ProCurve Networking by HP

ProCurve Networking Technical Brief

10-Gigabit Ethernet Cabling

Introduction

Born in the 1970s, Ethernet technology has continually evolved in order to meet the never-ending requirement for faster rates of data transmission. Through this ongoing evolution, it has matured into the foremost technology standard for local area networks (LANs) as newer, higher-performing iterations—such as 10-Gigabit Ethernet (10-GbE)—become more commonplace.

The demand for faster application speeds has also spurred technological evolution on data-carrying techniques. As such, copper and fiber transmission standards have progressed, providing greater bandwidth for transporting data over Ethernet architectures with reduced cost and complexity.

This paper highlights various Ethernet standards and data-carrying techniques, with particular emphasis on the utilization of existing fiber and copper cabling technologies for 10-GbE LAN use.

Why 10-Gigabit today?

Most LAN infrastructures employ a mixture of copper and fiber premises wiring. Many companies have legacy fiber connectivity for backbone links with copper wiring in place for wiring closets. These legacy backbones are generally sufficient as long as there are no demands for greater network performance or application bandwidth.

However, as companies grow their networks and support new applications and traffic types, they are increasingly migrating to gigabit links. With gigabit connectivity widely available for gigabit-based PCs, servers, data center storage, and high-end computing, gigabit technology is emerging as the connection of choice for many organizations.

So why is there a need for ten times gigabit performance, or 10-GbE, today?

More for less

In the past, 10-GbE was neither necessary nor affordable. As with most burgeoning technologies, those dynamics are changing. Technological advancements have resulted in higher performance at lower costs. As such, gigabit and 10-GbE bandwidth have become affordable for most companies.

Regardless of cost, there is also a distinct need. An increasing number of applications require considerable bandwidth to support the transfer and streaming of large data, video, and audio files. As bandwidth-intensive applications and latency-sensitive traffic types become ubiquitous, so does the need to support and transport them.

In addition, many companies are seeking to "future-proof" their networks to help ensure that they can support emerging technologies and preserve their initial investments. In the past, fiber and wire cabling systems were installed with a ten-year lifespan in mind. However, with the rapid, ongoing evolution of network technologies, companies must be concerned with their current infrastructure's ability to keep pace.

Costs associated with recabling a network can be exorbitant and organizations should take precautions to help ensure that their cabling systems can last well into the future. 10-GbE provides the very best assurance for being able to support forthcoming technologies and delivers the utmost investment protection.

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Data centers

For many institutions—especially those that utilize automated trading—uptime and response time is critical. Delays longer than a second can be exceedingly costly. With servers now being able to transmit near-gigabit bandwidth and network downtime proving catastrophic, today's enterprise data centers need extended bandwidth.

10-GbE is an ideal technology for moving large amounts of data quickly. The bandwidth it provides in conjunction with server consolidation is highly advantageous for Web caching, real-time application response, parallel processing, and storage.

Campus backbone links

Many organizations wish to connect their campus buildings with high-speed links. Carrier-based services offload the burden of establishing and maintaining a 10-GbE backbone, but limit flexibility and oftentimes prove too costly with expensive, unending monthly bills. This ongoing expense can be overwhelming for educational institutions, government organizations, and hospitals, as well as for enterprise organizations that do not have a set budget year to year.

Establishing a 10-GbE campus backbone is a one-time expense that can provide significant cost savings when compared to monthly communications link bills.

Metro area transmission

Many companies also need to send and receive data beyond their campus, oftentimes in the form of large or streaming files that require high-speed links. Traditionally an area for carriers, 10-GbE now offers an attractive alternative to costly monthly charges for long-distance data transmission.

