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Fiber-to-the-Desk: The Ultimate Structured Cabling System

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Introduction

What does the future of your network hold? A brief review of the latest networking publications probably leaves you wondering. Networking products seemingly evolve every month. From contention- to connection-based, from routed to switched, from low-speed to high, change is constant. One thing is clear: tomorrow's networks will run faster, support a greater number of applications and provide service to an increasing number of geographically diverse users.

With network requirements changing constantly, it is important to employ a cabling system that can keep up with the demand. Cabling systems, the backbone of any data communications system, must become utilities. That is, they must adapt to network requirements on demand. When a network needs more speed, the media should deliver it. The days of recabling to adopt new networking technologies are past. Today's Structured Cabling System should provide seamless migration to tomorrow's network services.

One media that provides utility-like service is optical fiber. Fiber optic cabling has been used in telecommunication networks for over 20 years, bringing unsurpassed reliability and expandability to that industry. Over the past decade, optical fibers have found their way into cable television networks—increasing reliability, providing expanded service and reducing costs. In the local area network (LAN), fiber cabling has been deployed as the primary media for campus and building backbones, offering high-speed connections between diverse LAN segments.

Today, with increasingly sophisticated applications like high-speed ISPs and e-commerce becoming standard, it's time to consider optical fiber as the primary media to provide data services to the desktop. In this paper, examples of fiber-based structured cabling systems are presented. We review the standards, discuss next-generation cabling systems and show how fiber can be used effectively to reduce costs and improve network connectivity.

Why Fiber?

What value does fiber provide in the horizontal network? Fiber has the largest bandwidth of any media available. It can transmit signals over the longest distance at the lowest cost, without errors and the least amount of maintenance. Fiber is immune to EMI and RFI. It cannot be tapped, so it's very secure. Fiber transmission systems are highly reliable. Network downtime is limited to catastrophic failures such as a cable cut, not soft failures such as loading problems. Interference does not affect fiber traffic and as a result, the number of retransmissions is reduced and network efficiency is increased. There are no crosstalk issues with optical fiber. It is impervious to lightning strikes and does not conduct electricity or support ground loops.

Fiber-based network segments can be extended 20 times farther than copper segments. A typical LAN grade multimode fiber has a length-to-bandwidth product of 500 MHz over one kilometer. Since the current structured cabling standard allows 100-meter lengths of horizontal fiber cabling from the telecom closet, each length can support several GHz of optical bandwidth. Recent developments in multimode fiber optics include enhanced glass designed to accommodate even higher-speed transmissions. With capabilities well above today's 10/100 Mbps Ethernet systems, fiber enables the migration to tomorrow's 10 Gigabit Ethernet ATM and SONET networking schemes without recabling.

What about the ability to upgrade? A key point to remember is that optical fiber is independent of the transmission frequency on a network. There are no crosstalk or attenuation mechanisms that can degrade or limit the performance of fiber as network speeds increase. Further, the bandwidth of an optical fiber channel cannot be altered in any manner by installation practices. Once a fiber is installed, tested and certified to be "good," then that channel will work at 1 Mbps, 10 Mbps, 100 Mbps, 500 Mbps, 1 Gbps or 10 Gbps. This guarantees that a fiber cable plant installed today will be capable of handling any networking technology that may come along in the next 15 to 20 years.

Designing Networks with Fiber

Over the past decade, a new term has become associated with data networks—structured cabling. Structured cabling, as opposed to the proprietary data networks of the past, is a way to provide vendor-independent interconnection of various network hubs, switches, routers and bridges. TIA/EIA-568-A defines the requirements for building and campus structured cabling systems. It sets the structure and specifications for the cabling products and connectorization or interconnect products used in a cabling plant. It defines the rules for electrical, optical and mechanical interoperability of various physical layer components. It also defines fiber and copper horizontal cabling systems.

The horizontal distance limitations placed on fiber by TIA/EIA-568-A (see table 1 below) are based on the performance characteristics of copper cabling. Several committees, TIA/EIA-568-B.3 among them, are currently evaluating the extended performance capabilities of optical fiber. These committees are trying to take advantage of fiber's bandwidth and operating distance characteristics to create more robust structured cabling systems. Terms like "centralized cabling," "multi-user outlet" and "zone cabling" have found their way into the standards language.

What are these designs and how do they leverage fiber to provide cost-effective, performance-based networks? A review of the current standard will facilitate an understanding of these terms and the designs they describe.

