliver information

data centralization
+ IP convergence

need for large amounts of aggregated bandwith in the backbone

Enterprises are faced with this growing bandwidth need to the desktop, in the backbone and in the data centers to support applications such as Storage Area Networks (SAN), Network Attached Storage (NAS), sever virtualization, high-performance computing, multi-site collaboration, streaming multimedia, data warehousing and grid computing.

The increase in speed, technology and protocols for data transmission has been fast over the past 30 years. Development has taken parallel paths for both optical-fiber and copper transmission media; various methods were developed, including Token Ring, Fiber Channel, Fiber Distributed Data Interface (FDDI), and Ethernet.

Of all the Local Area Network (LAN) protocols, Ethernet is clearly the market favorite. As Ethernet evolves to higher-speed forms, it addresses the needs of customers with a cost-effective, reliable solution to their data networking needs. Additionally, switched Ethernet networks have shown themselves to be extremely robust, performing over every physical media layer available, from twisted pair cables to all types of fiber optic cables, and almost all network traffic today starts out as Ethernet and IP traffic.

Therefore, building Ethernet networks with the next step up in speed is the easiest way to scale enterprise and service-provider networks. 10G moves the decimal point from one to ten gigabits per second, and 100G will move it one step further, enabling Ethernet to match and exceed the speed of the fastest technology in metropolitan area networks (MANs) and wide-area networks (WANs).

10G Ethernet over fiber optic and twisted pair cabling is already a reality, and development of 40G and 100G Ethernet is well underway. For the near term, 10G will be used for the interconnection of high-performance servers, switches and CAD stations, as well as in backbone applications. However, 10G speeds to the desktop will become a reality due to steadily increasing bandwidth demands, coupled with the reducing cost of interface electronics and the adoption of technologies such as grid computing. And as that happens, the aggregate effects of user bandwith will drive even higher speeds in data centers and network backbones.

Advantages of Ethernet:

LANs:
- Scale existing 10Mbps, 100Mbps, 1Gbps and 10Gbps networks
- Leverage installed equipment investment
- Use existing network management tools
- Utilize IT staff expertise
- Take advantage of standard components

MANs/WANs:
- High-speed, cost-effective links
- Easily managed with Ethernet tools
- Match existing high speed MAN/WAN backbone speeds
- Scale distances from 100 m to 1 km to 10 km

THE 10G STANDARDS

Cabling Standards at a Glance

There are three main structured cabling standards:

ISO/IEC 11801: International standard

ANSI/TIA/EIA 568: US-based standard

EN50173: European standard

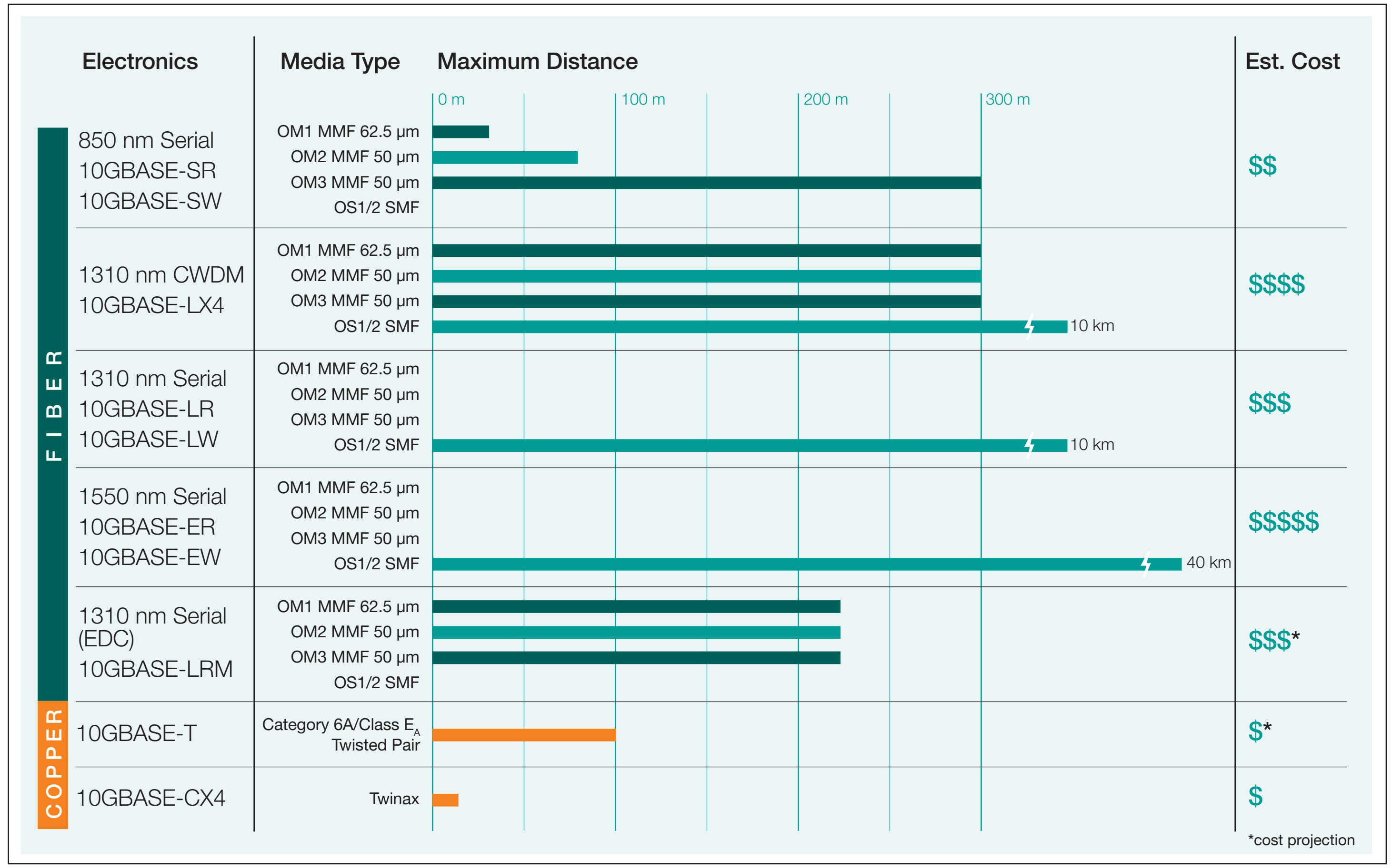
For installation and infrastructure guidance, there are also three standards to be aware of: ISO/IEC TR 14763, ANSI/TIA/EIA 569, and EN50174.

10G Ethernet Standards

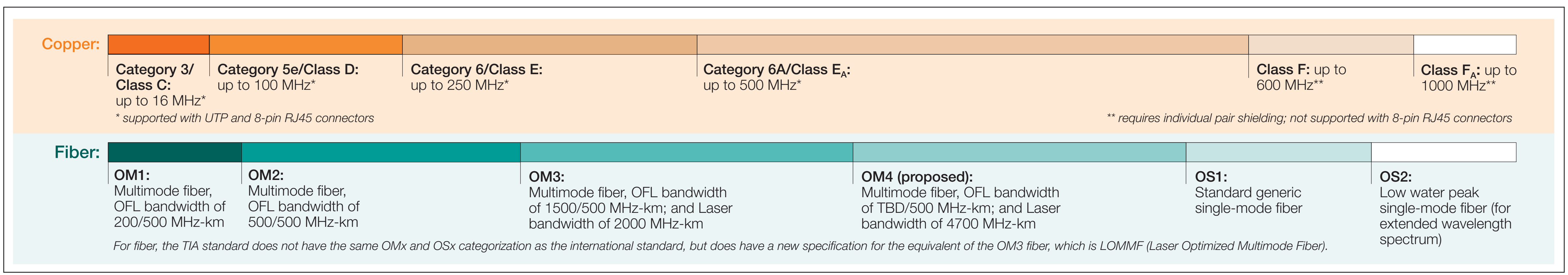
The initial 10G standard was undertaken by the IEEE 802.3ae Committee, based primarily on fiber optic technology (see **"IEEE 10G Options"**).

Although the enterprise 10G fiber electronics are maturing and gaining acceptance, they remain costly compared to copper. The cost of 10G copper systems is projected to remain significantly lower than that of 10G fiber products and is expected to widen over time. Hence, at shorter distances with a large number of links, the use of copper-based 10G systems will remain the most cost-effective option.

IEEE 10G Options



Copper and Fiber Cabling Options



Performance, Price, Power - Implications for 10G

For enterprise LAN applications, 10GBASE-T Ethernet enables network managers to scale their Ethernet networks from 10 Mbps, 100 Mbps or 1000 Mbps to 10,000 Mbps in one interface through auto-negotiation, while leveraging their investments in Ethernet as they increase their network performance. For service provider metropolitan and wide-area applications, 10 Gigabit Ethernet provides high-performance, cost-effective links that are easily managed with Ethernet tools and, with the adoption of wavelength division multiplexing (WDM) techniques, scale up to terabit speeds and beyond. With WDM, hundreds of 10Gbps channels can be transmitted onto a single fiber at different optical wavelengths or colors of light. 10G Ethernet lends itself to both fiber optic and copper based network technology, and the choice will be dependent on cost, distance supported and complexity of implementation and configuration.