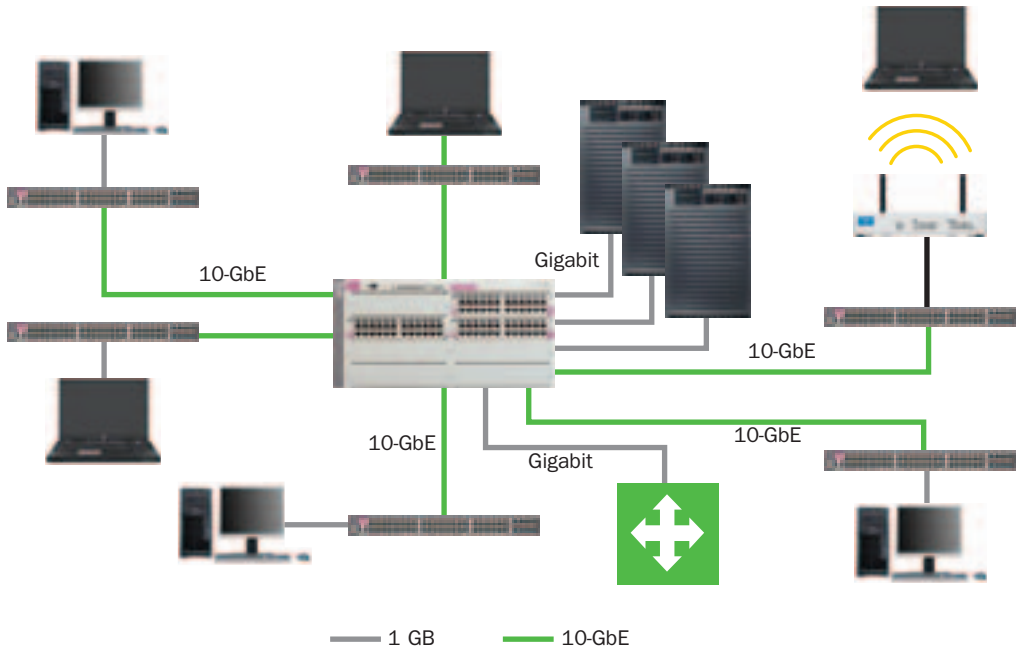
Many carriers offer expensive transmission services utilizing SONET OC-48 or OC-192c standards. These are considered "lit" services, where a company has to add protocol conversion to be able to link from end to end.

Conversely, "un-lit" fiber—called "dark fiber"—is now being offered by carriers to companies that are able to provide their own connectivity. In these cases, routing switches supporting the 10-GbE standard can provide their own transmission. Taking advantage of 10-GbE performance in tandem with carriers' Dark Fiber services can dramatically reduce costs when compared to "lit" transmission services.

Copper versus fiber

Once the decision is made to implement 10-GbE functionality, organizations must consider the data-carrying techniques that facilitate such bandwidth. Copper and fiber cabling are the preeminent technologies for data transmission and provide their own unique benefits and drawbacks.

Enterprise data center with 10-GbE backbone



Copper is the de facto standard for transmitting data between devices due to its low cost, easy installation, and flexibility. It also possesses distinct shortcomings. Copper is best when utilized in short lengths, typically 100 m or less. When employed over long distances, electromagnetic signal characteristics hinder performance. In addition, bundling copper cabling can cause interference, making it difficult to employ as a comprehensive backbone. For these reasons, copper cabling has become the principal data-carrying technique for communication among PCs and LANs, but not for campus or long-distance transmission.

On the other hand, fiber cabling is typically used for remote campus connectivity, crowded wiring closets, long-distance communications, and environments that need protection from interference, such as manufacturing areas. Because it is very reliable and less susceptible to attenuation, it is ideal for sending data beyond 100 m. However, fiber is also more costly than copper and its use is typically limited to those applications that demand it.

As a result, most organizations utilize a combination of copper and fiber cabling. As these companies transition to 10-GbE functionality, they must have a solid understanding of the various cabling technologies and a sound migration strategy to provide a cabling infrastructure that will support their network infrastructure, both today and tomorrow.

The evolution of cabling technologies

Just as gigabit and 10-GbE technologies have changed, so have the cabling technologies that support them. In fact, evolutions of cabling technologies have walked in-step with, and been largely driven by, evolutions to gigabit and 10-GbE standards. Both IEEE 802.3 standards and the associated cabling technologies have assumed many forms in order to enhance a variety of environments.

A grasp of the particular gigabit or 10-GbE standard being employed is just as important as an understanding of the circumstance and environment—factoring distance of data transmission, equipment being utilized, and budget—in order to determine what cabling strategy best suits a particular organization. Just as the difference between sending data 100 m and 100 km affects the more effective cabling strategy, so does the difference between sending data with IEEE 802.3ae and IEEE 802.3ak standards.

