Enterprise Design Guide

Physical Layer Handbook
for Designers and Installers
April 2010
Contents

Section 1  Introduction  3
Section 2  Network Topologies - the way data flows  9
Section 3  Network Architecture - how cabling is organized  13
Section 4  Transmission Media - relative performance  21
Section 5  Cable and Connectivity - cable, connectors and other equipment  37
Section 6  Telecommunications and Equipment Rooms  57
Section 7  Network Planning - how much capacity, what kind of cable  61
Section 8  Horizontal Cable Installation - planning and techniques  79
Section 9  Riser (Backbone) Cable Installation - planning and techniques  91
Section 10  Campus/Outdoor Cable Installation - planning and techniques  97
Section 11  Connectorization and Splicing - techniques for the final inch  107
Section 12  Testing & Documentation - standards, techniques and troubleshooting  119

Uniprise® Annex  Bill of Material Examples - walking through the specification process  133
SYSTIMAX® Annex  Bill of Material Examples - walking through the specification process  165

Glossary  195
Section 1

Introduction
How To Use This Guide

Planning a business communication system can be a daunting prospect even for the most experienced system designer. Integrating diverse technologies, combining different cabling types, matching capacity to traffic and, above all, making sure that the whole system performs reliably, is a complex task. Critical issues need to be addressed:

- What is the network architecture that best serves my needs?
- How much network capacity and speed do I need now?
- How do I plan for future needs?
- What are the trade-offs between expense and performance?
- Which media do I use (copper or fiber) and where?
- How do I ensure peak performance and maximum reliability?

The last question is the most important one. Architecture, capacity, installed cost and media all derive from performance and reliability. In this regard, CommScope solutions have no equal.

CommScope® is a leading manufacturer not only of twisted pair, fiber and coaxial cables, but of connectivity components that offer the highest levels of performance. CommScope integrates cable, connectivity and craft for systems with warranted capability. You can design and install networks from the desktop to the backbone and be assured of highest network speeds and reliability.

This guide is designed to lead you through the process of designing the best possible network for your needs, present and future. Keep in mind that when it comes to specifying the components, CommScope and its partners have the cable, connectivity and the know-how to make your network communicate.
Connectivity That Meets And Exceeds Networking Standards

The most comprehensive and authoritative standard for network performance is the ANSI/TIA/EIA-568 Commercial Building Telecommunications Cabling Standard, which dictates the parameters for network capacity, reliability and compatibility. While some manufacturers may treat these standards as goals to reach, CommScope defines them as minimums to be exceeded*. Some examples:

CommScope pioneered the development of innovations like foamed dielectrics and pair separators that made possible our Isolite® and Category 6 UTP cables. In 2009, CommScope released SYSTIMAX® GigaSPEED® X10D U/UTP 91 series cables, which exhibit an order of magnitude improvement in alien crosstalk, enabled via an optimized twist and strand scheme, dramatically enhancing high-frequency performance using the CommScope Labs Cable Twist Accuracy Technology. This improved performance produces a cable that is greatly reduced in diameter from previous 10G capable designs.

For backbone applications, the IEEE 802.3ae standard specifies a 10 gigabit Ethernet minimum transmission distance of only 82 m (269 feet) using standard OM2 50 μm multimode fiber for 10GBASE-SX. CommScope’s 50 μm high-bandwidth multimode solutions greatly exceed the standard by carrying 10 Gb/s signals up to 550 meters (1804 feet). These fibers also allow a step up to new, even higher data rate applications like 40 and 100 gigabit Ethernet.

CommScope developed the design of indoor/outdoor fiber optic cables that are tough enough to withstand exterior heat, cold and dampness, yet can enter a building well past the 15.2 meter (50 feet) limitation for outdoor cable, thus eliminating transition splices and their associated hardware.

We offer a full range of fiber and copper connectivity choices that provide end-to-end performance guarantees well above established standards. CommScope network solutions are designed and engineered to work across your entire network, providing a complete telecommunications infrastructure from fiber to copper, from outside to inside and from backbone to desktop. This system of cables, enclosures, panels, connectors and patch cords allows you to assemble an entire network with verified and warranted performance, with all of the components supplied from a single source.

Our efforts extend beyond total solution performance. We are also compliant with the RoHS (Restriction of Hazardous Substances) directive adopted by the European Union in 2006, by some states in the US and soon by China. The RoHS Directive is aimed at reducing the amount of certain environmentally hazardous substances in cabling components.

*Standards may be reviewed or purchased at www.tiaonline.org

CommScope delivers on the promise of high-speed networking with a family of high-speed craft-friendly connectivity products.
Fiber optic solutions make high-speed connections between offices and between cities.
Twisted pair copper solutions are used in homes and offices to keep voice and data flowing.

Coaxial solutions are used in broadband networks, cable and closed circuit video and cellular networks.
CommScope’s Design And Engineering Capabilities

As you start to strategize about your future infrastructure needs, this guide may not be enough of a resource to completely develop a full-blown network design. Your company may need support bringing a design into physical reality.

For more than 30 years, our team has been involved in cutting-edge infrastructure projects across the globe. We have helped translate vision to reality for cities, buildings, offices, data centers, educational institutions, healthcare facilities, and entertainment installations. We have served leading global corporations in the financial, technology, telecom, manufacturing, industrial, development and urban sectors. In 2009, CommScope pulled together Services oriented resources within the company into one business unit, and formally launched Enterprise Global Services.

Enterprise Global Services - the driving force for your network installation

CommScope now offers a complete range of network infrastructure services, including:

- design
- consulting
- project management
- and network planning,

all with the goal of meeting our customers’ specific needs. To ensure all projects integrate seamlessly with the architectural and engineering framework, Enterprise Global Services also offer comprehensive consulting, design, AutoCAD and specification services including planning, schematic design, design development, and construction document services in an a la carte or turnkey fashion. Ultimately, CommScope Global Enterprise Services aims to optimize, manage and extend the life of your enterprise network.

Our staff has core competencies and expertise across a wide range of disciplines. In addition to Professional Engineer, Electrical Engineer, RCDD, CISSP, CPP and PMP, the team has certifications in the areas of networking infrastructure, data centers, security, outside plant design, project management and more.

Enterprise Global Services builds multi-disciplined teams with engineering, planning and technical expertise across diverse fields of technology, allowing us to provide great cost value, on-time execution, and the highest level of performance and functionality. Our application and network design engineers – including fiber optic and networking specialists – help prevent design gaps and ensure that designs and construction documents meet the requirements of today’s demanding IP and analog low-voltage systems. Our cross-trained design/engineering team members all work together, applying their areas of expertise in conjunction with one another to minimize delays, budget overruns and change orders.

Please use this design guide as a tool to better understand the enterprise space. It will answer many of your questions, help explain where your network is today and where it should go tomorrow. And if you need a partner to augment your team’s design capabilities, to help create corporate Standards, or to turn that design document into a reality worth showcasing, then contact us and put CommScope Enterprise Global Services to work for you.
Section 2

Network Topologies
Network Logical Topologies - Bus, Ring, Star and Point-to-Point

Simply defined, a network is a communication system that seamlessly and efficiently connects voice, data, video and other selected applications together.

Network speed and complexity have increased over the past 40 years and certain standards emerged out of the various protocols that were created. Logical topologies define how the network operates - in effect, they define the signal’s operating path. The IEEE defines most of these logical topologies. These include:

**Bus**
Defined under IEEE 802.3, this is a popular protocol in which signals travel in both directions on a common path. In most 802.3 systems, collision detection software in the active equipment directs the traffic so that network subsystems do not try to send and receive at the same time. Common bus protocols include the Ethernet family and MAP (Manufacturing Automation Protocol).

**Ring (also called Token Ring)**
Defined under IEEE 802.5, signals travel in one direction on one path and the opposite direction on another (a counter-rotating ring). A ring’s advantage is reliability - if the connection should be cut or a node fail to function, the ring bypasses the failed component and continues to operate. Another version of a ring is FDDI (Fiber Distributed Data Interface defined under ANSI X3T9) written specifically for optical fiber.

**Star**
In a star, all of the components connect into a central node that distributes the traffic back out. Most private telephone networks are star topologies. Terminal/mainframe computer connections are normally stars.

**Point-to-Point**
This is the simplest type of connection, linking a minimum of two devices over a transmit/receive link. CCTV, Fibre Channel, ESCON and VSAT (and other satellite antenna links) are point-to-point topologies.
Network Physical Topologies - Star vs. Ring

Physical topologies describe how the devices of the network are connected. There are two basic ways:

Star Topologies
In a physical star topology, network devices are cabled to meet at a point of concentration, usually a piece of active electronics called a hub, router, switch or node. These actives are then connected to an intermediate point of concentration, and so on, until all traffic meets at a central point.

Logical buses, rings and stars can be cabled together into a physical star. The hierarchical and centralized nature of the star permits the easy concentration of cables and components, thus easing maintenance burdens. Network additions can be accommodated in a straightforward manner through a simply-achieved physical connection at any of the collection points.

Ring Topologies
In a physical ring topology, the nodes of a network are all connected in a closed loop. Instead of running back and forth between nodes, the signal travels in one direction around the ring. In some networks, active and stand-by parallel circuits operate in both directions simultaneously (counter-rotating ring). Rings are normally used in the campus backbone segment of a network. Their advantage is that if a cable is cut or a node fails, the network will continue to operate. However, adding more nodes to the ring is difficult. Trying to adapt bus or star logical topologies to a ring may result in unacceptable connection loss.
Section 3

Network Architecture
Network Architecture Basics

A communication network consists of four basic segments. Generally, these are divided at the point where one cable ends and another begins.

**Horizontal segment (for details, see page 16)**

The network begins when a device (computer, telephone, video monitor, etc.) is physically plugged into an outlet. That outlet is connected to a cable that leads back to the telecommunications room (TR) where it is terminated at a patch panel/wiring block.

The active equipment that powers that segment is connected by patch cables to the patch panel. The active equipment could link at a horizontal crossconnect to the backbone cabling. TIA/EIA standards permit a maximum link of 90 m (295 feet) for the twisted pair or fiber link plus another 10 m (33 feet) for patch cords and outlet extensions.

While twisted pair cables offer more than enough performance for most horizontal connections, fiber optic cable should be used for longer links or where very high network speeds are required.

An option for plugs/cables in the horizontal segment is wireless, which uses a transmit/receive (tx/rx) antenna system to replace cabling.

A hybrid of the horizontal and backbone segments is called fiber to the enclosure. See page 18 for details.
Riser (backbone) segment (for details, see page 19)

In a distributed (or intrabuilding/interbuilding) riser, cabling connects the equipment in the telecommunications rooms to a centralized location called the equipment room.

In a centralized or collapsed riser, fiber optic cable provides a direct connection to the equipment room, although the cable may be either spliced or connected to a crossconnect in the telecommunications room.

Campus segment (for details, see page 20)

Larger networks (multiple building university or medical campuses, military bases, corporate headquarters, manufacturing facilities, etc.) may interconnect different buildings or locations that could be hundreds, perhaps thousands, of meters (yards) apart.

The intermediate crossconnects (building distributors, or BDs) in each equipment room are linked together by cable or wireless. Depending on the size of the network, a hierarchical physical star may collect some segments of the campus at intermediate points, but they will all eventually meet at the main crossconnect.

Local access segment (for details, see page 21)

This is the demarcation point where the network meets the outside world. The service provider, such as the local telco, drops a connection to the network, usually at an underground vault, which is linked to the main crossconnect in the equipment room.

Depending on network needs, the connection could be as simple as a T-1 circuit or as massive as a multi-gigabit OC-192 connection. Generally, the user is required to make the physical connection from this access point to the main equipment room. This connection is usually via a multi-fiber optical cable, although twisted pair, high-bandwidth coax, microwave or free-space optical wireless may be used as well.
Even if present plans call for twisted pair, consider placing fiber simultaneously to cover future growth.

**Horizontal Subsystem (with Telecommunications Room)**

The horizontal subsystem is the most complex segment as far as the number of components and connections involved. Cables, connectors and apparatus should comply with the standards described in the TIA/EIA 568 standard.

From a connection standpoint, the horizontal subsystem is the most critical. A short horizontal channel may have more physical connections (outlets, patch cords, crossconnects, active equipment, etc.) than any other network subsystem.

**Outlet**

The outlet at the desktop is the starting point of the network. An outlet may have one or all of these components:

- 8P8C (or RJ-45) outlet for data (also called the dataport) or voice
  - Connected to a twisted pair cable, this links to a data network (such as Ethernet) or voice network (RJ-45s accommodate standard phone outlets and can replace the classic 6P6C [or RJ-11] outlets).

- Fiber outlet – generally for data and video networks
  - Fiber ports are generally connected in rx/tx pairs.

- BNC or F outlet for a video monitor, mainframe terminal or a cable modem
  - These connect to a coax cable for video (Series 59, 11 or 6 cables) or data (RG62, RG58, RG8 or RG213 cables).

**Wireless**

No outlets are required in a wireless system. The system antenna acts as the connection to the tx/rx device at the desktop. Wireless connections work best when devices are kept away from exterior walls.

**Cable**

Cable carries the signal to the telecommunications room. It may be a twisted pair, fiber or coax cable depending on the application (see Transmission Media/Section 4 for details). The cable may be installed in the wall, ceiling, conduit or raceway. Fire safety regulations will determine the cable rating and how it is to be installed (plenum, riser, tray, etc.). See page 35 for explanations of cable listings and ratings.
Telecommunications Room (TR)

The telecommunications room (TR) is the demarcation point between the horizontal cabling and the backbone (riser) cabling. Horizontal cables terminate in either the TR, or directly link to the equipment room (see page 19). Data cabling is usually terminated with a connector and plugged into a patch panel. Voice-only cabling can be directly wired to a punch-down block as well as being terminated at a patch panel. Depending on the network type, the patch panel may connect to a crossconnect with a series of short cables called patch cords. The active electronics (hub, router, switch, etc.) that direct and amplify signals may also reside here.

The TIA/EIA 568 standard sets 90 meters [295 feet] (plus a total of another 10 meters [33 feet] for the patch and equipment cords) as the maximum cabled distance for horizontal data links (voice-only links can extend to 800 meters [2624 feet], longer with repeating electronics). Do not exceed this distance with twisted pair cables. Optical cable, however, can greatly exceed this distance depending on the speed of the network (see the chart on page 23 for details).

Consolidation point

A consolidation point is a permanent mid-link connection for up to 12 horizontal segment twisted pair cables. The consolidation point should be at least 15 meters (50 feet) from the telecommunications room. Total link length, including the consolidation point, remains at a maximum of 90 meters (295 feet).

Multi-User Telecommunications Outlet Assembly (MUTOA)

MUTOAs are like consolidation points except they may be easily reconfigured. MUTOAs are used in open-office environments to serve a maximum of 12 work areas and should be at least 15 meters (50 feet) from the telecommunications room. MUTOAs allow trading off longer equipment cords for shorter horizontal links. Some examples are given below. Add 5 meters of patch cable to complete the link distance:

<table>
<thead>
<tr>
<th>MUTOA EQUIPMENT CABLE LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG equipment cable</td>
</tr>
<tr>
<td>13 meters [44 feet]</td>
</tr>
<tr>
<td>22 meters [71 feet]</td>
</tr>
</tbody>
</table>

Maximum 90 meter TIA/EIA recommended twisted pair link from outlet to patch panel/crossconnect

Maximum 300 meter TIA/EIA recommended collapsed backbone link to equipment room
Horizontal Subsystem with FTTE (Fiber To The Enclosure)

ANSI/TIA 568-C defines an alternative to the traditional telecommunications-room-to-the-desktop horizontal segment is called Fiber To The Enclosure, or FTTE. FTTE permits a wall or ceiling-mounted enclosure to act as a compliment to the TR (telecommunications room) or as a satellite telecommunications room. It permits the active equipment and patch panel to be placed closer to the devices it connects.

FTTE is designed to use smaller (and less expensive) active equipment. It also allows for a horizontal system to grow without increasing the size of the TR. (Refer to TIA 569 for the mandated size of the TR in relation to the area it serves.)

FTTE combines elements of the horizontal segment with a collapsed backbone (see page 19). Fiber optic cable comes up from the equipment room and passes through the TR out to the TE (telecommunications enclosure).

The TE contains active electronics and a copper or fiber patch panel that connects to the horizontal cabling. Cabling distances for the enclosure are the same 90 meters/10 meters (295 feet/33 feet) channel as for the TR.

FTTE offers system designers a great deal of flexibility. Distant zones of the network (those beyond 100 meters) can be served without adding another TR. Enclosures can be added as needed to accommodate growth or physical movement of people and equipment.

Use two fibers for every 8 or 12 ports plus a minimum of two additional fibers for redundancy and growth.
Intrabuilding Backbone Subsystem

A backbone can be either intrabuilding or inter-building. Intrabuilding backbones usually run between floors through passageways called risers. For fire safety, the cable must be listed as riser-rated, although a stricter rating may be required by local codes. It is important to note that where a cable may be installed depends on that cable’s listing (see page 35 for details).

In a distributed backbone, the horizontal cables that terminate in telecommunications rooms connect to riser backbone cables that reach the intermediate or main crossconnect in the equipment room. According to TIA/EIA 568, a intrabuilding backbone link may be as long as 300 meters (984 feet), but that distance can be exceeded by using high-bandwidth multimode fiber or single-mode fiber.

A distributed backbone offers more flexibility for network growth because it utilizes the horizontal crossconnect as a termination point.

In a collapsed backbone, a direct fiber optic cable link connects the desktop to the crossconnect in the equipment room (this can be via a continuous cable or a one-to-one patch in the telecommunications room).

The TIA/EIA standard states that a backbone link may be as long as 300 meters (984 feet), but that distance can be exceeded using single-mode or high-bandwidth multimode fiber. Collapsed backbones terminate all of the horizontal cable in one location which eases cable management and allows concentration of all of the active electronics in the equipment room. This greatly reduces the number and size of telecommunications rooms while also reducing the number of idle ports for lower electronics costs.

Wireless

The remote antenna unit in the office can be connected to active electronics in the equipment room by twisted pair, coaxial or fiber optic cable.
Campus (or Inter-building Backbone) Segment

Because of the long distance between facilities, fiber optic cable is the preferred method for connecting a campus data network. The campus segment is accessed by either: 1) a properly-listed indoor cable that links the active equipment to outdoor cable at a transition point called an entrance facility or 2) by using a campus indoor/outdoor cable (thus eliminating the labor involved with transition).

Campus cable may be placed aurally, in an underground conduit or directly buried. Microwave or free-space optical systems are sometimes used instead of cable between buildings, or parallel with them as redundant networks.

For 100 Mb/s links, multimode fiber cable will support transmission distances of up to 2 km using Fast Ethernet.

For 1 Gb/s links, the multimode fiber transmission distance shortens to a standards-recommended 300 meters (984 feet) although 1 km transmission is typically available with the use of laser-optimized 50 µm multimode fibers.

For 10 Gb/s links, high-bandwidth laser-optimized multimode fiber will support distances greater than 550 meters (1804 feet)*.

For longer distances or higher data rates, single-mode fiber cable is recommended. Single-mode links can be up to 70 km (43.8 miles) or longer with the proper electronics.

Except for networks with a physical ring topology (see section 2), all of the campus network will converge at an equipment room housing the main crossconnect.

Local access subsystem

This is where the signal coming out of the main crossconnect meets the public network. A cable connects the main equipment room to an entrance facility where the connection to the local loop is made. The entrance facility serves as the demarcation point between the public and private network.

Due to the speeds and capacities that are usually required for local access, single-mode fiber is the recommended connection media. Regardless of the calculated present capacity, single-mode fiber should be used to accommodate growth without recabling.

*These distances are achieved using laser-optimized 50 µm fibers
Section 4

Transmission Media
Transmission Media

Media are classified by their construction and the environments in which they can be installed. Each media offers specific benefits for the different network subsystems. They differ most in how they carry (or propagate) communication signals.

Twisted pair (for details, see page 24)
Two strands of thin (22 to 24 AWG) insulated copper wire are twisted together into a pair at a precise lay; the twist helps to reduce crosstalk and EMI. Stranded pairs are then jacketed together in a finished cable. Unshielded Twisted Pair (U/UTP, formerly UTP) is the most common type.

Foil Twisted Pair (F/UTP, also known as Screened Twisted Pair [ScTP]) has an aluminum foil shield over all four pairs plus a drain wire. Shielded Twisted Pair (S/FTP) has individually screened pairs plus an overall shield.

Twisted pair cables are relatively inexpensive and easy to handle and connectorize. They offer medium to high bandwidth over relatively short distances making them a good choice for horizontal cabling of up to 90 meters (295 feet). They are categorized by different levels of performance (Category 6A/Category 6/Category 5e/Category 3).

Fiber optic (for details, see page 26)
These very thin (125 microns or µm) strands of glass propagate light in an even smaller diameter core. Multimode fibers have (relatively) larger diameter cores (50 and 62.5 µm) that permit light to travel over hundreds of (or multiple) modes, or paths. Single-mode fiber’s smaller core permits only one path (a single ‘mode’).

Advances in connector technology have made fiber easier to work with. Media converters are needed in order to interface with copper cabling or electronics that connect to them. However, fiber’s low attenuation and superior bandwidth makes it an obvious choice for backbone and campus links. Although there is a trade-off with the higher cost of electronics, single-mode cables have the highest performance and can be used for links of 70 km (43.5 miles) and longer.

Coaxial (for details, see page 33)
A conductor is surrounded by a dielectric which is covered with one or more shields (copper or aluminum tubes, aluminum tape and/or braided wire) and is then encased in a jacket. The conductor varies per application. Coax is designed to conduct low-power analog and digital RF signals.

Coax is a proven technology for video (coax is the ‘cable’ in cable TV and radio frequency transmission [RFT]) and it offers very good bandwidth and low attenuation. Some data networks (ThickNet, ThinNet, mainframe terminals, etc.) specify coaxial media.

Wireless (for details, see page 34)
High-speed wireless is a data communication medium that is growing in popularity. Access points (APs) send and receive data from the desktop via signal enhancing antennas (SEA) that are wired to the network. SEAs can be powered over the data cabling, eliminating the need for remote power. Note that a “wireless” network will likely require backbone cabling to connect APs to the main network.
Network Cable Performance Criteria

Two critical factors in measuring data cable performance are insertion loss (also called attenuation) and bandwidth.

Insertion loss is the loss of power as a signal travels along a cable and controls its operating distance; insertion loss is expressed in decibels (dB) per a unit of distance. Lower numbers are better.

Bandwidth is the information-carrying capacity of a cable; it’s expressed in MHz for twisted pair and MHz•km for fiber. Higher numbers are better.

Broadly stated, the strength of a signal decreases over distance. Other factors, such as poor connections or splices, or even bends and kinks in cables, can also lead to loss of signal.

TIA/EIA 568 standards state the maximum operating distance as 90 meters (295 feet) for horizontal links (using either fiber or twisted pair) and 300 meters (984 feet) between horizontal and intermediate crossconnects using multimode fiber links.

Network speeds increase constantly. A few years ago, a typical system would have a 100 Mb/s backbone connecting 10 Mb/s horizontal subsystems. 10 gigabit backbones now support 1 Gb/s to the desktop, while 100 Gb/s backbones with 10 Gb/s to the desktop are on the horizon.

The chart below shows where twisted pair and fiber cables fit into the matrix of network speed and distance. Category 6A twisted pair supports 10 Gb/s systems within TIA/EIA recommendations for horizontal channels up to 100 meters (328 feet), while Category 6 and 5e twisted pair supports 1 Gb/s desktop connections.

In the past, the TIA/EIA operating standard mentioned only 62.5 µm fiber; the standard now supports higher bandwidth 50 µm fibers permitting faster network traffic over longer distances (see pages 27 through 29 for comparisons), and 50 µm laser-optimized fiber has become the standard multimode fiber chosen for new builds.
Specify cables with highest possible PSACR and with PSNEXT no more than 3 dB less than the NEXT.

**Twisted Pair Operating Standards for Categories 6A, 6 and 5e**

Advances in construction and materials now produce twisted pair cables with exceptional bandwidth that deliver high-speed transmission over horizontal (90 meter) distances. To achieve high speeds on twisted pair, all four pairs are used to simultaneously transmit and receive (full duplex parallel transmission). With all four pairs in use, TIA/EIA 568 has standardized performance values that measure not only performance within the pair, but among all four pairs. These are:

**Near End CrossTalk (NEXT)** is the ‘noise’ one pair induces into another and is measured in decibels at the receiver. Higher numbers are better.

**Attenuation to CrossTalk Ratio (ACR)** is NEXT minus insertion loss/attenuation. Higher numbers are better.

**Attenuation to CrossTalk Ratio Far End (ACRF)** is a Category 6A specification for the ‘noise’ one pair induces into another measured in decibels at the receiver minus insertion loss/attenuation. Higher numbers are better. Also known as *Equal Level Far End CrossTalk (ELFEXT).*

**PowerSum Near End CrossTalk (PSNEXT)** is a computation of the unwanted signal coming from multiple transmitters at the near-end into a pair measured at the near-end. Higher numbers are better.

**PowerSum Attenuation to CrossTalk Ratio (PSACR)** is PSNEXT minus insertion loss/attenuation. Higher numbers are better. Category 5e cables should have a PSACR of 10.3 dB @100 MHz. Category 6 cables should have a PSACR of 22.5 dB @100 MHz. The difference in performance is created by using a thicker conductor physically separating the pairs and altering the lay of the conductor’s twist.

**Power Sum Attenuation to CrossTalk Ration Far End (PSACRF)** is a computation of the ‘noise’ coming from multiple transmitters at the near-end into a pair measured at the far-end and normalized to the received signal level. Higher numbers are better. Also known as *PowerSum Equal Level Far End CrossTalk (PSELFEXT).*

**Far End CrossTalk Loss (FEXT loss)** is the unwanted signal coupling at the near-end transmitter into another pair measured at the far end. Higher numbers are better.

**Alien Near End CrossTalk (ANEXT)** is the ‘noise’ introduced into a circuit by nearby channels or connections. Higher numbers are better.

**Alien Far End CrossTalk (AFEXT)** is the ‘noise’ introduced into a circuit by nearby channels or connections measured at the far end. Higher numbers are better.

**Return Loss (RL)** is the strength of signal reflected back by the cable terminated to 100 ohms. Like structural return loss (SRL), it is a negative number. A higher absolute value is better (i.e. [-]20 dB is better than [-]110 dB).

**Propagation Delay** is the time required for a signal to travel from one end of the transmission path to the other end.

**Delay Skew** is the difference in propagation delay of the two conductors with the most/least delay.
Twisted Pair Cable Performance

Category 6A, Category 6 and Category 5e cables are capable of supporting full duplex parallel transmission required by gigabit Ethernet and can deliver fast transmission protocols such as broadband video.

A horizontal twisted pair link should deliver a minimum of 10 dB of PSACR at 100 MHz. While some equipment can accept signal as low as 3 dB, 10 dB is a good rule of thumb. However, an experienced designer knows that factors like transmission echo and impedance mismatch can cause crippling power loss and the breakdown of the channel. Using a cable with higher bandwidth, especially in links approaching the 90 meter limit, will keep high speed networks performing as required. Many network problems are eliminated by installing cables with the extra ‘headroom’ provided by higher bandwidth.

Typical vs. tested
Some cables have their performance listed in ‘typical’ performance values. However, sweep-testing is necessary to confirm actual performance. CommScope strongly recommends specifying cable that has been sweep-tested to the listed frequency with test confirmation available for inspection.

Because twisted pair cables are usually used in the horizontal segment of the network, they are usually plenum or riser listed. See Safety Listing/page 35 for details.

Insist on twisted pair cable that has been sweep-tested to verify performance
Fiber Optic Cable Standards

Fiber optic cables need to conform to basic physical and performance standards that are stated by TIA/EIA, Telcordia, ICEA and others. These govern the mechanical, environmental and optical performance of the fiber.

Bandwidth

Multimode fibers have core diameters of either 50 or 62.5 µm. These fibers propagate light over two standard wavelengths, 850 and 1300 nm. Light travels down multiple pathways (or modes) in a multimode fiber. A 62.5 µm core has about 1,100 possible modes at 850 nm; a 50 µm core has around 300. The higher the number of modes, the greater the modal dispersion (when light pulses ‘spread out’ and become unrecognizable by the receiver as individual pulses).

Low modal dispersion results in high bandwidth. TIA/EIA 568 C.3 specifies that multimode 62.5 µm fiber have a minimum bandwidth of 200 MHz•km at 850 nm and 500 MHz•km at 1300 nm (called OM1 fiber) using LEDs as the light sources*. However, Vertical Cavity Surface Emitting Lasers (VCSELs) are used to power networks with speeds of 1 Gb/s and faster.

Bandwidth measurement methods differ for LEDs and lasers because of their unique launch characteristics. Overfilled Launch (OFL) testing characterizes LED light; bandwidth is measured by ‘exciting’ all the modes in a fiber. Restricted Mode Launch (RML) testing simulates VCSEL light at 1 Gb/s systems by exciting a limited number of modes. In order to simulate a VCSEL light at 10 Gb/s, Differential Mode Delay (DMD) testing was designed to excite many different mode groups. DMD is used to determine the effective modal bandwidth (EMB) of the fiber to ‘laser-certify’ fiber for VCSEL compatibility in 10 Gb/s systems (see page 30). High resolution DMD testing is recommended to evaluate fibers designed to operate at 10 Gb/s speeds over the longest lengths, such as OM4 fiber designed to operate at 550 meters.

NOTE: Since single-mode fiber has only one mode, it does not experience the modal dispersion seen with multimode fiber. The bandwidth for single-mode fiber is not normally specified. Instead, attenuation and non-linear effects determine the distances used in single-mode systems.

Attenuation

Regardless of how dispersion and other factors are controlled, the light pulse will lose power over distance. This is called attenuation, and it is measured in decibels. TIA/EIA specifies that a standard grade multimode fiber operating at 850 nm will have an attenuation no worse than 3.5 dB/km and no worse than 1.5 dB/km at 1300 nm.

Single-mode fiber has much lower attenuation. TIA/EIA specifies that a standard grade single-mode fiber operating at 1310 or 1550 nm has a maximum attenuation of 0.50 dB/km (1.0 dB/km if tight buffered).
Fiber Optic Cable Distances for 100 Mb/s Networks

TIA/EIA 568 distance standards were initially written for a ‘FDDI (Fiber Distributed Data Interface) grade’ 62.5 µm multimode 160/500 MHz•km bandwidth fiber powered by 850 µm Light Emitting Diodes (LEDs). These standards were written to support 100 Mb/s backbones with 10 Mb/s horizontal links. Using a fiber with higher bandwidth, or even using single-mode fibers, will produce longer transmission distances than defined by the standard.

In a 100 Mb/s network, the 90 meters of horizontal cabling can be either twisted pair or multimode fiber. Collapsed backbone connections should be multimode fiber and limited to 300 meters. Campus links between active equipment should be limited to 2000 meters for multimode fiber.

Single-mode fiber can be used anywhere in the network, but it is necessary where the transmission distance exceeds 2000 meters. Remember that single-mode fibers require the use of more expensive electronics.

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Bandwidth (MHz•km) 850/1300 nm</th>
<th>100 Mb/s Range with 850 nm LED</th>
<th>100 Mb/s Range with 1300 nm LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 µm OM4</td>
<td>4700*/500</td>
<td>300 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>50 µm OM3</td>
<td>2000*/500</td>
<td>300 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>50 µm OM2+ multimode</td>
<td>950*/500</td>
<td>300 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>50 µm OM2 multimode</td>
<td>500/500</td>
<td>300 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>62.5 µm multimode</td>
<td>200 /500</td>
<td>300 m</td>
<td>2000 m</td>
</tr>
<tr>
<td>8.3 µm single-mode</td>
<td>NA</td>
<td>2 km and up**</td>
<td>2 km and up**</td>
</tr>
</tbody>
</table>

* Effective Modal Bandwidth (EMB)
** using 1310 & 1550 nm lasers
Fiber Optic Cable Distances for 1 Gb/s Networks

With the advent of faster electronics, gigabit (1 Gb/s or 1000 Mb/s) backbones with horizontal links of 100 Mb/s became possible. The 90 meters of horizontal cabling still can be either twisted pair or multimode fiber, and 62.5 µm fiber can be used for the 300 meter backbone. When planning a future link of 300 - 1000 meters, consider using high bandwidth 50 µm multimode fiber or single-mode fiber.

Avoid mixing 62.5 µm and 50 µm fiber in a system

When planning fiber cabling, do not connect fibers of different core diameters into one another. While transmitting from a 50 µm fiber into a 62.5 µm fiber may not result in a power loss, going from 62.5 µm to 50 µm will result in a significant loss of 3 to 4 dB, which is over 50% of the optical power at that location.

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Bandwidth (MHz•km)</th>
<th>1 Gb/s Range with 850 nm VCSEL</th>
<th>1 Gb/s Range with 1300 nm LASER</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 µm OM4</td>
<td>4700*/500</td>
<td>1100 m</td>
<td>600 m</td>
</tr>
<tr>
<td>50 µm OM3</td>
<td>2000*/500</td>
<td>1000 m</td>
<td>600 m</td>
</tr>
<tr>
<td>50 µm OM2+</td>
<td>950*/500</td>
<td>800 m</td>
<td>600 m</td>
</tr>
<tr>
<td>50 µm OM2</td>
<td>500/500</td>
<td>550 m</td>
<td>550 m</td>
</tr>
<tr>
<td>62.5 µm OM1</td>
<td>200/500</td>
<td>275 m</td>
<td>550 m</td>
</tr>
<tr>
<td>8.3 µm single-mode</td>
<td>NA</td>
<td>2 km and up**</td>
<td>2 km and up**</td>
</tr>
</tbody>
</table>

* Effective Modal Bandwidth (EMB)
** using 1310 & 1550 nm lasers
Fiber Optic Cable Distances for 10 Gb/s Networks

10 gigabit (10,000 Mb/s) backbones with horizontal links of 1 Gb/s are becoming common. While these speeds were possible before with single-mode fiber, the high electronics costs were a limiting factor. However, new and economical 850 nm Vertical Cavity Surface Emitting Lasers (VCSELs) make operating these very high speed networks possible over high-bandwidth laser-optimized 50 µm multimode fibers.

The 90 meters of 1 Gb/s horizontal cabling still can be either twisted pair or multimode fiber. Backbone connections of 300 meters must use laser-optimized 50 µm fiber or single-mode fiber. While standards limit campus transmission distances to 300 meters, links in the 500 - 600 meter range are possible with high bandwidth 50 µm fiber (at these operating distances, pay special attention to loss budgets). Distances beyond that require the use of single-mode transmission systems.

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Bandwidth (MHz•km) 850/1300 nm</th>
<th>10 Gb/s Range with 850 nm VCSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 µm OM4</td>
<td>4700*/500</td>
<td>550 m</td>
</tr>
<tr>
<td>50 µm OM3</td>
<td>2000*/500</td>
<td>300 m</td>
</tr>
<tr>
<td>50 µm OM2+</td>
<td>950*/500</td>
<td>150 m</td>
</tr>
<tr>
<td>50 µm OM2</td>
<td>500/500</td>
<td>82 m</td>
</tr>
<tr>
<td>62.5 µm OM1</td>
<td>200 /500</td>
<td>33 m - very limited distance</td>
</tr>
<tr>
<td>8.3 µm single-mode</td>
<td>NA</td>
<td>2 km and up**</td>
</tr>
</tbody>
</table>

* Effective Modal Bandwidth (EMB)
** using 1310 & 1550 nm lasers
Performance Assurance for Optical Cable in 10 Gb/s Networks

Bandwidth is greatly dependent on fiber quality. Even small defects can produce significant amounts of dispersion and Differential Modal Delay (DMD) which can blur optical pulses and make them unintelligible.