10G Ethernet technology continues to evolve, creating improvements that strongly support its wider adoption in growing segments of the computing market. Blade servers, networked enterprise switches, video servers, and other applications can benefit now from 10G Ethernet speeds in storage, system backup, teleconferencing, and surveillance systems. Technical advances have enabled the higher density, reduced power, and improved cost-effectiveness needed to attract all of the major system developers. 10GBASE-T will accelerate this market acceptance and adoption.

Power dissipation is an important factor for applications for 10G. It is expected that ongoing development will continue to reduce power consumptions for both optical and electrical interfaces as was the case for 1G interfaces. Clearly, if 10G requires substantially more power than alternative optical interfaces, its market will be limited. Therefore, developers will work hard to ensure power consumption levels are at least at parity with 10G optical interfaces. Circuit designers will find new methodologies or architectures and some chip vendors are already well along the path to this technology.

Copper or Fiber?

There are three strong reasons for the broad acceptance and rapid growth of UTP as the horizontal media: low initial cost, the ability to deliver higher data rate LAN services, and the flexibility to use one media for voice, data and power.

In fiber's favor, as speeds increase, copper-based LANs require more complex and expensive electronics. In addition, fiber's significant bandwidth-distance product gives it advantages over UTP in centralized architectures. However, a centralized architecture may be inappropriate or impractical to implement in many current building environments. In addition, in a traditional hierarchical star architecture, fiber loses some of its hard-fought advantages.

In the majority of situations, copper cabling remains the preferred choice to the desktop and other short links such as those in data centers.

UTP or FTP?

Selection of cabling media, UTP or FTP/STP, is dependent on factors such as performance, reliability, cost, environment, space consideration, ease of installation and use, and availability of good earthing/grounding points. Selection is a customer preference based on what is appropriate for the installation/environment.

A Category 6A/ Class E_A UTP solution is recommended for 10G installations and most environments. It is a true globally portable solution that delivers performance to the new standard's specifications, while remaining easy to install and maintain. The Category 6A/Class E_A FTP solution addresses customer environments where there is preference for FTP cabling, and overcomes performance deficiencies that exist with traditional Category 6 FTP solutions. Shielded systems may have benefits in some applications, but the addition of a foil shield to a twisted pair cabling system alters the characteristics of the system. As it is not required for 10GBASE-T applications, customers should consider options carefully.

	X10D UTP	**X10D FTP**
Support 10GBASE-T to 100 meters (up to 4 connector channel)	YES	YES
Meet or exceed ISO/IEC Class E_A (up to 4 connector channel)	YES	YES
Meet or exceed TIA Category 6A (up to 4 connector channel)	YES	YES
Meet or exceed ISO/IEC Class E and TIA Category 6	YES	YES
Meet guaranteed GigaSPEED X10D UTP minimum margin to 250 MHz	YES	NO
Meet guaranteed GigaSPEED X10D FTP minimum margin to 250 MHz	YES	YES
Backed by 20 year Product Warranty and Application Assurance	YES	YES
Supported by design and installation documentation	YES	YES
Avoid earthing/grounding requirements for cabling	YES	NO
Avoid Ground Loop problems	YES	NO
Avoid bonding requirements for cabling	YES	NO
Avoid power supply system requirements impact on cabling (TN-S system recommended for all FTP systems)	YES	NO
Meets Class A Emission requirements	YES	YES
Meets Immunity requirements per IEC CISPR 24,EN 55024 and IEC/EN 61000-6-1 (Office environments)	YES	YES
Meets Immunity requirements per IEC/EN 61000-6-2 (Heavy Industrial environments)	YES*	YES
Use of UTP cords	YES	NO
Use of FTP cords	NO	YES
Avoid extra termination steps related to screen, drain wire (i.e. shorter termination time)	YES	NO
Avoid maintenance of screen/shield integrity over time	YES	NO
Wide range of backbox and wall depth installation options	YES	NO
Wide range of connectivity options	YES	NO
True globally portable solution and technology	YES	NO

*In metal containment

Watch Out for the Tricks of the Trade

"Typical", "Nominal" or "Average" results are commonly used in specification sheets, sometimes to show compliance with a standard. These readings may be useful for statistical purposes, but cannot guarantee compliance to a specification since they are dependent on the quality and number of samples being measured. "Average worst case" sounds better than just plain "average," but it simply means averaging the worst results. Neither offers anything near 100% confidence.

End users should demand a minimum guarantee of performance from a manufacturer. However, even these must be scrutinized carefully to ensure that there is no small print in the channel specification.

Support for 10GBASE-T over Category 6/Class E UTP or FTP cable is possible, albeit to potentially limited distances, with possible mitigation procedures outlined in informative guidelines (TSB-155 by TIA/EIA and TR24750 by ISO/IEC). Reducing the number of connectors in a channel, separating the connectors and cables, adding the shield, reducing the channel length, or testing the cabling in less than the 6-around-1 cable bundle configuration might make 10G performance possible, but adds to the IT manager's concerns.

End users need to be aware that different cabling standards exist and bring with them different levels of capability. When claiming to "meet the standards", end users need to ask "which one?" and fully understand the required response. The ISO/IEC Class E_A specification is more stringent than the others, and compliance to this global specification offers peace of mind that all requirements are covered.

Time to Take Copper Cabling Technicalities Seriously

As speeds increase to 10Gbps, and cable and connector design improves, the LAN designer must account for the impact that all channel components and their installation have on performance.

The data-carrying capacity of a structured cabling system is affected by a number of impairments introduced into the channel by the system components and their surrounding environment (see graphics).

These potential impairments can cause bit errors, which reduce the overall throughput of a structured cabling system channel; minimizing bit errors is critical for high-speed, bandwidth-intensive applications. In data applications, higher bit error rate (BER) results in slower network performance due to signal retransmissions. In video applications, higher BER results in choppy displays, missed frames and the creation of white speckles (snow).

Delay and Delay Skew

A signal travelling from end to end on a twisted pair cabling channel is delayed in time, called propagation delay. Delay skew is the difference in propagation delay between any two pairs within the same cable sheath. Minimizing delay skew is critical for signals to arrive at the same time when more than one pair is used.

Insertion Loss/Attenuation

Insertion loss, also known as attenuation, is the loss in a signal when it passes through the cabling channel. This loss primarily determines the maximum distance that two devices can be separated.

Return Loss

The Channel Return Loss (RL) is a measure of the consistency of impedance through the entire channel—cable, connections and patch cables.

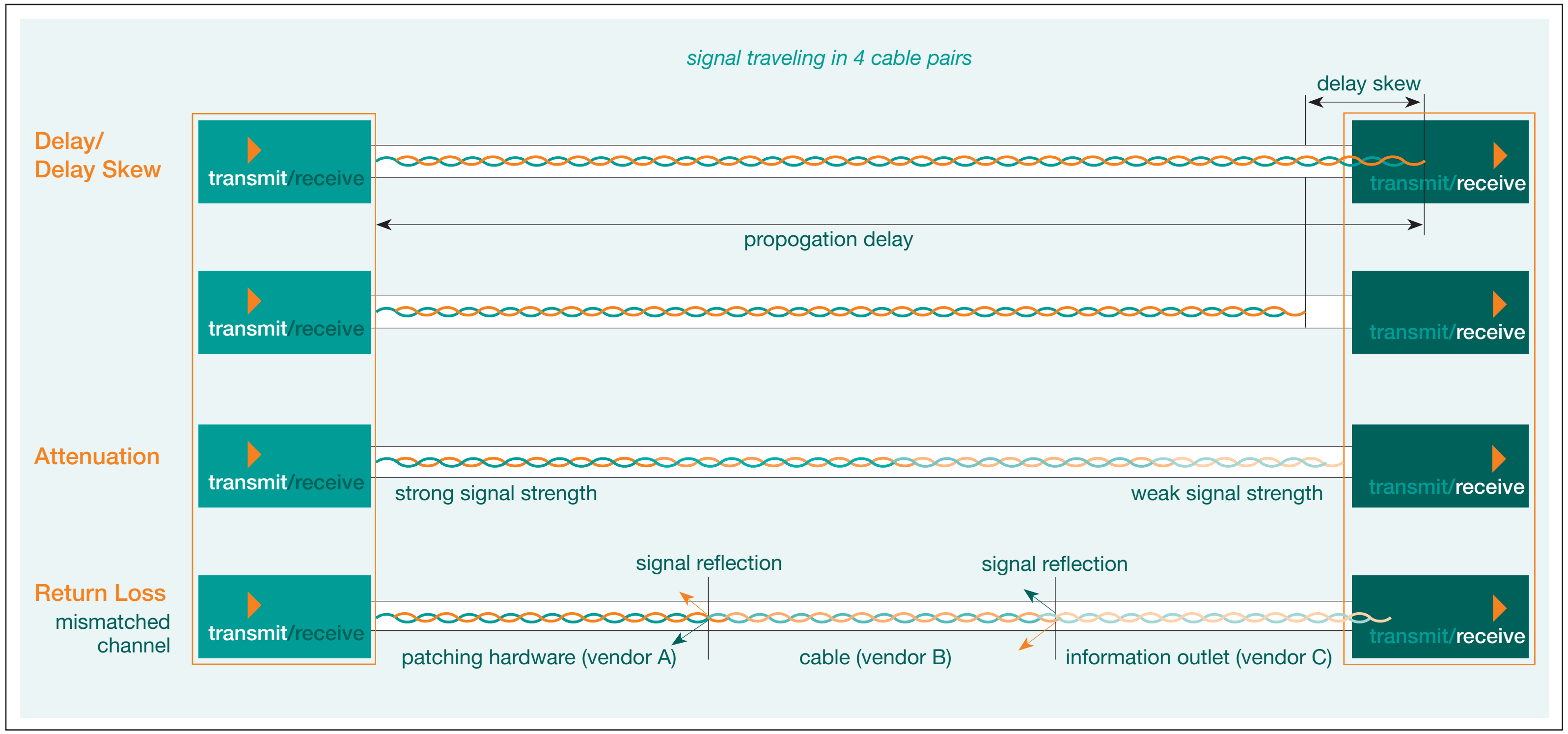
This variation in impedance causes a form of noise at the receiver. Minimizing impedance mismatch becomes critical in applications such as 1000BASE-T or 10GBASE-T that employ a hybrid function in the interface circuitry.