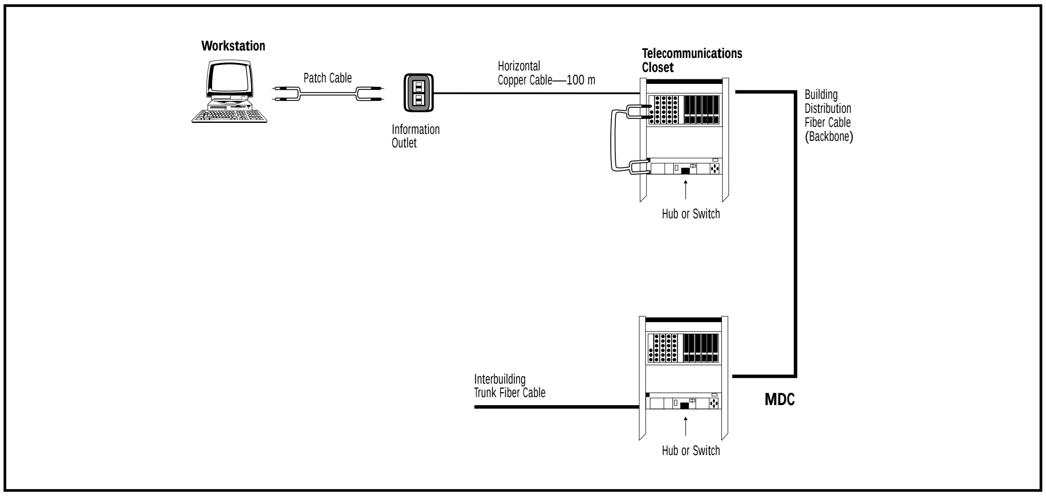
Table 1—*TIA/EIA-568-B.3 Optical Fiber Specifications*

Optical FiberType	Multimode		Single-mode
Dimensions	62.5/125 microns	50/125 microns	8.3/125 microns
Bandwidth			
Low speed (850 nm)	160 MHz•km	500 MHz•km	—
High speed (1300 nm)	500 MHz•km	500 MHz•km	>100 GHz
Attenuation			
Low speed	3.5 dB/km	—	—
High speed	1.5 dB/km	—	0.5 dB/km
Backbone Cable Length	2000 m	2000 m	3000 m
Horizontal Cable Length	100 m	100 m	Not Recommended
Applications	E-net, TR, FDDI	E-net, TR, FDDI	Channel Extension
155 Mbps ATM	155 Mbps ATM	FDDI, ATM (1.2 Gbps)	
Baseband Video	Baseband Video	Fiber Channel	
Security Systems	Security Systems	Broadband Video	
Connector Type: (T568-SC)	Beige Shroud	Beige Shroud	Blue Shroud

Typical TIA/EIA-568-A Cabling System

Whether a network is copper- or fiber-based, TIA/EIA-568-A (see figure 1 below) recommends multiple wiring closets distributed throughout a building. A network can be vertical with multiple wiring closets on each floor, or horizontal with multiple satellite closets located throughout a plant. The basic cabling structure is a star-cabled plant with the highest functionality networking components residing in the main distribution center (MDC). The MDC is interconnected via fiber backbone cable to intermediate distribution centers (IDCs) in the case of a campus backbone, or to telecommunications closets (TCs). From TC to desktop, up to 100 meters of Cat 5 UTP cable or optical fiber cable can be deployed. Typically, lower level network electronics are located in a TC and provide floor-level management and segmentation of a network. A TC also provides a point of presence for structured cabling support components, namely cable interconnect or cross-connect centers, cable storage and splices to backbone cabling.

Figure 1—*EIA/TIA-568 Cabling Scheme*



Collapsed Cabling Design

By leveraging fiber's natural distance performance, a horizontal distribution system can be redesigned to more efficiently use networking components, increase reliability and reduce maintenance and cost. One approach is to collapse all horizontal networking products into one closet and run fiber cables from this central TC to each user. Since optical fiber systems have sufficient transmission bandwidth to support most horizontal distances, it is not necessary to have multiple wiring closets throughout each floor. With this network design, management is centralized and the number of maintenance sites or troubleshooting points is reduced. Cutting the number of wiring closets saves money and space. It reduces the number of locations that must be fitted with additional power, heating, ventilating and air-conditioning facilities in a horizontal space. Testing, troubleshooting and documentation become easier. Moves, adds and changes are facilitated through network management software rather than patch cord manipulation. With this architecture, newly developed open-office cabling schemes (TIA/EIA TSB 75) can also be easily integrated into a network.