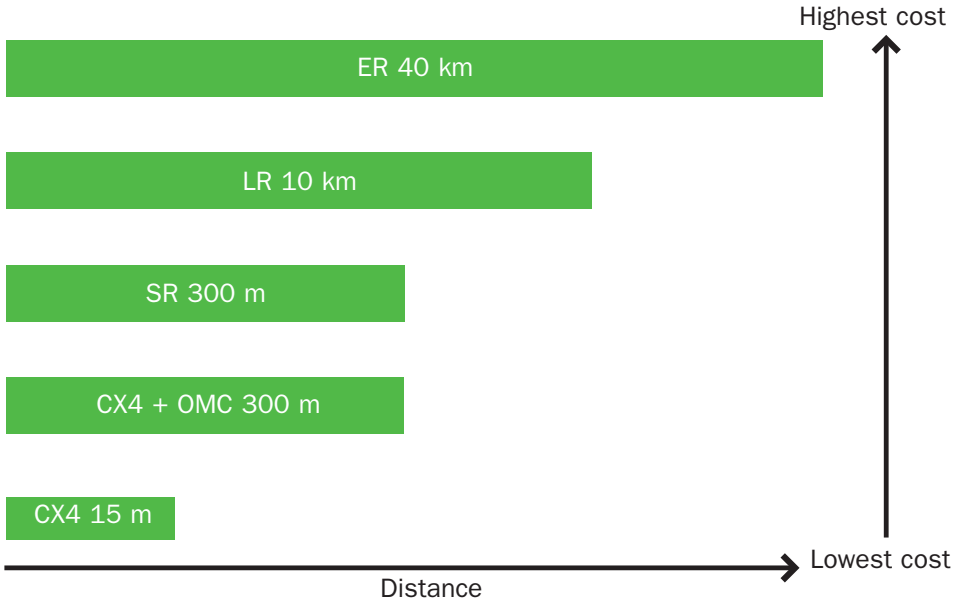
The 10-GbE standards outlined below help define and enhance the environment in which they operate and the cabling technologies over which they communicate.

IEEE 802.3ae

Ratified in June 2002, the IEEE 802.3ae LAN standard was developed to update the preexisting IEEE 802.3 standard for 10-GbE fiber transmission. With the new standard, six new media types were defined for LAN, metropolitan area network (MAN) and wide area network (WAN) connectivity:

- 10GBASE-SR—uses the lowest-cost optics (850 nm) to support 10-GbE transmission over standard multimode fiber for distances of 33 and 82 m. The SR standard also supports up to 300 m using the new 2000 MHz*km multimode fiber (laser optimized). SR is the lowest-cost optics of all defined 10-GbE optics.
- 10GBASE-LR—uses higher-cost optics (1310 nm) than SR and requires more complex alignment of the optics to support single-mode fiber up to 10 km.
- 10GBASE-LX4—supports traditional FDDI-grade multimode fiber for distances up to 300 m using Coarse Wavelength Division Multiplexing (CWDM), which lowers the transmission rate of each wavelength to 3.125 Gbaud. The LX4 standard also supports single-mode fiber for up to 10 km. LX4 is more expensive than both SR and LR because it requires four times the optical and electrical circuitry in addition to optical multiplexers. Over time, the quantity of components required to implement the technology may limit its ability to fit into smaller form factors.
- 10GBASE-ER—uses the most expensive optics (1550 nm) to support single-mode fiber up to 30 km. For 40 km, the fiber-optic connection must be an engineered link.
- 10GBASE-LRM—The LRM standard was ratified in November 2006, and supports up to 220 m over standard multimode fiber. Using a technology called Electronic Dispersion Compensation (EDC), 10GBASE-LRM can provide a long-distance solution based on multimode fiber and operates with a single wavelength (1310 nm).
- 10GBASE-SW, 10GBASE-LW, 10GBASE-EW—defined for use with a WAN PHY. These standards were defined to operate at the same baud rate as OC-192/STM-64 SONET/SDH equipment. They are the equivalent of the SR, LR, and ER standards and support the same fiber cabling. LX4 does not have an equivalent WAN PHY standard.