A twisted pair cabling solution where all the termination hardware, equipment and work area cords match the impedance of the cable provides a "tuned" channel that ensures optimum performance. A channel of cable and connectors with mismatched impedance will have poor return loss, caused by all the reflections originated at the connection.

Crosstalk

Probably the most important characteristic of twisted pair cabling for high-speed data applications, crosstalk is the undesired energy appearing in one signal path as a result of coupling from other signal paths. The induced signals can be significant enough to corrupt data and cause errors.

External noise sources have been significantly reduced through better cable and equipment design, compliance with government emission standards and improved installation procedures. However, even small amounts of crosstalk are critical in 10G applications (see diagram on next page).



Near End Crosstalk (NEXT)—the undesired coupling of signals from the transmit pair onto the receive pair on the same (near) end. NEXT isolation is expressed in dB and is a measure of how well the pairs in a cable are isolated from each other.

Pair-to-Pair NEXT—the amount of signal from one pair coupled into another pair in the cable.

Power Sum NEXT (PSNEXT)—the undesired coupling of signals from all other pairs into one pair, a more stringent specification. Power Sum measurement is applicable for parallel transmission when two or more pairs in the cable are used to transmit in each direction (e.g. 10GBASE-T).

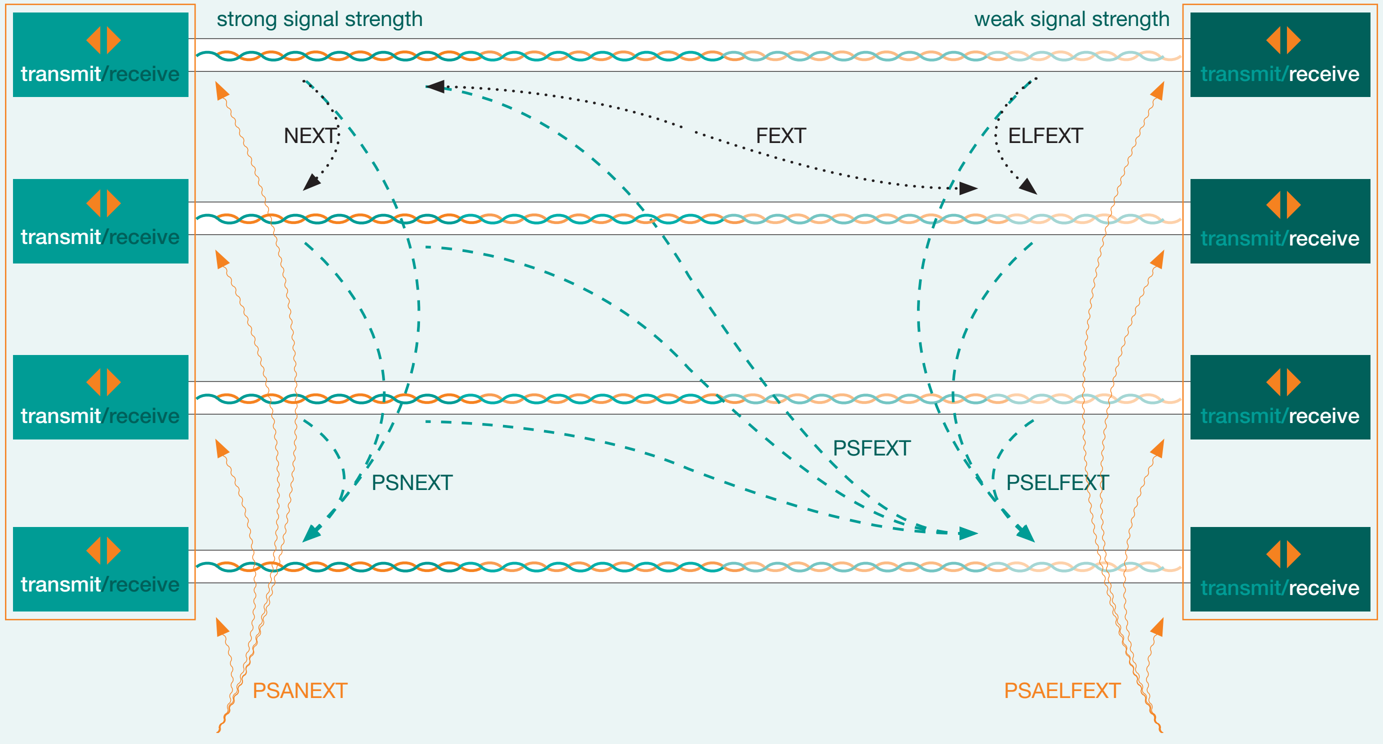
Far End Crosstalk (FEXT)—the undesired coupling of signals from the transmit pair onto the receive pair at the other (far) end.

Equal Level Far End Crosstalk (ELFEXT), or ACR-F—the same as FEXT, except that the coupled signal at the remote end is relative to the attenuated signal at the remote end.

Power Sum Equal Level Far End Crosstalk (PSELFEXT) or PSACR-F —the sum of the ELFEXT power from all other pairs in the cable.

Alien Crosstalk—noise picked up from signals in adjacent copper cabling channels, both Near End (PSANEXT) and Far End (PSAELFEXT or PSAACR-F).

Crosstalk



Plugs, Jacks and Crosstalk

Improving crosstalk cancellation in plugs and jacks. Historically, crosstalk was attributed primarily to cables, but as LAN speeds increased and the cables improved, other channel components and connectors, as well as installation factors, started to contribute to the crosstalk. The cumulative effect became known as Composite Crosstalk.

Connector crosstalk can be quite a problem, unless compensated for in the design of the connector. The crosstalk increases through mismatches between the patch cords, connectors and horizontal cable. If this is not accounted for in the design of all the components that make up the channel, a channel containing standards-compliant components may fail tests once installed. In order to achieve Category 6A/Class E_A performance, plugs and jacks need to be designed with crosstalk cancellation techniques. So how can the performance of this "weak link" be improved?

The answer is in creating the "perfect match" of backward-compatible plugs and jacks, first, by overcoming the variability in performance found in the plugs; second, by improving the mating performance of the jack. The net result of the improved crosstalk performance in cable and connecting hardware is the optimum performance of the installed channel.

COMMSCOPE® LEADING THE 10G REVOLUTION

SYSTIMAX® Copper Solution Advantages

The cabling channel requirements in the IEEE 802.3an 10GBASE-T specification, as well as new TIA/EIA and ISO/IEC cabling standards, challenge the performance of existing Category 5e and 6 solutions. As discussed, the use of mismatched components can make meeting the performance standards difficult, if not impossible.

CommScope has achieved significant advancements and breakthroughs in the development of 10G cabling technology. Unique expertise and proprietary tools have given us the ability to quantify and predict phenomena in the channel due to complex interactions among components that are not detected with traditional testing technology.

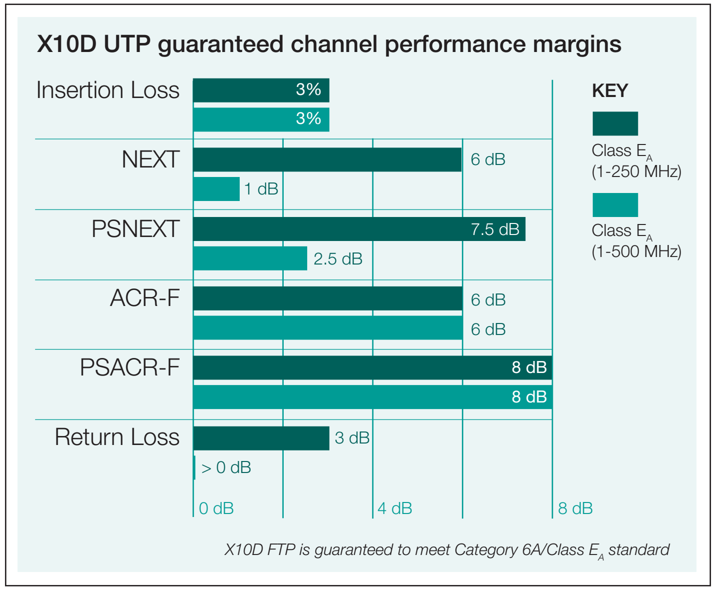
The SYSTIMAX GigaSPEED® X10D cabling system is designed specifically for the 10G application; as an added bonus it is also backward-compatible, supporting legacy applications. Engineered as a complete end-to-end solution and tested in worst-case conditions, the GigaSPEED X10D solution offers users excellent performance enhancements that set it apart.