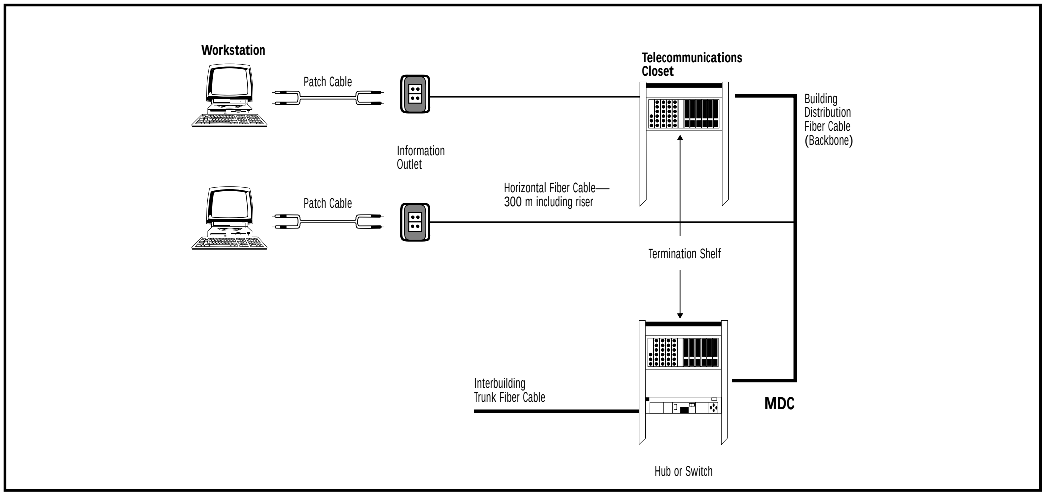
Centralized Cabling

Of course, collapsed cabling is only the first step. The natural extension of fiber's distance performance is summed up in a centralized cabling scheme. In a centralized cabling system, all network electronics reside in either the MDC or IDC (see figure 2 below). The idea is to connect the user directly from the desktop or workgroup to the centralized network electronics.

There are no active components at floor level. Connections are made between horizontal and riser cables through splice points or interconnect centers located in a TC. For short runs, a technique called fiber home run is used. It connects a workstation directly to the MDC. Low count (2 or 4 fibers) horizontal cable can be run to each workstation or office.
Also, multifiber cables (12 or more fibers) can support multiple users, providing backbone connections to workgroups in a modular office environment.

A centralized cabling network design provides the same benefits as a collapsed network—condensed electronics and more efficient use of chassis and rack spaces. By providing one central location for all network electronics, maintenance is simplified, troubleshooting time reduced and security enhanced. Moves, adds and changes are again addressed by software. Centralized cabling is described by the Technical Service Bulletin, TIA/EIA TSB 72, which recommends a maximum distance of 300 meters to allow Gigabit applications to be supported, as shown in Figure 2 below.

Figure 2—*Centralized Cabling Scheme*



Fiber Zone Cabling

One design concept is an interesting mix between a collapsed backbone and a centralized cabling scheme. Fiber zone cabling is a very effective way to bring fiber to a work area. It utilizes low-cost, copper-based electronics for Ethernet data communications, while providing a clear migration path to higher-speed technologies.

Like centralized cabling, a fiber zone cabling scheme (see figure 3 on page 7) has one central MDC. Multifiber cables are deployed from the MDC through a TC to the user group. A typical cable might contain 12 or 24 fibers. At the workgroup, the fiber cable is terminated in a multi-user telecommunications outlet (MUTO) and two of the fibers are connected to a workgroup hub. This local hub, supporting six to twelve users, has a fiber backbone connection and UTP user ports. Connections are made between the hub and workstation with simple UTP patch cords. The station network interface card (NIC) is also UTP-based. The remaining optical fibers are unused or left "dark" in the MUTO for future needs.

Dark fibers provide a simple mechanism for adding user channels to the workgroup or for upgrading the workgroup to more advanced high-speed network architectures like ATM, SONET or Gigabit Ethernet. Upgrades are accomplished by removing the hub and installing fiber jumper cables from the multi-user outlets to the workstation. Network electronics also need to be upgraded. This process converts the network segment to a fiber home run or centralized cabling scheme. It is a very flexible and cost-effective way to deploy fiber today while providing a future migration strategy for a network. Further, an investment made in UTP-based Ethernet connectivity products is not wasted; it is, in effect, extended.

Two new cabling products have entered the marketplace, offering zone cabling enclosures. One style mounts above a suspended ceiling, holding fiber and copper UTP cross connects, between hubs, switches and workstations. The other style, a much larger unit, replaces a 2' X 4' ceiling tile and has enough room to house a hub or other active electronics, as well as cross connects.

Evolving Standards and Technology

Over the past year, several new products have been developed that will aid in the deployment of optical fiber-to-the-desk. To date, the standards committees are evaluating new, higher-performance optical components that offer increased performance, ease of installation and lower costs. Among some of these exciting developments are small-form-factor connectors (SFFC), vertical cavity surface-emitting lasers (VCSEL) and next-generation fiber.