IEEE 802.3ae, the standard for 10 Gb/s networks, has specified 50 µm multimode fiber with a bandwidth of 2000 MHz•km at the 850 nm window and DMD-certified for 10 Gb/s transmission. VCSELs (Vertical Cavity Surface Emitting Lasers) must be used to power 10 Gb/s multimode networks.

When planning a 10 Gb/s network, specify fiber that passes the DMD laser testing as specified in TIA/EIA-492aaac-rev.a as a minimum. Although not yet in the standards, high resolution DMD test methods are being utilized today to validate the performance of the extended range OM4 type fibers.

High bandwidth 50 µm fiber is tested by launching a laser at precise steps across the core. The received pulse is charted to show the arrival time of the received signal. Once the signals are charted, a mask is overlaid with the maximum pulse arrival difference allowed between the leading edge of the first received pulse and the trailing edge of the last pulse. While this mask can be determined from the IEEE 802.3ae standard, some manufactures use an even tighter mask profile to really minimize the effects of DMD.

DMD testing is performed because VCSELs from various manufactures differ in their launch characteristics. Fiber that passes the bandwidth testing with one laser could conceivably fail when installed and used with another VCSEL. DMD testing to this tighter standard means that CommScope 50 µm fibers will support 10 Gb/s at longer distances or with less connector loss.

In this chart, fibers are listed by TIA’s LOMMF (Laser Optimized Multimode Fiber) and ISO’s OM (Optical Multimode) performance standards.

<table>
<thead>
<tr>
<th>Fiber Type or Name</th>
<th>EMB bandwidth (MHz•km)</th>
<th>1 Gb/s Range</th>
<th>10 Gb/s Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ISO OM designation)</td>
<td>850/1300 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OM4 50 µm</td>
<td>4700/500</td>
<td>1100 m</td>
<td>550 m</td>
</tr>
<tr>
<td>OM3 50 µm</td>
<td>2000/500</td>
<td>1000 m</td>
<td>300 m</td>
</tr>
<tr>
<td>OM2+ 50 µm</td>
<td>950*/500*</td>
<td>800 m</td>
<td>150 m</td>
</tr>
<tr>
<td>OM2 50 µm</td>
<td>500*/500*</td>
<td>600 m</td>
<td>82 m</td>
</tr>
<tr>
<td>OM1 62.5 µm</td>
<td>200*/500*</td>
<td>300 m</td>
<td>33 m</td>
</tr>
<tr>
<td>OS2 8.3 µm single-mode</td>
<td>NA</td>
<td>40 km**</td>
<td>40 km**</td>
</tr>
</tbody>
</table>

*OFL bandwidth
**using 1310 & 1550 nm lasers
Loose Tube Fiber Optic Cable Construction

Fiber cable starts with optical fiber. Optical fiber consists of a germanium doped silica core within a concentric layer of silica cladding that is 125 µm in diameter. The core and cladding are covered by two or three concentric layers of acrylate coatings which provide physical protection. The outer acrylate layer is typically colored for identification. The coated fiber diameter is approximately 250 µm.

Loose tube construction places several fibers in a small-diameter plastic buffer tube. Multiple buffer tubes can be cabled together around a central strength member for higher fiber-count cables. High-strength yarn is placed over the buffer tubes, and a jacket is applied. A variant of loose tube design is called central tube that uses a single large diameter tube to contain all the fibers.

Loose tube designs have lower attenuation than tight buffered cables and are usually used for longer distance single-mode cables. Loose tube cables offer optimum performance in campus subsystems. Loose tube design also helps fiber performance in areas with extremes of temperature.

Indoor/outdoor cables

Indoor/outdoor cables are NEC listed (and sometimes LSZH) cables that meet environmental requirements for outdoor usage. Indoor/outdoor cables can operate as underground or aerial links between buildings without a transition to a listed indoor cable. They are protected against moisture like outside plant cables [see below].

Outside plant

Outside plant cables are designed specifically for outdoor usage. They do not carry NEC listings and are not intended for indoor use except when placed in rigid or intermediate metal conduit (check local codes). Outdoor cables come in specialized constructions (armored, multiple jackets, special chemical-resistant jacket compounds) to help them withstand severe environments such as heat/cold, sunlight, petrochemical exposure and rodent attack.

Moisture ingress is addressed with either a water-blocking material in the buffer tubes, or with water-swellable tapes and binding threads that incorporate super-absorbent polymers (SAPs). These cables are intended for single-pass installation, whereas other aerial cables first require installation of a supporting messenger wire and subsequent overlashed installation of the fiber optic cable.

Self-supporting cables

Self-supporting cables are outdoor cables intended for aerial installation. They may have either steel or non-metallic (dielectric) strength members incorporated into their jackets. Depending on cable weight, messengered (figure-8 style) cables can span 400 meters (1312 feet) or longer.

Drop cables

Drop cables have low fiber counts (1 or 2 fibers) and are intended for short aerial, buried or duct installations. They are small in diameter and have less tensile strength than normal self-supporting cables.
Tight Buffered Fiber Optic Cable Construction

Tight buffered fibers have an additional plastic coating (900 µm diameter) that makes it easier to handle and connectorize. They are usually cabled with a high-strength yarn and are then jacketed with a flexible polymer. Tight buffered fiber is used for horizontal and backbone cabling because it stands up to the stress of physical handling associated in the telecommunications room or at the desktop.

Tight buffered cables are used in the following cable types:

**Cordage**

Cordage consists of one (simplex) or two (duplex) fibers and used for links throughout the horizontal subsystem, usually as a crossconnect patchcord. It is usually plenum or riser rated (see page 35/Cables and Fire Safety Listing).

**Breakout cables**

Breakout cable consists of several individually jacketed tight-buffered fibers (basically simplex cordage) cabled together. It is usually plenum or riser rated (see page 35/Cables and Fire Safety Listing).

**Distribution cable**

Distribution cable consists of jacketed groups of tight buffered fiber (subunits) consolidated in a single cable. Distribution cables are used in backbone subsystems, linking equipment rooms, telecommunications rooms and outlets. The fibers terminate into active equipment or interconnects; the subunits make the bundled fibers easier to install and manage. They are usually plenum or riser rated (see page 35/Cables and Fire Safety Listing) but can also be constructed as an indoor/outdoor or low-smoke (LSZH) cable.

**Indoor/Outdoor cable**

Indoor/Outdoor cables are NEC listed (and sometimes LSZH) cables that also meet environmental requirements for outdoor usage. Indoor/outdoor cables can operate as underground or aerial links between buildings without a transition to a listed indoor cable.

For a more detailed description of fiber optic cable types, see Section 5/Connectivity components.
Coaxial Cable Operating Standards and Performance

While coaxial cable was once the media of choice for data networking, its merits of fairly low attenuation and excellent protection from RF interference have been superseded by twisted pair and fiber. It is still the media of choice for video distribution.

Coaxial cable is in effect a waveguide; it efficiently channels radio/TV frequencies and is capable of carrying hundreds of different frequencies simultaneously. It is an ideal media for video transmission and for linking to satellite and microwave dishes. Coax is also used to transport signals between the hubs and remote antenna units that power wireless networks. Conductor materials vary per application; CCTV cables use solid bare copper while CATV cables use copper-clad steel conductors.

Impedance
Impedance is the resistance to current flow of the cable measured in ohms (Ω). The nominal impedance of the transmitter, receiver and cable must match precisely for a system to work at maximum efficiency. An incorrect match will produce return loss. Video cable is 75Ω; other values used are 50Ω and 93Ω.

Attenuation
Attenuation is the limiting factor for coax cable with higher transmission frequencies being more affected. Specifications are usually written with the maximum available loss in decibels per 100 feet or 100 meters for a set of frequencies. Cables with larger diameter center conductors tend to have lower attenuation.

Velocity of propagation
Another performance factor is the velocity of propagation (VP), or how close to the speed of light the signal travels. Higher numbers are better. CommScope video coax generally uses a foamed dielectric material that significantly increases VP.

Return loss
Return loss is the ratio of the power of the outgoing signal to the power of the reflected signal expressed in dB. Structural return loss is the measure of power loss on a cable caused by discontinuities in the cable conductor or dielectric. If these discontinuities are regularly spaced along a cable, they can cause severe transmission losses for frequencies whose wavelengths are fractional proportions (1/2, 1/3, 1/4, etc.) of the distance between these discontinuities. Lower numbers are better in both cases.

Coax is a viable media for industrial networking, especially in areas where the electromagnetic interference (EMI) created by electrical motors and manufacturing processes such as arc welding would render an unshielded cable useless. Protocols like ControlNet™ and MAP specify coaxial media.

Look for the lowest possible attenuation for the intended operating frequencies
Wireless Connections

Wireless networks, as defined by IEEE 802.11, do not require a cable connection to the desktop. Access points (APs) operating at 2.4 GHz use signal enhancing antennas (SEAs) to connect with devices enabled to act with a wireless network.

The main advantage of wireless networks is the freedom from a physical connection. Ideally, devices may connect to the network if located within 100 meters (328 feet) of an access point. Network speeds for wireless networks vary, although devices that support the latest iteration of the standard (802.11g) permit speeds of up 54 Mb/s.

Like any other electronic device, APs require power. However, some systems carry power to the APs over the same cable (power over Ethernet or PoE) that connects them to the network.

Wireless networks are ideal for data professionals that need to move within a facility, such as technical support personnel or troubleshooters.

However, wireless networks operate at slower speeds relative to cabled networks and do not have the inherent reliability of a hard connection. While wireless network offer the most flexibility in connectivity, they also offer opportunities for tapping. 802.11i standards include an advanced encryption standard that minimizes security concerns.
Cables and Fire Safety Listings

Fire safety is as important as cable performance. This chart shows cable ratings (or listings) for appropriate sections of the National Electric Code (NEC) and Canadian Electrical Code (CEC). Plenum cables are listed for use in plenum spaces. Riser cables are used in building risers, raceways and trays.

NEC 770 covers fiber optic cable; NEC 800 covers communication cable such as twisted pair and data coax; NEC 725 covers signal, remote control and closed circuit video cable; NEC 760 covers cables used in fire protection signaling; and NEC 820 covers cables for CATV.

It is important to know that local codes may supersede NEC regulations; for instance, some local fire codes require the use of plenum cables in risers. In all cases, obey local codes.

*Cable A may be substituted for Cable B with restrictions*

*Cable A may be substituted for Cable B*

*NEC 800 TO NEC 820 SUBSTITUTIONS ARE ONLY FOR COAXIAL CABLE
†OFNP AND CMP ALSO MEET CSA FT-6 - OFNR AND CMR MEET CSA FT-4 - CMH MEETS FT-1*
OSHA, NEC and NESC Information

Occupational Safety and Health Administration (OSHA)
OSHA regulations are federal requirements that are intended to enable employers and employees to recognize, understand, and control hazards in the workplace. Generally applicable OSHA standards are found in: Title 29 CFR Parts 1901.1 to 1910.441 General Industry, (OSHA), Order No. 869-019-00111-5; Excavations (OSHA 2226), Order No. 029-01600125-5; Underground Construction (Tunneling) (OSHA 3115); and Stairways and Ladders (OSHA 3124).

Copies of OSHA standards can be obtained from:
Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402
+01 (202) 783-3238 • http://www.osha.gov

National Electric Code (NEC)
The NEC typically identifies the construction techniques and materials necessary in building wiring requirements and was developed by the National Fire Protection Association’s (NFPA’s) National Electric Code committee. Committee members are professionals from the electrical and insurance industries. The NEC has been adopted by the American National Standards Institute (ANSI).

Copies of NEC standards can be obtained from:
National Fire Protection Association
1 Batterymarch Park/P.O. Box 9146
Quincy, MA 02269-3555
(800) 344-3555 • http://www.nfpa.org

National Electrical Safety Code (NESC)
The NESC is produced by the Institute of Electrical and Electronics Engineers (IEEE). The NESC relates to outside plant cabling as the NEC does to the inside of a building.

Copies of NESC standards can be obtained from:
Institute of Electrical and Electronics Engineers
IEEE Service Center
445 Hoes Lane/PO Box 1331
Piscataway, NJ 08855-1331
+01 (732) 981-0060 • http://standards.ieee.org/nesc/
Section 5

Cable and Connectivity
Overview

The connectivity components discussed briefly in sections 3 and 4 are covered in more detail here. The design and quality of these components can have a major impact on the performance and reliability of the entire network.

In horizontal segments, the desktop device uses an equipment cord to connect to a outlet. A cable (called the permanent link) links the outlet to the telecommunications room (TR) where it terminates by connectors or hard-wiring. Patch cords then connect the permanent links through the horizontal crossconnect, which is usually a patch panel mounted in a standard equipment rack with patch cords connecting the patch panel to ports on the active equipment. This is called the channel. The signal from the active equipment (usually optical) is jumpered to a patch panel. This is the transition point to the backbone.

Cable links the telecommunications room to the equipment room’s patch panel (intermediate crossconnect). The IC is patched to active equipment. This is connected by patch cords to a rack or wall-mounted fiber enclosure. This is the transition point to the campus backbone and eventually the main crossconnect.

If the cable used in the campus backbone is not listed for indoor use (see page 35), then it must be transitioned to a cable listed for indoor use. Note that the NEC permits no more than 15 meters (50 feet) of outside plant cable to enter a building. Dielectric fiber cables may enter further if the cable is in rigid or intermediate metal conduit. Please check local codes for other rules.
Channels, Testing and Performance Verification

Connectivity components play a major part of the performance of any portion of the network. This is especially true in the portion of the horizontal segment of the network called the channel.

Channels

The channel consists of the cable and components that connects the desktop to the active equipment in the telecommunications or equipment rooms. For twisted pair installations, the channel includes the equipment cord at the desktop, the horizontal cable, the telecommunications outlet (and the consolidation point, if installed), the patch panel or termination in the telecommunications or equipment rooms and the patch cable to the active equipment.

Any relevant measure of network performance must take the channel into account. Cable must be matched with properly engineered components to produce optimum performance.

Standard testing for a channel includes what are called 3, 4 and 6 connector specimens (shown below - installed cable is shown below in blue/patch cords are shown as orange).

The 3 connector specimen is a traditional cord/permanent link/patch cord configuration.

The 4 connector specimen adds a consolidation point.

The 6 connector specimen further adds an additional patch cord and outlet in the telecommunications room.

CommScope participates in third-party verification to ensure quality performance of our structured cabling products. This verification program is a process in which our products are tested by a third-party laboratory like UL or ETL SEMKO, a division of Intertek.

The laboratory performs extensive tests to confirm that our products meet and exceed required standards and to verify that our product performance claims are accurate.
Twisted Pair Cables

Twisted pair data cables are made to different levels of performance as well as for different operating environments. While all twisted pair cables have multiple pairs of twisted-together copper conductors, there are construction details that affect how they operate.

Because most twisted pair cables are used indoors, they are generally listed for plenum and riser use. Outdoor twisted pair cables are available.

Unshielded Twisted Pair (U/UTP) Category 5e Cables

A U/UTP cable is generally four twisted insulated solid copper conductors pairs jacketed together. Features such as conductor size and insulation materials help tune the cable to meet TIA/EIA standards for performance (see page 41).

Unshielded Twisted Pair (U/UTP) Category 6A and 6 Cables

Along with the features mentioned above, category 6A and 6 cables typically have a pair separator that helps decrease crosstalk and further improve performance (see page 41).

Foil or Screened Twisted Pair (F/UTP or ScTP)

These are twisted pair cables with a an overall tape/aluminum shield and drain wire to help fight the effects of external EMI.

Shielded Twisted Pair (S/FTP)

These are twisted pair cables with tape/aluminum screens over each pair and an overall shield to further lessen the effects of external EMI.

Multiple Subunit (24 pair) U/UTP

Six U/UTP cables can be jacketed together for ease of pulling. The U/UTP cables become individual subunits of the larger cable.
Twisted Pair Channel Performance

Twisted pair data cables are designed to TIA/EIA 568 C.2 standards of performance for the horizontal segment of the network. CommScope offers several cables that meet or exceed these standards. CommScope cables offer third-party-verified channel performance when used with matching CommScope connectivity components (next page).

Cable

By definition, all Category 6 and 5e twisted pair cables support gigabit Ethernet. In the real world, a cable with higher bandwidth will support it better. Network transmission depends on a signal with as little noise as possible; a noisy signal increases bit-error thus causing retransmission and slowing the throughput of the link. High bandwidth cables have less noise as expressed by the higher ACR value. When choosing a twisted pair cable, consider higher bandwidth cables for longer or higher speed links.

<table>
<thead>
<tr>
<th>all values in dB @ 100 MHz</th>
<th>Insertion loss (attenuation)</th>
<th>NEXT</th>
<th>ACR</th>
<th>PSum NEXT</th>
<th>PSum ACR</th>
<th>ELFEXT*</th>
<th>PSum ELFEXT**</th>
<th>Return Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 6A (500 MHz)</td>
<td>19.1</td>
<td>44.3</td>
<td>25.2</td>
<td>42.3</td>
<td>24.8</td>
<td>27.8</td>
<td>24.8</td>
<td>20.1</td>
</tr>
<tr>
<td>Category 6e (550 MHz)</td>
<td>19.6</td>
<td>42.9</td>
<td>23.3</td>
<td>42.1</td>
<td>22.5</td>
<td>29.3</td>
<td>27.3</td>
<td>16.0</td>
</tr>
<tr>
<td>Category 6 (400 MHz)</td>
<td>20.2</td>
<td>41.9</td>
<td>21.7</td>
<td>41.1</td>
<td>20.9</td>
<td>27.3</td>
<td>27.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Category 6 (350 MHz)</td>
<td>21.3</td>
<td>39.9</td>
<td>18.6</td>
<td>37.1</td>
<td>15.8</td>
<td>23.3</td>
<td>20.3</td>
<td>12.0</td>
</tr>
<tr>
<td>Category 5e (350 MHz)</td>
<td>22.1</td>
<td>34.1</td>
<td>12.0</td>
<td>32.6</td>
<td>10.5</td>
<td>22.9</td>
<td>19.9</td>
<td>13.0</td>
</tr>
<tr>
<td>Category 5e (200 MHz)</td>
<td>23.5</td>
<td>32.1</td>
<td>8.6</td>
<td>29.1</td>
<td>5.2</td>
<td>19.4</td>
<td>16.4</td>
<td>12.0</td>
</tr>
</tbody>
</table>

*Called ACRF in the Category 6A standard
**Called PSACRF in the Category 6A standard

Newer cable designs have reduced cable diameters to 7.24 mm (0.285 in), allowing for both high performance and greater cable density.

To support desktops with ‘average’ traffic (see page 70), Category 5e cable works very well. For heavier traffic, consider Category 6A or enhanced Category 6 cables. Consult local codes as to what type (plenum or non-plenum) of cable to install (see page 35).
Twisted Pair Outlets and Patch Cords

Twisted pair connectivity components are based around the 8P8C (also known as the RJ-45) style connector. By definition, any 8P8C/RJ45 plug will fit into any 8P8C/RJ45 jack. However, like U/UTP cables, twisted pair connectivity components not only have design differences between Category 5e and 6, but performance differences between manufacturers as well. When specifying outlets and patch cords, make sure they are specified for the category of cable being installed.

CommScope matches cable and components for superior quality connectivity. All three, four and six connector channels have all been third-party-verified for stated performance.

Outlets

Twisted pair outlets vary in design and manufacturing. Features to look for include a wide channel between the left/right termination strips (for easier termination and lower crosstalk) and the ability to be placed in the faceplate at either a 90° or 45° angle. Color-coded outlets are helpful installation aids. Make sure the cable and outlets match categories (Category 6 cable with Category 6 outlets). Special tools are available to ease and speed termination.

Patch cords

Patch cords are terminated in male plugs. They come in lengths of 0.9 meters (3 feet) to 15.2 meters (50 feet). Look for cords with a ruggedized plug/cable union to handle repeated plugging/unplugging and features such as “snag-resistant” latches. Since patch cords are often the weakest link in the channel, and receive the most abuse from network moves/adds/changes, always install high quality factory-built patch cords.

Patch panels

Patch panels are strips of 24 or 48 outlet ports built to fit in a standard 48 cm (19 inch) rack. The ports may be subdivided into groups of 6.

110 wiring blocks

These are traditional telephony wiring panels that have been updated to work with twisted pair data cabling. Wiring is terminated by direct connection (“punched down”) or by the use of a repositionable connecting block.
Premises (Indoor) Fiber Optic Cable -
Cordage and Breakout cable

Fiber optic cables have evolved into families of cables for specific purposes within the network. While twisted pair cables are typically classified by performance, fiber cable types are classified by how and where they are installed.

**Cordage**

Cordage is a cable group that includes simplex, zipcord, interconnect and duplex cable. Cordage is used in the horizontal segment and for patch and equipment cables. It is available for plenum, riser and indoor/outdoor environments.

**Simplex cable**

Simplex cable is a single tight buffered fiber surrounded by aramid yarn and jacketed with a flexible fire-rated polymer in various diameters up to 2.9 mm. It can be spliced or connectorized and is normally used for pigtails and patch cables.

**Zipcord**

Zipcord is two simplex units cabled together to give the resulting transmit/receive fiber pair better organization. Zipcord is designed for use in patch cords.

**Interconnect cable**

Interconnect cable is two tight buffered fibers surrounded by aramid yarn and jacketed. It is most commonly used for horizontal links.

**Breakout cable**

Breakout cable is several simplex cables jacketed together for ease of handling in horizontal links.
Premises (Indoor) Fiber Optic Cable - Distribution Cable

Distribution cables are a compact solution for transporting up to 144 tight buffered fibers (bundled in 12 fiber subunits) over a long distance. Aramid yarn provides tensile strength while a dielectric strength member gives support for pulling and for long riser installations. Distribution cables are more rugged than cordage due to the harsher installation environment. Because tight buffered fiber is easier to handle and requires less preparation than loose tube buffered fiber, distribution cables can be installed more quickly and economically.

Distribution cables

CommScope engineers distribution cables that are up to 30% smaller in diameter and up to 50% lighter than comparable products. This is a major benefit when duct or riser space is scarce. Their ease of handling and high fiber counts make them ideal for backbone applications.

Distribution cables start as single unit cables in constructions of up to 24 fibers. Cables with more than 24 fibers are composed of multiple single cable subunits. The multiunit construction permits easy placement and tracing of single-mode and multimode fibers in the same cable (called a composite cable). These composite cables help a network prepare for future growth (see page 68 for more detail).

Distribution cables are available plenum and riser-rated versions.

Interlocking armored cables

Distribution cables can be overlaid with interlocking aluminum armor that provides protection against damage due to extreme conditions. This eliminates the need for installing conventional conduit or innerduct, thus reducing the overall time and cost of the installation. Interlocking armor offers superior protection combined with excellent installation flexibility.

Interlocking armored cables are NEC & CEC compliant for OFCR, OFCP and OFCR-LS (Low Smoke) applications.
Indoor/Outdoor Fiber Optic Cables

Indoor/outdoor cables may be plenum or riser-rated yet are tough enough for use outside. A water-blocking technology swells on contact with water to arrest moisture ingress and eliminate the need for a gel outside of the buffer tube. In loose tube cables, water-blocking technologies (either gel or gel-free) may be inside of the tube as further protection against moisture ingress.

Cordage
CommScope offers simplex, duplex, zipcord and interconnect tight buffered cordage similar to the versions described on page 43, but with riser-rated UV-stable jackets designed for outdoor use.

Distribution (tight buffer)
Indoor/outdoor distribution cables are based on 12-fiber subunits, supported with a central dielectric strength member and protected with strength yarns impregnated with water blocking materials, cabled around another central strength member, then jacketed with a UV-resistant compound. The riser rating eliminates the need for a splice point at the building entrance. These cables are available in versions of 4 to 72 fibers. Composite multimode/single-mode versions are available. Distribution cables can be used for risers and backbones.

Stranded Loose Tube
Stranded loose tube cable contains multiple buffer tubes laid around a central strength member. Yarn adds tensile strength. The buffer tubes contain up to twelve (12) individual fibers. Multiple tubes stranded in a reverse-oscillating lay to reduce fiber strain and this allows easier ‘mid-sheath’ entry. In other words, if some fibers are going to be ‘dropped’ along the route, the separate buffer tubes permit access to only the dropped fibers while the remainder stay protected within their own buffer tubes.

Central Loose Tube
These are small diameter cables with a single tube that is thicker and stronger than a traditional buffer tube. That strength is augmented with several dielectric strength members embedded in the UV-resistant jacketing material. At some fiber counts, the central tube cable may have a smaller diameter compared to a similar loose tube design, although with some loss in manageability.

Interlocking armored cables
Armoring is available on all indoor/outdoor cables except for central loose tube.
Outside Plant Fiber Optic Cables

Outside plant cables are typically loose tube construction, which better handles environmental extremes. Outside plant cable is not NEC listed, so no more than 15 meters (50 feet) of it can be placed inside a building unless it's a dielectric fiber cable in rigid metal conduit (check local codes).

Many outside plant cables offer armor and multiple jacket constructions to defend against the forces of direct burial and rodent attack. Stranded loose tube cables use water-blocking technologies (either gel or gel-free super absorbent polymers) inside the tube as protection against moisture ingress.

**Stranded Loose Tube**

Non-armored all-dielectric cables feature buffer tubes arrayed around a central strength member, covered with aramid yarn, and jacketed in a tough polyethylene jacket. They are preferred for aerial and conduit installation and are available in 2 to 576 fibers. The advantage of all-dielectric construction is that the cable does not have to be grounded while having inherently better lightning resistance.

Armored loose tube cables offer the same basic construction as non-armored cables, but with a layer of protective corrugated steel tape. Additional inner jackets are available for added protection and ease of use.

Multiple armor/multiple jacket cables are made for truly demanding environments, especially direct buried rocky installations or where low temperature is a concern. Double and triple-jacketed versions offer up to 576 fibers.

Self-supporting loose tube cables have a internal steel messenger wire for aerial applications. Armored versions are available. Both offer counts of up to 288 fibers.

**Central Loose Tube**

These offer several advantages for campus applications; they are lightweight, strong and can be installed aerially. Armored and dielectric versions for conduit and underground use can have as many as 96 fibers. A drop cable version with an integrated messenger is used for fiber-to-the-home applications.
Fiber Optic Connectors

While many fiber optic connectors have been developed, three main types are presently in use—the ST, SC and LC. These connectors are designed to fit onto 900 µm tight buffered fiber, loose tube cable with fan-out kits, or 1.6 or 2.9 mm cordage. Ceramic ferrules are customarily used to position the fiber.

A fiber connectorized at one end is called a pigtail; if connectorized at both ends, it's called a patchcord. Pre-terminated patch cords and pigtails are readily available.

LC connectors

LC connectors are Small Form Factor (SFF) connectors about half the size of SC/ST connectors. They come in both simplex and duplex versions. They can be easily snapped in and out and offer excellent optical performance in a very small size. Most LC connectors have a ceramic ferrule. TIA/EIA 568 allows for the use of SFF connectors such as the LC. The LC connector is increasingly popular in enterprise networks and is often the connector used in network switches.

SC connectors

SC connectors are a push/pull design about the same size as an ST. They are sturdy, easy to handle, pull-proof when used in cordage and can be yoked together into a convenient duplex assembly. The SC connector has a long heritage of successful deployments around the world. They offer excellent optical performance and are recommended by TIA/EIA 568 to illustrate fiber systems. Most SC connectors have a ceramic ferrule.

ST connectors

ST connectors are bayonet-style; they push into position and twist to lock in place. STs are easy to handle and relatively inexpensive, though somewhat awkward when used as duplex patchcords. STs offer slightly more insertion loss than other connector types, but have a large installed base from years of use.

Most connectors and adapters (see next page) are color-coded as specified in TIA-568 for easy recognition:

- Single-mode components are blue.
- SM/APC (Single-Mode Angled Polish Contact) components are green.
- Multimode components are beige.
- Aqua is used to designate 50 µm laser optimized components.
Fiber Optic Adapters, Panels, Enclosures and Entrance Facilities

Adapters or couplers
Adapters are used to hold and align the end faces of two connectorized fibers. Unlike U/UTP jacks and plugs, the optical adapter aligns and retains two-fiber connectors plugged in from opposite ends. The adapters are arranged on adapter panels and housed within a fiber enclosure (the optical version of a patch panel) or entrance facility. A duplex single-mode LC to LC adapter is shown; there are adapters that permit the mating of different connector styles.

Adapter panels
These are the building blocks of fiber connectivity. They hold the adapters and arrange them in multiples of six, eight or twelve and are designed to fit within fiber management enclosures and entrance facilities. A panel with twelve duplex LC adapters with dust covers is shown.

Fiber enclosures
Fiber enclosures may act as the intermediate cross/interconnect and may be wall or rack mounted (panel pre-installation is optional). Incoming fiber may be directly terminated with a connector or be spliced to pigtails within the enclosure and protected within an internal splice holder. Capacities vary depending on whether simplex or duplex connectors are being used and if connectorized fibers are being combined with spliced fibers.

Entrance facilities
An entrance facility is required when transitioning outside plant cable to the inside of the building. NEC regulations permit no more than 15 meters (50 feet) of unlisted cable inside a building unless it is a dielectric fiber cable in rigid metal conduit (check local codes). Outside plant cable is spliced to an indoor cable that leads to the equipment room. Internally, splice trays support the spliced fibers.
Coaxial Cables and Components

Coaxial cable is usually employed in a video or specialized data network (certain types of Ethernet or manufacturing automation systems). Video uses 75 ohm Series 59, 11 or 6 cables, while data systems use a variety of cables (RG62, RG58, RG8 or RG213) with different impedance.

Cable

Coaxial cable is composed of a central conductor (bare copper, copper covered steel, etc.), a dielectric (usually a foamed polyethylene or Teflon®), a metallic shield and an outer jacket. The shield may consist of some combination of metal braids and foil tapes. At minimum, a dual braid/foil shield (top picture) is required. A quad-shield (bottom picture - foil/braid/foil/braid) may be needed for environments where EMI is unusually high.

For broadband video purposes, Series 11 cables offer the best performance over distance with an operating range of up to 120 meters (400 feet). Series 6 cables operate up to 75 meters (250 feet), and Series 59 cables operate up to 30 meters (100 feet). Operating distances of coax data cables also vary per application; please consult with the transmission equipment supplier for recommended operating distances and speeds.

Connectivity hardware - video outlets, connectors and patch panels

‘F-style’ connectors are the preferred method for terminating broadband video coaxial cable. The center conductor is placed through the center of the connector (thus becoming the ‘pin’ of the connector for 59 and 6 series cables) while the sleeve is attached to the shield and jacket. Specialized tools help make connectorization fast and secure. The conductors make physical contact by entering through either side of a threaded receptacle. Positive contact between the connector pins is required for good transmission.

‘BNC-style’ bayonet-style connectors require that the center conductor be soldered or crimped to the connection pin. Regardless of the connector style, make sure the connector size and impedance match that of the cable being installed.

Coax patch panels are usually arrays of receptacles mounted in a standard equipment rack.

Data connectivity hardware

ThinNet Ethernet uses BNC-style connectors to attach desktop links to its coax bus cable. Some coaxial cables require special connectors. Consult the manufacturer for details.
Security Cables

Technically, any of the preceding cable types could be considered security cables. Coax is the traditional medium for CCTV; both twisted pair and fiber are making inroads into integrated security systems. However, many security applications simply use a quality multi-conductor copper cable.

Control cables

Commercial control cables consist of insulated copper conductors encased in a jacket. While their construction may vary in the number of conductors (from one to four pairs), the size of the conductors (22 to 18 AWG) and their construction (usually stranded), all control cables must meet NEC article 725. The CMP rating is for plenum cables and the CMR rating is for riser and tray cables.

Shielded control cables may be required if the placement of the cable is in an electronically ‘noisy’ area, such as fluorescent lights or large electric motors.

Fire cables

Fire signal and alarm cables generally have larger (18 to 14 AWG) solid copper conductors than control cables. They are described under NEC article 760 with an FPLP designation for plenum and FPLR for riser-rated cables. They commonly use a red jacket [although that is not a standard].

Coaxial cable with power

Many security cameras feature the ability to pan, tilt and zoom (PTZ) as directed from the control room. Power and control are provided by a power ‘leg’ extruded onto the video coaxial cable.
Section 6

Telecommunications Spaces
Telecommunications Spaces

There are five types of building telecommunications spaces:

Access provider space
The access (or provider) space is where the cabling from an outside provider (i.e. telco, CATV) enters the building. It should be large enough to accommodate more than one provider and have room for growth. It should also be located as close as possible to (and may reside within) the equipment room. The access provider usually equips this space.

Equipment room
The Equipment Room (ER) is the collection point for all of the building's communication cabling. ER dimensions depend on the area of the building being served, although special-use structures (hospitals, laboratories, etc.) have the ER size based on the number of work areas. Larger equipment rooms may resemble data centers, with raised floors, redundant power and “hot and cold aisles.” A portion of the ER may be used as the telecommunications room for that floor.

Telecommunications room
The Telecommunications Room (TR) is central collection point for the horizontal cabling on a floor. The TR houses the patch panels, cross-connects and active equipment that connects the work areas with the equipment room. In almost all cases, there must be at least one TR per floor (and possibly more). Its size will depend on the area being served.

Telecommunications enclosure
The telecommunications enclosure acts as a junior version of the telecommunications room to serve small areas or zones. It may connect to the TR or it may directly route to the equipment room. The telecommunication enclosure may act as the TR under conditions where a full-sized TR would be overkill.

Entrance facility
The entrance facility is the access point for outside plant cables to enter a campus building. It consists primarily of cable management hardware and splicing enclosures.

General considerations
Telecommunications spaces are dedicated solely to tele/data communications. They should be positioned within the operating range of the cabling type being used (i.e. 90 meter channels for U/UTP cables). They should be located away from possible sources of electromagnetic interference (EMI). Do not locate them where growth may be inhibited by fixed walls or elevator shafts. HVAC access is essential. Also, there must be a clear path to the space to permit delivery of cable reels, racks and enclosures used for installing the connection and active equipment.

Some designers prefer to separate voice and data wiring and use wall-mounted punchdown (i.e. 110-style) terminals. To ease their installation, all telecommunications spaces should have at least one wall paneled with 19 mm (¾ in.) thick A-C, fire-rated and kiln-dried plywood, 2.4 m (8 ft) high. Spaces should be 3 m (10 ft) floor to ceiling. Dropped ceilings are not recommended.

Many buildings/floors have multiple tenants, meaning that the TR and ER may have to accommodate discrete racks of equipment, sometimes segregated by mesh walls. These ‘common’ rooms (CTR and CER) will tend to be larger than those in buildings with a single tenant.

Finally, security should always be a concern where data pathways are involved. All spaces should be behind locked doors and accessible only to authorized staff.

Note: the descriptions and specifications for these spaces are adapted from the ANSI/TIA-569-B-2004 standard ©2004 TIA. Refer to this standard for complete information on telecommunications spaces.
Access Provider Space

Access /server provider spaces hold the equipment that connects the building network to the outside world. It is customary for the access/service providers to provision this space with their equipment, racks, etc. Like all telecommunications spaces, the access provider space should be convenient to cable pathways, positioned for growth, located away from EMI sources and securable behind either solid partitions or mesh cage walls (preferred for air circulation purposes). It can be located within the equipment room.

Size and construction

A typical access provider space of 3 m² (24 ft²) is shown here. One wall should be covered with kiln-dried plywood. Minimum clear height should be 2.4 m (8 ft) without obstructions, as well as a minimum of 3 m (10 ft) from floor to the lowest ceiling point. Suspended ceilings are not advised.

Lighting shall be a minimum of 500 lx (50 foot-candles) measured 1 m (3 ft) above the finished floor. The room should be painted in light colors to improve illumination. Light switches are located near the entrance and on a separate circuit from the room equipment.