Alien Crosstalk performance, crucial to successful 10G transmission, is guaranteed for the complete channel—not just cable—across the entire swept frequency (1-500 MHz) and tested in a stringent 6-around-1 configuration representative of worst-case installation conditions. By utilizing unique design tools, the technologies implemented in the GigaSPEED X10D Solution are capable of suppressing interference from external pairs without degrading the internal channel transmission performance. In addition, Insertion Loss, NEXT, PSNEXT, ELFEXT (ACR-F), PSELFEXT (PSACR-F), Return Loss, Delay and Delay Skew have been improved with performance specified out to 500 MHz. As a result, the TIA/EIA Category 6A and ISO/IEC Class E_A channel performance is guaranteed.

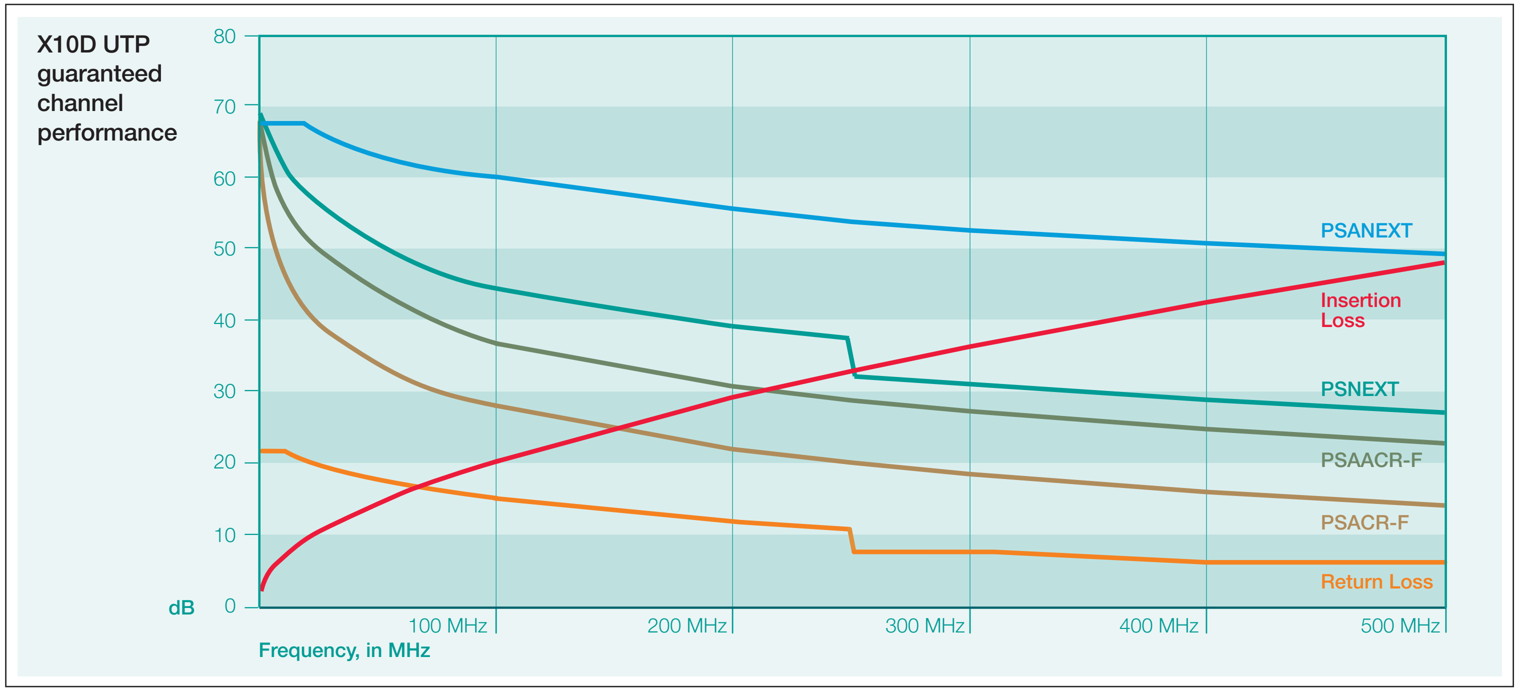
Based on a defined set of formulas and backed by extensive testing and modeling, assurance of performance is given at all frequencies (from 1 to 500 MHz), eliminating the confusion of unrealistic average values or artificially high margins at discrete frequencies. GigaSPEED X10D performance claims are backed by extensive UL test reports and results.

GigaSPEED X10D solutions are available in UTP and FTP versions to suit customer preference. In addition, intelligent infrastructure options add extra vision, knowledge and control to your network, and pre-terminated solutions offer flexibility, especially in data centers.

GigaSPEED X10D UTP margins



GigaSPEED X10D UTP channel performance



Time to Take Fiber Optic Cabling Technicalities Seriously

With optical transmission, technical talk about data rates, bandwidth, loss, fiber core size and the distances supported can be misleading. To make the right choice for 10G and beyond, it pays to know the language.

Channel or Link Loss The total path loss or attenuation between the transmitter and receiver is the sum of various loss mechanisms: scattering, microbending, macrobending and interconnection. These limit the maximum system length and the number of connections allowed.

Scattering The intrinsic fiber loss is dominated by what is known as Rayleigh scattering, which results from variations in density and compositions of the glass. This loss varies with the wavelengths of light applied. It is worthy to note that cable loss is NOT the same as fiber loss, as the cabling process may increase the loss above that of the fiber. For example, fiber loss may be given as 2.5 dB/km at 850 nm, while the cable made from that fiber may be rated at 3.5 dB/km at 850 nm.

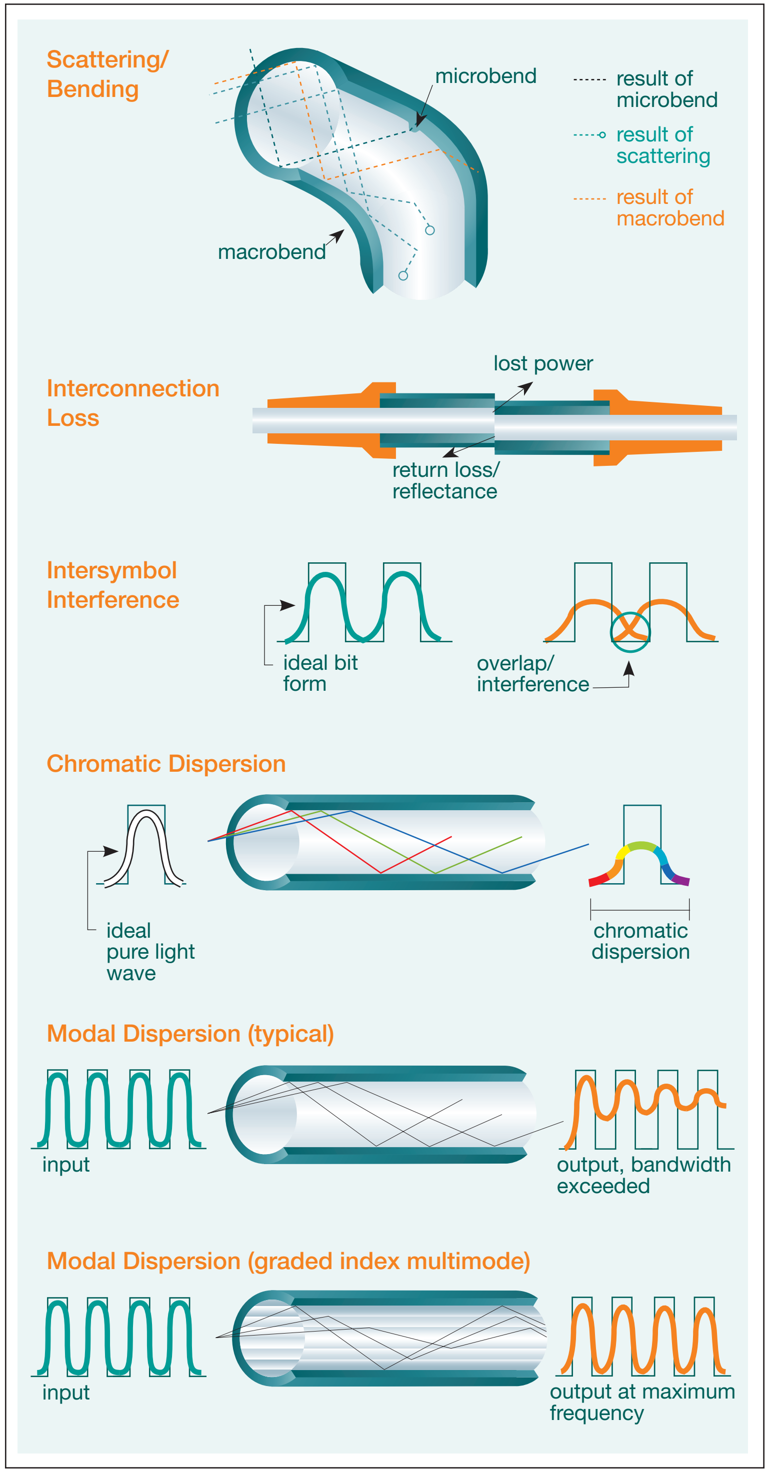
Microbending/macrobending A microbend is a local deflection of the fiber axis, with amplitude much less than the fiber diameter. Microbends can cause a light ray to strike the core-cladding interface at an extensive angle, allowing it to escape and increase loss. A macrobend is a bend or loop in the fiber with a radius of curvature of several millimeters or more, causing power to be lost from the core and inducing additional loss.

