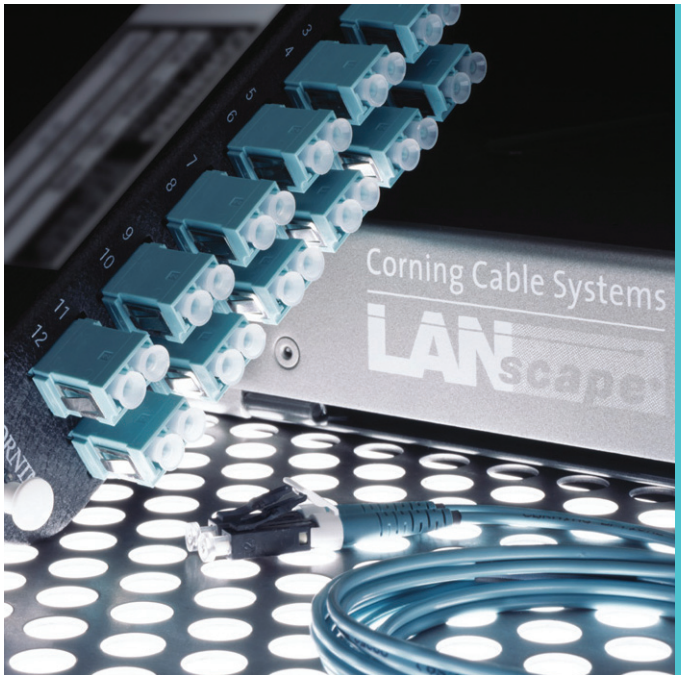
Just the Technical Facts



If you plan to deploy, or migrate, your network to 10 Gb/s, don't let those bulky, twisted-pair copper cables fool you. Complex to design with and install, UTP copper cables create more issues than they resolve at 10 Gb/s and beyond.

The Real Facts About Copper Twisted-Pair at 10 Gb/s and Beyond

The time is now for 10G optical connectivity in the local area network (LAN) and data center. The transmission performance, data rate scalability, pathway and space utilization, electronics port density, power and cooling efficiencies, ease of installation and testing make optical connectivity the choice solution when compared to 10GBASE-T copper connectivity.

The IEEE (Institute of Electrical and Electronics Engineers) 802.3ae released the optical 10G Ethernet standard in 2002 with the 10GBASE-SR physical media dependent (PMD) for short-range links up to 300 m. 10GBASE-LR and 10GBASE-ER PMDs are for lengths beyond 300 m.

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The IEEE 802.3an 10GBASE-T Standard was approved in July 2006. This standard provides guidance for data transmission of 10 Gb/s in which multi-gigabit rates are sent over 4-pair copper cable within a 500 MHz bandwidth. The outlook for transmission faster than 10 Gb/s on twisted-pair copper links is doubtful, due to the required distances in the data center as well as the local area network (LAN). End-users installing 10G twisted-pair copper today will most likely need to replace their copper cables when they transition to speeds greater than 10 Gigabit.

Distance Capabilities for 10G over Twisted-Pair Copper Depends on the Cable Design

Category 6 UTP (unshielded twisted-pair), Category 6 F/UTP (foil shielded) and Category 7 S/FTP (shielded twisted-pair) are the only three standardized cable solutions currently available to support 10GBASE-T. The CAT 6 UTP reach is rated in the range 37-55 m, but many industry experts believe that anything longer than 37 m may be subject to alien cross talk failures. CAT 6 UTP has system reliability concerns, since the

cable is only specified to operate up to 250 MHz. Most 10G copper systems will require removal of legacy CAT 6 UTP cable and the installation of CAT 6A UTP cable. Copper UTP cable is the de facto standard copper cable used in North America.

CAT 6 F/UTP and CAT 7 S/FTP are rated to 100 m. Minimal shielded copper cables have been deployed in the United States, Canada and Mexico, due to special installation and termination practices. Cable stiffness, weight, large bend radii, as well as grounding and bonding issues, make them complex to install. In addition, industry experts believe they present power-over-Ethernet concerns due to heat dissipation issues. BSRIA, an independent market research group, reported in 2005 that less than 1.5 percent of structured cable meters installed in the United States use shielded cable.