Lockable double doors with a removable center post, at least 0.9 m (36 in) wide and 2 m (80 in) high, without doorsills and hinged to open outward (code permitting) are advised.

Air handling

The access/service provider space requires an uninterrupted supply of cool, clean air – at least 9 m³ (300 ft³) of 12 °C (55 °F) conditioned and filtered air per 20 A receptacle dedicated to powering active equipment. Temperature should range from 18 °C (65 °F) to 24 °C (75 °F) with 30% to 55% relative humidity. Positive air pressure should be maintained to keep contaminants out of the area.

Power

There should be at least one 20 A receptacle per equipment rack or cabinet, and one or more receptacles for installer convenience. Power conditioning equipment up to 100 kVA capacity may installed in the space. All equipment should be grounded to a buss per J-STD-607-A.
Equipment Room

The Equipment Room (ER) is the collection point for all of a building’s data and voice cabling. It also houses the greatest concentration of electronic equipment. More than any other telecommunications space, it should be positioned for growth. Cable pathways will terminate here. It should be located as far away as possible from EMI sources (transformers, generators, X-ray equipment, radio or radar transmitters and induction sealing devices).

Equipment rooms often share space with data processing equipment, servers, routers and data storage devices. These machines require specialized cooling and air handling environments including air-handling spaces under raised access floors. For more information on this type of construction, see our Data Center Planning Guide. In any case, layouts should be verified with equipment providers for weight and distance limitations.

Size and construction

Equipment rooms should be a minimum of 14 m² (150 ft²). ER area is calculated at a ratio of 0.07 m² (0.75 ft²) of equipment room space for every 10 m² (100 ft²) of work area space. If the work areas are more dense, the ER area needs to increase accordingly.

For special use buildings (hotels, hospitals, laboratories, etc.), the size of the ER is based on the number, and not the size of the work areas (see chart to the left).

Maximum Contaminants

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>0.01 ppm</td>
</tr>
<tr>
<td>Dust</td>
<td>100μg/m³/24 h</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>4μg/m³/24 h</td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>0.05 ppm</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>0.1 ppm</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>0.3 ppm</td>
</tr>
</tbody>
</table>

Lighting, plywood wall and door requirements are the same as the access provider space. Double doors are preferred.

Air handling

Like the access provider space, the ER needs cool filtered air. In addition to the access space requirements, the ER should not exceed the amounts of contaminants in the chart to the left.

Power

There should be at least one 20 A receptacle per equipment rack or cabinet, and one or more receptacles for installer convenience. Power conditioning equipment up to 100 kVA capacity may installed in the room. All equipment should be grounded to a buss per J-STD-607-A.
Telecommunication Room

The Telecommunications Room (TR) is where the horizontal cabling meets the building backbone. It should be centrally located and within operating distances of the cabling it serves. In multi-story buildings, TRs should be stacked one above the other to facilitate cable routing in the riser. In almost all cases, there must be at least one TR per floor and more if indicated by traffic (see below for exceptions).

Size and construction

Telecommunication rooms dimensions are calculated based on the area they serve, with the average size of a work area assumed to be 10 m² (100 ft²). Examples are given at left.

Additional TRs are required when the served area exceeds 1000 m² (10,000 ft²) or the horizontal distribution distance to any work area exceeds 90 m (295 ft). Multiple TRs should be connected by a minimum of one 78 (3) sized conduit. Sleeves and slots for installing cable should be in place and firestopped after all cables are placed.

Walk-in rooms should be a minimum of 1.3 m deep by 1.3 m wide (4.5 ft by 4.5 ft) to serve a floor area of up to 500 m² (5000 ft²). Shallow rooms should be a minimum of 0.6 m (24 in) deep by 2.6 m (8.5 ft) wide to serve a floor area of up to 500 m² (5000 ft²). Spaces smaller than 500 m² (5000 ft²) may be served by small rooms or telecommunications enclosures instead of TRs (see next page).

For buildings of less than 100 m² (1000 ft²), telecommunications enclosures may be a better choice.

Lighting and plywood walls are installed per the equipment room specification. A single lockable door at least 0.9 m (36 in) wide and 2 m (80 in) high, without doorsills and hinged to open outward (code permitting) is fine.

Air handling

The telecommunications room requires the same level of air quality and temperature as the equipment room (see previous page).

Power

The S60-8 standard requires a minimum of two dedicated 120 VAC 20 A duplex electrical receptacles in the TR. CommScope suggests at least one receptacle per loaded rack or cabinet. Convenience duplex outlets shall be placed at 1.8 m (6 ft) intervals. It’s a good idea to power the telecommunications room through a dedicated power panel. All equipment should be grounded to a buss per J-STD-607-A. Backup power is recommended.
Telecommunication Enclosure

The Telecommunications Enclosure (TE) serves areas no larger than 335 m² (3600 ft²). It may either feed a TR or be directly routed to the equipment room. It normally houses passive equipment, but a small amount of active equipment can be installed there as well. Telecommunications enclosures are not be used to replace TRs - in some cases, they can be a simple as a wall mounted enclosure.

Like TRs, they should be centrally located and within the 90 m (295 ft) horizontal operating distance of U/UTP cable. They may be installed in the ceiling, below access flooring, or in wall units or modular furniture wall panels if that furniture is permanently secured to the building structure.

Size and construction

There is no minimum size for a telecommunications enclosure. TEs should be large enough to handle present equipment needs as well as accommodate foreseeable growth. When sizing the TE, take into consideration the bend radius limitations of the installed cables - larger cables will require a larger TE.

Plywood backboard may be secured to the back or sides of the interior.

The TE door may be hinged or removable. If hinged, the door should swing a minimum of 90 degrees open. When open, the door must provide unobstructed access and remain open until closed by the technician.

If the TE is constructed of metal, it must be bonded to ground.

Air handling

Telecommunications enclosures require no special cooling or conditioning. Any active equipment should be cooled as suggested by the equipment manufacturer.

Power

A single 20 A outlet should be able to power any equipment, and a convenience outlet (wired to a separate circuit) should be installed nearby or in the enclosure. Backup power is recommended.
Entrance facility

The entrance room is the transition point for outside plant and indoor cabling. These transitions may be housed in wall-mounted enclosures or in cross-connect racks and panels. The entrance room should be big enough to accommodate large reels of cable, as the entrance facility is often the starting point for campus cable installation.

Grounding is an essential component for the entrance room. Therefore, it should be as close as possible to the building’s electrical service room.

Size and construction

Technically, an entrance room need not be an actual ‘room’ - it can be the wall next to the cable entry point. It may share space within the equipment room or reside in a cage. If the building exceeds 2000 m² (20,000 ft²) usable floor space, a discrete room should be used. For security purposes, it should be behind a lockable door of at least 910 mm (36 in) wide and 2000 mm (80 in) high, without doorsill. A double door is preferred.

If the building is under 10000 m² (100,000 ft²) of served space, wall-mounted enclosures are acceptable. The length of that wall is shown in the chart to the left.

If the building is over 10000 m² (100,000 ft²) of served space, floor mounted racks are the preferred method for cross-connection. Areas are shown in the second chart to the left.

A minimum of one wall of the facility should be covered with 19 mm (¾ in) thick plywood as described on page 52. Lighting is the standard 50 lx (500 foot-candles).

Air handling

The entrance facility requires the same level of air quality and temperature as the access provider space (see page 53).

Power

The 569-B standard requires a minimum of two dedicated 120 VAC 20 A duplex electrical receptacles in the entrance facility. CommScope suggests at least one receptacle per loaded rack or cabinet. Install at least one convenience duplex outlet. All equipment should be grounded to a buss per J-STD-607-A. Backup power is recommended.
Enclosures - Racks, Cabinets, and Cable Management

All of the spaces defined in this section are populated by some combination of racks, cabinets, and enclosures. Racks and cabinets come in two widths — 483 mm (to accept ‘19 inch’ wide components) and 584 mm (to accept ‘23 inch’ wide components). Capacity is measured in Us, with one 1 U being 44.5 mm (1.75 in). Equipment intended for rack/cabinet installation is designed in multiples of Us (U1, U2, U3). Enclosure size is also given in Us (16U, 20U, etc.).

Enclosures should be both strong and rigid. Construction may be of aluminum (for weight considerations) and steel (for greater capacity and strength).

Racks

Racks are open frames ready to be loaded with connection panels and/or active equipment. They can be floor-mounted or wall-mounted. Floor mounted racks are of either two or four post construction. Wall mounted versions usually have a swinging frontpiece to ease equipment access.

The traditional 7-foot floor mounted rack has a capacity of 45U. It could potentially hold up to 45 1U shelves, or 11 4U shelves, or any combination of equipment and shelves that add up to 45U or less. Taller 8-foot racks are available that hold up to 52U.

Look for racks that offer horizontal and vertical cable management hardware options. Vertical cable management systems are essential for dependable network operation in that they keep cable organized, keep cables (especially fiber) from kinking and exceeding minimum bend radii, and offer additional security.

Note that use of horizontal cable management will take up rack space the same way as shelves containing copper or fiber terminations. This should be carefully planned for when estimating the capacity of each rack.

The availability and placement of power strips is an important consideration if the installation includes active equipment.

Wall mounted enclosures

Wall mounted cabinets (also called enclosures, as in ‘telecommunications enclosure’) are fully encased, with front and rear doors for access to cables and equipment. Swing-out frames also help in that regard. They are vented for air circulation and may have fans for additional cooling.
Enclosures - Floor-Mounted Cabinets

Floor-mounted cabinets are fully enclosed units with metal sides and glass or metal front and rear doors. Cabinets are available to support 42U, 45U, or other capacities. Like racks, cabinet have rails that hold active equipment and shelves.

Cabinets are designed to facilitate equipment cooling as much as they are for equipment containment and security. Despite its compact size, data communications hardware can generate immense amounts of heat. Since heat can degrade active electronic’s performance, permitting cool airflow is an essential part of cabinet design.

Cabinets are designed to act like chimneys. Cool air (or chilled air in larger equipment rooms and data centers) enters the cabinet from underneath the floor. As the active equipment heats the air, it rises and exits through the top of the cabinet. This creates a continuous circulation of cold air through the cabinet that cools the electronics. This natural convection can only draw away so much heat, so fans can be added at the top of the cabinet to increase airflow. With or without fans, it is important to limit the amount of air that enters or escapes at mid-height. Therefore, cabinet doors are usually solid.

Another common cooling method is to set up ‘hot and cold aisles.’ This is a scenario where cabinets are set up in rows with fronts facing fronts/backs facing backs so that vented cabinet doors allow cold air to be drawn through the front and pushed out the back. CommScope recommends that the vented area be at least 60% open to allow unrestricted air flow.

CommScope cabinets come with patented X-Frame technology, a cross-bracing system that combines strength with access. Cabinets are usually built and provisioned before being rolled into position on casters. The X-Frame provides rigid construction without the crossmembers that typically interfere with cable access and placement during final installation.

Server cabinets

Server cabinets are built to handle high densities of datacom active equipment and therefore support more weight. Additionally, server cabinets are typically deeper to accommodate the larger server equipment.

Since there is no standard server depth, it can be difficult to accommodate more than one manufacturer’s servers within the same cabinet. However, CommScope server cabinets have vertical rails that can be adjusted to up to three different depths to handle multiple servers within the same cabinet.

Network cabinets

Network cabinets are designed more for patchcord management. They have greater depth between the closed doors and rails to allow more room for patchcords organization.
Intelligent Infrastructure Solution

Racks and cabinets can quickly become filled with active equipment, patch panels and cordage. Regardless of the level of organization, placing the proper connector in the precise port can be a daunting task in a rack filled with literally hundreds of patchcords. The consequences of improperly routed circuits can be hours of downtime and a crippling loss of productivity.

Intelligent infrastructure solves this problem. Systems like the CommScope SYSTIMAX iPatch® automatically organize, report and aid in the correct connection and rerouting of the physical layer of the network. iPatch works both with U/UTP and optical fiber hardware.

Remote network mapping

From a central point, iPatch software lets the network administrator constantly monitor the connections within the network. It also maps the location of all IP (internet protocol) endpoints such as servers, switches and desktop computers. Traffic and capacity can be monitored as well.

This information is provided by iPatch ‘rack managers,’ electronics mounted at the rack/cabinet. Using sensors located at the iPatch rack/panel, rack managers monitor the status of every port at that location. Information detected by the rack managers include end-to-end connectivity of a circuit and the devices at both ends of a circuit.

Guided patching

For the technician, iPatch both speeds and clarifies the work of patching. Electronic work orders are issued by the administrator and instantly sent to the rack manager where they are displayed on the its screen. The repatching is guided with video and audio prompts. Fully-equipped iPatch patch panels will signal the correct port with a light.

Patching errors are instantly detected and a successful patch announced. Also, if the system detects operational problems, an alarm is instantly flashed to the rack manager.

Although some intelligent patching systems require specialized patch cords with an extra conductor, the CommScope SYSTIMAX iPatch solution uses standard patch cords. This permits an eventual upgrade to an intelligent patching solution without having to replace your investment in patchcords.

Improved security

iPatch’s level of detailed knowledge about the status of every port in the network results in greater security. Unauthorized movement of patches or equipment are instantly conveyed to the network manager.
Section 7

Network Planning
Networking Overview - Logical Topologies

Before addressing the particulars of network design, let’s review some of the more popular networking protocols and their benefits and drawbacks.

Ethernet

Popular and widely installed, Ethernet uses a logical bus topology that operates quite well in a physical star topology. Standardized under IEEE 802.3, Ethernet was one of the first networking protocols, and it has evolved successfully to be the most commonly installed type of data network. Many manufacturers offer Ethernet backbone switches (active electronics) in speeds of up to 10 Gb/s. Because of its wide use, most of the examples in this book are based on Ethernet applications.

FDDI

This token ring protocol is specifically for fiber. Two pairs of fibers carry counter-rotating traffic in a physical ring at speeds of up to 200 Mb/s over distances of up to 10 km (6.2 miles). The counter-rotating ring is self-healing in case of a cut link, although network speed drops to 100 Mb/s. Not as common as it once was, FDDI is a reliable, if somewhat slow, protocol.

SONET

Originally developed for high-volume telco voice traffic, this ring topology has been adapted for large campus fiber backbones. SONET switches are available up to 10 Gb/s, can handle voice very effectively and are adaptable to carry data (although they are not the most effective way of transporting it). SONET is somewhat expensive to deploy as these systems require single-mode fiber and electronics.

Token Ring

This logical/physical ring topology can use copper or fiber media. It carries data at 16 Mb/s over a self-healing counter-rotating ring. Slow by today’s standards, it’s rarely installed.

Fibre Channel

This point-to-point data protocol operates at speeds up to 10 Gb/s. Campus connections of up to 10 km (6.2 miles) are possible. Despite its name, Fibre Channel can operate over copper, albeit at slower speeds. While originally conceived as a one-to-one link, multiple devices can now be linked over a single Fibre Channel using copper or fiber.
Networking Overview - Physical Topologies

Regardless of their logical topologies (bus, ring, star or point-to-point), horizontal segments should be cabled as a star physical topology with all the links meeting at a central point in the telecommunications room. The backbone links then further collect and connect the traffic from the telecommunication rooms (or the collapsed backbone links) into another physical star in the equipment room. These stars-connecting-to-stars form what is called a hierarchical star.

CommScope recommends cabling horizontal and backbone segments in a physical hierarchical star topology (per the 568 C standard). Voice and video networks should also be configured as star topologies.

The campus segment can either be cabled as another level in the hierarchical star or as a counter-rotating ring. As shown on page 11, each design has its benefits.

In brief:

If reliability is the primary concern, plan to install a campus ring network. A counter-rotating ring will continue to operate if a node fails or if one of the cables is cut. Rings may use less cable in the campus segment. However, adding additional nodes may be difficult. Trying to adapt bus or star logical topologies to a ring may result in unacceptable connection loss.

If managing growth and flexibility are of prime importance, choose a hierarchical star physical campus topology. Additional reliability can be built into a star by planning secondary cable routes or using other transmission methods such as point-to-point wireless. However, systems (such as Ethernet) may not automatically switch over to a backup circuit and may have to be manually rerouted.
Other Planning Issues -
Voice and Video Networks, Redundant Networks

Voice networks
Because voice signals use limited bandwidth, they can operate over longer distances with little problem. The effective range from desktop to main PBX can be as long as 5.4 km (3.3 miles) without amplification and longer with the use of amplifiers or load coils*. Historically, voice uses its own network, wired with voice-grade twisted pair cable. Unlike data systems where several physical connections are concentrated into a single cable at the active electronics, a voice circuit links the desktop directly to the central PBX (Private Branch Exchange) which is in effect a centralized hierarchical star network.

With the proper electronics (such as packet switches that multiplex voice signals into the data stream), some data networks will accept voice traffic (also called Voice over Information Protocol, or VoIP). This is becoming more common on campus backbones. Also, networks designed for voice (such as a SONET campus backbone) can be used to send data, although not as quickly as a purely data network. It should be noted that a separate voice network offers a valuable redundancy factor - if for some reason the data network goes down, the phones will still work (and vice versa). A typical installation will have separate voice and data networks.

TIA/EIA standards infer that all desktop data outlets be paired with a voice outlet wired with Category 3 cable. However, CommScope strongly recommends that voice networks be wired with Category 5e (or better) twisted pair; this permits migration to VoIP as well as making a voice circuit a potential data circuit.

Video networks
Most video networks are buses. Coaxial cable is a proven media for CATV and CCTV systems, although fiber is an excellent alternative. Video over U/UTP is increasingly being used in CCTV systems.

System redundancy
Increasing system reliability can be achieved in several ways. Campus ring topologies are inherently redundant with their counter-rotating self-healing circuits. Alternate cabling paths, such as placing cable in a parallel riser, are another way of averting an outage due to a cut cable. Point-to-point wireless can be installed to complement a cable network. Of course, the best way to ensure reliability is to install media, passive components and active electronics that are robust and reliable.

*NOTE: Load coils cannot be used for digital signals such as DSL.
Security Applications - Access Control, Fire, CCTV and More

Combined security solutions

Security has traditionally been treated as a network separate from data or voice (traditionally Closed Circuit TV and alarm systems). However, it has grown to encompass electronic access, environmental control, facilities management, access control and more. Most of these systems have been cabled independently.

However, ANSI/TIA/EIA-862 sets standards for a building automation system (BAS) and specifies a generic cabling system for use in commercial buildings. This BAS standard addresses combined cabling for security systems.

Structured cabling solutions can integrate control of all the building services (advanced security and access control systems, sophisticated fire safety controls, environmental control and monitoring) under a uniform cabling infrastructure. A standardized cabling interface with familiar Category 6A/Category 6/Category 5e U/UTP connectivity components eliminates the need for proprietary wiring.

It is strongly recommended that fire alarm and control cabling be wired redundantly.

CCTV media selection

CCTV is sometimes a stand-alone component of security. Coaxial cable carrying an analog signal is a proven media for CCTV application in that the cable carries signal and can be used to order camera movement. However, improved technology allows twisted pair or fiber cable to be used in CCTV solutions.

Deciding which media to use involves three factors: transmission distance, signal quality and component cost. Coaxial is an excellent choice at distances of up to 450 meters (1475 feet). However, U/UTP is emerging as a viable CCTV media as it offers reasonable performance over distances of up to 450 meters (1475 feet) and similar to coax at distances of up to 900 meters (2952 feet). Fiber is an excellent choice for CCTV applications, especially those over long distances and where additional security (fiber is difficult to tap without detection) or lightning damage is a concern.
Mixed-Use Network Solutions (MDU) and Small Commercial Structure Applications

Despite efforts at consolidation, phone, internet and video services generally arrive over multiple media. This creates some connectivity issues at multiple dwelling units (MDUs) such as apartments and condominiums and at multi-user commercial structures such as office complexes and strip malls. Literally dozens of network interface units (NIUs) could be attached to alley walls.

A structured wiring solution with a centralized access point would eliminate the need for literally thousands of meters/feet of drop cable while providing the basis for a manageable interior wiring scheme. Such a solution would permit connections to twisted pair, coaxial (both CATV and satellite) and fiber cable. The EIA/TIA 570 standard addresses residential wiring and the range of cable types used in residences.

MDU distribution enclosures are designed to create a fully integrated network environment that supports all current and emerging communication and video entertainment applications. These units are designed specifically for MDU installations in condominiums, town homes, stick-built homes, and small commercial buildings. Incoming signals are fed into a media distribution device, then distributed to individual room outlets. Once the system is installed, all electronic equipment, including CATV, satellite, computers, printers, telephones and fax machines can be connected and networked to virtually any outlet in the MDU.
Media Types and Planning for Growth

Network speeds (and the power of the computers that utilize that speed) are ever increasing. Generally speaking, the speed (and resultant need for increased network capacity) doubles every 18 to 24 months. Therefore, any installation planned now must take into account the fact that there will be need for increased bandwidth in the very near future.

Presently, 1 Gb/s networks (1 Gb/s backbones feeding 100 Mb/s horizontal connections) are the de facto installed standard. However, active electronics are now available that will support 10 Gb/s backbones with 1 Gb/s to the desktop. Designers need to keep in mind that by installing cable that supports higher speeds now, they will save money, time and effort when making inevitable upgrades later.

Horizontal connections of 1 Gb/s can be supported by Category 6A, Category 6 and Category 5e twisted pair as well as multimode and single-mode fiber.

The riser and campus backbones are a trickier proposition. Using fiber makes good sense; the question is, which type? The answer is derived by considering data rates and channel distances. 62.5 µm fiber can handle gigabit Ethernet speeds at distances of up to 300 meters (984 feet), but only supports 10 Gb/s up to 33 meters (108 feet). On the other hand, 50 µm fiber will support gigabit traffic in excess of 1100 meters (3608 feet). If needed, single-mode fiber can handle 10Gb/s to longer distances.

<table>
<thead>
<tr>
<th>Media type</th>
<th>100 Mb/s Range</th>
<th>1 Gb/s Range</th>
<th>10 Gb/s Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 6A 500 MHz U/UTP</td>
<td>90 m</td>
<td>90 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Category 6 550 MHz U/UTP</td>
<td>90 m</td>
<td>90 m</td>
<td>not recommended</td>
</tr>
<tr>
<td>Category 5e 350 MHz U/UTP</td>
<td>90 m</td>
<td>90 m</td>
<td>not recommended</td>
</tr>
<tr>
<td>OM4 50 µm 4700 MHz•km multimode</td>
<td>2 km</td>
<td>1100 m</td>
<td>550 m</td>
</tr>
<tr>
<td>OM3 50 µm 2000 MHz•km multimode</td>
<td>2 km</td>
<td>1000 m</td>
<td>300 m</td>
</tr>
<tr>
<td>OM2+ 50 µm 950 MHz•km multimode</td>
<td>2 km</td>
<td>800 m</td>
<td>150 m</td>
</tr>
<tr>
<td>OM2 50 µm 500 MHz•km multimode</td>
<td>2 km</td>
<td>550 m</td>
<td>82 m</td>
</tr>
<tr>
<td>OM1 62.5 µm 200 MHz•km multimode</td>
<td>2 km</td>
<td>300 m</td>
<td>33 m</td>
</tr>
<tr>
<td>8.3 µm single-mode</td>
<td>2+ km</td>
<td>2+ km</td>
<td>2+ km</td>
</tr>
</tbody>
</table>

100 Mb/s multimode fiber applications are powered by 1300 nm LEDs
1 and 10 Gb/s multimode fiber applications are powered by 850 nm VCSELs
All single-mode fiber applications are powered by 1310 and 1550 nm lasers
Fiber Selection Criteria

The size and kind of fiber to be installed depends on two factors - budget and future performance.

Budget
Given the relatively high expense of single-mode fiber systems, it’s surprising to discover that single-mode fiber cable is less expensive than multimode. It is the price of the associated electronics that makes single-mode systems higher in cost; this usually limits their use to very long and/or very high-traffic links. Still, electronics costs tend to decrease over time. CommScope recommends installing single-mode fiber alongside multimode, either separately or in a composite cable (such as an 18 fiber cable that has 12 multimode fibers and 6 single-mode fibers). Interbuilding backbones should be predominantly single-mode with riser backbones a mix of single-mode and multimode. The taller the building, the more single-mode (percentage-wise) should be used.

Future performance
Faster network speeds are inevitable (40 and 100 Gb/s systems are on the horizon), so it makes sense to install the highest performance fiber permitted by budget. There may not be much of a price difference between 62.5 µm OM1 and laser optimized 50 µm OM2+ fiber types. OM2+ fiber offers extended distance performance over 1 Gb/s Ethernet while offering a growth path to 10 Gb/s. Unless there is an overriding reason for specifying 62.5 µm fiber, high-bandwidth 50 µm fibers offer a superior growth path.

A final note: installing single-mode fiber alongside multimode fiber in a composite cable makes sense from both growth and cost standpoints. This way, single-mode fiber will be in place when network speeds require its higher performance at no additional installation expense. A good rule of thumb is to place two single-mode fibers for every four multimode fibers. Multimode fibers operate in transmit/receive pairs, so these cables inherently have even numbers of fibers, with common fiber counts as 2, 4, 6, 12 and 24. Above 24 fibers, fiber counts are in multiples of twelve, with natural standard counts of 36, 48, 60, 72, 96, and 144 fibers.
Calculating Network Capacity for Horizontal Segments

When calculating network capacity requirements, it is essential to plan beyond present needs for both a growing number of users and the inevitable thirst for greater network speed and capacity.

Calculate the horizontal segment traffic first

First, calculate the anticipated traffic for each horizontal segment. This is done by first counting the number of devices planned for each segment. Double that number. Multiply that total by the estimated usage factor of the planned horizontal link speed. This is the anticipated network traffic or:

\[ \text{N devices} \times 2 \times \text{usage\% of horizontal link speed} = \text{Anticipated Network Traffic}. \]

Why double the number of planned devices?

Counting the number of network devices in a horizontal segment seems like a straightforward process of looking at the floorplan and counting the desks. However, it’s safe to say that additional devices will be installed at some point; equipment could be added even as the cable is being pulled. This is why this calculation of the anticipated traffic should be doubled.

Why a 40% estimate for a usage factor?

The method for estimating usage is not as clear cut. A typical horizontal segment (an ‘average’ office) will utilize 40% or less of its network capacity; in fact, an average office may use only 10% or 20%, but 40% is a good rule of thumb to follow, especially since the need for network speed and capacity always increases. If a segment is to support higher bandwidth applications such as CAD/CAM or medical imaging, this factor may be higher. If the horizontal segment is meant to support these more demanding applications, CommScope recommend installing at minimum Category 6A twisted pair or OM3 (or better) multimode fiber.

Allowing for growth in the telecommunications room

Anticipating an increase in devices requires an increase in the number and capacity of the equipment that goes in the telecommunications and equipment rooms. We recommend installing twice the number of passive equipment ports (patch panels/interconnects) as the planned population of devices. This covers growth as well as provides a healthy redundancy in case of component failure.

For active equipment, install 2.5% more ports than presently needed for U/UTP and distributed fiber horizontal segments, and 10% more ports for a collapsed fiber backbone.
Calculating the ‘Average’ Horizontal Segment - an Example

An ‘average’ office is to be outfitted with eight desktop computers and two networked printers (a total of 10 devices). The plan is to use Gigabit Ethernet with 1 Gb/s per hub up the riser backbone and 100 Mb/s to each desktop (although a switched hub can deliver a full Gb/s to a single desktop if required).

Using the 40% usage factor produces a calculation of 10 devices x 2 x (40% of 100 Mb/s) = 800 Mb/s of traffic for this segment. This means the planned 1 Gb/s backbone will be able to provide enough capacity for this office. Both twisted pair and multimode fiber support 1 Gb/s from the desktop to the telecommunications room. Use a multimode fiber pair as the backbone link.

Double the number of planned devices to get a passive port total of 20. Multiply the devices by 125% to get an active port total of 13 (port counts are rounded up to whole numbers). Since patch panels and hubs come in multiples of six or eight, further round the patch population up to 24 and the number of ports on the active equipment to 16. Use two 8-port actives; in case one of the hubs fails, at least a part of the network can continue to operate.

The eight desktop computers will have telephones next to them. Although voice needs only Category 3 to operate, CommScope recommends wiring voice networks with a Category 5e (or better) twisted pair. Should you move to VoIP (page 64) or add data equipment, cable capable of supporting it is already in place.
Calculating Network Capacity - High Traffic Horizontal Segments

The 40% rule is a generous estimate for the usage on an ‘average’ network. However, be aware that 40% is a low figure for some applications. For example, an office with CAD/CAM workstations, video production or medical imaging may require 80% or 90% usage. A gigabit backbone may not be enough capacity for these higher traffic networks. When planning, be sure to make allowances for potentially bandwidth-hungry segments, both now and for the future.

In these examples, a design facility on one floor needs to support 10 CAD workstations, a file server and a printer (a total of 12 devices). 10 CAD units and a printer (a total of 11 devices) are on another floor.

Example A has these devices presently served with 100 Mb/s links. The network is estimated to operate at 70% of capacity. Using the N devices x 2 x usage% formula, the first floor (12 devices x 2 x [100 Mb/s x 70%]) would need 1.68 Gb/s. The second floor (11 devices x 2 x [100 Mb/s x 70%]) would need 1.54 Gb/s. At present speeds, these systems could be supported horizontally with either twisted pair or multimode fiber pairs. Each floor’s telecommunications room would have a 24 port patch panel (2x devices rounded up to multiples of 6 or 8) and two 8 port 1 Gb/s hubs (devices x 125% rounded up to a multiple of 6 or 8). Using two 8 port hubs instead of a single 16 port hub provides backup should one hub fail.

Example B anticipates an upgrade to 1 Gb/s links (ten times the present speed). A good way to handle this would be to use a collapsed fiber backbone with the actives concentrated in the equipment room. Each floor still has a 24 port patch, but would be linked via a 48-fiber distribution-style fiber cable (24 ports x 2 fibers per port) to actives (33 devices x 110% = 36.3 rounding up to 40 ports) in the equipment room. A collapsed backbone uses a smaller growth factor than a distributed system.
Fiber Requirements for Various Network Types

Once the horizontal segment traffic has been estimated, the amount and kind of fiber required for the backbone cabling can be calculated. Here, the example is a five story building:

- the fifth floor has several devices supported by a single Fibre Channel;
- the fourth floor uses an FDDI ring;
- the third floor has several devices using 1 Gb/s Ethernet - these could be served by using a collapsed backbone with the active electronics in the equipment room;
- the second floor is operating 1 Gb/s Ethernet with 100 Mb/s horizontal connections linking to a telecommunications room;
- the first floor is operating a 100 Mb/s Ethernet.

For distributed backbone links, use two fibers (one fiber to transmit, the other to receive) per channel for bus, point-to-point topologies and simple rings and four fibers (an active pair and a stand-by pair) per channel for counter-rotating ring networks.

For collapsed backbones, CommScope recommends a minimum cabling solution of two multimode fibers per device multiplied by two for growth, spares, etc. All spares should be terminated and ready for use. Never leave an installed fiber unterminated or untested.

Presently, all five floors could be served with a minimum performance backbone solution of 200/500 MHz•km 62.5 µm multimode fiber as all links would carry 1 Gb/s for less than 300 meters. With 10 Gb/s backbones being installed, it would be necessary to cable all backbone links with high bandwidth laser-optimized 50 µm fiber.

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Fibers Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gb/s Fibre Channel</td>
<td>2 fibers per channel</td>
</tr>
<tr>
<td>100 Mb/s FDDI</td>
<td>4 fibers (2 active, 2 backup)</td>
</tr>
<tr>
<td>1/10 Gb/s Ethernet</td>
<td>Collapsed backbone 2 x N fibers</td>
</tr>
<tr>
<td>100 Mb/s/1 Gb/s Ethernet</td>
<td>Distributed backbone 2 fibers per Gb/s</td>
</tr>
<tr>
<td>10/100 Mb/s Ethernet</td>
<td>2 fibers per active</td>
</tr>
</tbody>
</table>
Calculating Capacity/Fiber Counts for Riser (Backbone) Segments

In another example, a five story office building is going to have one Ethernet network per floor. The first four floors will operate with 100 Mb/s on the horizontal segment and 1 Gb/s on the backbone. The top floor has devices that require 1 Gb/s connections to the desktop.

Using the formula from page 69 (N devices x 2 x 40% of horizontal data rate), calculate the required capacity for the first four floors and round up to the nearest whole number. Figure a minimum of two fibers for each Gb/s. For growth, double the amount of calculated fibers and add another 33% to 50% of that figure in single-mode fibers.

In this example, the top floor has a very large bandwidth requirement. In a distributed backbone, the estimated 30 Gb/s of traffic would be handled by three 10 Gb/s switches in the telecommunications room, using a minimum of six 50 µm fibers. If a collapsed backbone is desired, a minimum of two fibers per device (44 in this case) is required.

<table>
<thead>
<tr>
<th>Minimum fibers per horizontal network</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 ( \times 2 ) (1 Gb/s x 70%) = [30.8 \text{ Gb/s} \rightarrow 31 \text{ Gb/s} ]</td>
</tr>
<tr>
<td>Distributed backbone &gt; 6 fibers [5]</td>
</tr>
<tr>
<td>Collapsed backbone &gt; 44 fibers [5]</td>
</tr>
<tr>
<td>34 ( \times 2 ) (100 Mb/s x 40%) = [2.72 \text{ Gb/s} \rightarrow 3 \text{ Gb/s} ]</td>
</tr>
<tr>
<td>Distributed backbone &gt; 6 fibers [4]</td>
</tr>
<tr>
<td>10 ( \times 2 ) (100 Mb/s x 40%) = [800 \text{ Mb/s} \rightarrow 1 \text{ Gb/s} ]</td>
</tr>
<tr>
<td>Distributed backbone &gt; 2 fibers [3]</td>
</tr>
<tr>
<td>11 ( \times 2 ) (100 Mb/s x 40%) = [880 \text{ Mb/s} \rightarrow 1 \text{ Gb/s} ]</td>
</tr>
<tr>
<td>Distributed backbone &gt; 2 fibers [2]</td>
</tr>
<tr>
<td>15 ( \times 2 ) (100 Mb/s x 40%) = [1.2 \text{ Gb/s} \rightarrow 2 \text{ Gb/s} ]</td>
</tr>
<tr>
<td>Distributed backbone &gt; 4 fibers [1]</td>
</tr>
<tr>
<td>total to the equipment room [38 \text{ Gb/s} ]</td>
</tr>
</tbody>
</table>

For distributed backbones, CommScope recommends a minimum cabling solution of an 18 fiber distribution-style cable containing 12 multimode and 6 single-mode fibers. This cable is compact, easy to install and has enough capacity for the foreseeable future of these networks. 

For collapsed backbones, CommScope recommends a minimum cabling solution of two multimode fibers per device multiplied by two for growth, spares, etc. All spares should be terminated and ready for use. Never leave an installed fiber unterminated or untested.
Fiber Types and Counts for Campus Segments

Once the amount of traffic anticipated at each intermediate interconnect is known, the number of fibers needed in the campus segments can be calculated.

In this example, five locations are to be linked on a campus network. When figuring the length of cable to be used, take the measured distance and add a minimum of 10%. A public street will need to be crossed. The local access vault is located on the right-of-way next to the street.

There are several ways this campus could be configured. Distances, network speed, growth and physical topology (star vs. ring) all need to be considered. Other issues, such as right-of-way and how to cross the street, need to be addressed as well. There are several ways to do this; each way is correct depending on operational priorities.

A basic solution would be to use 100 Mb/s transmission equipment over multimode fiber. The distance chart on page 27 shows that multimode fiber would support this network with two fibers for each 100 Mb/s transmitter.