Interconnection Loss Interconnection loss associated with splices and connectors can be divided into intrinsic and extrinsic loss. Intrinsic mechanisms are a result of manufacturing tolerances on fiber core diameter, ovality, eccentricity and numerical aperture. Extrinsic mechanisms depend on the connection hardware and its ability to control separation between the fiber ends. Transverse, axial and angular misalignment of the fiber cores result in connector insertion loss. For simplex and duplex connections, the specific characteristics of the LC connector, including better fiber alignment, precision mating and easy connector cleaning combine to produce overall superior performance for factory-terminated and field installed connectors.

Intersymbol Interference (ISI) Within the optical fiber, bits of data are represented by pulses of light. Each pulse of light will spread, or disperse, over time as it travels along the length of the fiber. When these spreading pulses overlap, intersymbol interference results. The less intersymbol interference caused by dispersion, the greater the fiber's capacity to transmit information. There are two main types of dispersion in optical fiber in the LAN environment.

Chromatic Dispersion Chromatic dispersion describes the tendency for different wavelengths to travel at different speeds in a fiber. If operated at wavelengths where chromatic dispersion is high, optical pulses tend to broaden as a function of time or distance and cause intersymbol interference. Although multimode fiber exhibits relatively high chromatic dispersion at the 850 nm wavelength, the use of narrow spectral width lasers (e.g. VCSELs) in gigabit networks and the distances in the LAN minimize the effects.

Modal Dispersion In multimode fiber systems, the majority of the dispersion is caused by modal dispersion. Modal dispersion exists because the different light rays (modes) have a different optical path length along the fiber; therefore, rays entering at the same time will not arrive at the far end of the fiber at the same time. Light travels faster in the low-index regions near the cladding and slower in the high-index regions near the center of the core. This dispersion effect limits the bandwidth as shown in the illustrations.



Multimode or Single-mode?

Multimode fiber has the capability to meet both the distance and data rate demands of most LAN networks today. Generally, multimode systems cost less than single-mode systems, since the optoelectronics that can be used with multimode fiber are less costly than those used with single-mode fiber. This cost advantage explains the overwhelming popularity of multimode fiber over single-mode fiber in most premises networks.

In contrast to premises networks, single-mode fiber is virtually the only fiber used by telephone and cable television companies. These industries require the very long distance capability and high information carrying capacity of single-mode fiber. In these applications, single-mode systems are cost-effective because fewer optoelectronic devices are needed.

The Differences Between Fibers

Which fiber is better? The answer depends on the parameters of the network: the applications the network will need to support over the next few years and the length of the links. It also depends on whether you are evaluating a new installation or upgrading from an installed base.

The performance difference lies in the fibers' loss, its bandwidth, or information-carrying capacity, and in the power-coupling efficiency to light-emitting-diode (LED) sources. Bandwidth is specified as a bandwidth-distance product with units of MHz-km, and as the data rate goes up (MHz), the distance that rate can be transmitted (km) goes down. Thus, a higher fiber bandwidth can enable you to transmit at higher data rates or for longer distances.

But while fiber loss and bandwidth is important in determining link length and data rate, transmitter and receiver characteristics also play a critical role. Any statements on the distance capabilities of a particular fiber must be made in the context of the full suite of specifications for a given application.

■ How to Ensure Correct Comparison Between Multimode Fiber Types

How fiber is qualified and tested should be one of the first questions asked in any situation. The bandwidth of a multimode fiber is always specified in MHz-km and at specific wavelengths (e.g. 850 nm); however, test methods differ.

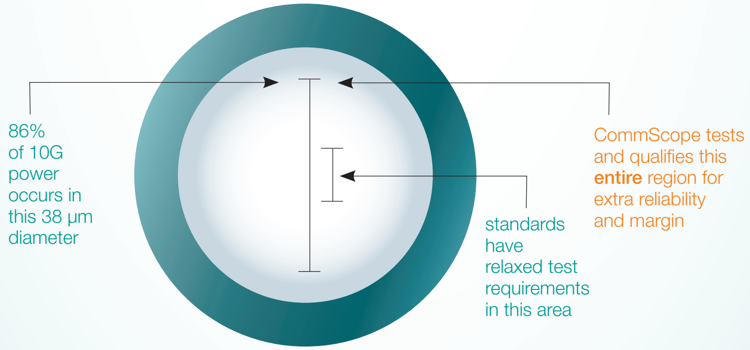
Historically, multimode fiber was tested and bandwidth specified using the OFL (Overfilled Launch) method. This method was optimized for use with LEDs. But as the gigabit era kicked in, lasers (VCSELs) became needed to transmit speeds above 1Gbps, so a new test method was required. In the DMD process, a laser is used to transmit pulses across the entire fiber core. As each of these pulses is received by a high-speed detector at the far end, the pulse delay is plotted and the DMD is calculated. This process is automated and covers all laser launch modes.

It is important to note that “laser” bandwidth, also referred to as Effective Modal Bandwith (EMB), is NOT the same as “overfilled” bandwidth (OFL).

Why the CommScope DMD Specification is Better

The standard DMD measurement scans the output from a single-mode fiber across the core of the sample multimode fiber core in radial launch positions separated by incremental steps of 2 µm. The CommScope Labs DMD testing facility uses a more precise laser and extracts even higher resolution information by reducing the step size to 1 µm, effectively doubling the number of scanning positions.

Further, CommScope disallows the relaxation permitted by the standard within the very center of the core for the LazrSPEED® solution. CommScope has shown that this High Resolution DMD provides greater assurance of adequate bandwidth for a wider set of fibers and laser launch conditions (see diagram below). As vendors look for looser laser specifications to reduce cost for 10G and 100G, HRDMD will become more important.



In addition, CommScope has UL certifications for its DMD test bench, assuring that the product meets both the standard and internal specifications.

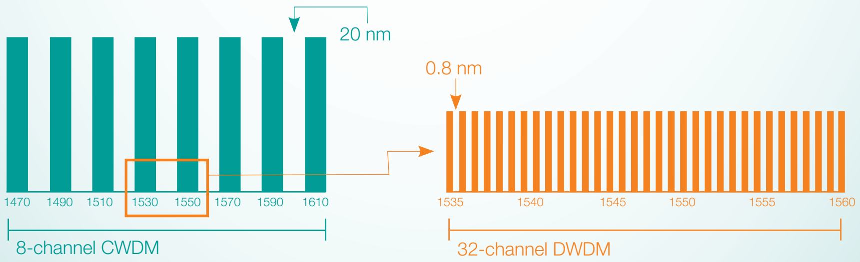
Extending Optical Fiber Capabilities

Several options exist for extending the capability of optical fiber. For example, LAN standards have yet to use multi-level coding on multimode fiber to increase transmission capacity using less bandwidth, a technique very popular in copper-based LANs. LANs can also take advantage of wavelength division multiplexing (WDM), which provides additional channels over the same fiber by using different colors (wavelengths) of light.

Parallel transmission is another way of increasing link speeds, with multiple fibers used to transmit data, combined with arrays of lasers and detectors capable of cost-effective data rate scaling over multimode fiber. As LAN speeds continue to evolve ever higher, these new technologies and approaches will continue to be developed and deployed.

CWDM and DWDM

Coarse Wave Division Multiplexing (CWDM) is a lower-cost alternative to Dense WDM because the different channels can share the fiber at greater wavelength separations, allowing lower tolerance transmitters and receivers. ITU recently standardized a CWDM grid with 20 nm separations between channels.



SYSTIMAX Fiber Solutions Advantages

Multimode: Lighting up the LazrSPEED® Specification

The SYSTIMAX LazrSPEED fiber specifications served as a blueprint that resulted in the publication of standards for Laser Optimized Multimode Fiber, including the detailed specification for the fiber, TIA-492AAAC Laser-Optimized Multimode Fiber specifications (also known as OM3 fiber) and the TIA FOTP-220 (IEC-60793-1-49) Differential Mode Delay (DMD) test method, as well as the inclusion of this media in the TIA/EIA-568 and ISO/ IEC 11801 cabling standards. These standards are also being considered as the basis for short-reach options for 40G and 100G applications.