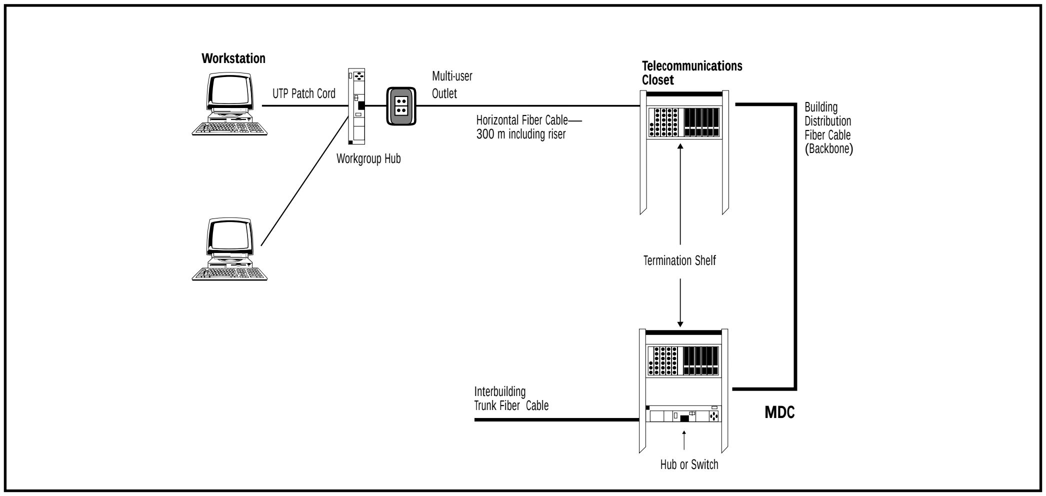
Advancements in fiber connectors are continuing to make fiber as viable an answer as copper. Traditionally, fiber systems required twice as many connectors as copper cabling—crowding telecommunication closets with additional patch panels and electronics. Recently, manufacturers have introduced small-form-factor connectors that provide twice as much density as previous fiber connectors. These mini-fiber connectors hold the send and receive fibers in one housing. This reduces the space required for a fiber connection. More importantly, it decreases the footprint required on the hubs and switches for fiber transceivers. The net result is a cost reduction nearly four times to that of a conventional fiber system.

Complimenting the SFFC components are new vertical cavity surface-emitting lasers. This fiber optic transmission source combines the power and bandwidth of a laser at the lower cost of a light-emitting diode (LED). VCSELs, when integrated into SFFC transceivers, allow for the development of higher-speed, higher-bandwidth optical systems, further extending the reach and capability of the FTTD cable system.

Small Form Factor Connectors

Next-generation fiber is 50/125 micron with a laser bandwidth greater than 2000 MHz/km at 850 nm. This fiber allows serial transmission at 10 Gigabits up to 300 meters. This next-generation fiber coupled with a 10 Gigabit, 850 nm VCSEL allows the lowest cost 10 Gigabit solution.

Figure 3—*Fiber Zone Cabling Scheme*



Conclusion

Structured cabling systems that employ fiber for horizontal links as well as the backbone offer network designers significant advantages: more flexible designs, less space consumption, increased security and easier troubleshooting, among others. Fiber's low attenuation and immunity to electromagnetic interference make it the ideal media for today's network. Its high bandwidth provides a path for the cabling system to expand as network demands dictate—without recalling.

Recent developments in fiber optics include:

- Enhanced glass design to accommodate high-speed transmission
- Smaller-size connectors that save space and lower cost
- Vertical cavity surface emitting laser technology for high-speed transmission over longer distances at low cost
- A vast array of new support hardware designed for Fiber Zone Cabling

Fiber-to-the-desk is a cost-effective design that utilizes fiber in today's low-speed network while providing a simple migration strategy for tomorrow's high-speed connections. Fiber-to-the-desk combines the best attributes of a copper-based network (low-cost electronics) with the best of fiber (superior physical characteristics and upgradability) to provide unequaled network service and reliability.

For additional information on fiber performance, see *The Origins of the Anixter Fiber Testing Program White Paper (#226563)*.

Source

This visionary article was originally written as a white paper by Paul Kopera, Anixter Director of Fiber Optics, in 1996-97 and updated in 2001. As a graduate of the Illinois Institute of Technology and with over 20 years of experience in the fiber industry, Paul has published numerous papers in the area of fiber optic components and has been awarded four patents. He is a member of several organizations including IEEE, OSA, SPIE and BICSI. He is the past chairman of the SPIE conference on Optical Fiber Devices and past committee member of the IWCS, the International Wire and Cable Symposium.

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