However, a 100 Mb/s solution has problems. Even if the capacity required for the network were as low as a few Gb/s per building, a prohibitive amount of actives would be required. An upgrade to a 1 Gb/s campus network would be impossible without recabling.

Another solution would be to use point-to-point wireless between buildings. While wireless would handle the traffic, concerns such as rain, fog or line-of-sight requirements can cause degraded performance. Cable should always be the first choice for campus networks.
Star Campus Configuration and Local Access Link

Network speeds will always increase; the challenge is to be ready when that happens. The capacity requirements shown in this diagram are representative of an ‘average’ campus drawn from examples earlier in this section. This network is a physical and logical hierarchal star which is the most flexible solution when accommodating growth.

The active electronics in the equipment rooms are packet switches transmitting over pairs of single-mode fibers; multimode fibers cannot operate at 10 Gb/s speeds at these distances.

For this example, CommScope recommends using single-mode six-fiber tight buffered indoor/outdoor cable for campus and local access links. Indoor/outdoor cable eliminates entrance facilities which are required when using an outside plant cable. The cable is installed in a buried conduit. While two fibers are the minimum requirement, a six-fiber cable offers additional capacity for growth and spares. A 24 fiber outdoor cable is used for the local access link. A bill of materials (BOM) for this example can be found on pages 146/147 and 178/179.

The fiber from the two outermost buildings bypasses the intermediate crossconnects on their way to the main crossconnect, thus eliminating some termination hardware and effort. Future campus links can join the network at any of the intermediate interconnects.

Redundancy

If a backup system is required, point-to-point wireless and free-space optics are attractive options. Network speeds of up to 10 Gb/s can be supported. However, as noted before, environmental factors such as rain or lack of line-of-sight can limit their speed and reliability.
Ring Campus Configuration and Local Access Link

If network reliability is the prime concern, installing a counter-rotating ring topology is the answer. The counter-rotating signal path (two fibers operating clockwise, two fibers operating counterclockwise) restores itself within microseconds in the case of a cut cable. A switch failing at one of the intermediate crossconnects would not affect operations at or between the other locations.

The active electronics in the equipment rooms are packet switches transmitting over two pairs of single-mode fibers; multimode fibers could not operate over these distances at these speeds.

For this example, CommScope recommends using single-mode six-fiber tight buffered indoor/outdoor cable for campus and local access links. Indoor/outdoor cable eliminates entrance facilities, which are required when using an outside plant cable. The cable is installed in buried conduit. While two fibers is the minimum requirement, a six-fiber cable offers additional capacity for growth and spares. A 24 fiber outdoor cable is used for the local access link. A full bill of materials (BOM) for this example can be found on pages 152/153 and 184/185.

Keep in mind that it is more difficult to add a new campus location to a counter-rotating ring topology (see dotted line). A new node has to be introduced into the ring, while it just plugs into the network at an existing crossconnect in a star topology.

Redundancy

A counter-rotating ring is inherently redundant. Wireless and free-space optical systems can be installed as backhaul, but they cannot be configured into the same ring topology, and they require separate network electronics.
Voice, Video and Wireless Networks

Voice networks

Voice networks can be handled in two ways. The traditional method is to treat the system as a physical and logical star, directly wiring each phone to the PBX which is usually located in or near the main crossconnect. Each voice signal travels over its own circuit. A voice circuit carried by voice-grade Category 3 twisted pair can travel as far as 5400 meters. CommScope recommends using Category 5e or better twisted pair to cable voice systems. This puts a data-ready solution in place should the need arise.

The other method is to gather voice circuits at each building’s equipment room, concentrate them through multiplexing for placement over the campus network. A SONET ring (page 62) is specially designed to carry both voice and data.

Voice can be carried over other operating systems with special active electronics.

Video networks

Video networks are usually cabled as a bus connected with coaxial cable. However, CommScope recommends cabling them as hierarchical stars.

Wireless

Microwave and free-space optical systems can operate at up to 10 Gb/s per channel using a variety of protocols, including multiplexed SONET signals. Keep in mind that wireless can be disrupted by rain and free-space optical systems require line of sight between the transmitters.
Section 8

Horizontal Cable Installation
Overview

Previous sections have discussed how to calculate the type and amount of cable and components required to support the network. The next three sections detail the planning and techniques needed to successfully install that cable.

This Guide offers practical advice for cable installation. Standards for the placement, organization and labeling of network cabling can be found in TIA/EIA 568 standard for telecommunications pathways and spaces and TIA/EIA-606 standard for commercial telecommunications infrastructure.

Before installing horizontal cabling

Prior to installation, carefully study the blueprints and wiring schematics for the location. Some installations will take place in suspended ceilings, so cable routing will depend on the planned location for HVAC ducting, sprinkler plumbing, fluorescent lighting fixtures and electrical power wiring. HVAC and sprinkler systems will offer physical barriers which need to be worked under, over or around. Fluorescent lighting ballasts and electrical wiring produce electromagnetic interference (EMI) that may cause problems with unshielded twisted pair cable. DO NOT place twisted pair cable any closer than 5 cm (2 inches) to electrical power wiring. EMI can be minimized by placing network cabling perpendicular to the power wiring and by NOT placing cable over fluorescent fixtures.

If the installation is taking place in a structure with closed walls and ceilings (such as retrofitting an older building), there are creative ways to disguise installed cable (see pages 88 and 89). Cable can also be placed using traditional methods, such as ‘fishing’ the cable within a wall (see page 87).

When to place cable

Ideally, the time to place cable is after the installation of the HVAC, sprinkler and electrical systems, but prior to the installation of the suspended ceiling grid. This eases the placement of installation hardware such as cable hooks, ladders and raceways.

Plenum ceilings

A plenum ceiling is one that uses the space between the top of the suspended ceiling and the bottom of the floor above to handle air for ventilation. All suspended ceilings are not plenums; some may use HVAC ductwork to move air to returns and diffusers located in the ceiling tiles (a ‘dead’ ceiling). Consult the local code authority to confirm if a suspended ceiling is considered a plenum.

The NEC requires the use of plenum-rated cable (or cable in rigid or intermediate metal conduit) for plenum spaces but permits general purpose-rated cable in non-air handling ceilings and walls. However, this requirement may be superseded by local codes; for example, conduit may be required even with plenum cable. Know the local code before installing, or even ordering, the cable.
Telecommunications/Equipment Room Layout

Horizontal cable installation begins in the telecommunications room. Here, cable is paid out to the desktops and backbone cable dropped to the equipment room. Literally hundreds of cables may terminate here. Therefore, it is critical that every effort be made to maintain organization both during the pull and afterwards. Time spent in planning the pull and documenting each cable will be well-rewarded in easier system installation, documentation and maintenance.

Equipment racks
Install equipment racks in the telecommunications and equipment rooms to permit easy access to both front and rear (see NEC 110-26). Personnel should be able to walk comfortably around the rack. All cabling (communications and power) should be dropped from overhead or brought up from the floor so that access to equipment and panels is not impeded. Use cable ladders or raceways (page 82) to secure and organize cable above the racks.

While there is no reason why different equipment types cannot share a single rack, large installations may be better served with actives and crossconnects organized on different racks.

Wall-mounted equipment
Panels and enclosures should be mounted at a comfortable working height.

Grounding
All racks and metallic cable conveyance need to be grounded to the telecommunications busbar per TIA/EIA standard J-STD-607-A.

Cable diagrams
For fast reference, it is often helpful to have mounted on the wall of the telecommunications room a wiring schematic of the racks and the current ‘as-built’ floorplan of the served area.

Housekeeping prior to termination
After installation, organize the slack in the telecommunications room (see page 85) by forming it into a ‘U’ or ‘S’ shape, or by figure-eighting it and (if possible) placing it in the ceiling or on the cable ladder. DO NOT COIL twisted pair or coaxial cable; coiling creates induction which degrades performance. It is important that the cable be easily accessed but not damaged nor act as an impediment.
Horizontal cable is installed from the telecommunications room to the outlet. Horizontal twisted pair cables are available on reels or in boxes, usually in lengths of 1000 feet (304 meters) although longer reel lengths are available.

At minimum, one voice-grade and one data-grade twisted pair should be installed at each outlet. CommScope recommends using Category 5e or Category 6 twisted pair cable for voice circuits and further suggests installing dual 50 µm multimode fibers to each outlet along with the twisted pair data cable to provide an upgrade path.

Cable Conveyance

Multiple cables are routed through the ceiling space on a conveyance (ladders, raceways or trays) suspended from the ‘red iron’ in the ceiling. J-hooks can be used alone or in combination with ladders/trays to drop cable from the main conveyance.

Standard cabling tools and supplies include wire cutters, electrical tape, cable ties, hook-and-pile closures and marking pens. Consider also using:

Cable Stands and Trees

If several cables are being pulled to one location, a cable tree or multiple reel cable stand can be helpful. This permits several reels of cable to be paid out while taking up a minimum of floor space.

Grouped Cable: Bundled, Hybrid and Siamese Configurations

Bundled cables are several cables (i.e. two twisted pair and a duplex fiber) tied together with a binder tape that meets TIA/EIA 568 C-2. Bundled cable allows multiple cables to pay off a single reel and to be pulled all at once for faster installation. Hybrid cables are several cables types in the same jacket. A Siamese cable is two cables attached in zipcord fashion.

Chute or Waterfall

This is a guide that eases the passage of cable into the ceiling while preventing it from kinking and bending. The waterfall should have a radius of curvature that matches the minimum required for the cabling. In a pinch, a temporary (we repeat - temporary) chute can be made from a square foot of cardboard and some tape.

Bull Wheels

These are large diameter pulleys that guide cable at any change of direction during the installation.
Planning the Installation

Refer to the ‘average’ network on page 70 as an example to address some of the issues involved in a typical installation. In the example, the network has ten data devices and ten phones. A CCTV video connection for a security camera has been added to the plan.

There are two offices on the north side of the floor which will have multiple outlets; the rest of the space is open office where a modular furniture system has been installed. Modular systems have power poles (for channeling communication and power cable) that reach to the ceiling. The plenum ceiling will have fluorescent lights as shown.

A good plan is to use a conveyance (ladder, tray, etc.) to carry cable to the cubicles, and then drop it down the power poles. Avoid placing cable over fluorescent lights. The offices and video camera can be addressed with J-hooks supporting the cable dropped from the main conveyance.

In this example, the best routing for the conveyance parallels the east wall and then turns 90° to come in above the cubicles. Whenever possible, cable is placed so that it crosses power lines at 90° angles. Since power is traditionally installed in a right-angled grid, data cable echoes that right-angle style of installation.
Placing Cable

Install the conveyance

As noted, there are several different conveyance systems available. Install and ground conveyance ladders and trays per the manufacturer’s instructions. Individual J-hooks do not need to be grounded.

Preparing to pull

Plan to start with the longest route (which in this case is the cable to the security camera). Locate helpers on ladders along the planned path, especially where the cable will turn to follow the conveyance (if bull wheels are not being used at the angles of the conveyance).

Alternate routings

While the customs of structured cabling indicate that all cable should be routed along the main conveyance, it sometimes makes sense to bring a cable directly to its termination point by an alternate routing. Here the CCTV camera is off the main cable routing. This camera can be served by cable supported on a series of J-hooks (see dotted line in the top diagram).

Pull cables in groups

If several cables are being pulled to a single outlet, pull all of those cables at once. If not installing a bundled or hybrid cable, use electrical tape or a grouping mechanism to bring the cable ends together to ease pulling and cable organization.
Pulling and Tracing

Label the cable

Before any cable is pulled, use a permanent marker to CLEARLY write the intended location (i.e. 2A-A01) on the cable AND on the box/reel. Do this at the end of the cable, again about a foot from the end and a third time about a meter from the end. This is an informal method of marking the cable during the pull; TIA/EIA 606 standards require that the final labels be mechanically generated.

With the reel paying out over the top, feed the cable up and along the conveyance. Use chutes (curved plastic guides, although a flap from a cardboard box will do in a pinch) when necessary to protect the cable being passed over the top of walls.

Using helpers, place and pull the cable along the conveyance. Be especially careful around bends and near sharp edges. Do not exceed minimum bend radii or the maximum pulling tension for the cable. Contact CommScope Technical Services by emailing support@commscope.com if these critical values are not known.

Leave enough cable slack at the outlet and the telecommunications room

Pull enough cable to reach the planned outlet (including the cable to be dropped down to the outlet) PLUS another 0.5 meters (18 inches) of copper or another meter (about 3 feet) of fiber for connectorization.

At the telecommunications room, pull enough cable to reach from where the cable enters the ceiling to the furthest corner of the room via the conveyance AND down to the floor PLUS another 3 meters (10 feet). Label the cable with the same notation used to mark the pulled ends. Then cleanly cut the cables between the notation and the box/reel.

Arrange the cable in the conveyance

Once all the cables have been pulled, cable wraps may be used to secure the cable to the conveyance.
Locating and Cutting Outlet Holes

The floorplan should indicate where outlets are located. Carefully check the area for any possible obstructions such as wall studs, plumbing or electrical wires.

Once the outlet location has been established, prepare to cut the holes. Data outlets should be located at the same height and orientation as the electrical outlets.

Mark the location

If box eliminators are allowed in an ‘old work’ installation, a telecommunication outlet will consist of the mounting bracket, the feet (which hold the bracket in the wall) and the faceplate. Use a stud finder to locate and avoid any studs. Using the mounting bracket as the template, trace a cutting pattern on the drywall. Check the orientation (vertical or horizontal) of the other outlets in the room and match them. Make sure the planned cut is plumb by using a level.

Cut the opening

Using a drywall knife, utility knife or saw, cut the opening. Do not install the bracket yet; the sharp edges may damage the cable during pulling and installation.

Drop the cable

Drop or fish the cable through the hole (see next page for fishing instructions). Leave enough slack for connectorization; 1/2 meter (19 inches) for copper cable and one meter (39 inches) for fiber optic cable. Once the cable has been pulled into place, install the bracket and terminate the cable (see section 11).
Fishing Cable in Walls

Most open-area office systems use wall systems with drywall or wallboard attached to metal studs. These systems allow access into the wall cavity through holes in the cap of the wall. Be sure to fit any hole with a grommet to prevent cable damage. Cable may be dropped between the studs, although 'fishing' the cable may be necessary (see below).

Some installers prefer to 'stub in' a length of conduit from the installed outlet to the ceiling. This allows a clean, direct path for cable installation.

Fishing a cable into place takes three basic steps:

Fish the tape
Cut the opening for the outlet as shown on page 86. If the wall cap is metal, place a grommet in the hole to protect the cable. From the ceiling, slide a non-metallic fish tape through the cap hole and into the wall. The helper below should be able to hear the tape slide down the wall. If the wrong wall cavity has been entered, move to or drill a new hole in the proper location. Once the tape has reached the outlet hole, have the helper attach a pull string to the fish tape. Retrieve the tape and the string.

Attach the cable to the string
Tie the pull string to the cable end, then use several turns of electrician’s tape to secure about 1.5 cm (6 inches) of the cable bundle to the string. For easier pulling, build the tape up into a shape with a tapered end.

Pull the cable down
While feeding the cable through the wall, have the helper pull the cable (be aware of pulling tensions, especially for twisted pair [25 lbs.]). If the cable snags, pull the cable back up and try again until successful.

Leave sufficient slack for termination. Cut off and discard the taped ends.
Alternate Routing -
Surface Mount Raceway and Behind Baseboard

It may be impossible to place cable in a wall due to masonry construction, difficulty in getting to the wall interior or because a direct drop from the ceiling is blocked by an obstruction such as a window. In these cases, alternate ways need to be used to convey and hide the cable.

Surface mount raceway and conduit

A common way to carry cable to an outlet is to use surface mount raceway which is a covered channel that attaches to the wall. There are several different raceway systems ranging in size and aesthetics. Consult a cable distributor for suggestions. Some raceways are designed to replace foot and crown moldings (see below). For code reasons, it may be required that cable be placed in electrical-grade conduit instead of just disguising it with raceway. Check local codes prior to installation.

Surface mount raceway and conduit may not answer the need to maintain the aesthetics of the location installation (such as retrofitting an historic building or a converting a residence to an office). For those times, creative installation may be required.

Under the wallboard

Many walls have a gap at the base that is covered by the floor molding. This gap is usually wide enough to provide a hidden cable path around a room.

Floor molding usually consists of a toe mold and a baseboard. Both must be very gradually removed in sections. Toe mold is usually nailed in at an angle. Loosen it gently, prying up from the floor and out from the wall every 50 cm (18 inches) or so. Place a cloth behind the prying tool to prevent damage to the floor or wall. Baseboards nails are usually driven in parallel to the floor. Gently pry the baseboard away from the wall a small bit at a time so as to evenly remove the entire board.

Cable can now be placed in the gap between the drywall and the floor. At the outlet location, use a drywall knife to carve a vertical channel wide enough for the cable and about 5 cm (2 inches) in height. Make sure the baseboard is tall enough to cover the channel. Use a drill to enter the wall. Pull the cable up to the outlet hole.
Alternate Routing -
Through the Floor and Behind Crown Molding

Through the floor
There are some installations that may require bringing a cable up from the floor below. For instance, a conference table may need a connection for a conference phone in its center. Drill down through the floor with the correct type of drill bit (masonry, wood, etc.) to make a hole large enough to comfortably admit this cable and two/three more. (Make room now for future installations.) Note that since the cable is passing between floors, the cable must be at least riser-rated and the hole firestopped (see page 94 for an explanation of firestopping).

If the cable is being brought up from a crawlspace or a basement through a wood floor, it is possible to make an invisible entry through the wall and to the outlet. At the outlet location, trace and cut the outlet hole. Then use a stiff, sharp piece of wire to drill a pilot hole at the base of the toe molding. To leave no sign of a pilot hole at all, remove the toe molding and drill at the base of the remaining mold or the wallboard. When the wire breaks through the floor, detach the drill from the wire and leave it in the floor.

Go under the floor and locate the wire. Measure in about 2.5 cm (1 inch) (or more if the hole was drilled at a very steep angle) and use a thin bit to drill a pilot hole straight up to confirm that the wall cavity has been entered. Enlarge the hole to accommodate the cable. Technically, any cable that passes between floors must be a riser-rated cable and the hole through which it passes must be firestopped.

Behind the crown molding
Most wooden and plastic crown moldings join the wall and ceiling leaving a space that can be used as a cable path. The molding is removed, the cable attached to the wall with cable clips (never use staples), and the molding reattached. Another method is to fish the cable from point to point inside the molding.

---

**Diagram:**

- Outlet hole
- Wall cavity
- Wire stays in floor as guide
- Wallboard
- Toe molding
- Insulation
- Support wire or sharpened coat hanger wire
- Drill bit
- Ceiling
- Space behind mold
- Crown mold
- Wall
Section 9

Riser (Backbone) Cable Installation
Riser (Backbone) Installation - Overview

The riser (backbone) segment is placed through risers. Simply stated, a riser is a pathway for cable to pass between floors. Most modern structures have risers placed directly above one another permitting telecommunications rooms to be stacked. If the telecommunications rooms are not stacked, riser cable may have to pass from one telecommunications room to the next by means of a conveyance in the ceiling or by one of the methods described above for placing horizontal cable. For instance, a cable traversing through a plenum ceiling would need to be plenum-rated for its entire length or a riser cable would have to be installed in metallic conduit (or whatever is demanded by local codes - see page 95).

Sleeves, conduit or slots

‘Trade size’ conduit and sleeves are 103 mm (4 inches) in diameter. TIA-569-B calls for four sleeves/conduits plus one sleeve/conduit per 4000 square meters (40,000 sq. ft.) of usable floor space and locations must be approved by a structural engineer. As an alternative, one slot of 0.04 square meters (60 square inches) is permitted for the same floor space and its location must also be approved by an engineer. The slot size should be increased by 0.04 square meters (60 square inches) for each additional 4000 square meters (40,000 sq. ft.) of usable floor space.

If there is no riser in place, one can be made by core-boring a hole through the concrete floor of the telecommunications room and placing a sleeve in it. Prior to boring, ALWAYS consult with a structural engineer. There are X-ray and other detection devices that can be used to locate rebar within the concrete so they can be avoided when boring.

Install the conveyance

Riser cable should be supported by a ladder or other type of conveyance, especially in the case of stacked telecommunications rooms. Attach the conveyance to the wall per the manufacturer’s instructions.

Remember, all conveyance must be grounded to a telecommunications busbar per standard J-STD-607-A. This same bus connects all equipment racks in the telecommunications rooms and the equipment room to a central grounding point.

Test each reel of cable for continuity prior to installation (see page 120)
Pulling Heavier/Copper Riser Backbone Cable

Riser backbone cables vary greatly in weight. While 30 meters of six-fiber tight buffered cable may weigh about 1 kg (2.2 lbs), the same amount of a 100-pair voice-grade copper cable weighs about 23 kg (50 pounds).

Largest cable first
Start at the top floor and install the largest/heaviest cable first. Set up a cable stand with a reel brake to control the speed of the pull. Use a permanent marker to CLEARLY write the intended location (i.e. 2A/3A:01) on the cable three times as described on page 85. Take a wire mesh grip of the correct strength and diameter and securely attach it to the building wall by means of a hook or hanger. While compressing the grip, place the end of the cable through the grip. While the reel brake is used to slow and stop the payout of the reel, the grip will act as a temporary emergency brake as well as a permanent hanging point.

Pull the cable
Attach a pull rope/string to the cable to help guide the cable as it unreels. Large heavy cables should be pulled no more than three floors at a time. In this example, a multipair copper cable will be pulled from the fifth to the second floor. At least 33 meters (about 110 feet) of cable will be needed to reach from the fifth floor to the equipment room including termination slack (the cable tray measurement plus 3 meters [10 feet] - see page 85) PLUS another three meters for a slack loop (see below). Always pay out more cable than you think you’ll need.

Form the slack loop
Pull the about 20 meters (66 feet) of cable into the room on the second floor. Place the pull rope/string and cable end through a wire mesh grip attached to the wall (as on the fifth floor). Form a slack loop above the grip and use cable wraps to fasten it to the ladder.

DO NOT coil the cable upon itself; this creates an induction loop that will degrade performance. Then pull or drop the remaining cable to the equipment room.
Pulling Lighter/Fiber Optic Riser Backbone Cable

Some of the techniques on page 93, such as pulling a few floors at a time and forming slack loops, are not necessary for lighter fiber optic cables or for short distances. Cable can be directly paid off a reel and pulled/dropped down several floors directly to the equipment room.

Mark and pull the cable

Set up a cable stand with a reel brake to control the speed of the pull. Use a permanent marker to CLEARLY write the intended location (i.e. 2A/3A-01) on the cable three times as described on page 85. Place a mesh grip over the cable end now. Compress the grip to let the cable pass.

Strip about 30 cm (1 foot) of jacket, and tie the aramid strength yarn to the pull rope/string. Cut off and properly discard the exposed optical fiber.

Pull the cable down through the risers. Place enough cable for equipment room installation purposes (tray measurement plus 3 meters [10 feet]). Set the grip and pull the tray-plus-3-meters of cable needed for termination and cut the cable.

Complete the pull and tie the cable at irregular intervals

Repeat this process for every cable, working your way down the building. Cable ties are used to prevent unintentional movement; use them every 1 to 1.5 meters [3 to 5 feet]. Take care to space the ties in an irregular fashion on twisted pair cables; cable attached at too-regular intervals may develop a type of structural return loss. Attach the cable in a slightly winding path down the ladder as this helps ease hanging tension.

Firestop the riser

Once all cables are placed, fill the penetrations with a substance that matches the fire barrier capabilities of the floor through which it passes. This is called firestopping. Methods range from physical plugs to caulks or concrete-like fillers. Consult with firestop manufacturer for the method best suited to your application.
Alternate Riser Backbone Installations

Traversing the ceiling
In buildings where the telecommunications rooms are not stacked, the cable may have to be pulled in the ceiling across to the next riser. In non-plenum ceilings, riser-rated cable may be laid in conveyance or placed in J-hooks when routed to the next telecommunications room. A plenum-rated cable will be required if passing through a plenum space. However, local codes may be more strict and require the use of conduit. Always follow local codes.

Alternate riser paths
A riser does not necessarily have to go through a telecommunications room. Riser-rated cable (dotted orange line) could be fished through a wall or pulled between floor in a broom closet. If an alternate route is used, make sure the cable is not exposed. Cover it with surface mount raceway or a similar product, or use conduit. Be aware that local codes may require the use of metal conduit. Be sure to firestop the risers once the cable has been installed (page 94). Label the cable as “telecommunications cable” at least every 1.8 meters (6 feet) where it enters and leaves the firestop.

Outside installation
Conditions may require that cable (black dotted line) be installed on the outside of the building. (Check local codes and get the building owner’s permission prior to installation.) Use an indoor/outdoor fiber cable with a riser rating, although a non-listed outdoor cable may be used if no more than 1.5 meters (50 feet) of cable enters the building.

Use the proper size and type (wood, masonry, etc.) of bit for drilling the wall. Make sure that there are no electrical wires near the hole. The drilled hole should have a slanted path that is higher on the inside than the outside. Place a grommet or a piece of PVC pipe or duct in the hole to help protect the cable. Pay strict attention to cable bend radii in this kind of pull.

Drill a slanted hole like the one above at the point of entry into the equipment room and insert a grommet or duct. Pull the cable inside, being careful not to exceed its pulling tension or bend radius. Form a 360° cable drip loop outside the hole. Use silicone caulk to make the hole watertight.
Section 10

Campus/Outdoor Cable Installation
Outside (Campus Backbone and Local Access) Installations

Campus backbone cables are placed underground in new or existing conduit, directly buried or installed aerially between buildings. All factors being equal, underground installations using ductwork are the most popular method for campus backbones although any of the above methods may be practiced.

Environmental concerns and cable selection

Weather and installation environment will determine which cable type and which installation method should be chosen. Generally, loose tube buffering offers better performance for outdoor installations especially at low (-40°C or -40°F and below) temperatures. Extremely cold environments (down to -55°C/-67°F) may require the use of a multi-jacketed cable certified for use in severe temperatures. Milder environments may support the use of an indoor/outdoor cable that can be installed in a building and avoid a transition at the entrance facility. Armored cables are useful for protection against rodent attack and are recommended for direct burial. Aerial cables may not be the best idea for regions with harsh environments where ice loading or tree limbs broken by ice could cause problems. Contact CommScope Technical Support at support@commscope.com for aid in cable selection.

Underground conduit

Conduit offers additional environmental protection for cable, making all-dielectric outside plant cable an excellent choice. Cable should be pulled into existing conduit or innerduct (smaller multiple ducts within a larger conduit) if the passage is empty. Pulling cable through an occupied conduit or inner-duct may be attempted under the right circumstances (see next page).

A convenient way to place both conduit and cable at the same time is to install ConQuest® Cable-In-Conduit (CIC). CommScope cable can be factory-installed in high-density polyethylene conduit so that no cable pulling is required. CIC can be buried or plowed into place like a direct burial cable. A toneable version of conduit is available (see page 102).

Direct burial

Direct burial cables can be placed directly in a trench or plowed into place. Armored and multijacket versions provide extra mechanical protection against environmental stresses.

Armored cables should be grounded when placed into the earth even if they are not expected to be terminated or utilized for some time. This provides lightning protection during the entire lifespan of the cable.

Besides protecting the cable physically, metallic armor is often chosen for direct buried applications to make it easier to find the cable once covered up. Non-armored, all-dielectric cables cannot be detected with standard locating equipment. A metallic tape or other specialized locating equipment should be buried along side a non-metallic cable for future locating purposes.

Aerial installation

Aerial cable is usually messengered (comes with an attached high-strength messenger wire that supports the cable). The length of the span is determined by cable weight; a heavier armored cable will span a shorter distance than a lighter cable.
Outside (Campus Backbone and Local Access)
Conduit Installation

Existing underground conduit offers a convenient way to place campus cables. One or more cables may be installed during a single pull. Depending on the length and diameter of the conduit, a horizontal conduit installation may offer more tension than pulling cable down a riser. A dynamometer is essential to ensure that installation pulling tensions are not exceeded. When pulling multiple cables, the maximum pulling force should not exceed that of the cable with the lowest pull rating.

CommScope suggests installing innerduct if the conduit is unoccupied and if future installations are anticipated. Innerduct subdivides conduit into discreet spaces that ease cable installation.

Calculating conduit capacity

Conduit capacity is calculated by determining the fill ratio. The fill ratio for one cable/conduit is 53%, two cables is 33% and three or more cables is 40%. Fill ratio is calculated by squaring the diameter of the cable (d2) and then dividing it by the square of the inner diameter of the conduit (D2) or \( d^2 / D^2 = 0.40 \). When pulling multiple cables, use the width of the cable bundle for d.

Pulling and blowing cable

If no pull string is in place, run a fish tape through the conduit and attach a pull string to the end of the tape. Draw the tape back. Tie a pull string to the cable end; then use several turns of electrician’s tape to secure about 15 cm (6 inches) of the cable bundle to the string. For easier pulling, build the tape up into a shape with a tapered end. A cable lubricant such as CommScope’s Whupp™ can be applied to the cable to ease the pull. The second string remains in place to aid future installations.

Cable may also be blown (or jetted) through empty conduit by using forced air systems.

Placing cable in an occupied conduit

Generally cable may be placed in an occupied conduit if the fill ratio of the new and existing cables does not exceed 40%. This is not a firm rule; an existing cable could block an installation attempt. Test the ease of the potential pull by trying to pass a fish tape through the conduit. If the tape snags, do not try to pull another cable.
Plowed ConQuest®/Buried Cable Installation

Direct burial cable and ConQuest® Cable-In-Conduit (CIC) may be installed by plowing or trenching. Direct burial cable and CIC should be installed at least 61 cm (24 inches) deep and deeper if the frost line is farther down.

When plowing, select a plow chute with a bend radius the same size or larger than the minimum bend radius of the cable or CIC being installed. The chute width should be at least 1.25 cm (1/2 inch) larger in diameter than the cable/CIC.

Dig a receiving pit to a depth of at least 61 cm (24 inches) and deeper if needed to reach a below-ground entry point. The pit should be about 15 cm (6 inches) wide, 45 cm (18 inches) long and run in the direction of the planned line of installation. The plow blade should fit easily inside the pit. Dig a similar pit at the other end of the cable path.

With a walk-behind plow, pay the cable or CIC over the top of the reel on the tractor. Do not use reel brakes. With a stationary reel, pull the cable or CIC from the reel to the plow at the receiving pit. Feed the cable or CIC through the plow blade and run it to the bottom of the pit.

Handling ConQuest CIC

Conduit is slightly longer than the cable it contains. Allow an average of 1.5% of cable withdrawal back toward the reel during unspooling (example: 2000’ of conduit will yield 1970’ of cable). Cable withdrawal will be greater as the end of the reel is approached.

Prior to installation, remove the CIC end cap and cut the cable restraint. This relaxes the cable and transfers all of the pulling tension to the conduit. Replace the cap immediately.
Plowed ConQuest/Buried Cable Installation

Bending ConQuest CIC

CIC can be easily shaped by ‘rolling’ a bend into it. Take 3 to 3.5 meters (10 - 12 feet) of CIC and pull the free end toward you forming a ‘horizontal U.’ Push into the bend lightly and roll the entire radius of the conduit forward. Do not bend the CIC any further if it begins to show signs of ovality (begins to bulge). Do not press down on the cable with your foot as you bend it.

If the building entry is underground, feed the cable/CIC through the wall. Make sure there is enough cable for connectorization (room diagonal measurement plus 3 meters [10 feet]) PLUS enough cable for the service loop. If the entrance point is above ground, make sure there is enough cable to reach it PLUS another 3 meters (10 feet). For CIC installations, support the conduit by tamping some earth (called backfill) beneath the bend.

![Diagram of plowed ConQuest/Buried Cable Installation](image-url)
Trenched ConQuest/Buried Cable Installation

Trenching is accomplished with specialized trenching tractors which cut the trench and remove the soil in a single action. Detailed equipment operation and excavation procedures are specified by the construction equipment manufacturer.

If using traditional methods (backhoe, shovels, etc.) to dig a trench, dig it as straight, level and as rock-free as possible. Avoid tight curves. If there are rapid grade changes and CIC is being installed, use backfill to support the conduit. Trenches should be at least 61 cm (24 inches) deep or below the frost line. Remove all rocks and large stones from the trench and the backfill to prevent damage to the cable. Push some clean fill into the trench to cushion the cable as it is installed in the trench.

Place the cable or CIC reels in line with the trench to prevent any unnecessary bending of the cable. Mount the reel so that pay off is underneath toward the direction of the pull. If using CIC, make sure the conduit is capped. Follow the directions on page 100 for digging the receiving pits and installing enough cable or CIC at the building entry point.

When filling the trench, bury warning tape 15 cm (6 inches) above the cable. Tamp or flood the trench to provide compaction to prevent the trench from receding later. Add additional fill as required.

Toneable conduit

Locating cable after burial is difficult if the cable is all dielectric and therefore cannot be located by a metal detector. Toneable conduit has an embedded wire that conducts an inserted ‘tone’ that makes the conduit cable easy to locate with a detector.
Aerial Cable Installation - Overview

Aerial installations offer several advantages, not the least of which is having a lower cost than direct burial. They favor a direct route between buildings and can easily cross obstructions such as roads. Their chief disadvantage is that they tend to be more environmentally exposed, especially to wind, ice and falling tree limbs. Local building requirements may specify all buried utilities for aesthetic reasons. However, a properly installed aerial cable should be able to withstand severe weather without problem.

Fiber optic aerial installation falls under National Electrical Safety Code (NESC) rules. This chart, derived from NESC publications, shows the clearances required for a fiber cable (meeting NESC rules 230C2 or 230C3) depending on the type of surface it spans. For a complete listing, please contact the NESC at (800) 678-4333.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Minimum Vertical Clearance meters (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railroad tracks (except electrified railroads using overhead trolley conductors)</td>
<td>7.2 (23.6)</td>
</tr>
<tr>
<td>Roads, streets, and other areas subject to truck traffic</td>
<td>4.7 (15.4)</td>
</tr>
<tr>
<td>Driveways, parking lots and alleys</td>
<td>4.7 (15.4)</td>
</tr>
<tr>
<td>Other land traversed by vehicles, such as cultivated, grazing, forest, orchard, etc.</td>
<td>4.7 (15.4)</td>
</tr>
<tr>
<td>Spaces and ways subject to pedestrians or restricted traffic only</td>
<td>2.9 (9.5)</td>
</tr>
<tr>
<td>Water areas not suitable for sailboating or where sailboating is prohibited</td>
<td>4.0 (13.2)</td>
</tr>
<tr>
<td>Water areas suitable for sailboating with an unobstructed surface area of:</td>
<td></td>
</tr>
<tr>
<td>Less than 20 acres</td>
<td>5.3 (17.4)</td>
</tr>
<tr>
<td>Over 20 to 200 acres</td>
<td>7.8 (25.6)</td>
</tr>
<tr>
<td>Over 200 to 2000 acres</td>
<td>9.6 (31.5)</td>
</tr>
<tr>
<td>Over 2000 acres</td>
<td>11.4 (37.4)</td>
</tr>
<tr>
<td>Land adjoining water areas posted for rigging or launching sailboats with an unobstructed surface area of:</td>
<td></td>
</tr>
<tr>
<td>Less than 20 acres</td>
<td>6.8 (22.3)</td>
</tr>
<tr>
<td>Over 20 to 200 acres</td>
<td>9.3 (30.5)</td>
</tr>
<tr>
<td>Over 200 to 2000 acres</td>
<td>11.1 (36.4)</td>
</tr>
<tr>
<td>Over 2000 acres</td>
<td>12.9 (42.3)</td>
</tr>
<tr>
<td>Where cables run along and within limits (but do not overhang) of highways/ROW</td>
<td></td>
</tr>
<tr>
<td>Road, streets or alleys</td>
<td>4.7 (15.4)</td>
</tr>
<tr>
<td>Roads where it is unlikely that vehicles will be crossing under the cable</td>
<td>4.1 (13.4)</td>
</tr>
</tbody>
</table>
Planning an Aerial Installation

The aerial section deals with the installation of messengered fiber cable. The maximum length for messengered spans varies for the size and fiber count of each cable; check span data prior to ordering cable. Longer links may require that the cable be lashed to a separate wire. Contact CommScope Technical Support at support@commscope.com for more information on lashing cable to a span.