LazrSPEED cables provide low attenuation at both 850 and 1300 nm and are available in 150, 300 and 550 versions. The difference between these options is their respective bandwidth at 850 nm and their supported distance for 10GBASE-SR. These cables, combined with the low loss of the SYSTIMAX LC connector family, stretch the small power budgets of today's high-speed applications to enable greater configuration flexibility and longer lengths. In addition, intelligent infrastructure options add extra vision, knowledge and control to your network; and pre-terminated solutions offer flexibility, especially in data centers.

Single-mode: Testing the TeraSPEED® Specification

For single-mode fibers, important optical transmission performance criteria include spectral attenuation (the attenuation characteristics across a range of wavelengths) and dispersion (how the signal at any wavelength will spread out as it travels).

TeraSPEED cables provide the widest possible usable spectrum by eliminating the high loss caused by water impurities in the 1400 nm region. With this water peak eliminated, the entire spectrum from 1260 to 1620 nm is available, allowing future expansion of data rates and additional services by the use of coarse wavelength division multiplexing (CWDM) (see **"CWDM and DWDM"**).

LazrSPEED® 150, 300 and 550 Specifications

Physical characteristics

Core Diameter	50.0 ± 2.5 µm
Cladding Diameter	125.0 ± 1.0 µm
Core/Clad Offset	≤ 1.5 µm
Coating Diameter (Uncolored)	245 ± 10 µm
Coating Diameter (Colored)	254 ± 7 µm
Coating/Cladding Concentricity Error, max	6 µm
Clad Non-Circularity	≤ 1%

Mechanical characteristics

Proof Test	100 kpsi (0.69 Gpa)
Coating Strip Force	0.3 - 2.0 lbf (1.3 - 8.9 N)
Dynamic Fatigue Parameter (nd)	≥ 18
Macrobending, max.	0.50 dB

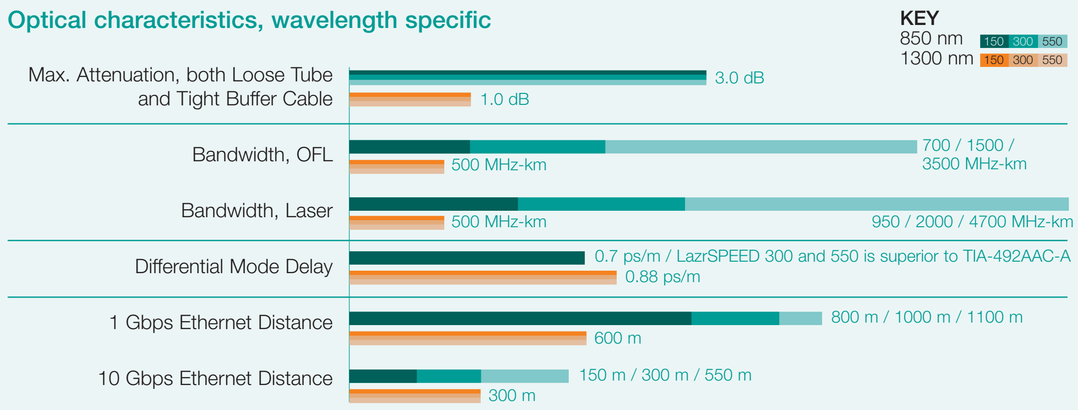
Optical characteristics, general

Numerical Aperature	0.200 ± 0.015
Point Defects, Max.	0.15 dB
Zero Dispersion Wavelength	1297-1316 nm
Zero Dispersion Slope	0.105 ps/[km-nm-nm]

Environmental characteristics

Temperature Dependence -76°F to 185°F (-60°C to 85°C)	≤ 0.10 dB
Temperature Humidity Cycling 14°F to 185°F (-10°C to 85°C) up to 95% RH	≤ 0.10 dB
Water Immersion, 73.4°F (23°C)	≤ 0.20 dB
Heat Aging, 185°F (85°C)	≤ 0.20 dB

Optical characteristics, wavelength specific



TeraSPEED® Specifications

Physical characteristics

Core Diameter	8.3 µm
Cladding Diameter	125.0 ± 0.7 µm
Core/Clad Offset	≤ 0.5 µm
Coating Diameter (Uncolored)	245 ± 10 µm
Coating Diameter (Colored)	254 ± 7 µm
Coating/Cladding Concentricity Error, max	12 µm
Clad Non-Circularity	≤ 1%

Mechanical characteristics

Proof Test	100 kpsi (0.69 Gpa)
Coating Strip Force	0.3 - 2.0 lbf (1.3 - 8.9 N)
Fiber Curl	≥ 4 m
Dynamic Fatigue Parameter (nd)	≥ 18
Macrobending, Max.	0.05 dB

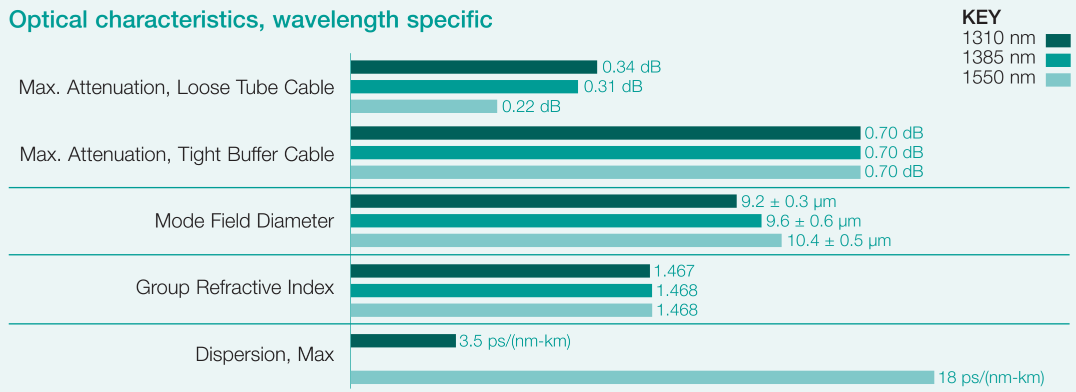
Optical characteristics, general

Point Defects, Max.	0.10 dB
Cut-off Wavelength	≤ 1260
Zero Dispersion Wavelength	1,302-1,322 nm
Zero Dispersion Slope, Max.	0.090 ps/[km-nm-nm]
Polarization Mode Dispersion Link Design Value	≤ 0.06 ps/sqrt (km)

Environmental characteristics

Temperature Dependence -76°F to 185°F (-60°C to 85°C)	≤ 0.05 dB
Temperature Humidity Cycling 14 °F to 185°F (-10°C to 85°C) up to 95% RH	≤ 0.05 dB
Water Immersion, 73.4°F (23°C)	≤ 0.05 dB
Heat Aging, 185°F (85°C)	≤ 0.05 dB

Optical characteristics, wavelength specific

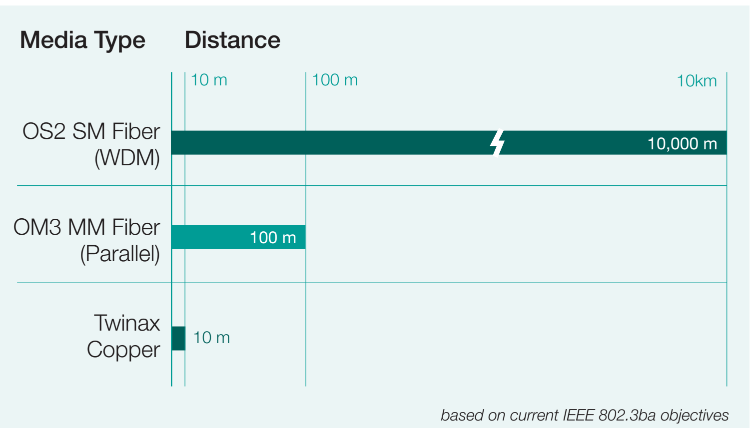


40G and 100G Ethernet Standards

The 40G and 100G standards are under development by the IEEE 802.3ba Task Force, based primarily on fiber optic technology (see "IEEE 40 and 100G Options").

Clearly, networking standards are not stopping at 10Gbps transmission speeds. The economic viability of 100GbE will depend on the transceiver options, which in turn depend on the PMD (Physical Media Dependent) options. There are several PMD options being considered by IEEE, the differences being distance supported, media used, transmission scheme and cost. For copper, consideration is being given to distances up to 10 meters, using twinaxial cable. For multimode fiber, OM3 is being considered for distances to at least 100 meters, using parallel transmission technology (longer distance may be possible using higher bandwidth fibers). For single-mode fiber, distances in excess of 10 kilometers are being considered using serial and WDM techniques.