10GBASE-T Requires a New UTP Copper Cable Design

Performance issues of CAT 6 UTP resulted in the development of yet another UTP copper cable called augmented CAT 6 (CAT 6A) that is intended to support 10G operation up to 100 m. Today, the CAT 6A detailed cable standards from TIA (Telecommunications Industry Association) and IEC (International Engineering Consortium) have not yet been completed. All CAT 6A networks installed before the standards are completed are effectively proprietary solutions with potential interoperable issues. Minimal 10G interoperability has been demonstrated among different CAT 6A cable and hardware manufacturers. For operation at 10G, the most reliable and standards-compliant solution is optical fiber, such as laser-optimized 50 µm multimode OM3 fiber.

10G copper systems operate across a 500 MHz frequency spectrum and require substantial power to operate the electronics. The extended frequency range requires higher power consumption (10-15 W) of the 10G interfaces due to increased insertion loss, as well as needing to overcome internal and external cross talk issues. Extensive data encoding and signal processing is required to achieve an acceptable bit error rate (BER). Electronic digital signal processing (DSP) techniques are required to correct internal noise impairments, which contributes significantly to an inherent time delay while recovering the transmitted data packets, otherwise known as latency.

Data centers demand low latency performance. Most 10G interfaces will be on servers, switches, high-performance computers (HPCs) and storage systems used inside corporate data centers, where high latency is not acceptable. *InformationWeek*, April 23, 2007, states, "A one-millisecond advantage in trading applications can be worth $100 million a year to a major brokerage firm, by one estimate." 10G optical PHY latency has 1000 times better latency performance than 10G copper. 10G optical has typical PHY latency measurable in the nanosecond range, whereas 10G copper has PHY latency in microseconds. Sun Microsystems IEEE 302.3an Task Force, states that "PHY latency should not exceed one microsecond ... it may start affecting Ethernet over TCP/IP application performance in the foreseeable future." DSP algorithms cannot be used to mitigate alien cross talk or other external sources of electro-magnetic interference due to their random statistical nature. The UTP cable must totally rely on the larger cable design and physical configuration in pathways and spaces to address alien cross talk noise ingress.

CAT 6A cable has a larger diameter, designed to alleviate internal and external cross talk noise issues. The larger diameter cable increases the isolation of the internal twisted-pairs as well as the neighboring, bundled external cables. The 0.35 in maximum cable diameter is 40 percent larger than CAT 6 (0.25 in). However, it contributes to significant pathway and space problems when routing in wire baskets, trays, conduits, patch panels and racks. *Cabling Installation & Maintenance*, March 2007, states, "For example, TIA recommends that a 0.75-in (21-mm) conduit will hold two CAT 6 cables, but only one CAT 6A cable, at 40 percent fill. Similar capacity reductions are noted for other cabling pathways." Two CAT 6A UTP cables consume the same area equivalent of a single 216-fiber ribbon cable. Because of the larger diameter and abundance of copper cable, there is a substantial additional amount of jacketing and insulating materials that cause additional fuel load in the pathways and increases the volume of hazardous waste going into land fills from construction debris. CAT 6A cables running 10G are not recommended to be mixed in pathways with other UTP cable types (e.g., CAT 3, CAT 4, CAT 5, CAT 5E, CAT 6) due to alien cross talk concerns.

Just the Technical Facts

The Real Facts About Copper Twisted-Pair at 10 Gb/s and Beyond

Installation and Field Testing of 10G Twisted-Pair Copper is Complex and Time Consuming

A typical plenum CAT 6A UTP cable weighs 46 lbs per 1000 ft of cable. The accumulated weight of CAT 6A cabling alone to serve a 108 circuit, 200 ft length, 10G installation will be approximately 1000 lbs, compared with just 40 lbs for the same length of a 216-fiber optical cable. The 25x greater weight of CAT 6A cables will require additional hardware costs to support the load and may contribute to cable strain-relief issues in hardware, as well as compression issues in trays and conduits.

Installers must be especially careful not to exceed the 10G copper cable 25 lb tensile rating in order to avoid disruption to the 10G copper cable 23 American Wire Gauge (AWG) conductor and wire twist, which must be maintained to within 13 mm (0.5 in) of the termination point. In addition, care must be taken not to violate copper cable bend radius; violating the bend radius distorts the cable's physical geometric properties which degrades transmission performance (see Table 1). Optical cable is more mechanically robust than copper cable. A single-fiber 2.0 mm diameter simplex jumper has a 50 lb tensile rating while multifiber count cables have a typical 200-600 lb tensile rating. Optical cable has a 15x cable diameter installation bend radius and 10x cable diameter long-term bend radius specification that easily facilitates installation without compromising transmission performance. Field connectorization of optical cable is very simple, taking less than one minute when using no epoxy/no polish UniCam® Connectors.