Choose a clear route between the buildings. Avoid trees with overhanging limbs. If planning to pass cable over a public road or railroad, be sure to get right-of-way permission from the correct municipal or transportation authority. Keep in mind the NESC minimum clearances shown on page 103. The attachment point should not be any closer than 10 cm (4 inches) from a telephone cable or 30 cm (1 foot) from a power line.

Begin the installation by locating points of attachment on the buildings. A ‘P’ or ‘Q’ hook (used in CATV installation) screwed through or bolted into a wall or other structural element should work. This hook will have to support the hanging weight and tension of the cable under a variety of storm conditions, so make sure it is securely attached.

Set up the cable reel beneath one hook and walk the cable end toward the second attachment point. Avoid kinking, scraping or tangling the cable as it pays out from the reel. Block traffic from running over it.

Once at the destination, continue to pull enough cable to cover the distance from the attachment point to the building entrance facility. Measure the distance carefully AND include extra cable for the service loop.

Another way of making sure enough cable has been pulled is to carry the cable up to the attachment point. The cable can then be marked with a strip of vinyl tape to show where to stop separating the messenger from the cable. In any case, pull a few more meters of cable than your most liberal estimate of the amount required to reach the entrance facility.

Neatly figure-8 the excess cable.
Separating, Trimming and Attaching the Messenger

Separate the messenger from the cable

Use heavy wire cutters to start a split in the webbing between the messenger and the cable. Take the messenger in one hand and the cable in the other and smoothly pull your hands apart to split the webbing. Pull across the webbing (known as a scissors pull) instead of pulling the webbing directly apart.

Separate the messenger and cable up to the calculated/measured point of attachment. Cut off the excess messenger, leaving about 60 cm (2 feet) for attachment.

Attach the messenger to the building

If the messenger is stranded wire, use a strand vice and attach it per the manufacturer’s instructions.

If the messenger is solid wire, use the 2-4-4 method to tie it off. The messenger is threaded two times through the hook, wrapped four times around the messenger itself and four times around the messenger/cable. The next three paragraphs describe this method in detail:

Take the 60 cm (2 feet) of messenger and thread the messenger through the hook twice. Pull it tight. The unseparated messenger/cable should be about 1.5 cm (6 inches) from the hook.

Wrap the messenger four times tightly around itself.

Wrap the messenger four times around the messenger/cable. These multiple loops distribute tension and help keep the cable from deforming. Finally, knot the last loop in a simple clove hitch. Trim off any excess messenger.

Attach the cable to the building

Using the scissors pull, strip the unused messenger from the cable. Secure the cable to the building with cable clips or similar devices. If possible, place the cable along architectural elements that will hide it.
Lifting and Tensioning the Cable

Taking the cable in hand, climb or ride up to the second attachment point. Pull the cable taut until the sag is 1% of the overall length of the span (i.e. for a 30 meter [approx. 100 foot]) span, the sag should be 0.3 meters (1 foot). Mark the place on the cable where the cable and the hook meet while maintaining proper sag. Do not pull the cable through or attach it to the hook at this time.

Cut the messenger

Select a point on the cable at least 60 cm (2 feet) beyond where the cable and hook would meet. Using wire or side cutters, cut the messenger wire, being careful not to nick the cable jacket. Using the scissors pull from page 105, pull the messenger and the cable apart to free about 60 cm (2 feet) of messenger.

Attach the messenger to the building

Use a strand vice for stranded messenger (or the 2-4-4 method for solid messenger shown on page 105) to tie the messenger to the hook. Remove the unneeded remaining messenger as you climb or ride down to the reel. Unreel enough cable to reach the entrance facility. Cut the cable.

Attach the cable to the building

Using the scissors pull, strip the unused messenger from the cable. Secure the cable to the building with cable clips or similar devices. If possible, place the cable along architectural elements that will hide it.
Section 11

Connectorization and Splicing
Connectorization and Splicing

The connector can be referred to as the last inch (or the last 2.5 cm if using the metric system) of cabling to be installed. A link may have many connections and/or splices between the desktop and the main crossconnect; each one must be made as accurately as possible.

Twisted pair wiring schemes (for details, see page 109)

The twist of the pairs in Category 5e and 6 cables is necessary to maintain high performance. All connectorization techniques require that the twist be maintained up to the point where the individual wires enter the connector or a piece of equipment (two-pair non-high performance phone wire does not require close attention to maintaining the twist).

While twisted pair connectors are interchangeable (one manufacturer’s 8P8C style jack fits into another’s outlet), they do vary in termination techniques. See each manufacturer’s instructions for particulars.

Twisted pair wiring is designed so that the same wires continuously connect from one end of the system to the other (i.e. green to green) just like electrical wiring. This differs from fiber optics (see below).

Fiber optic schemes (for details, see page 110 through 115)

Optical fibers can be either spliced together by fusion or mechanical methods (see pages 111 through 114) or terminated with a connector (see page 115).

Optical signals travel over transmit/receive pairs. The integrity of the tx/rx signals are maintained by a system of polarity where connector orientation reverses at each end of the pair.

Coaxial wiring (for details, see page 116)

Coaxial cable has a center conductor and an outer conductor which acts as a shield. F-style and BNC-style connectors are two popular methods of termination. Specialized connectors exist for other coaxial cable types; contact CommScope Technical Support at support@commscope.com for more information.
Twisted Pair Termination

Twisted pair cables typically terminate in one of two TIA/EIAs recognized standards; T568A and T568B. The US government and residential installations employ T568A; commercial installations typically employ T568B. Either method is acceptable. However, it is important that only ONE method be used consistently throughout the entire network.

This page explains general practices. U/UTP data connectors are of the Insulation Displacement Connector (IDC) type in an 8P8C size (eight pin). As the wires are crimped or inserted into place, the connector automatically displaces the insulation to permit clean conductor contact and a gas-tight seal.

Maintaining conductor twist is essential for top performance especially at termination. Other proprietary tools and methods exist; always refer to the connector manufacturer’s specifications.

Use a ring tool to remove about 7.5 cm (3 inches) of jacketing. This will expose four twisted pairs color-coded as pair 1 (blue with white/blue), pair 2 (orange with white/orange), pair 3 (green with white/green) and 4 (brown with white/brown). Separate the pairs but DO NOT UNTWIST the conductors while preparing them for connectorization.

Place the conductors in the appropriate slots in the jack or the outlet module (striped conductors in the odd numbered slots, solid in the even,) and crimp or insert them into place with the appropriate tool. Rack termination (i.e. punch-down blocks) are usually color-coded to aid in placing the pairs. Follow the same untwist rule as connectors. Refer to the manufacturer’s instructions for the actual connection.

Labeling termination
TIA/EIA standard 606-A call for machine-generated labels to be used for circuit identification at both the desktop and the telecommunications and equipment rooms. This applies to all cable media.
Fiber Optic Polarity

Fiber polarity is defined in the TIA/EIA 568-C.3 standard. In order to maintain integrity of transmission and reception, connectorized fiber acts as one continuous circuit with a transmitter at one end and a receiver at the other. In a fiber pair, the data flows in opposite directions like cars on a two-lane highway. In order to keep the traffic flowing in the right direction, fibers need to be interconnected with the correct polarity.

The color coding on a fiber equates to a numbering system (i.e. blue fiber is ONE, orange fiber is TWO, etc.). In this example, the connector pair on the desktop ‘side’ of the adapter has B-A polarity; the odd numbered fiber (blue #1) is B and the even numbered fiber (orange #2) is A. This is reversed at the other end of the fiber pair where the adapters face away from the desktop; the odd numbered fiber is designated A and the even numbered fiber is B (A-B polarity). It is helpful to color-key the heat shrink tubes of the installed connectors (example: A/white, B/yellow).

When the connectors meet at the adapter, the A connector plugs into the A adapter position where it meets the B adapter/fiber on the other side of the panel. Keyed adapters and duplex connectors help to maintain network polarity. Most adapters come marked with As and Bs for easy identification.

A good way to keep this straight is to picture the fibers and crossconnects as a continuous path leading from the desktop to the telecommunications room and on to the equipment room. Assign B-A polarity to the adapters on the desktop side of a connection and A-B polarity to adapters facing away from the desktop. It makes no difference which polarity is chosen as long as the same polarity is maintained throughout the network.

Duplex LC and SC patch cords should arrive from the factory with the correct orientation. A system that has the correct polarity will not require patch cord adjustments. A technician should be able to connect to electronics or cross-connect without having to “fix” the patch cord by swapping the connectors on one end.
Fiber Splicing - General Cable Preparation

Optical fibers are spliced in two ways. Fusion splicing uses a machine that precisely aligns and melts together two prepared fiber ends with an electric arc; the splice is then reinforced with a splice protector. Mechanical splicing holds two prepared fiber ends together in a sleeve filled with index matching gel. Indoors, spliced fibers are placed in splice trays and secured in a rack. Outdoors, spliced fibers are placed in splice trays that are usually sealed in a waterproof splice enclosure.

The splicing environment should be as free as possible from dirt and humidity. Outdoor splicing is normally performed in a specialized vehicle or trailer. Splicing can also be performed in a ventilated vault or a tent. Fusion splicing in a cable vault is not recommended due to the possible presence of explosive gas. Regardless of your splicing location, make sure to follow all OSHA procedures (see page 36).

Before exposing cable components and working with the splice closures, the installer should consider how the cable and closure will lay when the process is finished. The cable can be test-routed to make sure that it can fit into the location and that the cable bend radius can be maintained. This is good practice whether splicing indoors, down a manhole, or aerially.

Cable preparation/jacket removal for splice

Prior to splicing, secure the cable to the splice closure. The cable end can then be prepared for splicing. The instructions for the facility/enclosure tell how much of the jacket to strip away. Measure that distance from the end of the cable. Mark that location by wrapping vinyl tape above and below it. This location is called the "choke point."

Carefully make a ring cut through the jacket at the choke point using the appropriate cable prep tool. DO NOT cut or nick the ripcord or buffer tubes. Make a second cut about 15 cm (6 inches) from the cable end and remove that part of the jacket to access the ripcord. Make a small notch in the jacket to be removed. Place the ripcord in the notch. Wrap the ripcord around the shaft of a screwdriver and use the screwdriver as a handle to pull the ripcord to the choke point. Carefully remove the ripped jacket. Use snips to cut off the ripcord.

Removing non-fiber elements

Trim the strength members to the length specified by the closure instructions. If the spliced fiber is going in an enclosure, the manufacturer's instructions will tell how the cable should be secured. If there are strength members in the jacket, cut them to the recommended length for clamping in the enclosure. Cut and remove any water-swellable tape and cable binder.
Fiber Splicing - Loose Tube Fiber Preparation

This page addresses techniques specific to loose tube fiber preparation, specifically buffer tube removal and fiber furcation or ‘break out’. If splicing tight buffered fiber, go to page 113.

Remove the tape and binders
Unwrap the buffer tubes. DO NOT BEND the buffer tubes enough to cause kinking. Place the buffer tubes in the splicing work area.

Trim the buffer tube
The buffer tubes must be carefully removed to reveal the fibers. Use a buffer tube cutter to score the buffer tube at intervals of 30 - 40 cm (12 - 16 inches). Flex the buffer tube back and forth until it snaps, then slide the tube off the fibers. The shelf or enclosure instructions tell how much buffer tube to remove.

Clean the fibers
Buffer tubes are sometimes flooded with a water-blocking gel. Remove the gel from the fibers with a lint-free cloth soaked in gel-removal solvent. Remove the solvent residue with a solution of 97% isopropyl alcohol. Dry the fibers with a rosin bag or talcum powder, being careful not to leave too much powder. This could make it difficult to slide the fibers into furcation tubing. NOTE: dry construction designs do not require cleaning.

Furcate the fibers
Furcate or ‘break out’ the fibers by placing a proper-sized adapter over the end of the buffer tube. Fit each fiber with a furcation tube (a 900 µm diameter sleeve that strengthens the fiber for handling). Refer to the instructions provided by the connector/splice manufacturer for the length of fiber that should extend beyond the furcation tube.

Seal the buffer tube to keep the water-repellent gel (if present) from flowing out of the tube.
Fiber Splicing - Mechanical Splicing

Mechanical splicing positions two fibers end-to-end and physically holds them in place. While fusion splicing (see page 114) offers generally lower loss, mechanical splicing works fine for campus links involving multimode fiber. These are general instructions on mechanical splicing; always refer to the instructions provided by the splice manufacturer.

Fiber stripping
Use a fiber stripping tool to cleanly remove the acrylate coating (and buffering material if splicing tight buffered fibers). The length of the cleaned, stripped area will be determined by the splice being used; again, consult the manufacturer’s instructions.

Once a fiber is stripped, clean it with a lint-free cloth soaked in a solution of 97% isopropyl alcohol to remove the coating residue. Keep the handling of bare fibers to a minimum.

Fiber cleaving
Cleave the fiber end using a quality fiber cleaver. Small hand-held cleavers (called beaver tail cleavers) are not recommended for precision cleaves. The cleave should be clean (free of edge chips) and be within 1° of perpendicular. Once cleaved, do not set the fiber down or allow the end to touch any surfaces so as to avoid contamination.

Insert the fiber into the splice
Place the fiber in the splice per the manufacturer’s instructions. Strip and cleave the second fiber as outlined above.

Activate the splice
Activating the splice locks the fibers in place. Splice activation techniques vary widely (pressing a key, twisting, screwing into position, etc.). Read the manufacturer’s instructions.

Place the splice in the holder
Splices require the additional support of a holder or a closure. Place the spliced fibers in the holder.

TIA/EIA-568 C.3 specifies splice loss of no more than 0.3 dB/splice, although less than 0.1 dB can be achieved with experience. Power meter/light source testing is the most accurate way to test for insertion loss. Accurate splice loss measurements can be obtained using bidirectional OTDR testing (see page 124). One-way OTDR testing typically will not yield true splice loss due to the nature in which OTDRs measure point defects.
Fiber Splicing - Fusion Splicing

Fiber stripping and cleaving
Strip, clean and cleave the fiber like preparing for a mechanical splice (page 113).

Fusion splicers
There are several brands of fusion splicers available. Most integrate these features:

- fusion heat source, usually an electric arc;
- V-groove clamps for holding the fibers;
- fiber positioning system; and
- splice viewing system.

Procedures vary depending on the fusion splicer being used. The simplest units use a 'V' groove to mechanically match the fiber’s outer diameters. More sophisticated splicers feature automatic alignment of the fiber cores for the lowest-loss splices.

Fiber alignment
Some splicers come equipped with LID (Light Injection and Detection) where the fibers are bent around a small post so that light can actually be “injected” into the fiber. The light crosses through the alignment point and is measured on the output side. The fibers are then manually or automatically positioned until the most light is passing through the aligned fibers. LID systems also monitor the fibers as they are being fused and shut off the arc when the lowest splice loss is detected.

Splicers equipped with a Profile Alignment System (PAS) project an image that shows the fiber cores and manually or automatically brings them into alignment. Other alignment systems may align the fiber cladding instead of the core, or use a fixed alignment system that relies on v-grooves to align the fiber ends. Evaluate the quality of a fusion splicer based on not just the typical loss, but the accuracy of the loss estimation.

Splice protection
CommScope recommends that the spliced fibers be mechanically reinforced. A heat-shrink sleeve may be placed over the fiber prior to splicing. Once the splice is completed, the sleeve is placed over the splice and heated to shrink. There are other methods such as crimpable sleeves, butterflies and sealants.

TIA/EIA-568 C.3 specifies splice loss of no more than 0.3 dB/splice, although less than 0.1 dB can be achieved with experience. Accurate splice loss measurements can be obtained using bidirectional OTDR testing (see page 124). One-way OTDR testing typically will not yield true splice loss due to the nature in which OTDRs measure point defects.
Fiber Connectorization

Due to the different styles and manufacturers of fiber optic connectors, this page covers only general practices. Refer to the connector manufacturer’s specific instructions for detailed procedures.

NOTE: for many cable types, CommScope can provide factory terminated cables. Call for details.

Loose tube preparation
Prepare the cable end for termination (page 112 and 113). If the cable is loose tube buffered, furcate the fibers as described on page 112. Furcation is not required for tight buffered fibers unless the connectivity occurs outside of a protected enclosure.

Fiber stripping
Use a fiber stripping tool to cleanly remove the acrylate coating. The stripped length will be determined by the connector being used; consult the manufacturer’s instructions.

Remove the coating residue from the stripped fiber with a lint-free cloth soaked in a solution of 97% isopropyl alcohol. Avoid handling the bare fibers as much as possible.

If using a polish-type connector
Follow the manufacturer’s instructions for connector preparation (adhesive placement, etc.) and place the fiber in the connector. If an adhesive is being used to hold the fiber in place, allow it to cure; again, refer to the instructions. Once the fiber is secure in the assembled connector, scribe the fiber and remove the excess fiber from the face of the connector. Polish the connector face per instructions. Clean the fiber with the isopropyl alcohol.

Deviating from the manufacturer’s procedure, using non-recommended materials, or using out of date adhesives are not recommended, and may cause performance issues either during installation or during the lifetime of product.

If using a no epoxy/no polish connector
These connectors typically have a short factory-polished fiber stub installed inside the connector. Therefore, it is important to verify that the fiber type of the connector matches that of the cable.

Cleave the fiber end of the cable using a quality fiber cleaver. The cleave should be clean, without chips and within 1° of perpendicular. Non-polish connectors use mechanical methods to hold the fiber in place. Insert the fiber into the connector and activate the holding mechanism per manufacturer’s instructions.

Again, following the manufacturer’s installation process is critical to success. As many no epoxy/no polish connectors are difficult to evaluate with a microscope, frequent testing is recommended so errors in process do not propagate throughout the installation.

Connector loss
TIA/EIA standards set connector power loss to be no greater than .75 dB per connector set. However, experienced craft personnel can prepare connector pairs to deliver loss of 0.5 dB or less.
Connectorizing Braid-Shielded Coax Cable

These instructions refer to general practices. Exact instructions may vary with the maker of the tools and connectors being used. Always refer to the manufacturer’s instructions.

If using a boot to protect the connection at the tap or if using a compression fitting with an independent sleeve, slide it over the cable end first. Strip the end of the coax cable by clamping a cable prep tool around the cable and making sure that the end of the cable is flush against the stop. Operate the tool per manufacturer’s instructions until a clean cut is achieved.

A clean cut will have a square end and the cable will have a round cross-section. The dimensions in the drawing are approximate; always check with the connector manufacturer for exact dimensions.

Carefully bend the braid back over the jacket. On tri- and quad-shielded cables, carefully trim outer layer of tape.

If using a crimp-style or one piece compression connector, slide it over the cable end and use the crimping tool to firmly attach the connector. A good connection will have solid contact between the neck of the connector and the braid under it. The conductor should extend no more than 3 mm (1/8 inch) beyond the front edge of the connector.

If a two-piece compression connector is being used, slide the main boot over the cable prior to cable preparation. Then slide the compression sleeve to the back of the connector. Use the proper compression tool to compress the connector per the manufacturer’s specifications.

If a non-crimpable connector is being used, follow the manufacturer’s specific instructions.
Outlet Trimout and Labeling

Once the cable is connectorized, the installation can be trimmed out.

Insert the bracket
Box eliminators are meant to install directly to the drywall and can also be used with “old work” existing installations. Place the cable through the bracket and insert the bracket in the wall. Properly attach and secure the bracket so as to trap the drywall. Tighten the attachment screw until the bracket is firmly set. Then attach the faceplate to the bracket.

U/UTP data and voice faceplates require termination to an outlet module. This is usually a separate component that snaps into the faceplate. Terminate the cable in the module like the jack on page 109. Make sure the same TIA/EIA 568 wiring scheme (T568A or T568B) is followed at all locations.

Fiber optic faceplates insert connectorized fibers into an adapter similar to the patch panel. Clean the connector ferrule and the adapter with a solution of 97% isopropyl alcohol prior to insertion.

Coax faceplates require terminating the cable with a connector and then attaching it to the female connection on the faceplate. To prevent cable twisting, rotate the faceplate when attaching it to the connector or just make sure that only the hex nut of the connector is turning, not the connector itself.

Trim out the hole
Once the cable or connector is attached, carefully place the excess cable into the hole, making sure not to exceed the bend radius or crimp the cable in any way. Attach the faceplate.

Labeling
All outlets and telecommunications/equipment room connections must be labeled with mechanically-generated labels per TIA/EIA 606-A.
Section 12

Testing
Testing and Documentation - Overview

CommScope goes to extra lengths to ensure that our cables perform as promised. CommScope solutions (cable and connectivity) are submitted to ETL for a very thorough third party evaluation. This Total Solutions Verification, simulates real-world, worst-case situations by testing solutions from among three different product batches, in multiple permanent link and channel configurations in two different run lengths.

WebTrak® Certified Report System is another confirmation of CommScope quality. WebTrak is an online certified report system for all our fiber cable and some copper cable products. By using the unique WebTrak identifier printed on the cable, a customer, distributor, or installer can enter this information into our online software and receive the test report for that specific reel of cable, whenever and wherever it is required.

Testing installed cable is critical to establishing network performance and integrity. It reveals problems like a cable bend tighter than its recommended minimum bend radius or a poorly installed connector.

Documenting the test results is equally essential as it provides a baseline for performance prior to actual network operation. Documentation helps troubleshooting efforts should there be problems during turn-up and operation. CommScope recommends end-to-end testing for each installed (or permanent) link as outlined in TIA/EIA 568 C.0 Annex E.

A note on power loss budgets and fiber optic testing

Testing is especially important when confirming the optical loss for a fiber optic system. The power loss budget is the allowable system loss between the transmitter and receiver. System gain, transmitter power and receiver sensitivity all influence the power loss budget.

For example: a system powered by 850 nm VCSEL lasers is operating over 50 µm fiber with an attenuation of 3.0 dB/km. The transmitter (tx) delivers -6 dB* of optical power. The receiver (rx) has a sensitivity of -17 dB. The dynamic range of this tx/rx pair is calculated by subtracting the rx sensitivity from the tx power (-6 dB - [-17 dB] = 11 dB). Subtract another 3 dB for a margin of excess to derive a power loss budget of 8 dB (11 dB - 3 dB = 8 dB). This means that the link can accept no more than 8 dB of loss.

In our example, the link is 500 meters (1640 feet) long and has three connector pairs (crossconnect, patch panel and desktop). The TIA/EIA maximum loss allowance for a connector pair is .75 dB (see page 112). Adding the fiber loss (3.0 dB/m x 0.5 km = 1.5 dB) to the loss from three connector pairs (.75 dB max x 3 = 2.25 dB) establishes a calculated total loss of 3.75 dB (1.5 + 2.25). This is well within power loss budget of 8 dB. It is possible for a link to deliver more power than the rx end can handle (called saturation). In this case, a device called an attenuator is installed at the rx end to add loss to the system.

*Technically, the power of active fiber components is expressed in dBm (decibels in millivolts).
Fiber Optic Testing - Power Meter ‘One Patchcord’ Method

Fiber optic links should be tested for continuity and attenuation. The methods for fiber testing are 1) using an OTLS (Optical Loss Test Set) which includes a hand-held power meter to measure the power of a light source connected to the opposite end of the link, 2) visual inspection with a Visual Fault Locator (VFL) or 3) using an Optical Time Domain Reflectometer (OTDR - see page 124). OTDRs should not be used in place of a power meter/light source to measure system attenuation. Testing should be done at both appropriate wavelengths for the fiber type - multimode fiber at 850/1300 nm and single-mode fiber at 1310/1550 nm - and bi-directionally. The VFL is used to determine if a fiber is broken and can often be used to find the point of the break.

Power meter test equipment and the “one patchcord” method

The power-meter-and-light-source method is the most accurate way to measure attenuation. TIA/EIA outlines testing procedures in documents 526-14A (multimode)* and 526-7 (single-mode). Hybrid patchcords can be used to connect the test equipment to the link. Thoroughly clean the patchcord connectors and adapters with a solution of 97% isopropyl alcohol and dry them with a lint-free cloth. Note that the integrity of the test cords should be determined as many failing test results can be traced back to dirty or worn out test cords.

Exact testing methods will differ with each power meter and its features, but this is the basic process for OTLS testing for one fiber at a time. Many OTLS units have dual transmitters and receivers that allow for testing two fibers at a time. This speeds up testing time but the installer should still rely on the same basic method of Step 1) patchcord reference, Step 2) patchcord check, and Step 3) system test.

Step 1: Connect the light source and the power meter with a test patchcord. Record the displayed optical power (P1) called the ‘reference power measurement’ OR ‘zero-out’ the power meter if so equipped.

Step 2: Disconnect the test patchcord from the optical power meter; DO NOT detach the patchcord from the light source. Add the second patch cord to the test meter port and connect to the first patchcord. Measure the total loss. If greater than 0.5 dB, the patchcord connectors must be cleaned and retested. If cleaning does not produce a loss below 0.5 dB, then replace one or both patchcords until a passing value is obtained. Do NOT reference out again at this step.

Step 3: Disconnect the two test patchcords from each other and connect to the ends of the system link being tested. Use a previously tested and verified patchcord to connect the meter to the other end of the link. Record the displayed optical power (P2) which is called the ‘test power measurement.’ The attenuation of the link is P1 - P2 or in this example (-10.0) - (-10.6) = 0.6 dB. In other words, this segment of the network will subtract 0.6 dB from the power budget (some meters perform this function automatically).

*Multimode fiber may show attenuation because of power loss in high-order modes. During testing, wrapping the patchcord five times around a mandrel (or smooth rod) of 25 mm diameter for 50 µm fiber and 20 mm for 62.5 µm fiber removes these losses. Be sure to unwrap the patchcord after testing. Refer to TIA/EIA 569 B.1 Section 11.3.3 for details.
**Fiber Optic Performance Standards**

**Loss budgets**

TIA/EIA specifies the following limits for insertion loss (attenuation) for the various parts of the network. Loss values should be better than these if good craft practices have been followed during installation.

<table>
<thead>
<tr>
<th>Network part</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splice</td>
<td>$\leq 0.3$ dB insertion loss at all wavelengths</td>
</tr>
<tr>
<td>Connector pair</td>
<td>$\leq 0.75$ dB insertion loss at all wavelengths</td>
</tr>
<tr>
<td>Horizontal link (100 meters max.) (maximum of 2 connector pairs)</td>
<td>$&lt; 2.0$ dB insertion loss at 850/1300 nm</td>
</tr>
<tr>
<td>Horizontal link (100 meters max.) w/consolidation point (splice or connector)</td>
<td>$&lt; 2.75$ dB insertion loss at 850/1300 nm</td>
</tr>
<tr>
<td>Collapsed backbone link (300 meters max.) (maximum of 3 connector pairs)</td>
<td>$&lt; 3.3$ dB insertion loss at 850/1300 nm</td>
</tr>
</tbody>
</table>

For example, if all the pairs in a three-connector-pair link with a consolidation point were tested at the permitted maximum of .75 dB, the loss would be an allowable .75 dB x 3 or 2.25 dB. Ideally, a connector pair should produce no more than 0.5 dB of loss.

It is important to note that loss values must be as low as possible for links with extended lengths (links beyond TIA/EIA standards).

The budgets above refer to TIA/EIA standard recommendations. Many CommScope products offer performance tighter than the standard. Please refer to the our specifications and/or link loss calculator to determine the loss budgets.

**Documentation**

Every link should be documented by recording attenuation values at the tested wavelengths, the date of test, the name(s) of the test personnel, the date of latest equipment calibration and a description of equipment used (manufacturer and model number). Some power meters record and download test results. In either case, store all test results with the ‘as-built’ drawings. Keep hard copies of this documentation in the telecommunication rooms.

Many end users will require delivery of test results as part of the system commissioning.
Fiber Optic Testing - Troubleshooting

Test equipment
Improper calibration (also called improper baseline setup) is a common reason for a link to indicate high loss. Follow the instructions on page 121 to make sure that your test equipment has been set to the proper wavelength, that your test patch cords are good and that the equipment has been properly set for the test to be performed. Review TIA/EIA 455-50B for detailed instructions on launch requirements for the light source being used.

TIA/EIA-568 C.0 Annex E suggests that a mandrel wrap and a Category 1 light source be used when testing multimode fiber. This holds true whether the system is expected to operate at low data rates with an LED as the power source or if the system is expected to operate a 1- or 10 gigabit Ethernet with a VCSEL as the source.

Failure to use the mandrel on short lengths with the Category 1 light source will result in measurement errors. All test equipment should be calibrated and certified annually (or more often as required).

Connector loss
Unacceptable power loss can occur due to poor connectorization or a lack of connector-to-connector contact at the adapter. Visually inspect all the connectors in the link for damage. Clean all connector faces with a solution of 97% isopropyl alcohol and dry them with a lint-free cloth. A CommScope inspection kit (shown at left) contains all of the items needed to inspect and clean optical connectors.

Fiber kinks and breaks
A fiber that has been severely bent will allow light to ‘leak’ out of the fiber. Check the fiber route (especially at the patch panels and where the cable is attached to conveyance) for kinks. Another method for checking connector or fiber damage is to use a visual fault locator which injects visible red laser light into a link. The light will cause a fiber to glow at a stress point or a break in a connector/cable.

Visual fault location may reveal a fault within a patchcord. OTDR testing can be used to determine the section of the link with the event (see page 124). Unkink or replace the cable as necessary and retest the link from both ends.

If all these methods fail to resolve the problem, you may have to replace the cable or, in a backbone cable, use a spare fiber.
Fiber Optic Testing - OTDR

Optical Time Domain Reflectometers (OTDRs) are attached to one end of a fiber to characterize the fiber link. OTDRs do not measure power, but detect the reflected light of an optical pulse moving through the fiber. While OTDRs are more expensive than power meters, they are indispensable for testing multi-kilometer lengths of fiber. They can locate ‘events’ (i.e. stressed or broken fibers, splices, etc.) over very long distances. Since the OTDR operates from only one end of the fiber, an opposite-end light meter is not required. In fact, the fiber should be open (not attached to anything) at the far end.

Testing should be done at both appropriate wavelengths for the tested fiber; multimode fiber at 850/1300 nm and single-mode fiber at 1310/1550 nm. For accurate loss measurements, testing should be done in both directions and the event losses averaged.

OTDR test equipment and methods

Exact operating methods and features will differ between OTDR manufacturers, but these procedures apply to most OTDRs. There are important settings within the OTDR that must be set according to fiber type before accurate testing can occur (i.e. index of refraction, backscatter coefficient). These can be provided by the cable manufacturer.

Like power meter testing, clean all connectors with a 97% isopropyl alcohol solution and dry them with a lint-free cloth.

An OTDR will not pick up flaws close to its transmitter because the time between launch and reception of the reflection is so small that the electronics cannot detect it (this distance is called the ‘front end dead zone’). In order to accurately measure events at the near end of the link, a launch cable (usually a ruggedized 1 km reel of fiber) is used to connect the OTDR to the link (see diagram below).

The OTDR displays a graph called a ‘trace’ that shows the location and amount of loss caused by events in the fiber.

Documentation

Every link should be documented by recording test procedure and method used (i.e 526-14A method B), loss measurements (including location, path and wavelength identification) and the test date.
Twisted Pair Cable Testing

Twisted pair cable is generally used in the network's horizontal segment. Test methods vary depending if the permanent link (the 90 meters from outlet to telecommunications room) or the entire channel (the permanent link plus the 10 meters of connection/interconnect cording) is being tested. Test all permanent links and document the results. Some warranty programs may require additional testing - see the warranty for details.

Permanent links and channels are tested for wiremap, length, insertion loss (or attenuation), NEXT loss, power sum NEXT, ELFEXT loss, power sum ELFEXT, return loss, propagation delay and delay skew. These are the same parameters used in testing cable master reels at the factory. A master test report (CommScope provides these for Category 6 and 5e box/reels) is a good benchmark for the expected performance of a link. Test reports are available at www.commscope.com.

Test equipment

Test twisted pair channels with a test set at one end and a remote at the other. For Category 6A/6 testing, use Level III meters; for Category 5e, use Level III or IIe testers. Exact testing methods will differ because of the wide variety of equipment and features, but these general rules apply:

Prior to testing, field-calibrate the test set. Make sure the equipment is set up for the proper network and cable type. Connect the test set and remote to the ends of the permanent link or channel either through directly plugging the patch cords into the tester or by using the appropriate adapter modules.