IEEE 40G and 100G Options



Preparing for 100G with the SYSTIMAX InstaPATCH® Plus Array Connectivity Solution

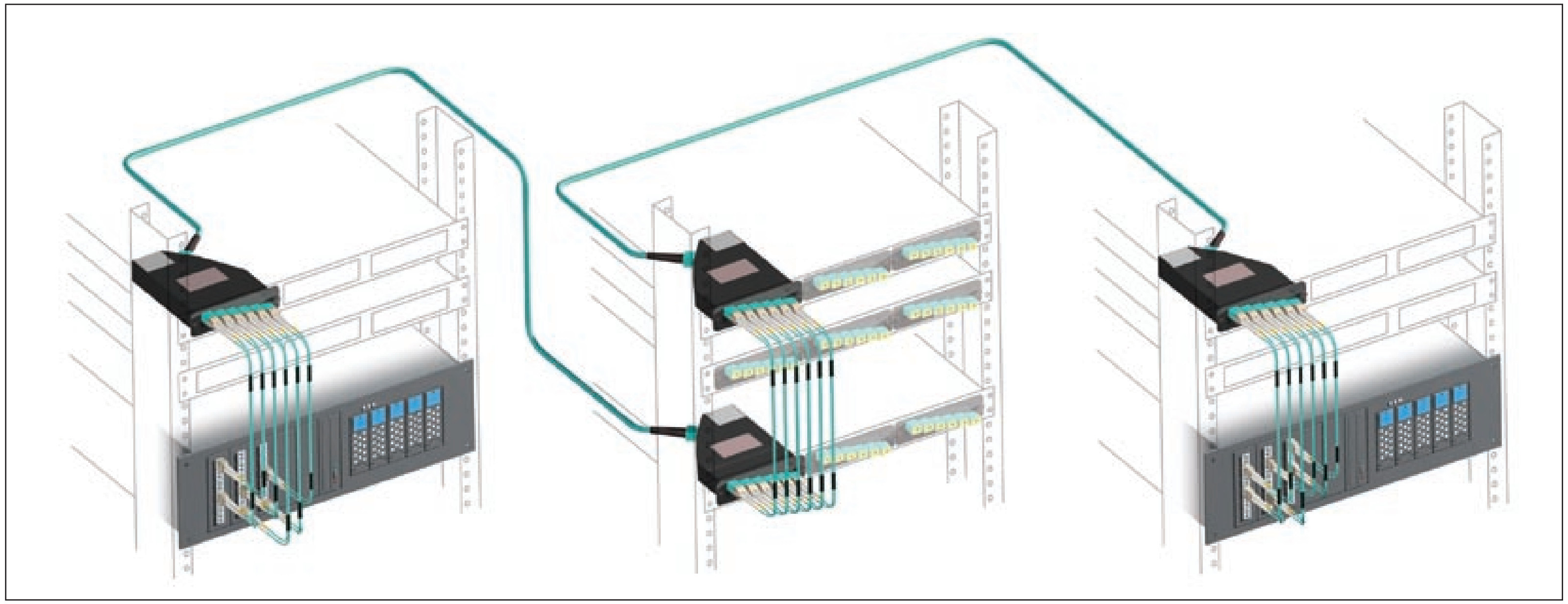
The SYSTIMAX InstaPATCH Plus system features a high-density, factory-terminated, factory-tested, modular fiber connectivity solution that allows installers to simply and quickly connect system components together. This modular system approach enables 96 fibers to be ready for service in the time it takes to make a single fiber connection with traditional systems. The InstaPATCH Plus System incorporates LazrSPEED multimode and TeraSPEED singlemode fiber technologies to support today's most demanding applications, while allowing easy migration and a future upgrade path to future 100G technology.

The InstaPATCH Plus system utilizes MPO array fiber connectors for plug-and-play connectivity. This solution allows fast, predictable and easy installation of high-density fiber applications, a key requirement for data center projects. The fiber cables and MPO connections, coupled with the polarity features of the InstaPATCH Plus pre-configured high-density patch panels, allow fiber networks to be deployed effectively onsite in less time and provide critical density by grouping many server connections together.

The InstaPATCH Plus System utilizes TIA 568 Method B to assure polarity, with NO special components required in the link design. Any combination of InstaPATCH Plus components will deliver correct polarity. The InstaPATCH Plus system supports parallel applications with no modification to the trunk cables and with standard array patch cords.

Benefits for data center designers include ease of installation for today, while providing a simple, cost-effective migration path for higher bandwitdth in the future. The InstaPATCH Plus system is engineered to anticipate the transition to parallel transmission schemes, such as those proposed for 100G. To move from serial to full paralell, it is a simple process to remove the duplex modules, insert the MPO-only modules, and attach addtional trunk cables to the network equipment.

InstaPATCH Plus Channel



Data Center Infrastructures: High in Fiber, Low in Network Saturates

Data Centers (DCs) offer a secure and reliable environment for high performance server hosting, data storage, redundant business backup, as well as redundant high-speed access to the Internet and corporate intranet. DCs use high-speed application servers, switches and storage devices and support high equipment densities, so environmental systems (especially cooling) are also very important.

With **extreme service reliability** being a trademark of these installations, DCs are addressed with high quality cabling solutions that allow for:

- Operational reliability
- High density
- High bandwidth
- Flexibility and modularity
- Secure access
- Quick changes and additions; rapid expansion
- Enhanced management, monitoring and service provisioning

With high bandwidth and high density requirements, fiber optic cabling is used in large parts of the DC, including the Storage Area Network (SAN), mainframe, switch and tape/disk drive connectivity. Twisted pair cabling is the common local equipment connection, such as in the Network Attached Storage (NAS) areas.