Table 1

10 GbE Twisted-Pair Copper Cabling

Cable	Maximum Diameter (in)	Bend Radius
Category 6	0.25	4 x OD
Category 6A	0.35	4 x OD
Category 6 F/UTP	0.35	4 x OD
Category 7 S/FTP	0.35	4 x OD

A labor premium over traditional 1000BASE-T systems is anticipated for the installation and testing of 10GBASE-T systems. 10G copper is much more complex to field test and requires well-trained technicians, as well as expensive and sophisticated test equipment. Testing is performed on each cable across the 1-500 MHz frequency spectrum to determine conformance for insertion loss, return loss, pair-to-pair NEXT, power sum NEXT, pair-to-pair ELFEXT, power sum ELFEXT, propagation delay, length, delay skew and wiremap. These measurements typically take 1-2 minutes per cable. In addition, complex and time-consuming alien cross talk measurements must be made. Industry experts have stated that it typically takes 17 minutes to perform a single alien cross talk measurement and as much as three hours and 45 minutes to perform alien cross talk measurements on a bundle of 24 copper cables. Some CAT 6A UTP cable manufacturers and others are suggesting random alien cross talk field testing to demonstrate total installed cable conformance. Considering the negative financial impact of data center downtime, contractors, network designers and end-users are not expected to accept random testing.

Conversely, 10G field testing for optical cables simply requires the standard end-to-end link loss measurement.

10GBASE-T Requires One CAT 6A UTP Cable per Circuit

Transmission is bi-directional with 2.5 Gb/s transmitted per twisted-pair. An 8-port 10GBASE-T line card would require eight CAT 6A cables with an effective total diameter of 1.0 in. A 0.66-in diameter optical cable would contain 216 fibers to support 108 10G optical circuits. 10G twisted-pair copper cable's physical design contributes to significant patch panel and electronic cable management problems.

CAT 6A UTP Cables are Susceptible to Security Breeches

The electromagnetic properties of 10G copper UTP cabling can have an adverse impact on the security of UTP copper networks. In this increasingly data-driven world, the security of information is of prime concern for the private individual as well as for large corporations. The electromagnetic energy inherently radiated by copper cables can be detected in a metal-based

conductor without any interference to the transmitted signal. Hence, with the appropriate technology, unprotected UTP cables can be tapped and therefore present a security risk. In contrast, optical fibers cannot be tapped without interrupting the transmitted signal and therefore offer much greater levels of security.

10G Copper Systems Lack Switch Line Card Density and Server Card Adapter Performance