IEEE 802.3 cabling cost and distance considerations



IEEE 802.3ak/10GBASE-CX4

Approved in February 2004, 10GBASE-CX4 is a low-cost 10-GbE solution intended for copper cabling with short-distance connectivity that makes it ideal for wiring closet and data center connectivity. The first 10-GbE copper cabling standard, 10GBASE-CX4 provides immediate advantages with its affordability and wide availability.

The CX4 standard transmits 10-GbE over four channels using twin-axial cables. The cables were derived from InfiniBand connectors and cable, but the CX4 standards committee defined the cables to be tighter in electrical specifications. Therefore, longer-length (>10 m) InfiniBand cables will not necessarily work for CX4 applications and it is recommended that networks use only cables that are designed to meet IEEE 802.3ak specifications when using CX4.

Another aspect of the CX4 cable is the rigidity and thickness of the cable. The longer the cable length used, the thicker the cable will be. CX4 cables start at 30 American Wire Gauge (AWG) for short lengths to 24 AWG thickness for a full 15 m. CX4 cables must also be factory terminated to meet defined specifications, so they should be ordered to length.

IEEE 802.3an/10GBASE-T

Proposed in November 2002, 10GBASE-T is the latest 10-GbE standard for use with unshielded twisted pair (UTP) style cabling. The goal of this copper standard, ratified in June 2006, is to approximate RJ-45 connectivity of 100 m. It is intended to improve the performance and distance of copper cabling at a cost that is lower or similar to fiber.

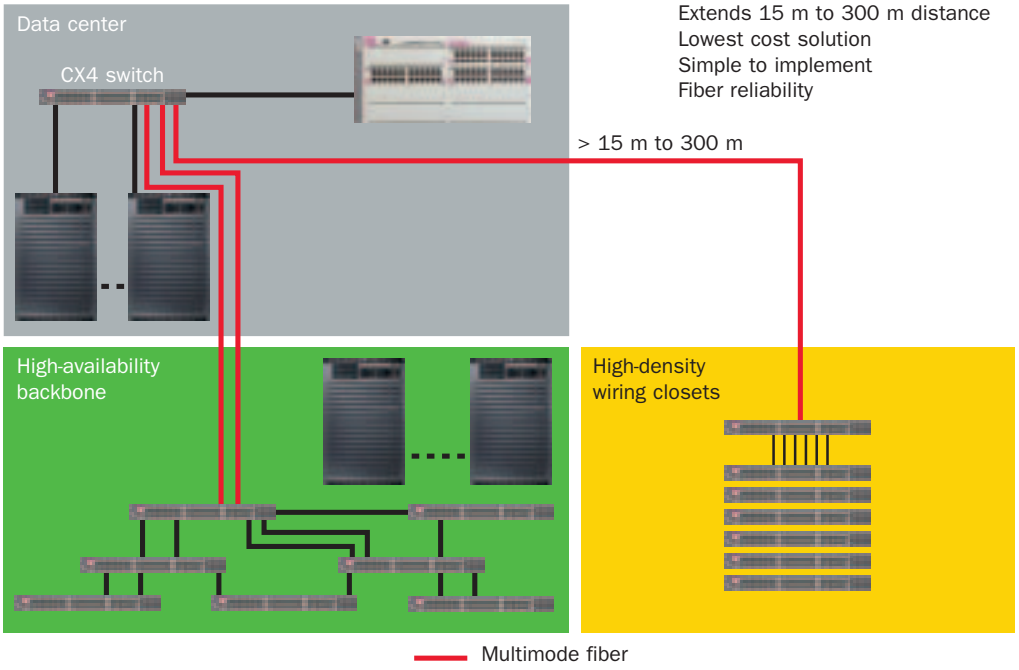
Category 5 (Cat 5) and Category 6 (Cat 6) are the most common cabling systems being installed today, but Cat 5 is not capable of meeting the bandwidth and crosstalk demands of 10-GbE's higher transmission speeds. In a large percentage of installations, cabling will need to be modified to support it. To meet the needs of 10-GbE, a Telecommunications Industry Association (TIA) subcommittee for cabling specifications is working to provide additional specifications that will help vendors create sufficient cabling.