The link must be tested at several frequencies from 1 MHz up to 100 MHz for Category 5e and 250 MHz for Category 6A/6. Worst-case values for link and channels are shown on the next three pages.
## Category 6A U/UTP Performance Standards (TIA/EIA 568 C.2)

<table>
<thead>
<tr>
<th>MHz</th>
<th>Insertion Loss (dB)</th>
<th>NEXT (dB)</th>
<th>PSum NEXT (dB)</th>
<th>ACRF (dB)</th>
<th>PSum ACRF (dB)</th>
<th>Return Loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Channel/Link</td>
<td>Channel/Link</td>
<td>Channel/Link</td>
<td>Channel/Link</td>
<td>Channel/Link</td>
<td>Channel/Link</td>
</tr>
<tr>
<td>1</td>
<td>2.3/1.9</td>
<td>65.0/65.0</td>
<td>62.0/62.0</td>
<td>63.3/64.2</td>
<td>60.3/61.2</td>
<td>19.0/19.1</td>
</tr>
<tr>
<td>4</td>
<td>4.2/3.5</td>
<td>63.0/64.1</td>
<td>60.5/61.8</td>
<td>51.2/52.1</td>
<td>48.2/49.1</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>8</td>
<td>5.8/5.0</td>
<td>58.2/59.4</td>
<td>55.6/57.0</td>
<td>45.2/46.1</td>
<td>42.2/43.1</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>10</td>
<td>6.5/5.5</td>
<td>56.6/57.8</td>
<td>54.0/55.5</td>
<td>43.3/44.2</td>
<td>40.3/41.2</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>16</td>
<td>8.2/7.0</td>
<td>53.2/54.6</td>
<td>50.6/52.2</td>
<td>39.2/40.1</td>
<td>36.2/37.1</td>
<td>18.0/20.0</td>
</tr>
<tr>
<td>20</td>
<td>9.2/7.8</td>
<td>51.6/53.1</td>
<td>49.0/50.7</td>
<td>37.2/38.2</td>
<td>34.2/35.2</td>
<td>17.5/19.5</td>
</tr>
<tr>
<td>25</td>
<td>10.2/8.8</td>
<td>50.0/51.5</td>
<td>47.3/49.1</td>
<td>35.3/36.2</td>
<td>32.3/33.2</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>31.25</td>
<td>11.5/9.8</td>
<td>48.4/50.0</td>
<td>45.7/47.5</td>
<td>33.4/34.3</td>
<td>30.4/31.3</td>
<td>16.5/18.5</td>
</tr>
<tr>
<td>62.5</td>
<td>16.4/14.1</td>
<td>43.4/45.1</td>
<td>40.6/42.7</td>
<td>27.3/28.3</td>
<td>24.3/25.3</td>
<td>14.0/16.0</td>
</tr>
<tr>
<td>100</td>
<td>20.9/18.0</td>
<td>39.9/41.8</td>
<td>37.1/39.3</td>
<td>23.3/24.2</td>
<td>20.3/21.2</td>
<td>12.0/14.0</td>
</tr>
<tr>
<td>200</td>
<td>30.1/26.1</td>
<td>34.8/36.9</td>
<td>31.9/34.3</td>
<td>17.2/18.2</td>
<td>14.2/15.2</td>
<td>9.0/11.0</td>
</tr>
<tr>
<td>250</td>
<td>33.9/29.5</td>
<td>33.1/35.3</td>
<td>30.2/32.7</td>
<td>15.3/16.2</td>
<td>12.3/13.2</td>
<td>8.0/10.0</td>
</tr>
<tr>
<td>300</td>
<td>37.4/32.7</td>
<td>31.7/34.0</td>
<td>28.8/31.4</td>
<td>13.7/14.6</td>
<td>10.7/11.6</td>
<td>7.2/9.2</td>
</tr>
<tr>
<td>400</td>
<td>43.7/38.5</td>
<td>28.7/29.9</td>
<td>25.8/27.1</td>
<td>11.2/12.1</td>
<td>8.2/9.1</td>
<td>6.0/8.0</td>
</tr>
<tr>
<td>500</td>
<td>49.3/43.8</td>
<td>26.1/26.7</td>
<td>23.2/23.8</td>
<td>9.3/10.2</td>
<td>6.3/7.2</td>
<td>6.0/8.0</td>
</tr>
</tbody>
</table>

**NOTE:** Propagation Delay is 555 nanoseconds for channel/498 nanoseconds for link tested at 10 MHz.

**NOTE:** Delay Skew is 50 nanoseconds for channel/44 nanoseconds for link tested at 10 MHz.

### Documentation

Document each channel’s performance for the criteria listed above, the test date, the name(s) of the test personnel and the equipment used (manufacturer, model number and calibration date). Record (or download if the equipment has that function) the test results and store them with the as-built drawings. Keep hard copies of the documentation in the telecommunication or equipment room.
Category 6 U/UTP Performance Standards
(TIA/EIA 568 C.2)

<table>
<thead>
<tr>
<th>MHz</th>
<th>Insertion Loss (dB) Channel/Link</th>
<th>NEXT (dB) Channel/Link</th>
<th>PSum NEXT (dB) Channel/Link</th>
<th>ACRF (dB) Channel/Link</th>
<th>PSum ACRF (dB) Channel/Link</th>
<th>Return Loss (dB) Channel/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.1/1.9</td>
<td>65.0/65.0</td>
<td>62.0/62.0</td>
<td>63.3/64.2</td>
<td>60.3/61.2</td>
<td>19.0/19.1</td>
</tr>
<tr>
<td>4</td>
<td>4.0/3.5</td>
<td>63.0/64.1</td>
<td>60.5/61.8</td>
<td>51.2/52.1</td>
<td>48.2/49.1</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>8</td>
<td>5.7/5.0</td>
<td>58.2/59.4</td>
<td>55.6/57.0</td>
<td>45.2/46.1</td>
<td>42.2/43.1</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>10</td>
<td>6.3/5.5</td>
<td>56.6/57.8</td>
<td>54.0/55.5</td>
<td>43.3/44.2</td>
<td>40.3/41.2</td>
<td>19.0/21.0</td>
</tr>
<tr>
<td>16</td>
<td>8.0/7.0</td>
<td>53.2/54.6</td>
<td>50.6/52.2</td>
<td>39.2/40.1</td>
<td>36.2/37.1</td>
<td>18.0/20.0</td>
</tr>
<tr>
<td>20</td>
<td>9.0/7.9</td>
<td>51.6/53.1</td>
<td>49.0/50.7</td>
<td>37.2/38.2</td>
<td>34.2/35.2</td>
<td>17.5/19.5</td>
</tr>
<tr>
<td>25</td>
<td>10.1/8.9</td>
<td>50.0/51.5</td>
<td>47.3/49.1</td>
<td>35.3/36.2</td>
<td>32.3/33.2</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>31.25</td>
<td>11.4/10.0</td>
<td>48.4/50.0</td>
<td>45.7/47.5</td>
<td>33.4/34.3</td>
<td>30.4/31.3</td>
<td>16.5/18.5</td>
</tr>
<tr>
<td>62.5</td>
<td>16.5/14.4</td>
<td>43.4/45.1</td>
<td>40.6/42.7</td>
<td>27.3/28.3</td>
<td>24.3/25.3</td>
<td>14.0/16.0</td>
</tr>
<tr>
<td>100</td>
<td>21.3/18.6</td>
<td>39.9/41.8</td>
<td>37.1/39.3</td>
<td>23.3/24.2</td>
<td>20.3/21.2</td>
<td>12.0/14.0</td>
</tr>
<tr>
<td>200</td>
<td>31.5/27.4</td>
<td>34.8/36.9</td>
<td>31.9/34.3</td>
<td>17.2/18.2</td>
<td>14.2/15.2</td>
<td>9.0/11.0</td>
</tr>
<tr>
<td>250</td>
<td>35.9/31.1</td>
<td>33.1/35.3</td>
<td>30.2/32.7</td>
<td>15.3/16.2</td>
<td>12.3/13.2</td>
<td>8.0/10.0</td>
</tr>
</tbody>
</table>

NOTE: Propagation Delay is 555 nanoseconds for channel/498 nanoseconds for link at 10 MHz.
NOTE: Delay Skew is 50 nanoseconds for channel/44 nanoseconds for link for all frequencies.

Documentation
Document each channel’s performance for the criteria listed above, the test date, the name(s) of the test personnel and the equipment used (manufacturer, model number and calibration date). Record (or download if the equipment has that function) the test results and store them with the as-built drawings. Keep hard copies of the documentation in the telecommunication or equipment room.
## Category 5e U/UTP Performance Standards (TIA/EIA 568 C.2)

<table>
<thead>
<tr>
<th>MHz</th>
<th>Insertion Loss (dB) Channel/Link</th>
<th>NEXT (dB) Channel/Link</th>
<th>PSum NEXT (dB) Channel/Link</th>
<th>ACRF (dB) Channel/Link</th>
<th>PSum ACRF (dB) Channel/Link</th>
<th>Return Loss (dB) Channel/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.2/2.1</td>
<td>&gt;60/&gt;60</td>
<td>&gt;57/&gt;57</td>
<td>57.4/58.6</td>
<td>54.4/55.6</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>4</td>
<td>4.5/3.9</td>
<td>53.5/54.8</td>
<td>50.5/51.8</td>
<td>45.4/46.6</td>
<td>42.4/43.6</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>8</td>
<td>6.3/5.5</td>
<td>48.6/50.0</td>
<td>45.6/47.0</td>
<td>39.3/40.6</td>
<td>36.3/37.5</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>10</td>
<td>7.1/6.2</td>
<td>47.0/48.5</td>
<td>44.0/45.5</td>
<td>37.4/38.6</td>
<td>34.4/35.6</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>16</td>
<td>9.1/7.9</td>
<td>43.6/45.2</td>
<td>40.6/42.2</td>
<td>33.3/34.5</td>
<td>30.3/31.5</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>20</td>
<td>10.2/8.9</td>
<td>42.0/43.7</td>
<td>39.0/40.7</td>
<td>31.4/32.6</td>
<td>28.4/29.6</td>
<td>17.0/19.0</td>
</tr>
<tr>
<td>25</td>
<td>11.4/10.0</td>
<td>40.3/42.1</td>
<td>37.3/39.1</td>
<td>29.4/30.7</td>
<td>25.4/27.7</td>
<td>16.0/18.0</td>
</tr>
<tr>
<td>31.25</td>
<td>12.9/11.2</td>
<td>38.7/40.5</td>
<td>35.7/37.5</td>
<td>27.5/28.7</td>
<td>24.5/25.7</td>
<td>15.1/17.1</td>
</tr>
<tr>
<td>62.5</td>
<td>18.6/16.2</td>
<td>33.6/35.7</td>
<td>30.6/32.7</td>
<td>21.5/22.7</td>
<td>18.5/19.7</td>
<td>12.1/14.1</td>
</tr>
<tr>
<td>100</td>
<td>24.0/21.0</td>
<td>30.1/32.3</td>
<td>27.1/29.3</td>
<td>17.4/18.6</td>
<td>14.4/15.6</td>
<td>10.0/12.0</td>
</tr>
</tbody>
</table>

**NOTE:** Propagation Delay is 555 nanoseconds for channel/498 nanoseconds for link at 10 MHz. NOTE: Delay Skew is 50 nanoseconds for channel/44 nanoseconds for link for all frequencies.

### Documentation

Document each channel’s performance for the criteria listed above, the test date, the name(s) of the test personnel and the equipment used (manufacturer, model number and calibration date). Record (or download if the equipment has that function) the test results and store them with the as-built drawings. Keep hard copies of the documentation in the telecommunication or equipment room.
Twisted Pair Troubleshooting

Fail Wiremap
This error is caused by improperly wired connectors and is easily discovered and repaired. Most test sets will display a graphic representation of the problem (see diagram). Fix wiremap problems by inspecting and correcting miswired termination hardware.

<table>
<thead>
<tr>
<th>Correct display</th>
<th>Crossed pairs</th>
<th>Pin 1 not connected</th>
<th>Miswiring T568B to T568A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - - - 1</td>
<td>1 - - - - 2</td>
<td>2 - 2</td>
<td>2 - 2</td>
</tr>
<tr>
<td>3 - - - 3</td>
<td>3 - - - - 4</td>
<td>4 - 4</td>
<td>4 - 4</td>
</tr>
<tr>
<td>5 - - - 5</td>
<td>5 - - - - 6</td>
<td>6 - 6</td>
<td>6 - 6</td>
</tr>
<tr>
<td>7 - - - 7</td>
<td>7 - - - - 8</td>
<td>8 - 8</td>
<td>8 - 8</td>
</tr>
</tbody>
</table>

Fail Length (test set ± 10%)
This occurs when a link exceeds 90 meters; links sometimes ‘grow’ as cable may not be placed exactly as planned. Check if the master/meter is set for the correct Nominal Velocity of Propagation (NVP) of the cable being tested. For instance, a non-plenum cable has a lower NVP than a plenum cable.

If the test set is correctly set and the length test still fails, the system may have to be redesigned to eliminate the cable links that are too long (i.e. create a new telecommunications room to shorten the distance to the work area). If system redesign is not possible, retest to ensure the cable passes all other parameters. This link may be limited to slower equipment or services.

Fail Crosstalk or Return Loss (RL)
Fail crosstalk may be caused by several situations. The quickest check is to make sure that the test set is set up for the correct category (5e or 6) of cable. Another very common reason is untwist at the connector.

If the test set displays a distance to the failure, check that location for bends tighter than the minimum bend radius or for overly-tight cable ties. Check for kinks in conduit; the inside diameter of conduit decreases as it is bent, and these bends may be crushing the cable. If the distance to the failure is shown to be less than 3 meters, re-terminate the connection on the failing end.

If re-termination does not solve the problem, swap the locations of the test set and the remote and test the link from the opposite end. If the failure follows the test equipment (i.e. the failure was at the remote end and after switching locations is still at the remote end), the problem is the meter interface cable. If the problem location doesn’t move with the equipment, try replacing the outlet. If that fails, it may be that the installation caused cable damage and the cable may need to be replaced.
More Twisted Pair Troubleshooting

Fail Insertion Loss
Using the wrong category of cable or incorrect category of termination jack are two causes of this problem. It is corrected by installing the correct category of cable/hardware. Another common cause is that the cable is too long (see page 129/Fail length).

Post-testing problems
Some problems come up only when the active equipment is attached. These are a little more difficult to troubleshoot and repair.

Failure to Link (link light does not come on)
This has numerous causes; the most obvious is that the cabling cannot support the application. If using the correct cable, troubleshooting becomes more complex.

If installation testing rule out wiremap problems (see page 129/Fail wiremap), the most likely solution is that improper patching has produced an incomplete circuit path. Disconnect the equipment at the telecommunications room and the work area prior to testing the circuit path. Attach a tone generator to the cable in question, and use an inductive probe to check for tone at the far end. If tone is detected, then the link is continuous. If tone is not detected, the link is not continuous and each segment of the link must be tested until the broken segment is found.

If the circuit is continuous, use a tester with a ‘noise’ check test to see if this is the problem. Note that ‘too much’ noise is relative; the ‘noise floor’ varies with the application. If the noise floor is too great for the application, the only option is to re-route the cable to avoid the noise source (i.e. fluorescent lights, high-voltage electrical cable, etc.).

Other problems
If the link light is on but the circuit is not working, the cause could be that the horizontal cable is too short, and the receiver is being overpowered by too strong a signal. Solve this by using excessively long patch cables at either end of the link to add extra insertion loss to the circuit.

Another possibility is that the cable is fine but the active equipment is improperly configured. Check the active to ensure proper configuration.
Coaxial Testing

Coax testing devices vary in complexity. At their most basic, a tester connects to an installed cable’s BNC or F connector and generates a tone to determine if there are shorts (center conductor to ground) or opens (breaks) in the cable. The most complex can determine the location of a fault to within a meter.

Coaxial tester

The preferred hand-held tester reveals shorts, opens, miswires, reversals, split pairs, and shield continuity. Units are available for a few hundred dollars that provide this information as well as giving the approximate location of the problem as a distance from the tester. A basic hand-held tester should test for shorts, opens and length.

Instructions vary per tester. Please consults the directions that came with your unit.

Time Domain Reflectometer

Time Domain Reflectometer (TDR) testing is the most accurate method of determining all of the important parameters of an installed coaxial cable and displaying them in a graphic format. While highly accurate, they also are rather expensive.

Methods of operation will vary for each TDR; however, these are general guidelines for using one:

1) Set the velocity of propagation and impedance for the cable under test (refer to product specifications for accurate information).

2) Adjust the display for a sharp, clear baseline, and position the leading edge to a convenient starting point or graticule.

3) Set the pulse width as recommended by the TDR manufacturer.

4) Attach the test lead (coaxial cable test leads are preferred) to the cable under test. Connectors should match the impedance of the tested cable.

5) Adjust the display and control settings to show the entire length of the cable. The control settings can be adjusted to allow precise measurement of the distance to any impedance mismatch. Operator proficiency and proper equipment configuration are critical factors in making consistent and precise measurements.
Bill Of Materials (BOM) examples for Uniprise® Solutions

In this section, the information presented earlier is applied to networks of various size and complexity. These sample networks compare the advantages of various media and determine the amount of cable and components required to install various network types.

Remember that these are basic examples. When applying these lessons to the 'real world,' other factors, such as budgetary constraints, right of way issues, existing equipment and even the local weather, will affect which components are installed. The 'rules of thumb' may need to be cut and fit to adapt to particular circumstances. In any case, remember to contact CommScope Technical Support at support@commscope.com for expert advice.

For more information about cables, components, or services, contact CommScope Customer Care or visit www.commscope.com
For answers about installation procedures, contact CommScope Technical Support or email support@commscope.com
Small Horizontal Segment with Riser Backbone

In this example, a small network of 5 PCs and a shared printer make up a horizontal segment. All offices and the telecommunications room have a telephone wired to a central PBX via a discrete voice network. The data network supports 100 Mb/s horizontal links and concentrates at the active equipment (an Ethernet switch) for 1 Gb/s transmission to the building’s equipment room. Sample labeling is shown for the cables. A1-Axx connects to the fiber panel; A1-Bxx are data twisted pair; A1-Cxx are voice cables.

Cable types and count

The distances involved in this example are under 90 meters, so the 100 Mb/s horizontal links are supported by Category 6 twisted pair cable. For future growth, each desktop should be cabled with a pair of multimode fibers. The voice network can be wired with Category 5e twisted pair cable. Because the cable is carried along a conveyance in a plenum ceiling, plenum-rated cable is required. Riser-rated cable is used for the riser backbone. Local codes may supersede these recommendations.

Cable routing and amount

The conveyance is placed centrally as shown. Calculate cable length by taking the measured distance (taking a right-angled route) PLUS three meters for the ceiling-to-outlet drop and termination slack PLUS the length of the tray in the telecommunications room PLUS three meters for ceiling-to-floor in the telecommunications room. The orange line shown would be 21 meters (69 feet). Remember to add 10% to the total cable length. Cable is installed in the tray; J-hooks support cables to the outlets. While the cables can be pulled separately, a bundled cable may be used to speed installation.

Termination considerations

Using the formula for calculating the number of ports from page 69 (devices x 2), install 12 data ports at the horizontal crossconnect and 12 ports for the voice connections.

Twisted pair cables are hardwired into the back of the patch panel. Connectorize fiber optic cables and plug them into adapters in the fiber panels. The patch panel is connected to the active equipment by connectorized patch cords.
Small Horizontal Segment with Riser Backbone

Cable requirements
210 meters (690 feet) of plenum two-fiber 50 µm .......................... P-002-DS-5LFSUAQ
210 meters (690 feet) of plenum Media 6 Category 6 U/UTP .......... 65N4+
210 meters (690 feet) of plenum DataPipe Category 5e U/UTP ......... SE55
OR
210 meters (690 feet) bundled plenum ............................................ Special order
Two-fiber IC/Category 6/Category 5e

Work areas (x 7 for total quantity)
2 wall-mount faceplates (only 1 for telecommunications room) .......... no replacement yet
2 Category 6 outlets ....................................................................... UNJ600-XX
2 Category 5e outlets ................................................................. UNJ500-XX
2 duplex LC adapters with mounting modules ............................... UNFALC02-AQ
1 five meter Category 6 patchcord cable ....................................... UNC6-XX-15F
1 five meter Category 5e patchcord cable ..................................... UNC5-XX-15F
1 five meter LC duplex patchcord cable (for fiber to the desk) ......... FEXLCLC42-MXM005

Telecommunications Room
1 24 port Category 6 copper patch panel ................................. UNP610-24
1 48 port fiber rack with panels and adapters ............................ RFE-SLG-048-MFC-LC12-AQ
1 24 port Category 5e patch panel (voice) ................................. UNP510-24
12 LC connectors ........................................................................ MFC-LCR-09
12 five meter Category 6 patchcord cables ................................. UNC6-XX-15F
12 five meter Category 5e patchcord cable (voice) ................. UNCS-XX-15F
12 five meter LC patchcord cables .............................................. FEXLCLC42-MXM005

NOTE: Faceplates, outlets and cordage come in different colors.
Replace the XX in the part numbers with the code for the desired color:

<table>
<thead>
<tr>
<th>Color Code</th>
<th>Black (BK)</th>
<th>Blue (BL)</th>
<th>Cream (CM)</th>
<th>Gray (GY)</th>
<th>Green (GR)</th>
<th>Ivory (IV)</th>
<th>Orange (OR)</th>
<th>Red (RD)</th>
<th>Violet (VL)</th>
<th>Yellow (YL)</th>
<th>White (WH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faceplate</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Outlet</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cordage</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Cable management components will be required for any installation.
Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Larger Horizontal Segment with Riser Backbone

Pages 71 and 83 are the basis for this example which is slightly modified to add a voice connection at every outlet and a phone in the telecommunications room (every job has changes). Thirteen outlets will carry four Category 6 cables (one data/one voice/two for growth) and one two-fiber cable. All desktops support 100 Mb/s and can migrate to 1 Gb/s. Quad-shielded Series 6 (RG6-style) coax supports a CCTV camera.

Cable types and count

The distances involved in this example are under 90 meters, so the 100 Mb/s horizontal links are supported by Category 6 twisted pair cable. For future growth, each desktop has two additional twisted pair cables and one fiber optic pair. Cable the voice network with Category 6 twisted pair cable. The hung ceiling is not a plenum space, so riser-rated cable may be used (although this recommendation may be superseded by local codes).

Cable routing and amount

Place the conveyance as shown. Calculate cable length by taking the measured distance (taking a right-angled route) PLUS three meters for the ceiling-to-outlet drop and termination slack PLUS the length of the tray in the telecommunications room PLUS three meters for ceiling-to-floor in the telecommunications room. The orange line shown is 25 meters (82 feet). Remember to add 10% to the total cable length. Install cable in the tray; use J-hooks to support cables to the outlets. While the cables may be pulled separately, bundled or hybrid cables will speed the installation.

Termination considerations

Thirteen outlets times three data U/UTP equals 39 patch ports. Since growth is already figured in with the extra U/UTPs, a 48 port patch should be sufficient. Thirteen voice circuits times two is 26; a 24 port panel should work.

Thirteen fiber pairs times two is 52 fibers, so a 48 port panel should be large enough.
Larger Horizontal Segment with Riser Backbone

Cable requirements
262 meters (872 feet) of plenum two-fiber interconnect 50 µm........P-002-DS-5L-FSUAQ
1048 meters (3437 feet) (262 m / 872 ft x 4) of .............................6SN4+
Media 6 Category 6 U/UTP
16 meters (53 feet) of Series 6 quad-shielded coax..........................5781

Outlets (x 13 for total quantity)
1 faceplate (eight for modular furniture, five for walls) ......................no replacement yet
4 Category 6 outlets.......................................................................UN600-XX
2 LC connectors.............................................................................MFC-LCR-09
1 duplex LC adapter with mounting modules ..........................UNFA-LC02-AQ
2 five meter (one data/one voice) Category 6 patchcord cable .........UNC6-XX-15F
(four will be needed eventually)
1 five meter LC duplex patchcord cable (for fiber to the desk) ..........FEXLCLC42-MXM005

Coax connection
1 F-style connector

Telecommunications Room
1 48 port Category 6 copper patch panel (data).........................UNP610-48
1 24 port Category 6 copper patch panel (voice).........................UNP610-24
1 48 port fiber rack with panels and adapters.........................RFE-SLG-048-MFA-LC12-AQ
26 LC connectors..........................................................................MFC-LCR-09
1 F-style connector and female receptacle .................................UNA-F-F
26 five meter Category 6 patchcord cables (data and voice) ...........UNC6-XX-15F
13 five meter LC duplex patchcord cable (eventually) .................FEXLCLC42-MXM005

NOTE: Faceplates, outlets and cordage come in different colors.
Replace the XX in the part numbers with the code for the desired color:

<table>
<thead>
<tr>
<th>Color</th>
<th>Black (BK)</th>
<th>Blue (BL)</th>
<th>Cream (CM)</th>
<th>Gray (GY)</th>
<th>Green (GR)</th>
<th>Ivory (IV)</th>
<th>Orange (OR)</th>
<th>Red (RD)</th>
<th>Violet (VL)</th>
<th>Yellow (YL)</th>
<th>White (WH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faceplate</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Outlet</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cordage</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Cable management components will be required for any installation.
Order these on an as-needed basis:

- Telecom Racks
  RK3-45A
- Vertical Cable Managers
  VCMDS-84-10
- Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
  CR-SLR-10L18W
- Ladder tray radius
  CR90FCB-18W
- Ladder splice kit
  CRBSK
- Ladder wall support kit
  CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Distributed Backbone Segment

Page 73 is the basis for this example page which connects five telecommunications rooms to an equipment room. All TRs have active equipment for transmitting signals to the intermediate or main crossconnects. The first four floors have 100 Mb/s to 1 Gb/s connections; the fifth floor has full 1 Gb/s to the desktop and 10 Gb/s to the equipment room. The voice signals travel on their own network with each voice circuit carried to the equipment room by 25 pair Category 5e cabling (six U/UTP bundles per cable). Each story is 4.6 meters (15 feet) tall making the longest cable about 36 meters (118 feet) in length.

Cable types and count

LazrSPEED 300 multimode fiber works well over these speeds and distances. CommScope recommends using a riser-rated composite cable with 6 TeraSPEED single-mode fibers and 12 LazrSPEED 300 multimode fibers. This may seem like overkill, especially for floors 2 and 3. However, it provides ample capacity for growth while simplifying the purchasing process (only one type of cable to order). Remember to check local codes for confirmation of cable listing.

Cable routing and amount

For this example, take the height of the story and add five meters at each end for termination slack PLUS another three meters for the service loop. The top floor link requires 23 + 5 + 5 + 3 or 36 meters (about 118 feet) of cable. Remember to add another 10% (3 meters [10 feet]) to the total cable length. Subtract 4.6 meters for each lower floor link.

Termination considerations

Use connectorized patch cords to connect the patch panel to the active equipment.
Distributed Backbone Segment

Cable requirements
134 meters (440 feet) of 18 fiber riser cable ........................................ R-018-DS-CM-FMUOR/ (six TeraSPEED 8 µm/twelve LazrSPEED 300 50 µm) ........................................ 8W006/5L012

Telecommunications Rooms (each)
1 fiber rack-mount fiber patch panel .................................................. RFE-SLG-EMT/1U
1 12 port SM LC ganged adapter ......................................................... SFA-LC12-BL
1 12 port MM LC ganged adapter for 50 µm fiber .............................. MFA-LC12-AQ
18 LC connectors (6 single-mode/12 multimode) ................................. SFC-LCR-09 / MFC-LCR-09
9 five meter LC duplex patchcord cables .......................................... FEXLCLC42-MXM005 (3 single-mode/6 multimode) .............................................. FEWLCLC42-JXM005

Equipment Room
5 fiber rack-mount fiber patch panel .................................................. RFE-SLG-EMT/1U
5 12 port SM LC ganged adapter ......................................................... SFA-LC12-BL
5 12 port MM LC ganged adapter for 50 µm fiber .............................. MFA-LC12-AQ
90 LC connectors (30 single-mode/60 multimode) ............................... SFC-LCR-09 / MFC-LCR-09
45 five meter LC duplex patchcord cables ......................................... FEXLCLC42-MXM005 (15 single-mode/30 multimode) .............................................. FEWLCLC42-JXM005

Voice network
483 meters (1585 feet) of riser 25 pair Category 5e U/UTP cable .......... 5EN25
Category 5e outlets as required ......................................................... UNJS00-XX

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) ........................................... CR-SLR-10L18W
Ladder tray radius
CR90FCB-18W
Ladder splice kit
CRBSK
Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Collapsed Backbone Segment

This example is similar to page 138 except that collapsed backbones connect all the floors through patch panels in the telecommunication rooms. The voice signals travel on their own network with each voice circuit carried to the equipment room by 25 pair Category 5e cabling (six U/UTP bundles per cable). Each story is 4.6 meters (15 feet) tall making the longest cable about 36 meters (118 feet) in length.

A collapsed backbone is defined as a continuous link from the desktop to the equipment room. For flexibility the link will be patched in the telecommunications room. In this example, plenum horizontal cables are connectorized and patched to riser-rated cables.

Cable types and count

Using a riser-rated cable with 72 LazrSPEED 300 50 µm multimode fibers is recommended (additional single-mode fiber is not needed for these speeds and short distances). This much fiber may seem like overkill, especially for floors 1 - 3. However, it provides ample capacity for growth while simplifying the purchasing process (only one type of cable to order). Remember to check local codes before ordering cable.

Cable routing and amount

For this example, take the height of the story and add five meters at each end for termination slack PLUS another three meters for the service loop. The top floor link requires 23 + 5 + 5 + 3 or 36 meters (about 118 feet) of cable. Remember to add another 10% (3 meters (10 feet)) to the total cable length. Subtract 4.6 meters for each lower floor link.

Termination considerations

Use connectorized patch cords to connect the patch panel to the active equipment.
Collapsed Backbone Segment

Cable requirements
134 meters (440 feet) of 72 fiber LazrSPEED 300 .......... R-072-DS-5L-FMUAQ
50 µm multimode riser cable

Telecommunications Room (x 5 for total quantity)
1 fiber rack mount enclosure .................................... RFE-FXD-EMT-BK/4U
12 fiber panels with ganged adapters .......................... RFE-PNL-012-MFA-LC12-BK/4U-AQ
72 LC connectors .................................................. MFC-LCR-09

Telecommunications Room patch cords
92 one meter LC duplex patchcord cables
(one for each device) ............................................... FEXLCLC42-MXM001

Equipment Room
5 fiber rack mount enclosure ..................................... RFE-FXD-EMT-BK/4U
60 fiber panels with ganged adapters .......................... RFE-PNL-012-MFA-LC12-BK/4U-AQ
360 LC connectors .................................................. MFC-LCR-09
92 five meter LC duplex patchcord cables ..................... FEXLCLC42-MXM001

Voice network
483 meters (1585 feet) of riser 25 pair
Category 5e U/UTP cable ......................................... 5EN25
Category 5e outlets as required ................................. UNJ500-XX

Cable management components will be required for any installation.
Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Fiber to the Enclosure

In this example, a factory has sales offices on the second floor and a management suite on the third floor. Since the third floor has a relatively small population of twenty desktops and is located over 100 cabled meters from the second floor telecommunications room, the best combination of cost and performance is to serve the area with a fiber enclosure (FTTE) with active electronics and a patch panel. (NOTE: depending on the type and speed of the network, the suite may be served by a twisted pair, fiber or wireless technologies.)

Cable types and count

Because the cable will be conveyed through the ceiling, a plenum-rated LazrSPEED 300 multimode fiber cable (preferably but not necessarily unspliced) should be used to connect the enclosure to the equipment room. FTTE is designed to take advantage of the lower cost, small port count switches, so use two fibers for every 8 or 12 ports, with a minimum of two additional fibers for redundancy and growth.

Cable routing and amount

The cable will be conveyed by cable ladders in a plenum space. The horizontal distance is 100 meters, with two riser transitions of one story (4 meters) PLUS 3 meters to reach and enter the enclosure PLUS the equipment room’s diagonal-plus-three-meters slack PLUS three meters for ceiling-to-floor in the equipment room. Remember to add 10% to the total cable length.

Termination considerations

The fiber cable should be connectorized at both ends with the connector system of choice.
Fiber to the Enclosure

Cable requirements
150 meters (492 feet) of 6 fiber LazrSPEED 300 .................. P-006-DS-SL-FSUAQ
50 µm multimode plenum cable

Telecommunication Enclosure
1 wall-mounted enclosure ................................................. WFE-012-MFA-LC12-BK/2PAQ
6 LC connectors .............................................................. MFC-LCR09
1 fiber rack mount enclosure with adapters ......................... RFE-SLG-024-MFA-LC12-AQ
1 fiber patch cable connector ........................................... FEXLCLC42-AXM001
(NOTE: replace XXX with type on active equipment)

Equipment Room
6 LC connectors .............................................................. MFC-LCU09
1 fiber rack mount enclosure with adapters ......................... RFE-SLG-024-MFA-LC12-AQ
1 fiber patch cable connector ........................................... FEXLCLC42-AXM001
(NOTE: replace XXX with type on active equipment)

General
Tools and consumables for connectorization ......................... FOTKIT-TOL-SC/ST/LC-ANA
Adhesive and polish paper ............................................... FOTKITCON-MUNIV-100
and FOTKITCON-ANA

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10(L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Small Campus Backbone Segment

In this example, the equipment room at a corporate headquarters is connected to a factory 200 meters away. Terrain considerations (in this case, a stream) indicates the use of messengered aerial cable. Traffic speeds of 10 Gb/s can be handled over this distance by multi-mode fiber pairs (with single-mode fiber installed alongside them for future growth). The connection to the local access vault is an underground single-mode optical cable.

Cable types and count
LazrSPEED 300 multimode fiber works well at this speed and distance. A messengered outside plant loose tube cable with six 50 µm high-bandwidth multimode fibers can handle present campus backbone needs. Six more fibers should be added for future considerations. Another six TeraSPEED 8 µm single-mode fibers should be installed as well. The cable to the local access vault is an outside plant central tube single-mode cable. Furcation kits will be required.

Cable routing and amount
Messengered cable needs support about every 100 meters (330 feet) so a pole or two needs to be erected along the right of way. The “distance-plus-10%” rule applies for calculating the amount of cable, but be sure to factor in the distance from the building attachment points to the equipment rooms and any elevation changes (if MC is 60 meters higher than IC 1, then using $a^2 + b^2 = c^2$ shows the cabled distance to be 209 meters) plus equipment room drop and slack.

Termination considerations
The cables terminate at entrance facilities and will be mechanically or fusion spliced to pigtails.
Small Campus Backbone Segment

Cable requirements
110 meters of outside plant central tube .................. O-012-CN-8W-F12NS
with 12 TeraSPEED 8 µm single-mode fibers

230 meters of messengered outside plant ............ M-018-LN-CM-F12NS/8BW006/5L012
stranded loose tube with 6 single-mode fibers / 12 LazrSPEED 300 50 µm multimode fibers.

Local access connection to MC
1 each break-out kit .............................................. KIT-090-006 and KIT-090-012
1 entrance facility .............................................. WBE-FXC-024-WH
1 splice clip .......................................................... SPT-FXS-SFS-CLP/3P
1 twelve pack of colored single-mode SC pigtails..... RFT-12BF09-8W-SCU-03
2 fiber panels with ganged adapters ...................... RFE-PNL006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per incoming application .. FEWSCSC52-JXM010
from the service provider

At each Equipment Room (x 2 for total quantity)
1 each break-out kit .............................................. KIT-090-006 and KIT-090-012
1 fiber rack-mount fiber patch panel ...................... RFE-SLG-EMT/1U
1 6 port SM LC ganged adapter ............................... SFA-LC06-BL
1 6 port MM LC ganged adapter for 50 µm fiber .... MFA-LC06-AQ
1 six pack of colored single-mode SC pigtails ....... FAWSCUC0A-XXM003
1 twelve pack of multimode SC pigtails ................... FAXSCUC0C-XXM003
1 SC two-fiber patchcord per active equipment ........ FEWSCSC52-JXM010
FEXSCSC52-MXM010

General
1 package of 50 splice protectors* ...................... SFS-SLEEVE
1 package splice holders (1 per fiber shelf) ........... SPT-FXS-SFS-HLD/1U

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

Cable management components will be required for any installation.

Order these on an as-needed basis:
Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m [10 x 1.5 ft]
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Triathlon Indoor/Outdoor Cable

Page 75 is the basis for this example where five buildings are linked at multi-gigabit speeds using single-mode fiber pairs. Triathlon tight buffered cable is being used for the campus backbone while outside plant cable is recommended for the local access link. Indoor/outdoor cables eliminate the need for transition at the entrance facility. Tight buffered fibers eliminate the need for breakout kits and their associated labor.

Fiber count

The singlemode TeraSPEED six-fiber campus backbones provide a good upgrade path at minimal extra cost. The singlemode 24 fiber cable for the local access link has enough spare fiber to accommodate growth. Loose tube outside plant cable is specified for the local access link.

Cable routing and amount

The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be field connectorized; the local access fibers will have pigtails spliced onto them.

Tight buffered cables do not need to be furcated prior to termination, so furcation (or break-out) kits are not necessary for the campus cables.
Large Star Campus Using Triathlon Indoor/Outdoor Cable

Cable requirements
110 meters of outside plant loose tube cable ........................................ D-0241N-8WF12NS with 24 TeraSPEED 8 µm single-mode fibers

5300 meters of Triathlon tight-buffer with 6 single-mode fibers .. Z-006-DS-8W-FSUBK

Local access connection to MC
2 breakout kits ................................................................. KIT0900012
1 entrance facility ............................................................ VBE-FXC-048-WH
1 splice clip ...................................................................... SPTFXSSFSCLP/3P
2 twelve packs of single-mode SC pigtails ....................... RFT12BF09-8W-SCU-03
4 fiber panels with ganged adapters ................................ RFE-PNL006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per incoming application .............. FEWSCSC52JXM010

At each IC (x 4 for total quantity)
1 rack mounted fiber enclosure with adapters ................. RFE-SLG-024-SFA-SC06
6 single-mode SC connectors ........................................... SFC-SCR09
1 SC two-fiber patchcord per active equipment .............. FEWSCSC52JXM010

Campus cable connections at MC
1 fiber rack mount enclosure ........................................... RFE-FXD-EMT-BK/4U
24 single-mode SC connectors ............................................ SFC-SCR09
4 fiber panels with ganged adapters .............................. RFE-PNL006-SFA-SC06-BK/4U
8 blank panels ................................................................. RFE-PNLBLANK-BK/4U
1 SC two-fiber patchcord per active equipment .............. FEWSCSC52JXM010

General
1 package of 50 splice protectors* .................................... SFS-SLEEVE

*Cable management components will be required for any installation.