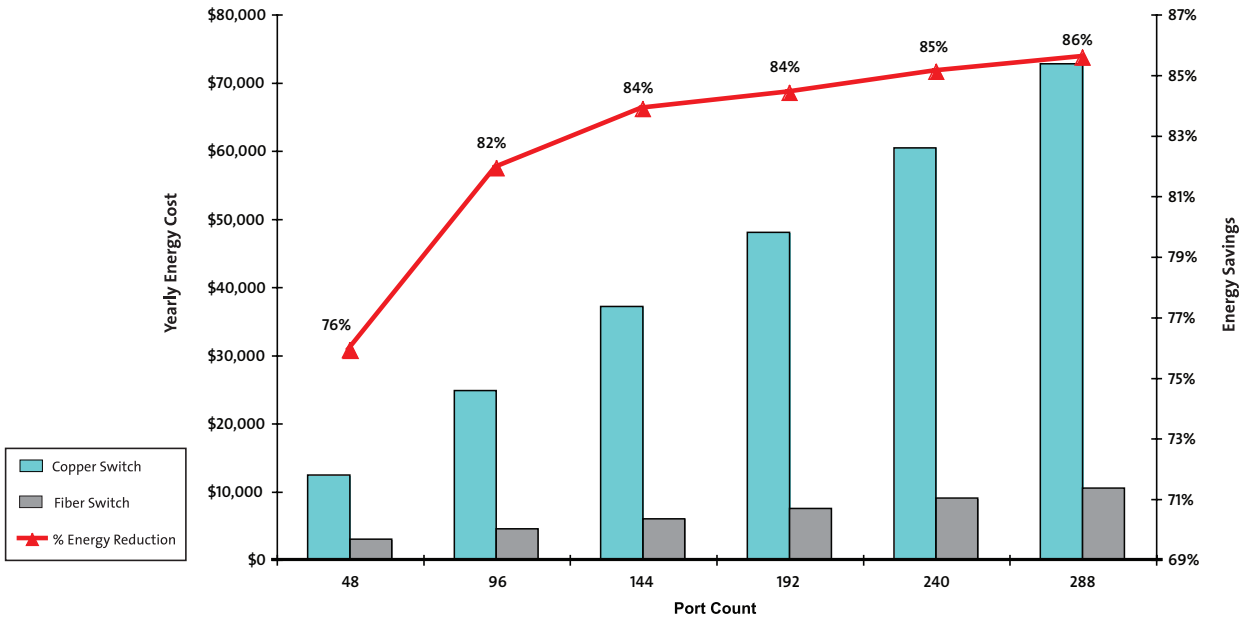
10G copper port density is expected to be four to eight ports per card due to huge power requirements of 10-15 W per port, as well as being limited by heat dissipation and cross talk issues. *Storage Magazine*, March 2007, states, "10GBASE-T over Category 6 or 7 twisted-pair cable can extend up to 100 m, but power requirements hinder its cost-effectiveness." In high-density applications, this power usage is significant, not only in consumption, but also in the generation of heat, which requires cooling to protect transmission equipment from rising temperatures. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) guidelines state that for every kW of power, an equal thermal unit of cooling is required. More power consumption requires greater cooling and humidity control which increases operational costs of un-

48 "Reduced Diameter" CAT 6A Cables are Required to Serve the Same Number of Ports as One 0.58 in Cable | Photo LAN874

interruptible power supply (UPS) systems and back-up power supplies. James Dow, principal and CTO of CS Technology Inc. stated during the Data Center Efficiency Workshop at the SIFMA Technology Conference that "every one cent increase in energy cost per kilowatt/hour can amount to $3 million per year in energy and cooling costs in a large data center." Also, Julius Neudorfer, director of network services, North American Access Technologies, states, "for every dollar spent on powering

Figure 1

Total Electronics and Cooling Energy Cost and Savings Comparison for 10GBASE-SR and 10GBASE-T.



servers and equipment in a data center, firms should expect to spend another dollar to as much as $2 to $3 to cool the hardware." Figure 1 illustrates the typical cumulative power savings as a function of 10G electronics and cooling energy consumption. Major Tier 1 switch manufacturers are not expected to release 10GBASE-T copper product until mid 2008; as silicon chip manufacturers continue to address power consumption issues.

10G optical electronics provide clear advantages over copper twisted-pair:

- 10G X2 transceivers support up to 16 ports per line card. Maximum power dissipation is 4 W per port.
- 10G XFP optical transceivers support up to 24-36 ports per line card. Maximum power dissipation is 2.5 W per port.
- Emerging 10G SFP+ optical transceivers will support up to 48 ports per line card. Maximum power dissipation will be 1 watt per port. The SFP+ transceiver will offer significantly lower cost compared to the X2 and XFP transceivers.

A 10G copper system will require more switches and line cards to match the bandwidth capability of 10G optical. For example, one optical 48-port line card equals six 8-port copper line cards. (See Figure 2)

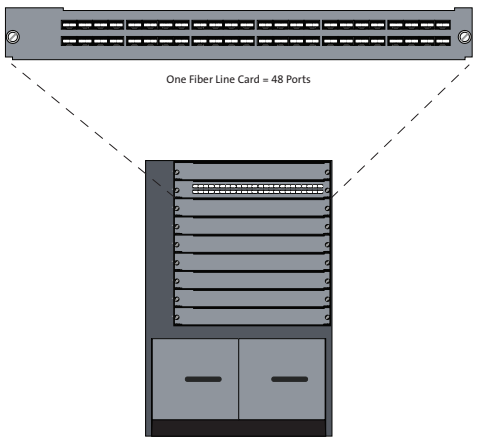
10GBASE-SR optical server adapter cards typically use less than 9 watts power to transmit up to 300 m. The optical adapter is easily powered from the server PCI-Express slot without an external power feed. Ethernet adapters were announced in late January 2007 to support 10GBASE-T. The adapter cards consume just less than 25 W to reach a maximum transmission distance of 30 m. Greater service distances would require an additional electrical feed to power the copper adapter card, since the PCI-Express slot can only provide up to 25 W. As with the 10G copper switches, the 10G copper server adapter card's high power consumption and cooling needs result in higher operational costs. To date, copper server and server adapter card manufacturers have demonstrated minimal interoperability with 10GBASE-T switch vendors. Switch vendor support is at least a year away due to power challenges.