The defined cabling standard is Category 6A (Cat 6A), which is designed with existing Cat 6 cable but measured and specified to higher frequencies. In addition to Cat 6A, 10GBASE-T will operate on Category 7 (Cat 7) cables.

Optical media converters

Optical media converters have traditionally been used in converting Ethernet LAN copper transmission to fiber-optic cabling for the express purpose of extending the copper distance past 100 m. More of an implementation tactic than cabling standard, optical media converters provide a way to utilize existing copper and support low-cost fiber transmission. In many cases, fiber can extend 100 Mb transmission over 100 km and 1000 Mb transmission up to 70 km.

Utilizing CX4 optical media converters



To extend the current distance limitation of 15 m for 10GBASE-CX4, ProCurve has introduced a 10-GbE optical media converter to extend the supported distance up to 300 m. These converters snap directly to the CX4 port and receive power through the CX4 connector to ease implementation for customers. The fiber cable used is 12-fiber 62.5 µm or 50 µm multimode ribbon cable terminated by standard Multiple Terminations Push-Pull Latch (MTP™) connectors in a simple crossover configuration. These cables are generically known as Multi-Fiber Push On, or MPO, cables.

ProCurve can now provide much higher flexibility and 10GBASE-SR distance at half the price using a 10GBASE-CX4 switch port.

10-GbE transceivers

IT professionals must also consider the devices that connect their cabling to their network. Transceivers provide the interface between the equipment sending and receiving data and the cabling transporting it. Just as there are distinct cabling technologies that coincide with distinct gigabit technologies, various transceivers are also available to match each gigabit standard.

Both gigabit and 10-GbE technologies have "pluggable" transceivers. For gigabit technology, there are two defined transceiver types: Gigabit Interface Connector (GBIC) with its large metal case for insertion into low-density interface modules and units (switches), and the newer "mini-GBIC" or Small Form Factor Pluggable (SFP).

10-GbE has five defined transceiver types. These transceivers are the result of Multi-Source Agreements (MSAs) that enable vendors to produce IEEE 802.3ae-compliant pluggable transceivers. The five types are:

- XENPAK—the first 10-GbE pluggable transceivers on the market to support the IEEE 802.3ae standard transmission optics. They are large and bulky, and are mainly used in LAN switches. These transceivers are "hot-pluggable" and support the new IEEE 802.3ak copper standard with vendors now producing transceivers to connect CX4 cables.
- XPAK—used primarily in network interface cards (NICs) and host bus adapter (HBA) markets for use in servers and NAS devices.
- X2—the smaller brother of the XENPAK pluggable transceivers, the X2 form factor is about two-thirds the size of the XENPAK. With the same "hot-pluggable" specifications and supporting all the 10-GbE standards (including copper), the X2 form factor allows for more port density on switches. X2 is being used by ProCurve and Cisco, thereby providing customers with a strong sense of assurance that this technology is the best choice for today and will have strong vendor support.

- XFP—the newest pluggable transceiver on the market, XFP is the closest in size to the SFP pluggable transceiver now used for gigabit technology. Because it relies on a high-speed interface (10.3125 Gbps), high-priced serializer/deserializer (SERDES) are required inside the switch to support it. Over time, the cost of such SERDES will decline, but today they add an unacceptable cost to the base system. Still, the positive aspect of the XFP form factor is it will allow switch vendors to increase port density in a smaller area for cost savings. A drawback of the XFP will be its inability to support the current copper (IEEE 802.3ak) or the 10GBASE-LX4 standards.
- SFP+—As the industry brings down the cost and power of 10-Gigabit optical devices, effort to increase the capacity of the existing SFP is being considered. For many customers, the possibility of achieving 10-Gibabit speeds and a mechanical form factor that allows 1-Gigabit or 10-Gigabit to reside in the same footprint might prove attractive. ProCurve continues to evaluate SFP+ as an alternative for the future.

Summary

As organizations grow their networks and support bandwidth-intensive applications and traffic types, 10-GbE technology is becoming evermore pervasive. 10-GbE functionality can provide immediate performance benefits and safeguard a company's investment well into the future.