Order these on an as-needed basis:

- Telecom Racks
  - RK3-45A
- Vertical Cable Managers
  - VCMDS-84-10
- Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
  - CR-SLR-10L18W
- Ladder tray radius
  - CR90FCB-18W
- Ladder splice kit
  - CRBSK
- Ladder wall support kit
  - CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Loose Tube Indoor/Outdoor Cable

Page 75 is the basis for this example which is expanded upon on page 146. Five buildings are linked at multi-gigabit speeds using single-mode fiber pairs. The difference is that riser-rated indoor/outdoor central tube cable has been installed in the buried conduit for the campus backbone. While not as environmentally robust at temperature extremes as a pure outside plant cable, indoor/outdoor cable does offer advantages in termination (see below). Outside plant cable is recommended for the local access link.

Fiber count

Fiber counts are identical to the tight buffered example on 146. The TeraSPEED single-mode six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The single-mode 24 fiber cable (a central tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable used for the campus backbone does not require transition at the entrance facility.

The cable fibers will be field connectorized. Loose tube cable must be furcated prior to connectorization (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Star Campus Using Loose Tube Indoor/Outdoor Cable

Cable requirements

110 meters of outside plant central tube ...................... O024CN-8WF12NS
with 24 TeraSPEED 8 µm single-mode fibers

5300 meters of indoor/outdoor central tube ...................... R006CN-8WF12BK
with 6 single-mode fibers

Local access connection to MC

2 break-out kits ............................................................ KIT090-012-CT
1 entrance facility ........................................................ WBE-FXC-048-WH
1 splice clip ............................................................... SPTFXS-SFS-CLP/3P
2 twelve packs of colored single-mode SC pigtails ............. RFT-12BF09-8W-SCU-03
4 fiber panels with ganged adapters ............................... RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per incoming ............................ FESWSC52-JXM010

Application from the service provider

At each IC (x 4 for total quantity)

2 break-out kits ............................................................ KIT090-006-CT
1 rack mounted fiber enclosure with adapters ..................... RFE-SLG-024-SFA-SC06
6 single-mode SC connectors ....................................... SFC-SCR09
1 SC two-fiber patchcord per active equipment ................ FESWSC52-JXM010

Campus cable connections at MC

8 break-out kits (two for each incoming cable) .................... KIT090-006-CT
1 rack mounted fiber enclosure with adapters ..................... RFE-SLG-024-SFA-SC06
24 single-mode SC connectors ...................................... SFC-SCR09
1 SC two-fiber patchcord per active equipment ................ FESWSC52-JXM010

General

1 package of 50 splice protectors* .................................. SFS-SLEEVE

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Loose Tube Outside Plant Cable

Page 75 is the basis for this example which is expanded upon on page 148. Five buildings are linked at multi-gigabit speeds using single-mode fiber pairs. The difference is that environmentally-robust outside plant central tube cable is being installed in buried conduit for all outdoor links.

Fiber count

Fiber counts are identical to the tight-buffered example on 148. The TeraSPEED single-mode six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The single-mode 24 fiber cable (a central tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Outside plant cable requires transition at the entrance facilities at each building. Although the local access cable could be terminated along with the campus cable at the main crossconnect (MC), housekeeping practices call for a separate fiber closure.

The outdoor cable’s fibers will be fusion or mechanically spliced to single-mode pigtails. Loose tube/central tube fibers must be furcated prior to splicing (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Star Campus Using Loose Tube Outside Plant Cable

Cable requirements

110 meters of outside plant central tube .................................. O-024-CN-8W-F12NS with TeraSPEED 8 µm 24 single-mode fibers

5300 meters of outside plant central tube ........................... O-006-CN-8W-F12NS with 6 single-mode fibers

Local access connection to MC

2 break-out kits ......................................................... KIT-090-012-CT
1 entrance facility ................................................. WBE-FXC-048-WH
1 splice clip ............................................................. SPT-FXS-SFS-CLP/3P
2 twelve packs of colored single-mode SC pigtails .............. RFT-12BF09-8W-SCU-03
4 fiber panels with ganged adapters ................................ RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per incoming ......................... FEWSCSC32-SC52-JX5010
application from the service provider

At each IC (x 4 for total quantity)

2 break-out kits ......................................................... KIT-090-006-CT
1 entrance facility ................................................ WBE-FXC-048-WH
1 splice clip ............................................................. SPT-FXS-SFS-CLP/3P
1 six pack of colored single-mode SC pigtails .............. RFT06BF09-8W-SCU-03
1 fiber panel with ganged adapters ................................ RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per active equipment ............ FEWSCSC32-SC52-JX5010

Campus cable connections at MC

8 break-out kits (two for each incoming cable) ............. KIT-090-006-CT
1 entrance facility ................................................ WBE-FXC-048-WH
1 splice clip ............................................................. SPT-FXS-SFS-CLP/3P
2 twelve packs of colored single-mode SC pigtails ........... RFT-12BF09-8W-SCU-03
4 fiber panels with ganged adapters ................................ RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per active equipment ............ FEWSCSC32-SC52-JX5010

General

2 package of 50 splice protectors* ................................... SFS-SLEEVE

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-11018W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.
Large Ring Campus Using Triathlon Indoor/Outdoor Cable

Page 76 is the basis for this example in which five buildings are linked in a counter-rotating ring at multi-gigabit speeds using single-mode fiber pairs. Triathlon indoor/outdoor tight-buffered cable is being used for the campus backbone while outside plant cable is recommended for the local access link. Indoor/outdoor cables eliminate the need for transition at the entrance facility. Tight buffered fibers eliminate the need for breakout kits and their associated labor.

Fiber count

A TeraSPEED single-mode fiber pair can support present campus traffic. However, installing a six fiber cable provides a good upgrade path at minimal extra cost. The single-mode 24 fiber cable for the local access link has enough spare fiber to accommodate growth. A stranded loose tube outside plant cable is used in this example.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be field connectorized; the local access fibers will have pigtails spliced onto them.

Tight buffered cables do not need to be furcated prior to termination so furcation, or break-out, kits are not necessary for the campus cables.
Large Ring Campus Using Triathlon Indoor/Outdoor Cable

**Cable requirements**

110 meters of outside plant loose tube .................................. D-024-LN-BW-F12NS with TeraSPEED 8 µm 24 single-mode fibers

5300 meters of Triathlon indoor/outdoor single unit ............... Z-006-DS-8W-FSUBK with 6 single-mode fibers

**Local access connection to MC**

1 breakout kit ................................................................. KIT-090-012

1 entrance facility .............................................................. WBE-FXC-048-WH

1 splice clip ................................................................. SPT-FXS-SFS-CLP/3P

2 twelve packs of colored single-mode SC pigtails ............... RFT-12BF09-BW-SCU-03

4 fiber panels with ganged adapters ................................ RFEPNL-006-SFA-SC06-WH/4U

1 SC two-fiber patchcord per incoming ................................. FEWSCSC52JXM010 application from the service provider

At each IC and the MC (x5 for total quantity)

1 rack mounted fiber enclosure with adapters ................................ RFE-SLG-024-SFA-SC06

12 single-mode SC connectors ........................................ SFC-SCR-09

2 SC two-fiber patchcord per active equipment per application. FEWSCSC52JXM010

**General**

1 package of 50 splice protectors* ...................................... SFS-SLEEVE

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

**Cable management components will be required for any installation.**

**Order these on an as-needed basis:**

- Telecom Racks
  - RK3-45A
- Vertical Cable Managers
  - VCMD-84-10
- Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
  - CR-SLR-10L18W
- Ladder tray radius
  - CR90FCB-18W
- Ladder splice kit
  - CRBSK
- Ladder wall support kit
  - CRTWSBK-18W

**NOTE:** See CommScope Enclosure Catalog for other accessories.
Large Ring Using Loose Tube Indoor/Outdoor Cable

Pages 76 and 152 are the basis for this example in which five buildings are linked in a counter-rotating ring at multi-gigabit speeds using single-mode fiber pairs. The difference is that riser-rated indoor/outdoor central tube cable has been installed in the buried conduit for the campus backbone. While not as environmentally robust at temperature extremes as a pure outside plant cable, indoor/outdoor cable does offer advantages in termination [see below]. Outside plant cable is recommended for the local access link.

Fiber count

Fiber counts are identical to the tight buffered example on 152. The TeraSPEED single-mode six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The single-mode 24 fiber cable (a central tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be connectorized; the local access fibers will have pigtails spliced onto them. The cable’s fibers will be connectorized. Loose tube cables must be furcated prior to connectorization (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Ring Using Loose Tube Indoor/Outdoor Cable

Cable requirements
110 meters of outside plant central tube ........................................... O-024-CN-8WF12NS
with TeraSPEED 8 µm 24 single-mode fibers

5300 meters of indoor/outdoor central tube with ....................... R-006-CN-8WF12BK
6 single-mode fibers

Local access connection to MC
2 break-out kits ........................................................................ KIT090-012-CT
1 entrance facility .................................................................... WBE-FXC-048-WH
1 splice clip .............................................................................. SPT-FXS-SFS-CLP/3P
2 twelve packs of colored single-mode SC pigtails ................. RFT-12BF09-8W-SCU-03
4 fiber panels with ganged adapters ................................. RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patchcord per incoming .............................. FEWSCSC52JXM010

At each IC and the MC (x 5 for total quantity)
4 break-out kits ........................................................................ KIT090-006-CT
1 rack mounted fiber enclosure with adapters ..................... RFE-SLG-004-SFA-SC06
12 single-mode SC connectors ................................................. SFC-SCR-09
2 SC two-fiber patchcord per active equipment per application .. FEWSCSC52JXM010

General
1 package of 50 splice protectors* ..................................... SFS-SLEEVE

*Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) ................................ CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Ring Campus Using Loose Tube Outside Plant Cable

Pages 76 and 154 are the basis for this example in which five buildings are to be linked in a counter-rotating ring at multi-gigabit speeds using single-mode fiber pairs. The difference is that environmentally-robust outside plant central tube cable is being installed in buried conduit for all outdoor links.

Fiber count

Fiber counts are identical to the tight buffered example on 154. The TerraSPEED single-mode six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The single-mode 24 fiber cable (a central tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Outside plant cable requires transition at the entrance facilities at each building. Although the local access cable could be terminated along with the campus cable at the main crossconnect (MC), housekeeping practices call for a separate fiber closure.

The outdoor cable’s fibers will be fusion or mechanically spliced to single-mode pigtails. Loose tube cables must be furcated prior to splicing (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Ring Campus Using Loose Tube Outside Plant Cable

Cable requirements

110 meters of outside plant central tube ............................................ O-024-CN-8W-F12NS with TeraSPEED 8 µm 24 single-mode fibers

5300 meters of outside plant central tube with 6 single-mode fibers ... O-006-CN-8W-F12NS

Local access connection to MC

2 break-out kits .................................................................................. KIT-090-012-CT
1 entrance facility ................................................................................ WBE-FXC-024
1 splice clip .......................................................................................... SPT-FXS-SFS-CLP/3P

2 twelve packs of colored single-mode SC pigtails .................. RFT-12BF09-8W-SCU-03
4 fiber panels with ganged adapters ............................................. RFE-PNL-006-SFA-SC06-WH/4U
1 SC two-fiber patch cord per incoming ...................................... FEWSCSC52JXM010

Application from the service provider

At each IC and the MC (x 5 for total quantity)

2 break-out kits .................................................................................. KIT-090-006-CT
1 entrance facility ................................................................................ WBE-FXC-024
1 splice clip .......................................................................................... SPT-FXS-SFS-CLP/3P
1 twelve pack of colored single-mode SC pigtails .................. RFT-12BF09-8W-SCU-03
2 fiber panels with ganged adapters ............................................. RFE-PNL-006-SFA-SC06-WH/4U
2 SC two-fiber patch cords per active equipment .................... FEWSCSC52JXM010

General

1 package of 50 splice protectors* .................................................. SFS-SLEEVE

*Cable management components will be required for any installation.

Order these on an as-needed basis:

- Telecom Racks
  RK3-45A

- Vertical Cable Managers
  VCMDS-84-10

- Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
  CR-SLR-10L18W

- Ladder tray radius
  CR90FCB-18W

- Ladder splice kit
  CRBSK

- Ladder wall support kit
  CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
CCTV Network

In this example, a college campus is being monitored by CCTV cameras cabled to a central location. The control room has both real-time monitors and digital video recording. The distances vary considerably; four local cameras are within 300 meters (just under 1000 ft) of the control room, while three cameras covering a remote campus are over 1200 meters (a little under 4000 feet) away. All cameras have PTZ (pan tilt zoom) control, which requires electrical power.

Cable types and count

Because this CCTV system is independent of the data system, all the cameras are cabled directly to the control room in a star topology. With this straightforward approach, the four local cameras can be connected with either RG 6-style coax with a power leg to supply the PTZ control OR Category 6 twisted pair cable. The Category 6 option will require additional electrical cable to power the cameras.

The three more distant locations are being served with fiber optic cable; power can be taken from the building or the light poles. All cables are directly buried or share conduit with other cabling systems. Distances are shown plus the rise of the poles in the parking lots and the buildings, plus the usual 10%.

Termination considerations

The fiber will require the use of electro-optical converters.
CCTV Network

Cable requirements
600 meters (1969 feet) of RG6-style coax cable with power leg .......... 5654
OR
600 meters (1969 feet) of Category 6 Media 6 U/UTP ........................ 65N4+

14,000 meters (45932 feet) of indoor/outdoor two-fiber ................. Z-002 IC-8W-F29BK interconnect cable with TeraSPEED 8 µm single-mode fibers

Two-conductor electrical wire for PTZ at campus location

Termination
6 single-mode SC connectors ......................................................... SCF-SCR-09

8 BNC connectors for coax cables as required
OR
8 Category 6 connectors for the U/UTP cable ............................. UNJ600XX

U/UTP patchcords ....................................................................... UNC6XFYY

Cable management components will be required for many installations.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Discrete Security Network

In this example, a manufacturing plant with several controlled entrances uses a variety of security devices wired back to a central control room. Each door has CCTV, carded entry and motion detectors as well as pull switches for a fire alarm.

Cable types and count

Transmission distances vary for each type of device. The CCTV cameras can be powered locally, so a standard riser RG6-style cable is recommended. Carded entry can be handled by a 22 AWG control cable; motion-detectors can use a six conductor 22 AWG cable; and the fire alarm can be wired with a two conductor 18 AWG cable.

Cable routing and amount

The cable will be conveyed by cable ladders, so riser cables are recommended in this example (note that local codes may require the use of plenum cables). Calculate cable length by taking the measured distance for each drop (taking a right-angled route) PLUS three meters slack PLUS three meters ceiling-to-floor in the control room. Remember to add 10% to the total cable length.

Termination considerations

The cameras will use standard BNC connectors. Consult the manufacturers of the other systems to determine their connection requirements. In many cases, wires are just stripped and terminated.
Discrete Security Network

Cable requirements
290 meters (950 feet) of riser-rated RG6-style coax cable .................. 5700
(2277V if plenum)

290 meters (950 feet) of two conductor control cable for carded entry .... S222USTR
(S222USTP if plenum)

290 meters (950 feet) of six conductor control cable for motion detectors . S622SSTR
(S622SSTP if plenum)

290 meters (950 feet) of S218USOR for fire alarm .......................... S218USOR
(S218USOR if plenum)

Termination
8 BNC connectors for coax cables as required* 

*C most security devices do not need special termination hardware

Cable management components will be required for many installations.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Integrated Security Network

In this example, a manufacturing plant with four controlled entrances will use twisted pair cable to carry a variety of security signals back to a central monitoring location. Carded entry, CCTV, electronic locks and motion detectors are used for all outside doors and a door above the entrance to the data processing facility. All of these units have Ethernet twisted pair adapters and are connected to an Ethernet hub above the door. Cables from each door feed back to the telecommunications room which then connects to the security control room.

Cable types and count

The distances involved in this example are under 90 meters, so the horizontal links can be supported by Category 6 twisted pair cable (recommended for the video portion of the connection).

Cable routing and amount

The riser-rated cable will be conveyed by cable ladders. Calculate cable length by taking the measured distance for each drop (taking a right-angled route) PLUS one meter for the drop to the hub PLUS the telecommunications room’s distance (follow the cable tray) PLUS three meters PLUS three meters ceiling-to-floor in the telecommunications room. Remember to add 10% to the total cable length.

Termination considerations

The four incoming cables will be added to the existing data network, using four incoming ports and one outgoing port for the connection to the security control room.
Integrated Security Network

Cable requirements
370 meters (1214 feet) of Category 6 Media 6 U/UTP ............................... 6SN4+
16 U/UTP patchcord (one for each devices/four per door) ............................ UNC6XF-YY

Telecommunications Room
5 U/UTP patchcord (one for each door x 4/one to security control room) ....... UNC6XF-YY
5 ports in the patch panel (4 for incoming and 1 link to security control room) . UNP610-24

Cable management components will be required for any installation.

Order these on an as-needed basis:

- Telecom Racks
  - RK3-45A
- Vertical Cable Managers
  - VCMDS-84-10
- Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
  - CR-SLR-10L18W
- Ladder tray radius
  - CR90FCB-18W
- Ladder splice kit
  - CRBSK
- Ladder wall support kit
  - CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
SYSTIMAX® Annex

Bill Of Materials (BOM) examples for SYSTIMAX Solutions

In this section, the information presented earlier is applied to networks of various size and complexity. These sample networks compare the advantages of various media and determine the amount of cable and components required to install various network types.

Remember that these are basic examples. When applying these lessons to the ‘real world,’ other factors, such as budgetary constraints, right of way issues, existing equipment and even the local weather, will affect which components are installed. The ‘rules of thumbs’ may need to be cut and fit to adapt to particular circumstances. In any case, remember to contact CommScope Technical Support at support@commscope.com for expert advice.

For more information about cables, components, or services, contact CommScope Customer Care or visit www.commscope.com

For answers about installation procedures, contact CommScope Technical Support or email support@commscope.com
Small Horizontal Segment with Riser Backbone

In this example, a small network of 5 PCs and a shared printer make up a horizontal segment. All offices and the telecommunications room have a telephone wired to a central PBX via a discrete voice network. The data network supports 100 Mb/s horizontal links and concentrates at the active equipment (an Ethernet switch) for 1 Gb/s transmission to the building’s equipment room. Sample labeling is shown for the cables. A1-Axx connects to the fiber panel; A1-Bxx are data twisted pair; A1-Cxx are voice cables.

Cable types and count

The distances involved in this example are under 90 meters, so the 100 Mb/s horizontal links are supported by Category 6 twisted pair cable. For future growth, each desktop should be cabled with a pair of multimode fibers. The voice network can be wired with Category 5e twisted pair cable. Because the cable is carried along a conveyance in a plenum ceiling, plenum-rated cable is required. Riser-rated cable is used for the riser backbone. Local codes may supersede these recommendations.

Cable routing and amount

The conveyance is placed centrally as shown. Calculate cable length by taking the measured distance (taking a right-angled route) PLUS three meters for the ceiling-to-outlet drop and termination slack PLUS the length of the tray in the telecommunications room PLUS three meters for ceiling-to-floor in the telecommunications room. The orange line shown would be 21 meters (69 feet). Remember to add 10% to the total cable length. Cable is installed in the tray; J-hooks support cables to the outlets. While the cables can be pulled separately, a bundled cable may be used to speed installation.

Termination considerations

Using the formula for calculating the number of ports from page 69 (devices x 2), install 12 data ports at the horizontal crossconnect and 12 ports for the voice connections.

Twisted pair cables are hardwired into the back of the patch panel. Connectorize fiber optic cables and plug them into adapters in the fiber panels. The patch panel is connected to the active equipment by connectorized patch cords.
Small Horizontal Segment with Riser Backbone

Cable requirements
210 meters (690 feet) of plenum two-fiber 50 μm cable ........... P-002-DS-5L-FSUAQ
210 meters (690 feet) of plenum XL7 Category 6 U/UTP cable..... 1071
210 meters (690 feet) of plenum PowerSUM Cat 5e U/UTP cable .... 1061

Work areas (x 7 for total quantity)
2 wall-mount faceplates (only 1 for telecommunications room) .... M12l-XXX
2 Category 6 jacks ........................................................... MGS400-XXX
2 Category 5e jacks ..................................................... MPS100E-XXX
2 duplex LC adapters with mounting modules ....................... MFA-LC03-AQ
Mounting collars (pack of 25) ........................................ M81LC-029-Collar
1 five meter Category 6 patchcord cable ............................ CPC3382-OXF015
1 five meter Category 5e patchcord cable ........................... CPC6642-OXF015
1 five meter LC duplex patchcord cable (for fiber to the desk) .... FEXLCLC42-MXF015

Telecommunications Room
1 24 port Category 6 copper patch panel ........................... 360-1100-GS3-24
1 48 port fiber rack-mounted panel .................................. 360G2-1UMOD-SD
4 modules with adapters .................................................. 360G2 Cartridge 12LCLS-015
1 24 port Category 5e patch panel (voice) ......................... 1100PSCAT5E-24
12 LC connectors ......................................................... MFC-LC09
12 five meter Category 6 patchcord cables ......................... CPC3382-OXF015
12 five meter Category 5e patchcord cable (voice) ............... CPC6642-OXF015
12 five meter LC patchcord cables .................................. FEXLCLC42-MXF015

NOTE: Faceplates, outlets and cordage come in different colors.
Replace the XXX in the faceplate/outlet part numbers with the code for the desired color:

<table>
<thead>
<tr>
<th>Color Code</th>
<th>Black 003</th>
<th>Orange 112</th>
<th>Yellow 123</th>
<th>Green 226</th>
<th>Ivory 246</th>
<th>White 262</th>
<th>Gray 270</th>
<th>Red 317</th>
<th>Blue 318</th>
<th>Violet 361</th>
<th>Cream 215</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faceplate</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Outlet</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Replace the X in the patchcord part number with the code for the desired color:

<table>
<thead>
<tr>
<th>Color Code</th>
<th>Black 003</th>
<th>Orange 112</th>
<th>Yellow 123</th>
<th>Green 226</th>
<th>Ivory 246</th>
<th>White 262</th>
<th>Gray 270</th>
<th>Red 317</th>
<th>Blue 318</th>
<th>Violet 361</th>
<th>Cream 215</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cordage</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Cable management components will be required for any installation.
Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-1018W

Ladder tray radius CR90FCB-18W

Ladder splice kit CRBSK

Ladder wall support kit CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Larger Horizontal Segment with Riser Backbone - 10 Gb/s

Pages 71 and 83 are the basis for this example which is slightly modified to add a voice connection at every outlet and a phone in the telecommunications room (every job has changes). In this scenario, an animation studio is leasing this space and will require high data rates to accommodate frequent transfer of large computer generated imagery (CGI) files. Thirteen outlets will carry four Category 6A cables (one data/one voice/two for growth) and one two-fiber cable. All desktops support 10 Gb/s.

Cable types and count

The distances involved in this example are under 90 meters, so the 10 Gb/s horizontal links are supported by Category 6A twisted pair cable. For future growth, each desktop has two additional twisted pair cables and one fiber optic pair. Cable the voice network with Category 6A twisted pair cable. The hung ceiling is not a plenum space, so riser-rated cable may be used (although this recommendation may be superseded by local codes).

Cable routing and amount

Place the conveyance as shown. Calculate cable length by taking the measured distance (taking a right-angled route) PLUS three meters for the ceiling-to-outlet drop and termination slack PLUS the length of the tray in the telecommunications room PLUS three meters for ceiling-to-floor in the telecommunications room. The orange line shown is 25 meters (82 feet). Remember to add 10% to the total cable length. Install cable in the tray; use J-hooks to support cables to the outlets. While the cables may be pulled separately, bundled or hybrid cables will speed the installation.

Termination considerations

Thirteen outlets times three data U/UTP equals 39 patch ports. Since growth is already figured in with the extra U/UTPs, a 48 port patch should be sufficient. Thirteen voice circuits times two is 26; a 24 port panel should work.

Thirteen fiber pairs times two is 52 fibers, so a 48 port panel should be large enough.
Larger Horizontal Segment with Riser Backbone - 10 Gb/s

Cable requirements
262 meters (872 feet) of plenum two-fiber interconnect 50 μm cable ..... P-002-DS-5L-FSUAQ
1048 meters (3437 feet) (262 m / 872 ft x 4).............................1091
of X10D Category 6A U/UTP

Outlets (x 13 for total quantity)
1 faceplate [eight for modular furniture, five for walls] ..................M12L-XXX
4 Category 6A jacks ..............................................................MGS500-XXX
2 LC connectors .................................................................MFC-LCR-09
1 duplex LC adapter with mounting modules ............................MGA-LC02-AQ
Mounting collars [pack of 25] ................................................M81LC-029-Collar
2 five meter (one data/one voice) Category 6 .........................CPC3382-0XF015
patchcord cable (four eventually)
1 five meter LC duplex patchcord cable [for fiber to the desk] ........FEXLCLC42-MXF015

Telecommunications Room
1 48 port Category 6A copper patch panel (data) .....................360-1100GS5-48
1 24 port Category 6A copper patch panel (voice) .....................360-1100GS5-24
1 48 port fiber rack-mounted panel .......................................360G2-1U-MOD-SD
4 modules with adapters ....................................................360G2 Cartridge
12-LC-LS-AQ

26 LC connectors ..............................................................MFC-LCR-09

26 five meter Category 6A patchcord cables [data and voice] ........CPC77G2-0XM005
13 five meter LC duplex patchcord cable [eventually] ...............FEXLCLC42-MXF015

NOTE: Faceplates, outlets and cordage come in different colors.
Replace the XXX in the faceplate/outlet part numbers with the code for the desired color:

<table>
<thead>
<tr>
<th>Color</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>003</td>
</tr>
<tr>
<td>Orange</td>
<td>112</td>
</tr>
<tr>
<td>Yellow</td>
<td>123</td>
</tr>
<tr>
<td>Green</td>
<td>226</td>
</tr>
<tr>
<td>Ivory</td>
<td>246</td>
</tr>
<tr>
<td>White</td>
<td>262</td>
</tr>
<tr>
<td>Gray</td>
<td>270</td>
</tr>
<tr>
<td>Red</td>
<td>317</td>
</tr>
<tr>
<td>Blue</td>
<td>318</td>
</tr>
<tr>
<td>Violet</td>
<td>361</td>
</tr>
<tr>
<td>Cream</td>
<td>215</td>
</tr>
</tbody>
</table>

Faceplate

Outlet

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m [10 x 1.5 ft] CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Distributed Backbone Segment

Page 73 is the basis for this example page which connects five telecommunications rooms to an equipment room. All TRs have active equipment for transmitting signals to the intermediate or main crossconnects. The first four floors have 100 Mb/s to 1 Gb/s connections; the fifth floor has a full 1 Gb/s to the desktop and 10 Gb/s to the equipment room. The voice signals travel on their own network with each voice circuit carried to the equipment room by 25 pair Category 5e cabling (six U/UTP per cable). Each story is 4.6 meters (15 feet) tall making the longest cable about 36 meters (118 feet) in length.

Cable types and count

LazrSPEED® 300 multimode fiber works well over these speeds and distances. CommScope recommends using a riser-rated hybrid cable with 6 TeraSPEED® single-mode fibers and 12 LazrSPEED 300 fibers. This may seem excessive, especially for floors 2 and 3. However, it provides ample capacity for growth while simplifying the purchasing process (only one type of cable to order). Remember to check local codes for confirmation of cable listing.

Cable routing and amount

For this example, take the height of the story and add five meters at each end for termination slack PLUS another three meters for the service loop. The top floor link requires 23 + 5 + 5 + 3 or 36 meters (about 118 feet) of cable. Remember to add another 10% (3 meters [10 feet]) to the total cable length. Subtract 4.6 meters for each lower floor link.

Termination considerations

Use connectorized patch cords to connect the patch panel to the active equipment.
Distributed Backbone Segment

Cable requirements
134 meters (440 feet) of 18 fiber ...........................................R-018-DS-CM-FSUAQ/
(six TeraSPEED/twelve LazrSPEED 300) riser cable 8W006/S1012

Telecommunications Rooms (each)
1 1U rack-mount fiber shelves ..................................................360G2-1U-MOD-SD
1 12-fiber G2 Module with TeraSPEED LC adapters ..........................360G2 Cartridge 12-LC-SM
1 12-fiber G2 Module with LazrSPEED LC adapters ..................................360G2 Cartridge 12-LC-LS
18 EZ-LC connectors™ (6 single-mode/12 multimode) ......................SFC-LCR-09 / MFC-LCR-09
9 five meter LC duplex patchcord cables (3 TeraSPEED/6 LazrSPEED) .......FEWLCLC42-JXM005 / FEXLCLC42-MXM005

Equipment Room
5 1U rack-mount fiber shelves ..................................................360G2-1U-MOD-SD
5 12-fiber G2 Module with TeraSPEED LC adapters ..........................360G2 Cartridge 12-LC-SM
5 12-fiber G2 Module with LazrSPEED LC adapters ..................................360G2 Cartridge 12-LC-LS
90 EZ-LC connectors™ (30 single-mode/60 multimode) ......................SFC-LCR-09 / MFC-LCR-09
45 five meter LC duplex patchcord cables (15 TeraSPEED/30 LazrSPEED) .......FEWLCLC42-JXM005 / FEXLCLC42-MXM005

Voice network
483 meters (1585 feet) of riser 25 pair Category 5e U/UTP cable ... 2061B WH 58/24
Category 5e outlets as required ..................................................MPS100E

Cable management components will be required for any installation.
Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Collapsed Backbone Segment

This example is similar to page 170 except that collapsed backbones connect all the floors through patch panels in the telecommunication rooms. The voice signals travel on their own network with each voice circuit carried to the equipment room by 25 pair Category 5e cabling (six U/UTP per cable). Each story is 4.6 meters (15 feet) tall making the longest cable about 36 meters (118 feet) in length.

A collapsed backbone is defined as a continuous link from the desktop to the equipment room. For flexibility the link will be patched in the telecommunications room. In this example, plenum horizontal cables are connectorized and patched to riser-rated cables.

Cable types and count

Using a riser-rated cable with 72 LazrSPEED 300 50 µm multimode fibers is recommended (additional single-mode fiber is not needed for these speeds and short distances). This much fiber may seem excessive, especially for floors 1 - 3. However, it provides ample capacity for growth while simplifying the purchasing process (only one type of cable to order). Remember to check local codes before ordering cable.

Cable routing and amount

For this example, take the height of the story and add five meters at each end for termination slack PLUS another three meters for the service loop. The top floor link requires 23 + 5 + 5 + 3 or 36 meters (about 118 feet) of cable. Remember to add another 10% (3 meters [10 feet]) to the total cable length. Subtract 4.6 meters for each lower floor link.

Termination considerations

Use connectorized patch cords to connect the patch panel to the active equipment.
Collapsed Backbone Segment

Cable requirements
134 meters (440 feet) of 72 fiber 50 μm LazrSPEED 300 ............. R-072-DS-5L-FMU AQ multimode riser cable

Telecommunications Room (x 5 for total quantity)
1 1U rack mounted fiber shelf ................................................ 360G2-4U-MOD-FX
12-fiber G2 modules with LazrSPEED LC adapters .................... 360G2 Cartridge 12-LC-LS
72 multimode EZ-LC connectors™ ......................................... MFC-LCR-09

Telecommunications Room patch cords
92 one meter LazrSPEED LC duplex patchcord cables ................ FEXLCLC42-MMF015 (one for each device)

Equipment Room
5 4U rack mounted fiber shelves ........................................... 360G2-4U-MOD-FX
60 12-fiber G2 modules with LazrSPEED LC adapters ............ 360G2 Cartridge 12-LC-LS
360 multimode EZ-LC connectors™ ..................................... MFC-LCR-09
92 five meter LazrSPEED LC duplex patchcord cables .......... FEXLCLC42-MMW005

Voice network
483 meters (1585 feet) of riser 25 pair Category 5e U/UTP cable ...... 2061B WH 58/24
Category 5e outlets as required ........................................... MPS100E

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Fiber to the Enclosure

In this example, a factory has sales offices on the second floor and a management suite on the third floor. Since the third floor has a relatively small population of twenty desktops and is located over 100 cabled meters from the second floor telecommunications room, the best combination of cost and performance is to serve the area with a fiber enclosure (FTTE) with active electronics and a patch panel. (NOTE: depending on the type and speed of the network, the suite may be served by a twisted pair, fiber or wireless technologies.)

Cable types and count
Because the cable will be conveyed through the ceiling, a plenum-rated LazrSPEED multimode fiber cable (preferably but not necessarily unspliced) should be used to connect the enclosure to the equipment room. FTTE is designed to take advantage of the lower cost, small port count switches, so only two fibers for every 8 or 12 ports are required, adding a minimum of two additional fibers for redundancy and growth.

Cable routing and amount
The cable will be conveyed by cable ladders in a plenum space. The horizontal distance is 100 meters, with two riser transitions of one story (4 meters) PLUS 3 meters to reach and enter the enclosure PLUS the equipment room’s diagonal-plus-three-meters slack PLUS three meters for ceiling-to-floor in the equipment room. Remember to add 10% to the total cable length.

Termination considerations
The fiber cable should be connectorized at both ends with the connector system of choice.
Fiber to the Enclosure

Cable requirements
150 meters (492 feet) of 6 fiber 50 μm .................................. P-006-DS-CM-
LazrSPEED 300 plenum cable FSUAQ/8W002/SL006

Telecommunication Enclosure
1 wall-mounted fiber enclosure ............................................ 100LS LIU1
12-fiber LC LIU Panel ......................................................... 10PLC-LS
6 LazrSPEED Qwik-LCII connectors® ..................................... QwikLCII, BTW
1 1U rack mounted fiber shelf ............................................. 360G2:1UMOD-FX 760103150
1 G2 module with LazrSPEED LC adapters ........................... 360G2 Cartridge 12LC-LS
1 fiber patch cord ............................................................. FEXLCIC42-MXM001
(NOTE: replace XX with connector type on active equipment)

Equipment Room
6 Qwik-LCII connectors® ..................................................... QwikLCII, BTW
1 1U rack mounted fiber shelf ............................................. 360G2:1UMOD-FX 760103150
1 12-fiber G2 module with LazrSPEED LC adapters .............. 360G2 Cartridge 12LC-LS
1 fiber patch cable ............................................................ FEXLCIC42-MXM001
(NOTE: replace XX with connector type on active equipment)

General
Tools and consumables for Qwik connectorization ............ Qwik Master Termination Tool Kit LC/SC/ST 760070664

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-10L18W

Ladder tray radius CR90FCB-18W

Ladder splice kit CRBSK

Ladder wall support kit CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Small Campus Backbone Segment

In this example, the equipment room at a corporate headquarters is connected to a factory 200 meters away. Terrain considerations (in this case, a stream) indicates the use of messaged aerial cable. Traffic speeds of 10 Gb/s can be handled over this distance by all-dry loose tube LazrSPEED 300 multimode fiber pairs (with TeraSPEED single-mode fiber installed alongside them for future growth). The connection to the local access vault is an underground single-mode optical cable.

Cable types and count

LazrSPEED 300 fiber works well at this speed and distance. An armored messengered outside plant loose tube cable with six 50 μm high-bandwidth LazrSPEED 300 fibers can handle present campus backbone needs. Six more fibers should be added for future considerations. Another six TeraSPEED fibers should be installed as well. The cable to the local access vault is an outside plant loose tube TeraSPEED cable. Furation kits will be required.