10G Optical Connectivity Offers Many Significant Benefits over 10G Copper Connectivity

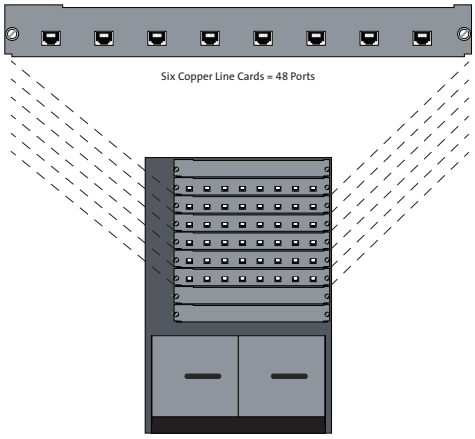
Extended distance capability

Laser-optimized 50 µm multimode OM3 fiber provides 10G serial transmission to a maximum distance of 300-550 m. Fiber offers network designers more flexibility in their planning and the advantage of being able to use new and re-configurable architecture in the LAN, data center and HPC. OM3 50 µm fiber supports data rates beyond 10G and is to be included in the IEEE 100G Project Authorization Request (PAR) to operate at a minimum 100 m distance. In the best case scenario,

Figure 2



Optical Line Card Density | Drawing ZA-3148



Copper Line Card Density | Drawing ZA-3149

Just the Technical Facts

The Real Facts About Copper Twisted-Pair at 10 Gb/s and Beyond

CAT 6A, CAT 6 F/UTP and CAT 7 copper are limited to 100 m and are restricted to four connections in the 10GBASE-T channel.

Power and Cooling
10G optical switch electronics and server adapter cards require less power to operate compared to 10G copper. 10G SFP+ optical transceivers will consume a maximum 1.0 W per port compared to 10-15 watts per port for a 10GBASE-T copper switch. 10GBASE-SR server adapter cards typically use less than 9 W to transmit up to 300 m while recently announced 10GBASE-T cards use 25 W to reach up to 30 m.

Significant silicon chip development will be required to reduce the power consumption of 10G copper interfaces. Although industry expectation is that silicon-chip power consumption may be reduced, the high insertion loss of copper cables at the extended frequency range needed to support 10G and electronic DSP noise-reduction circuitry means that energy consumption will inevitably be higher than that of low-loss fiber interconnects. The silicon chip size-reduction work is not expected to be completed in the near future as major performance issues such as electrostatic discharge (ESD), which impacts reliability, must be resolved.

The extreme power consumption of 10G copper electronics and adapter cards will drive the need for excessive cooling, meaning greater energy use and running costs for data centers and possibly larger UPS (un-interruptible power supplies).

Port density
Fiber provides a higher 10G port density per electronic line card and patch panel as compared to copper. Many manufacturers' 10G UTP copper patch panel densities are reduced by up to 50 percent to mitigate cross talk impaired by increased spacing between connector ports. Fiber can accommodate higher port densities up to 1728 fibers in a 4U housing.

Less congestion in pathways and spaces
The high-fiber density, combined with the small diameter of optical cable, maximizes the raised floor pathway and space utilization for routing and cooling. Optical cables also offer superior pathway usage when routed in aerial cable trays. The larger CAT 6A outer diameter impacts conduit size and fill rate as well as cable management due to the increased bend radius. Common commercial cable pulling lubricants have been shown to affect copper cable attenuation at the high operating 10G frequencies. Copper cable congestion in pathways increases the potential for damage to electronics due to air cooling damming effects and interferes with the ability of ventilation systems to remove dust and dirt. Bundled copper cable also interferes with removal of abandoned cable and presents serious alien cross talk issues in raised floor and aerial pathways. Optical cable offers better system density and cable management, as well as minimizes air flow obstructions.