Just as there are many manifestations of the gigabit and 10-GbE standards to suit various networking environments, there are also many copper and fiber cabling technologies to support them. Companies must have a solid understanding of not only their environment and need, but also the different standards and cabling technologies available to them. Doing so will help them develop a sound migration and cabling strategy, enabling them to reap the benefits of 10-GbE for years to come.

Appendix—cabling specifications

Table 1. Ethernet LAN cabling standards

IEEE standard	Cabling standard	Speed	Cabling type
802.3	10BASE-5, 10BASE-2	10 Mb	Coaxial cabling
802.3i	10BASE-T	10 Mb	RJ-45 cat 3
802.3u	100BASE-TX	100 Mb	RJ-45 cat 5
802.3u	100BASE-FX	100 Mb	62.5µ multimode fiber, 50µ multimode fiber
802.3z	1000BASE-CX	1000 Mb	2-pair, 150 ohm twinaxial cable/DB-9
802.3z	1000BASE-SX	1000 Mb	62.5µ multimode fiber, 50µ multimode fiber
802.3z	1000BASE-LX	1000 Mb	62.5µ multimode fiber, 50µ multimode fiber, 9µ single-mode fiber
802.3ab	1000BASE-T	1000 Mb	RJ-45 cat 5e, 6
802.3ae	10GBASE-SR	10 Gb	62.5µ multimode fiber, 50µ multimode fiber
802.3ae	10GBASE-LR	10 Gb	9µ single-mode fiber
802.3ae	10GBASE-ER	10 Gb	9µ single-mode fiber
802.3ae	10GBASE-LX4	10 Gb	62.5µ multimode fiber, 50µ multimode fiber, 9µ single-mode fiber
802.3ak	10GBASE-CX4	10 Gb	8 pair, 100 ohm twinaxial cabling
802.3an	10GBASE-T	10 Gb	RJ-45 cat 6A, 7

Table 2. Gigabit Ethernet distances—fiber

Gigabit Ethernet	Wavelength (nm)	Fiber type (µm)	Modal bandwidth (MHz*km)	Range (m)
1000BASE-SX	850	62.5/125	160	2–220
			200	2–275
		50/125	400	2–500
			500	2–550
1000BASE-LX	1310	62.5/125	500	2–550*
		50/125	500	2–550*
		9/125	N/A	2–10,000

* Requires mode conditioning patch cord to launch optical power properly into fiber

Table 3. Gigabit Ethernet distances—copper

Gigabit Ethernet	Connector	Cable	Range
1000BASE-T	RJ-45	Cat 5e, 6	100 m

Table 4. Gigabit vs. 10-GbE fiber

Gigabit Ethernet	10-GbE
CSMA/CD + full duplex	Full duplex only
Leveraged Fibre Channel PMDs	New optical PMDs
8B/10B coding	New 64B/66B coding
Support LAN to 70 km (proprietary method)	Support LAN to 40 km

Table 5. Gigabit vs. 10-GbE copper

Gigabit Ethernet	10GBASE-CX4
CSMA/CD + full duplex	Full duplex only
Complex DSP to stay below 125 Mbaud on Cat 5e	4 channels at 3.125 GHz on high-performance cable assemblies
4-dimensional PAM 5 coding	8B/10B coding
Support 100 m of Cat 5e, Cat 6 cables	Support 15 m custom cable Optical media converters using MMF, to 300 m

Table 6. 10GBASE-SR

Fiber type	Modal bandwidth at 850 nm (MHz*km)	Minimum range (meters)
62.5/125 µm MMF	160	2–26
62.5/125 µm MMF	200	2–33
50/125 µm MMF	400	2–66
50/125 µm MMF	500	2–82
50/125 µm MMF (laser-optimized)	2000	2–300

Table 7. 10GBASE-LR

Fiber type	Nominal wavelength (nm)	Minimum range (meters)
9/125 µm SMF	1310	2–10,000

Table 8. 10GBASE-ER

Fiber type	Nominal wavelength (nm)	Minimum range (meters)
9/125 µm SMF	1550	2–30,000*

* Requires engineered link for 40 km distance

For more information

To find out more about ProCurve Networking products and solutions, visit our Web site at **www.procurve.com**

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