A Main Distribution Area

B Horizontal Distribution Area

C Storage room

D Electrical/mechanical rooms

E Telecommunications room

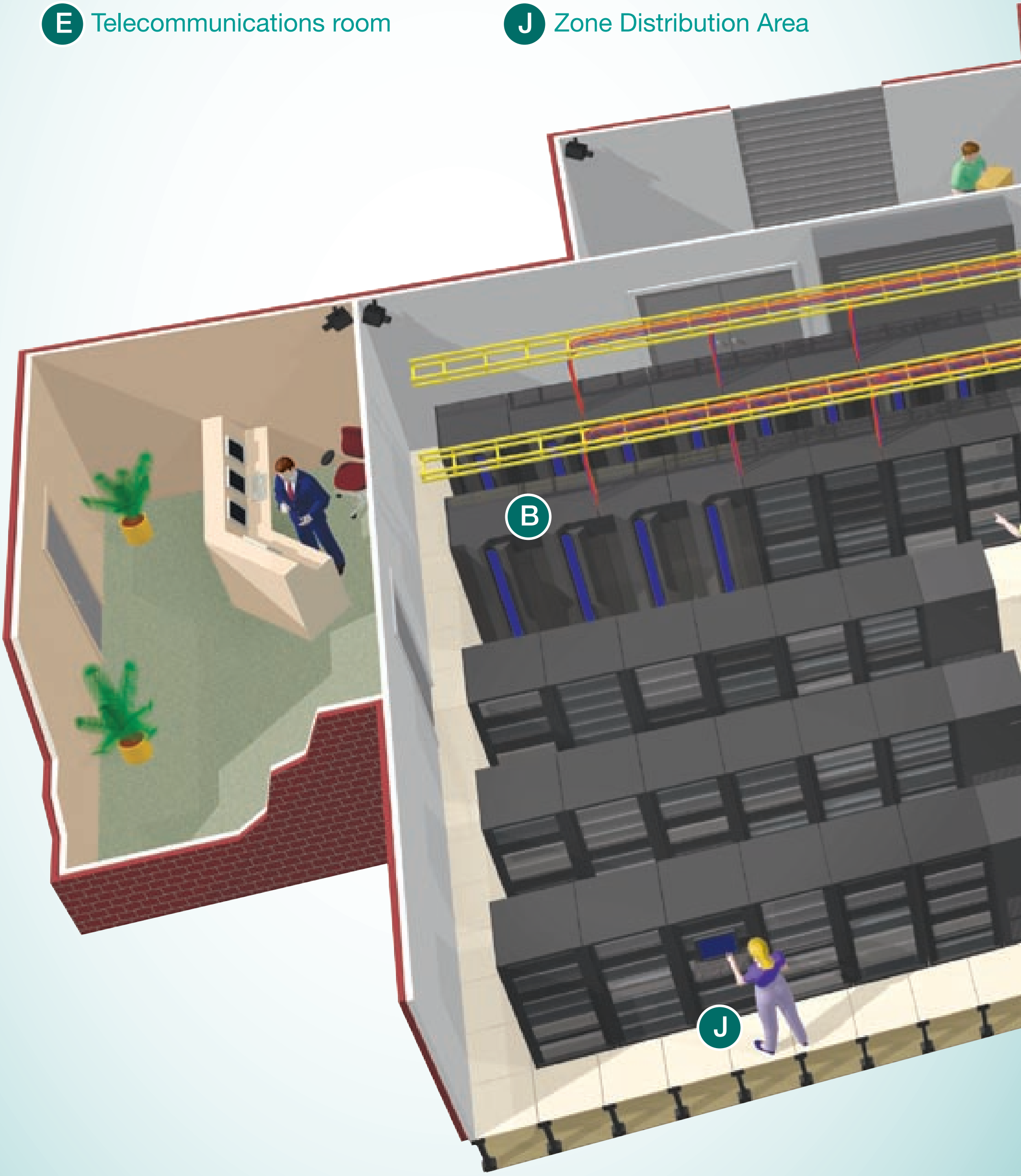
F Operations center

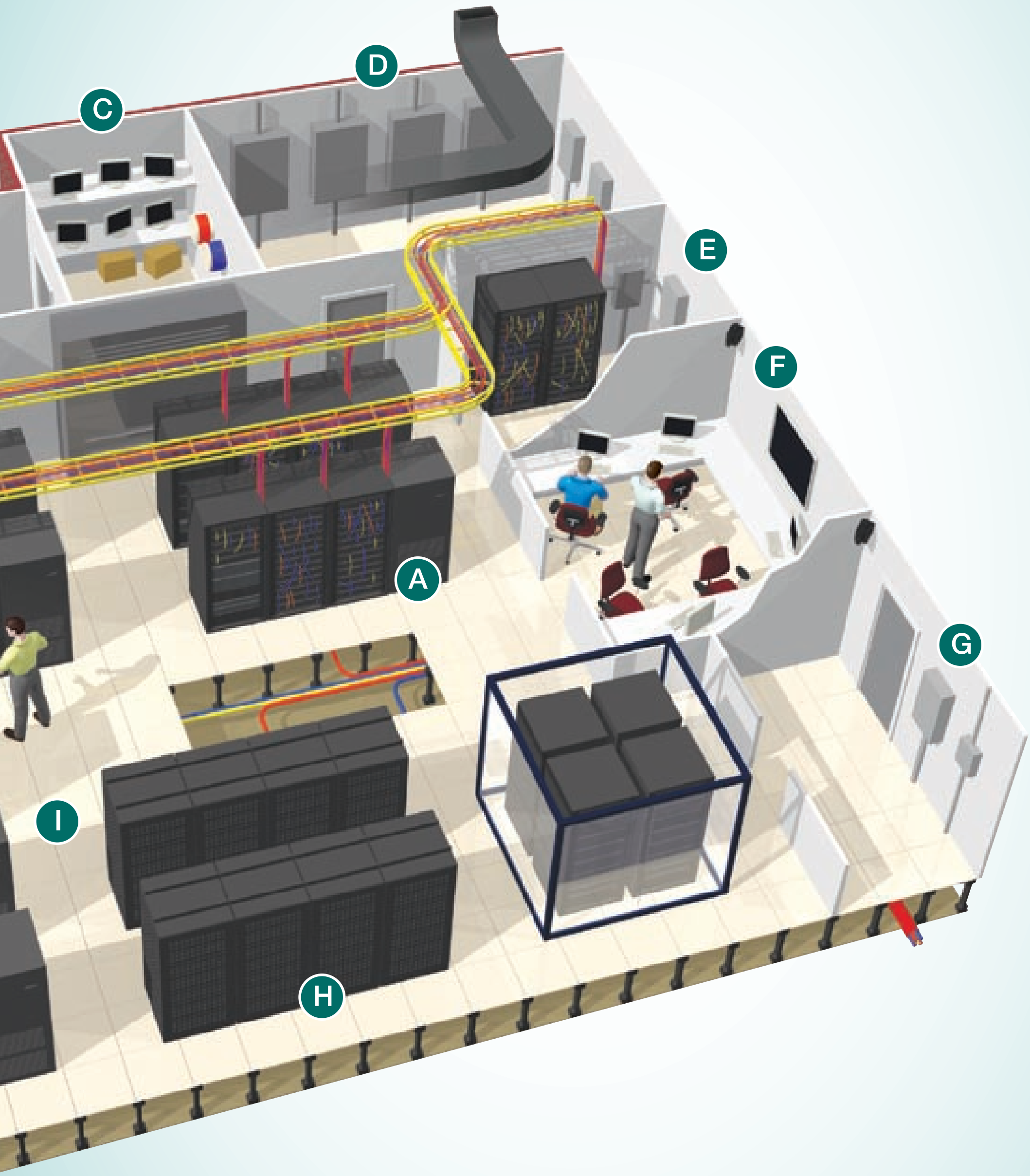
G Entrance room

H Equipment Distribution Area

I Computer room

J Zone Distribution Area




C
D
E
F
A
G
I
H

Converging Communication Networks – Emerging Cabling Considerations

In the core networks, such as long distance carrier segments, surging tributaries of packets and cells come together and get transported to other destinations. The characteristics of aggregated traffic here make bandwidth requirements relatively stable and predictable, but extremely large (Terabits per second). The trend for the core is toward high performance single-mode fiber, capitalizing on the low loss and multiple wavelength techniques such as WDM.

“Edge” networking, where wide-area networking and high-capacity private connections come into play, may be handled by an enterprise or Internet service provider, by a telecom carrier, or both. From the edge to the end user, traffic volume tends to be in the realm of tens of Gbps and much more variable than in the core. The trend here is toward wide-area networking with single-mode fiber such as Zero Water Peak (ZWP) fiber, which has opened up a larger window of wavelengths for use with WDM applications in metro/campus applications.

Within the enterprise, laser optimized OM3 multimode fiber will predominate in the building, data center and small campus backbones, supporting up to 100Gbps. At the desktop and other short connections, high-performance Category 6A copper cabling will allow cost-effective gigabit and 10 gigabit Ethernet LANs, and beyond.

To 10G and Beyond

Key 10G Over Twisted Pair Checklist:

- Are all the performance guarantees based on 4-connector, 100 meter, UTP channels?
- Does the vendor's 4-connector, 100 meter channel meet insertion loss, PSANEXT and PSAELFEXT (PSAACR-F) of IEEE 802.3an requirements extended to 500 MHz?
- Do the vendor's 4-connector, 100 meter channel meet Category 6A/Class E_A Insertion Loss, Return Loss, NEXT, PSNEXT, ELFEXT (ACR-F), PSELFEXT (PSACR-F), PSANEXT and PSAELFEXT (PSAACR-F) requirements extended to 500 MHz, as per the ISO/IEC and TIA/EIA standards?
- Is the extended channel performance also achievable in short channel configurations?
- Are the Alien NEXT and ELFEXT (ACR-F) specifications clearly stated and provided for up to 100 meter, 4-connector channels in a 6-around-1 configuration?
- Can the vendor provide test results and independent verification for all the above that clearly indicate the test configuration?
- Does the solution require mitigation steps to achieve 10G performance and what are they?

Key 10G/100G Over Multimode Fiber Checklist:

- Are the cables DMD tested to specify Effective Modal Bandwidth (EMB)?
- If DMD tested, does the supplier disallow relaxation of DMD in the center of the core?
- If DMD tested, does the supplier use a third-party certified DMD test bench?
- Does the supplier test system-level lengths of cables (300-550 m)?
- Does the supplier provide EMB ratings at 1300 nm?
- Does the supplier disallow the use of Restricted Mode Launch (RML) metrics instead of DMD/EMB?
- Does the supplier certify 1300 nm laser applications like 1000BASE-LX (long wavelength Gigabit Ethernet) to operate to full standard distances without the use of offset-launch mode-conditioning patch cords?
- Are the same specifications being compared? (E.g. don't compare cable to fiber attenuation.)
- Is the attenuation specification a worst case (maximum) value, or a typical, or nominal value? (The only fair comparison to our specifications is the supplier's maximum value.)
- Does the supplier's attenuation specification apply to all the cable constructions the customer needs?

Key 10G/100G Over Single-mode Fiber Checklist:

- Is the fiber a low-water peak type?
- Is the water peak attenuation specified and lower than the attenuation at 1310 nm?
- Are the same specs being compared? (Don't compare fiber attenuation to cable attenuation.)
- Is the dispersion as low or the applicable wave-length range as wide as that of TeraSPEED cables?
- Is the zero dispersion wavelength range as narrow as that of TeraSPEED cables?
- Is the zero dispersion slope as low as that of TeraSPEED cables?

Key Fiber Connector Checklist:

- Does the supplier offer LC connectors?
- Is the loss specified by a mean and standard deviation, or by only average or typical values? (Terms like "typical" have no defined meaning in specifications and are used to inflate claims; only mean and standard deviation specifications allow full assessment of the loss of completed channels.)
- Does the supplier document the supportable link configurations for all applications and stand behind them with a warranty?

Key Array Connectivity Checklist:

- How flexible/durable is the pre-terminated cordage during installation and MAC's?
- Do the trunk cables and cords utilize a round loose-tube sub-unit in it's assemblies, resulting in a flexible ribbon-free cable?
- What is the highest fiber count available? Is it available with options up to 144 fibers?
- How does the pre-terminated fiber array system assure traditional dual-fiber polarity? Is the solution standards-based? Does it utilize TIA 568 Method B to assure polarity, with NO special components required in the link design?
- Can the system support parallel applications? Does it support parallel applications with no modification to the trunk cables and with standard array patchcords?
- What is the maximum port density of the system? Are there options for 96 LC ports in 1RU (HD Shelf), 288LC ports in 4RU (modules)?
- What is the maximum fiber count of a break-out cable (MPO-to-single fiber connector)?

Visit our Web site at **www.commscope.com** or contact your local CommScope representative or BusinessPartner for more information.