Migration path to faster speeds
Laser-optimized 50 µm multimode fiber provides a migration path for supporting higher data rates such as 16G and 32G Fibre Channel and 100G Ethernet. Kevin Kettler, Dell Chief Technology Officer, stated in *Electronic Engineering Times*, June 26, 2006, "… instead of a wholesale transition to 10G over copper, the networking industry may well segue into optical fibre. The next speed is 100GigE and copper will not work over required distances at those data rates."

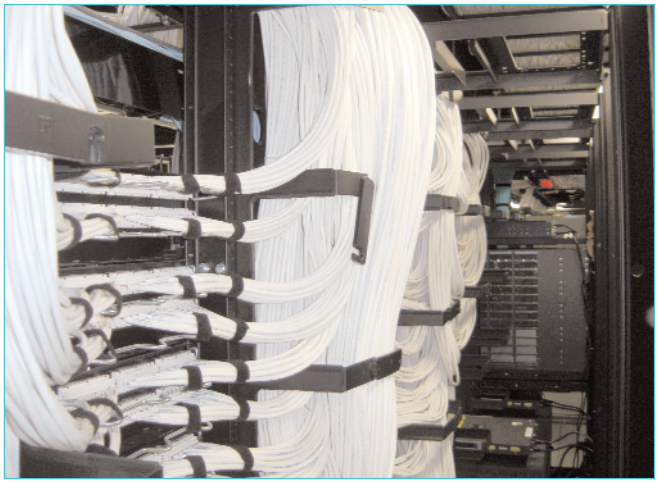
The Time is Now for Optical Connectivity

Should you ever require cabling infrastructure to support 10G speeds, now is the time for optical connectivity in the LAN and the data center. Optical cable with laser-optimized 50 µm OM3 fiber provides bandwidth capabilities that support legacy and future data rate applications without the costs and downtime of retiring yet another copper cable plant and re-cabling. Optical fiber connectivity provides optimized transmission performance, extended distance capability, best utilization of pathways and spaces, ease of installation and testing, reduction in power consumption, cooling costs and electronic costs, and the highest 10G electronic and patch panel densities. 10GBASE-T with copper connectivity falls short when compared to optical fiber connectivity performance and value propositions.

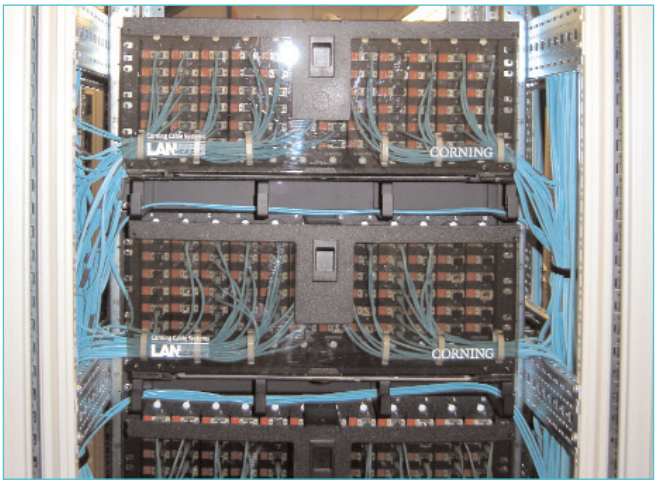
Twisted-pair copper cable has been struggling to keep up with bandwidth demands virtually since it entered the data center market. There have been seven generations of copper cable in just the past 20 years, each one

designed to address the next wave of bandwidth demand and each one becoming more complex to design around and install. A single generation of multimode optical fiber has outlived, and continues to surpass, the bandwidth capability of every one of those copper designs and fiber has gotten easier and cheaper to design with and install. Make the right choice in your next LAN and data center application ... choose optical fiber connectivity.

Contact Doug Coleman, Manager, Technology and Standards, (828) 901-5580, doug.coleman@corning.com if you have any questions or require additional information.



Lower Port-Density for 10G Copper Electronics and Larger Copper Cables (above) Result in Crowded Pathways and Difficult Cable Management Compared with Fiber Optic Cable (below)
Photos LAN877, LAN878



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