Cable routing and amount

Messaged cable needs support about every 100 meters (330 feet) so a pole or two needs to be erected along the right of way. The “distance-plus-10%” rule applies for calculating the amount of cable, but be sure to factor in the distance from the building attachment points to the equipment rooms and any elevation changes (if MC is 60 meters higher than IC 1, then using \(a^2 + b^2 = c^2\) shows the cabled distance to be 209 meters) plus equipment room drop and slack.

Termination considerations

The cables terminate at entrance facilities and will be mechanically or fusion spliced to pigtails.
Small Campus Backbone Segment

Cable requirements

110 meters of outside plant loose-tube with 12 TeraSPEED fibers ........................ D-012-LN-8W-F12NS

230 meters of messengered outside plant stranded loose tube with 6 TeraSPEED fibers / 12 LazrSPEED 300 fibers M-018-LA-CM-F12NS/8W006/5L012

Local access connection to MC

1 6-fiber break-out kit ....................................................... 6 Fiber Breakout Kit 760018820

1 12-fiber break-out kit ..................................................... 12 Fiber Breakout Kit 760018838

1 entrance facility .......................................................... SME-4-G2

1 splice holder ............................................................. RS-2AF-16SF

Pair of G2 modules with SC LazrSPEED pigtails ................... 360G2 Cartridge 6SCLSAQ-Pigtails A and 360G2 Cartridge 6SCLSAQ-Pigtails B

1 SC two-fiber patchcord per incoming application .......... FEXSCSC52-MM010

from the service provider

At each Equipment Room (x 2 for total quantity)

1 6-fiber break-out kit ....................................................... 6 Fiber Breakout Kit 760018820

1 12-fiber break-out kit ..................................................... 12 Fiber Breakout Kit 760018838

1 1U rack-mount fiber shelf, sliding .................................. 360G2-1U-MOD-SD

Splice holder .............................................................. RS-2AF-16SF

1 6-fiber G2 module with TeraSPEED SC pigtails .............. 360G2 Cartridge 6SC-SM

2 6-fiber G2 module with LazrSPEED SC pigtails .............. 360G2 Cartridge 6SC-LS

1 SC two-fiber patchcord per active equipment .......... FEXSCSC52-MM010

General

1 package of 50 splice protectors* .................................. SFS-SLEEVE

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Tight-Buffered Indoor/Outdoor Cable

Page 75 is the basis for this example where five buildings are linked at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. Tight buffered cable is being used for the campus backbone while outside plant cable is recommended for the local access link. Indoor/outdoor cables eliminate the need for transition at the entrance facility. Tight buffered fibers eliminate the need for breakout kits and their associated labor.

Fiber count
The TeraSPEED six-fiber campus backbones provide a good upgrade path at minimal extra cost. The TeraSPEED single-mode 24 fiber cable for the local access link has enough spare fiber to accommodate growth. All-dry loose tube outside plant cable is specified for the local access link.

Cable routing and amount
The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations
Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be field connectorized; the local access fibers will have pigtails spliced onto them.

Tight buffered cables do not need to be furredated prior to termination, so furcation (or break-out) kits are not necessary for the campus cables.
Large Star Campus Using Tight-Buffered Indoor/Outdoor Cable

Cable requirements

110 meters of outside plant all-dry loose tube cable .......... D-024-LN-8W-F12NS with 24 single-mode fibers

5300 meters of indoor/outdoor tight-buffered .................. Z-006-DS-8W-FSUBK with 6 TeraSPEED fibers

Local access connection to MC

2 12-fiber break-out kits ............................................. 12 Fiber Breakout Kit 760018838
1 entrance facility ...................................................... SME-4-G2
4 6-fiber LazrSPEED SC G2 modules w/pigtails .......... 360G2 Cartridge 6-SC-LS
1 splice holder .............................................. RS-2AF-16SF
1 SC two-fiber patchcord per incoming application ....... FEWSCSC52-JXM010 from the service provider

At each IC (x 4 for total quantity)

1 rack mounted fiber enclosure 1U .......................... 360G2-1U-MOD-SD
4 – 6-fiber G2 modules with TeraSPEED SC adapters .. 360G2 Cartridge 6-SC-SM
6 single-mode EZ-SC connectorsTM .......................... SFC-SCR-09
1 SC two-fiber patchcord per active equipment .......... FEWSCSC52-JXM010

Campus cable connections at MC

1 fiber rack mount shelf ............................................. 360G2-1U-MOD-FD
24 single-mode EZ-SC connectors ........................... SFC-SCR-09
4 – 6-fiber G2 modules with TeraSPEED SC adapters .. 360G2 Cartridge 6-SC-SM
1 SC two-fiber patch cord per active equipment .......... FEWSCSC52-JXM010

General

1 package of 50 splice protectors* ......................... SFS-SLEEVE

*Cable management components will be required for any installation.

Order these on an as-needed basis:

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecom Racks</td>
</tr>
<tr>
<td>RK3-45A</td>
</tr>
<tr>
<td>Vertical Cable Managers</td>
</tr>
<tr>
<td>VCMDS-84-10</td>
</tr>
<tr>
<td>Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)</td>
</tr>
<tr>
<td>Ladder tray radius</td>
</tr>
<tr>
<td>CR90FCB-18W</td>
</tr>
<tr>
<td>Ladder splice kit</td>
</tr>
<tr>
<td>CRBSK</td>
</tr>
<tr>
<td>Ladder wall support kit</td>
</tr>
<tr>
<td>CRTWSBK-18W</td>
</tr>
</tbody>
</table>

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Loose Tube Indoor/Outdoor Cable

Page 75 is the basis for this example which is expanded upon on page 178. Five buildings are linked at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. The difference is that riser-rated indoor/outdoor all-dry loose tube cable has been installed in the buried conduit for the campus backbone. While not as environmentally robust at temperature extremes as a pure outside plant cable, indoor/outdoor cable does offer advantages in termination [see below]. Outside plant cable is recommended for the local access link.

Fiber count

Fiber counts are identical to the tight buffered example on 178. The TeraSPEED six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The TeraSPEED 24 fiber cable (an all-dry loose tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable used for the campus backbone do not require transition at the entrance facility.

The cable fibers will be field connectorized. Loose tube cable must be furcated prior to connectorization (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Star Campus Using Loose Tube Indoor/Outdoor Cable

Cable requirements
110 meters of outside plant all-dry loose tube.......................D-024-LN-8W-F12NS with 24 single-mode fibers
5300 meters of indoor/outdoor loose tube..........................R-006-LN-8W-F06BK/25D with 6 single-mode fibers

Local access connection to MC
2 12-fiber break-out kits....................................................12 Fiber Breakout Kit 760018838
1 entrance facility............................................................SME-4-G2
Splice holder.................................................................RS-2AF-16SF
4 6-fiber G2 modules with TeraSPEED SC pigtails .................360G2 Cartridge 6-SC-LS
1 SC two-fiber patchcord per incoming application.............FEWSCSCS2-jXM010 from the service provider

At each IC (x 4 for total quantity)
2 6-fiber break-out kits......................................................6-Fiber Breakout Kit 760018820
1 rack mounted fiber enclosure .........................................360G2-1U-MOD-SD
1 6-fiber G2 module with TeraSPEED SC adapters.............360G2 Cartridge 6-SC-SM
6 single-mode EZ-SC connectors.......................................SFC-SCR-09
1 SC two-fiber patchcord per active equipment ..................FPCWSCSC32RM010

Campus cable connections at MC
8 6-fiber break-out kits (two for each incoming cable) .......6-Fiber Breakout Kit 760018820
1 rack mounted fiber enclosure .........................................360G2-1U-MOD-SD
24 single-mode EZ-SC connectors.................................SFC-SCR-09
4 6-fiber G2 module with TeraSPEED SC adapters ..........360G2 Cartridge 6-SC-SM
1 SC two-fiber patchcord per active equipment ...............FPCWSCSC32RM010

General
1 package of 50 splice protectors* ...................................SFS-SLEEVE

*Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Star Campus Using Loose Tube Outside Plant Cable

Page 75 is the basis for this example which is expanded upon on page 178. Five buildings are linked at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. The difference is that environmentally robust outside plant loose tube cable is being installed in buried conduit for all outdoor links.

Fiber count

Fiber counts are identical to the tight buffered example on 178. The TeraSPEED 6 fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The TeraSPEED 24 fiber cable (a loose tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cable from IC2 will pass uninterrupted through the entrance facility at IC1 and share conduit with the IC1 cable to the main crossconnect (MC). The IC4 and IC3 cabling will take a similar routing to the MC. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Outside plant cable requires transition at the entrance facilities at each building. Although the local access cable could be terminated along with the campus cable at the main crossconnect (MC), housekeeping practices call for a separate fiber closure.

The outdoor cable’s fibers will be fusion or mechanically spliced to TeraSPEED pigtails. Loose tube fibers should be furcated prior to splicing when using inside plant apparatus [see page 112] so a furcation, or break-out, kit will be required at each cable termination.
Large Star Campus Using Loose Tube Outside Plant Cable

Cable requirements
110 meters of outside plant all-dry loose tube .........................D-024-LN-BW-F12NS  with 24 single-mode fibers
5300 meters of outside plant all-dry loose tube .....................D-006-LN-BW-F06NS  with 6 single-mode fibers

Local access connection to MC
2 12-fiber break-out kits ..............................................12 Fiber Breakout Kit 760018838
1 entrance facility ......................................................SWE-4-G2
1 splice holder .........................................................RS-2AF-16SF
4 6-fiber G2 modules with TeraSPEED SC pigtails ............360G2 Cartridge 6-SCöLS
1 SC two-fiber patchcord per incoming application ..........FEWSCSC52jKW010
from the service provider

At each IC (x 4 for total quantity)
2 6-fiber break-out kits ..............................................6-Fiber Breakout Kit 760018820
1 entrance facility ......................................................SWE-4-G2
1 splice holder .........................................................RS-2AF-16SF
1 6-fiber G2 Module with TeraSPEED SC pigtails ..........360G2 Cartridge 6-SCöLS
1 SC two-fiber patchcord per active equipment ..........FEWSCSC52jKW010

Campus cable connections at MC
8 6-fiber break-out kits (two for each incoming cable) ....6-Fiber Breakout Kit 760018820
1 entrance facility ......................................................SWE-4-G2
1 splice holder .........................................................RS-2AF-16SF
4 6-fiber G2 Module with TeraSPEED SC pigtails ..........360G2 Cartridge 6-SCöLS
1 SC two-fiber patchcord per active equipment ..........FEWSCSC52jKW010

General
2 package of 50 splice protectors* ..............................SFS-SLEEVE

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10118W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.
Large Ring Campus Using Tight-Buffered Indoor/Outdoor Cable

Page 76 is the basis for this example in which five buildings are linked in a counter-rotating ring at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. Tight buffered cable is being used for the campus backbone while outside plant cable is recommended for the local access link. Indoor/outdoor cables eliminate the need for transition at the entrance facility. Tight buffered fibers eliminate the need for breakout kits and their associated labor.

Fiber count

A TeraSPEED fiber pair can support present campus traffic. However, installing a six fiber cable provides a good upgrade path at minimal extra cost. The TeraSPEED 24 fiber cable for the local access link has enough spare fiber to accommodate growth. An all-dry stranded loose tube outside plant cable is used in this example.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be field connectorized; the local access fibers will have pigtails spliced onto them.

Tight buffered cables do not need to be furcated prior to termination so furcation, or break-out, kits are not necessary for the campus cables.
Large Ring Campus Using Tight-Buffered Indoor/Outdoor Cable

Cable requirements
110 meters of outside plant all-dry loose tube ................. D-024-LN-8W-F12NS with 24 TeraSPEED fibers

5300 meters of indoor/outdoor tight-buffered ................. Z-006-DS-8W-FSUBK with 6 TeraSPEED fibers

Local access connection to MC
1 12-fiber break-out kit ................................................ 12 Fiber Breakout Kit 760018838
1 entrance facility ....................................................... SME-4-G2
1 splice holder ........................................................... RS-2AF-16SF
4 6-fiber G2 module with TeraSPEED SC pigtails ............. 360G2 Cartridge 6-SC-LS
1 SC two-fiber patchcord per incoming application .......... FEWSCSC52jXW010
from the service provider

At each IC and the MC (x5 for total quantity)
1 rack mounted fiber enclosure ..................................... 360G2-1U-MOD-SD
4 6-fiber G2 module with TeraSPEED SC adapters .......... 360G2 Cartridge 6-SC-SCM
12 single-mode EZ-SC connectors* ............................... SFC-SCR-09
2 SC two-fiber patchcord per active equipment per application . FEWSCSC52jXW010

General
1 package of 50 splice protectors* ............................... SFS-SLEEVE

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-10L18W

Ladder tray radius CR90FCB-18W

Ladder splice kit CRBSK

Ladder wall support kit CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Ring Using Loose Tube Indoor/Outdoor Cable

Pages 76 and 184 are the basis for this example in which five buildings are linked in a counter-rotating ring at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. The difference is that riser-rated indoor/outdoor loose tube cable has been installed in the buried conduit for the campus backbone. While not as environmentally robust at temperature extremes as a pure outside plant cable, indoor/outdoor cable does offer advantages in termination (see below). Outside plant cable is recommended for the local access link.

Fiber count

Fiber counts are identical to the tight buffered example on 184. The TeraSPEED six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The TeraSPEED 24 fiber cable (a loose tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Indoor/outdoor cable does not require transition at the entrance facilities. The backbone cables will be connectorized; the local access fibers will have pigtails spliced onto them.

The cable’s fibers will be connectorized. Loose tube cables must be furcated prior to connectorization (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Ring Using Loose Tube Indoor/Outdoor Cable

Cable requirements
110 meters of outside plant all-dry loose tube .................. D-024-LN-8W-F12NS with 24 TeraSPEED fibers
5300 meters of indoor/outdoor all-dry loose tube ............ Z-006-DS-8W-FSUBK with 6 TeraSPEED fibers

Local access connection to MC
2 12-fiber break-out kits ............................................... 12 Fiber Breakout Kit 760018838
1 entrance facility ....................................................... SME-4-G2
1 splice holder ........................................................... RS-2AF-16SF
4 6-fiber G2 module with TeraSPEED SC pigtails .......... 360G2 Cartridge 6-SC-SM
1 SC two-fiber patchcord per incoming application ......... FEWSCSC52-JXW010 from the service provider

At each IC and the MC (x 5 for total quantity)
4 6-fiber break-out kits ............................................... 6-Fiber Breakout Kit 760018820
1 rack mounted fiber shelf ............................................. 360G2-1U-MOD-SD
4 6-fiber G2 module with TeraSPEED SC adapters ........ 360G2 Cartridge 6-SC-SM
12 single-mode EZ-SC connectors™ ............................... SFC-SCR-09
2 SC two-fiber patch cords per active equipment per application .... FEWSCSC52-JXW010

General
1 package of 50 splice protectors* .................................. SFS-SLEEVE

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.

Cable management components will be required for any installation.

Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft) CR-SLR-10118W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Large Ring Campus Using Loose Tube Outside Plant Cable

Pages 76 and 186 are the basis for this example in which five buildings are to be linked in a counter-rotating ring at multi-gigabit speeds using TeraSPEED single-mode fiber pairs. The difference is that environmentally-robust outside plant loose tube cable is being installed in buried conduit for all outdoor links.

Fiber count

Fiber counts are identical to the tight buffered example on 186. The TeraSPEED six fiber campus backbones provide a comfortable upgrade path at minimal extra cost. The TeraSPEED 24 fiber cable (a loose tube cable in this example) used for the local access link has enough spare fiber to accommodate growth.

Cable routing and amount

The cables are installed in a ring topology except for the direct link to the local access. The required amount of cable is measured distance plus 10% PLUS 6 meters for service loops.

Termination considerations

Outside plant cable requires transition at the entrance facilities at each building. Although the local access cable could be terminated along with the campus cable at the main crossconnect (MC), housekeeping practices call for a separate fiber closure.

The outdoor cable’s fibers will be fusion or mechanically spliced to single-mode pigtails. Loose tube cables must be furcated prior to splicing (see page 112) so a furcation, or break-out, kit will be required at each cable termination.
Large Ring Campus Using Loose Tube Outside Plant Cable

Cable requirements
110 meters of outside plant all-dry loose tube ...................... D-024-LN-8W-F12NS with 24 TeraSPEED fibers
5300 meters of outside plant all-dry loose tube .................. D-006-LN-8W-F06NS with 6 TeraSPEED fibers

Local access connection to MC
2 12-fiber break-out kits ................................................. 12 Fiber Breakout Kit 760018838
1 entrance facility .......................................................... SME-4-G2
1 splice holder ............................................................. RS-2AF-16SF
4 6-fiber G2 module with TeraSPEED SC pigtails .......... 360G2 Cartridge 6-SC-LS
1 SC two-fiber patchcord per incoming application ............ FEWSCSC52JXM010 from the service provider

At each IC and the MC (x 5 for total quantity)
2 6-fiber break-out kits ..................................................... 6-Fiber Breakout Kit 760018820
1 entrance facility .......................................................... SME-4-G2
1 splice holder ............................................................. RS-2AF-16SF
4 6-fiber G2 module with TeraSPEED SC pigtails .......... 360G2 Cartridge 6-SC-LS
2 SC two-fiber patch cords per active equipment ............... FEWSCSC52JXM010

General
1 package of 50 splice protectors* ................................... SFS-SLEEVE

Cable management components will be required for any installation.
Order these on an as-needed basis:

- Telecom Racks
  RK3-45A

- Vertical Cable Managers
  VCMDS-84-10

- Ladder trays 3.04 x 0.45 m [10 x 1.5 ft]
  CR-SLR-10L18W

- Ladder tray radius
  CR90FCB-18W

- Ladder splice kit
  CRBSK

- Ladder wall support kit
  CRTWSBK-18W

*Note: If mechanical splices are used, see catalog for appropriate fiber management hardware.
Integrating Security Network

In this example, a manufacturing plant with four controlled entrances will use twisted pair cable to carry a variety of security signals back to a central monitoring location. Carded entry, CCTV, electronic locks and motion detectors are used for all outside doors and a door above the entrance to the data processing facility. All of these units have Ethernet twisted pair adapters and are connected to an Ethernet hub above the door. Cables from each door feed back to the telecommunications room which then connects to the security control room.

Cable types and count
The distances involved in this example are under 90 meters, so the horizontal links can be supported by Category 6 twisted pair cable (recommended for the video portion of the connection).

Cable routing and amount
The riser-rated cable will be conveyed by cable ladders. Calculate cable length by taking the measured distance for each drop (taking a right-angled route) PLUS one meter for the drop to the hub PLUS the telecommunications room’s distance (follow the cable tray) PLUS three meters PLUS three meters ceiling-to-floor in the telecommunications room. Remember to add 10% to the total cable length.

Termination considerations
The four incoming cables will be added to the existing data network, using four incoming ports and one outgoing port for the connection to the security control room.
Integrated Security Network

Cable requirements
370 meters (1214 feet) of XL7 Category 6 U/UTP ................................................. 1061
16 Category 6 U/UTP patchcord (one for each devices/four per door) .... CPC3382-0XF015

Telecommunications Room
5 Category 6 U/UTP patchcord .......................................................... CPC3382-0XF015 (one for each door x 4/one to security control room)
5 ports in the patch panel (4 for incoming and 1 link to security control room)

Cable management components will be required for any installation.
Order these on an as-needed basis:

Telecom Racks
RK3-45A

Vertical Cable Managers
VCMDS-84-10

Ladder trays 3.04 x 0.45 m (10 x 1.5 ft)
CR-SLR-10L18W

Ladder tray radius
CR90FCB-18W

Ladder splice kit
CRBSK

Ladder wall support kit
CRTWSBK-18W

NOTE: See CommScope Enclosure Catalog for other accessories.
Intelligent Infrastructure

The necessary monitoring of the equipment in the telecommunications room is provided by iPatch Rack Managers.

The lead unit is a Rack Manager Plus (highlighted in green) and it resides in the first rack. Rack Managers (highlighted in blue) reside on the other racks and report back to the Rack Manager Plus.

Rack managers monitor the individual ports on the racks. These ports can be any combination of fiber and copper. A typical installation drawing is shown below.
Intelligent Infrastructure

Telecommunications Room (first rack)
iPatch Rack Manager Plus to connect to the network ......................... IP-RACK-MGR-PLUS
This unit needs to be installed in the first rack

All other racks (one per rack)
iPatch Panel Manager ..........................................................360-IP-PANEL-MGR

Fiber distribution
360 iPatch G2 HD Fiber Shelf, Slide ........................................360-IP-HD-2U-IP-SD

With needed modules:
for LazrSPEED 50 µm ......................................................360-IP-HD-MOD1C-LS
for TeraSPEED single-mode .............................................360-IP-HD-MOD1C-TS
for OptiSPEED 62.5 µm ..................................................360-IP-HD-MOD1C-OS

Copper distribution
With needed patch panels:
for Category 6 connections .............................................360-IP-1100-GS3-24 or
360-IP-1100-GS3-48
for Category 6A connections ...........................................360-IP-1100-GS5-24 or
360-IP-1100-GS5-48
10 Gigabit Ethernet  IEEE 802.3 is the standard specifying 10 Gb/s transmission for single-mode fiber or 50 µm multimode fiber
ACR  see Attenuation to Crosstalk Ratio
ADM  see Add/Drop Multiplexing
ANSI  see American National Standards Institute
APD  see Avalanche Photodiode
ASTM  see American Society for Testing and Materials
ATM  see Asynchronous Transfer Mode
AWG  see American Wire Gauge
Acceptance Angle  largest possible angle for launching light into an optical fiber; this angle is used to determine the numerical aperture (NA) of a fiber
Access Connection  the physical connection at a central office connecting a local channel to an interoffice channel
Access Floor  a system of raised flooring that has removable and interchangeable floor panels
Adapter  a mechanical media termination device designed to align and join fiber optic connectors; often referred to as a coupling, bulkhead or interconnect sleeve
Add/Drop (ADM)  multiplexers used at a network node to separate a signal from a multiplexed signal or to combine a lower-speed local signal into a higher-speed transport signal
Administration  the method for labeling, identification, documentation and usage needed to implement moves, adds and changes to the telecommunications infrastructure; TIA/EIA 606
Aerial  a type of cable installation where the cable is connected to poles or towers by means of cable clamps or other pole attachment hardware; refer to lashed, messenger, figure-eight or self-support
Aerial cable  telecommunication cable installed on aerial supporting structures such as poles, sides of buildings, and other structures
Air Handling Plenum  a compartment or chamber with one or more air ducts connected and that forms part of the environmental air distribution system
All-Dielectric Self-Supporting  refers to an aerial cable design that is intended for long spans where electric fields from lightning or nearby high-voltage cabled could cause elevated temperatures or other unwanted effects in cables with metallic elements; it is used as an alternative to OPGW on electric power company aerial high-voltage transmission routes
Alternate Entrance  a supplemental entrance facility into a building using a different routing to provide diversity of service and assurance of service continuity
Ambient Temperature  the temperature of a medium (gas or liquid) surrounding an object
American National Standards Institute (ANSI)  refers to a standards organization that organizes committees and oversees the development and publication of standards, including standards for network interfaces, communication protocols, and other communication technologies
American Society for Testing and Materials (ASTM)  a nonprofit industry-wide organization which publishes standards, methods of test, recommended practices, definitions and other related material
American Wire Gauge (AWG)  a standard system for designation wire diameter; also referred to as the Brown and Sharpe (B&S) wire gauge
Ampere  the unit of current; one ampere is the current flowing through one ohm of resistance at one volt potential
Analog  a continuously varying signal; analog signals may have an unlimited number of values, as amplitude and/or frequency may vary
ANSI/TIA/EIA 568  Commercial Building Telecommunications Standard; it gives guidelines on implementing structured cabling within a building; it also defines the minimum mechanical and transmission performance criteria for U/UTP, F/UTP, S/FTP, coax, and fiber optic cabling
ANSI X3T9.5  the ANSI committee responsible for FDDI
Approved Ground  a grounding bus or strap approved for use as a telecommunications ground; refer to EIA/TIA 607 and the National Electric Code
Aramid Yarn  a non-conductive strength element used in cable to provide support and additional protection of fiber bundles
Armor  the protective element added to cables; it is usually made of steel, but can also be heavy plastic or aluminum

Armored additional protection between jacketing layers to provide protection against severe outdoor elements; usually made of plastic-coated steel, corrugated for flexibility; may also be called armoring

ASCII  American Standard Code for Information Interchange

Asynchronous (or Async) a transmission and switching technology that relies on the use of bits or strings of bits at the beginning and the end of the data payload, these are called “farming bits”; this technology differs from synchronous transmission, where the data payload is referenced to a clock

Asynchronous Transfer Mode (ATM)  standard for cell switching to route packets of digital information, designed to accommodate burst data transmission; an ATM cell has fixed length of 53 bytes: 5 operation at bit rates from 1.544 Mbps up to 2 Gbps; the standard defines both the multiplexing and cell relay protocols

Attenuation  loss of signal in a length of cable (in dB)

Attenuation Coefficient  attenuation expressed as a function of distance (dB/km); sometimes listed as the Greek letter alpha (α)

Attenuation to Crosstalk Ratio (ACR)  calculated as the crosstalk value (dB) minus the attenuation value (dB); typically, ACR may be given for a cable, link or channel and is a key indicator of performance for U/UTP systems

Backboard  a panel, wood or metal, used for mounting equipment

Backbone  the part of the distribution system that include the main cable routing from the equipment room to remote locations; this may include distribution to the same or different floors within a building

Backbone Raceway  the portion of the pathway system that permits the placing of main or high-volume cables between the entrance location and all cross-connect points within a building or between buildings

Backfill  materials used to fill an excavation; may be crushed stone, sand or soil

Backscattering  the scattering of a fiber optic signal in the opposite direction from its intended course

Balanced Transmission  refers to the transmission of equal but opposite voltages across each conductor of a pair; if each conductor is identical, with respect to each other and the environment, then the pair is said to be perfectly balanced and the transmission will be immune to ElectroMagnetic Interference (EMI)

Bandwidth or Bandwidth-Distance Product  the information-carrying capacity of a transmission medium is normally referred to in units of MHz•km; this is called the bandwidth-distance product or, more commonly, bandwidth; the amount of information that can be transmitted over any medium changes according to distance; the relationship is not linear, however; a 500 MHz•km fiber does not translate to 250 MHz for a 2 kilometer length or 1000 MHz for a 0.5 kilometer length; it is important, therefore, when comparing media to ensure that the same units of distance are being used

Barrier  a permanent partition installed in a raceway or cable tray to provide complete separation of the adjacent compartment

Baud  a unit for characterizing the signaling rate of a digital data link or transmission device; it refers to the number of digital signal transitions in one second; with some data encoding formulas, the baud rate is equal to the bits per second; this would be the case with non-return-to-zero formats; in others, such as Manchester, two transitions per bit are required

Beamsplitter  a device used to divide a optical beam into two or more beams

Bend Radius  the radius a cable may be bent before the risk of breakage or an increase in attenuation, may also be called cable bend radius

Bend Radius, Minimum  the radius of curvature of the fiber or cable that will result in excessive signal loss or breakage

Binder Groups  for fiber, the grouping of fibers into units of 12, using a thread; the color code for binder groups is: Blue-orange-green-brown-slate-whitered-black-yellow-violet-rose-aqua for fiber; for copper, group of 25 pairs identified by colored material

Bit  basic unit of information in digital transmission
Bonding Conductor for Telecommunications the conductor interconnecting the telecommunications bonding infrastructure to the building’s service equipment (electrical power) ground

Braid a fibrous or metallic group of filaments interwoven in cylindrical form to form a covering over one or more wires

Braid Angle the smaller of the two angles formed by the shielding strand and the axis of the cable being shielded

Breakout Cable a multifiber cable where each fiber is further protected by an additional jacket and optional strength elements

Buffering a protective material extruded directly on the fiber coating to protect the fiber from the environment; or extruding a tube around the coated fiber to allow isolation of the fiber from stresses on the cable

Buffer Tubes loose-fitting covers over optical fibers, used for protection and isolation

Building Backbone this refers to a network segment between at least two equipment closets and the network interface for the building; see section 5 of EIA/TIA 568 Commercial Building Wiring Standards for the maximum distance for building backbone segments

Building Backbone Cable from ISO/IEC 11801: connects the building distributor to the floor distributor, which may also connect floor distributors in the same building

Building Distributor from ISO/IEC 11801: a distributor in which the building backbone cable(s) terminate(s) and where connections to the campus backbone cable(s) may be made

Building Entrance Facilities from ISO/IEC 11801: provides all necessary mechanical and electrical services for the entry of telecommunications cable into a building

Buried communications cable that is installed in direct contact with the earth; common installation methods include trenching, plowing or boring

Buried Cable a cable installed directly in the earth without use of underground conduit; also called “direct burial cable”

Byte one character of information, usually 8 bits

CATV see Cable Television (Community Antenna TV)

CCTV see Closed Circuit Television

CPE see Customer Premises Equipment

CSA see Canadian Standards Association

CO see Central Office

CT see Central Tube

Cable Assembly a completed cable and its associated hardware ready to install

Cable Bend Radius cable bend radius during installation infers that the cable is experiencing a tensile load; free bend infers a smaller allowable bend radius, because it is at a condition of no load

Cable Element from Cenelec EN5017: smallest construction unit in a cable, may have a screen; e.g., a pair, a quad and a single fibre are cable elements

Cable Rack vertical or horizontal open support attached to a ceiling or wall

Cable Sheath a covering over the conductor assembly that may include one or more metallic members, strength members or jackets

Cable Television (CATV) the initials derive originally from Community Antenna Television; the CATV industry or its networks also are sometimes referred to as “cable” which can be confusing in discussions of cable markets

Cable Tray a ladder, trough, solid bottom or channel raceway intended for, but not limited to, the support of telecommunications cable

Cable Unit from Cenelec EN50173: single assembly of one or more cable elements, may have a screen

Cabling the twisting together of two or more insulated conductors to form a cable

Campus the building and grounds of a complex; e.g., a university, college, industrial park, or military establishment

Campus Backbone this refers to a network region between at least two buildings; see TIA/EIA 568 Commercial Building Wiring Standards for the maximum distance for campus backbone segments

Campus Backbone Cable from ISO/IEC 11801: connects the campus distributor to the building distributor; may also connect building distributors directly
Campus Distributor from ISO/IEC 11801: a distributor from which the campus backbone emanates.

Canadian Standards Association (CSA) a non-profit, independent organization which operates a listing service for electrical and electronic materials and equipment; the Canadian counterpart of the Underwriters Laboratories |CSA T527 see EIA 607; CSA T528 see EIA 606; CSA T529 see EIA 568; CSA T530 see EIA 569

Capacitance: the ratio of the electrostatic charge on a conductor to the potential difference between the conductors required to maintain that charge

Capacitance Unbalance: a measurement of a cable’s impedance based on a curve fit equation using the cable’s raw input impedance, specified by ANSI/TIA/EIA 568A but not ISO/IEC11801

Cenelec EN50173 European standard for generic cabling systems; based on ISO/IEC 11801

Centralized Cabling: a cabling topology used with centralized electronics, connecting the optical horizontal cabling with the building backbone cabling passively in the telecommunications room

Central Member: the center component of a cable, an anti-buckling element to resist temperature-induced stress; constructed of steel, fiberglass or glass-reinforced plastic; also sometimes a strength element

Central Office (CO): refers to a phone company’s switch or exchange location or the building that houses the switch, also called “serving office” and “exchange.”

Central Tube (CT): refers to the type of cable that has the fibers housed in a single buffer tube; the fibers may either be bundled together with a binder yarn, or loose within the central tube; the bundled approach usually is used for counts of 12 or more; most central tube cables usually have multiple strength members on opposite sides of the central tube

Channel: the end-to-end communications path between two points including equipment cords and patch cords; also a photonic communications path between two or more points of termination

Characteristic Impedance: the impedance that, when connected to the output terminals of a transmission line of any length, makes the line appear infinitely long; the ratio of voltage to current at every point along a transmission line on which there are no standing waves

Chromatic Dispersion: the effect of different wavelengths of light traveling at different speeds within the optical fiber; this effect will cause a change in shape of a pulse traveling within the fiber

Cladding: the optically transparent material, which surrounds the core of an optical fiber; for standard fibers, this material is a glass, which has a lower refractive index than the core glass; material surrounding the core of an optical waveguide

Closed Circuit Television (CCTV): refers to any security video system

Coarse Wave Division Multiplexing: refers to wavelength division multiplexing systems with relatively wide channel spacing (typically 20 nm)

Coating: the plastic protective layer(s) that are applied to the cladding during the drawing process for protection

Coaxial Cable: a cable consisting of two cylindrical conductors with a common axis, separated by a dielectric

Collapsed Backbone: a star topology that connects desktop devices directly to the equipment room without going through a crossconnect the telecommunications room (TR)

Color Code: a system for identification through use of colors; fiber specified in ANSI/TIA/EIA-598-A “Optical Fiber Cable Color Coding”

Composite Cable: a cable containing both fiber and copper media per NEC article 770; can also be a fiber cable with both single-mode and multimode fibers

Compression: a method to reduce the number of bits required to represent data

Concentrator: a device which concentrates many low-speed channels into or out of one or more higher-speed channels

Conduit: a raceway of circular cross-section

Connecting Hardware: a device providing mechanical cable terminations

Connector: a mechanical device used to align or attach two conductors
**Connector Panel** a panel designed for use with patch panels; it contains either 6, 8, or 12 adapters preinstalled for use when field-connectorizing fibers

**Connector Panel Module** a module designed for use with patch panels; it contains either 6 or 12 connectorized fibers that are spliced to backbone cable fibers

**Continuity Check** a test to determine end-to-end viability of a transmission media

**Core** central region of an optical fiber through which light is transmitted

**Core Area** that horizontal section of a building core set aside or used for utility service

**Core Concentricity** a measure of the relationship between the geometric center of the core of an optical fiber with the geometric center of the cladding

**Core Ovality** a ratio of the minimum to maximum diameters of the core within an optical fiber

**Count Loop Diversity** loop diversity that assigns circuits among different binder groups within one cable

**Coverage** expressed in percent (%), represents the percent coverage by the braid of the underlying surface

**Crossconnect** a facility enabling the termination of cable elements and their interconnection, and/or cross-connection, usually by means of a patch cord or patchcord

**Crossconnection** a connection scheme between cabling runs, subsystems and equipment using patch cords or patch cords that attach to connecting hardware at each end

**Crosstalk** a measure of conductor uniformity within a pair, hence the cable’s balance; the lower the unbalance, the better the cable will support balanced transmission

**CSMA/CA** Carrier Sense Multiple Access/ Collision Avoidance

**Customer Premises Equipment (CPE)** telephones, answering machines, or other terminal equipment located within the customer’s premises

**Cut-Off Wavelength** the shortest wavelength at which the propagation of one path of light can occur

**dB** see Decibel

**DCR** see Direct Current Resistance

**DMD** see Differential Mode Delay

**DWDM** see Dense Wave Division Multiplexing

**Dark Fiber** unused fiber through which no light is transmitted, or installed fiber optic cable not carrying a signal; the dark fiber is sold without light communications transmission equipment, and the customer is expected to install electronics and signals on the fiber and light it

**Data Center** a room or network of rooms that houses the interconnected data processing, storage and communications assets of one or more enterprises, as defined by TIA-942 and EN 50173-5.200X

**Decibel (dB)** a unit for measuring the relative strength of a signal

**Demarcation Point** a point where operational control or ownership changes

**Dense Wavelength Division Multiplexing (DWDM)** refers to wavelength division multiplexing systems with very tight spacing in the same transmission window; see also WDM

**Dielectric** a material, which does not conduct electricity, a material that is nonmetallic and non-conductive; this term is typically used to describe a non-metallic cable

**Dielectric Constant (K)** the ratio of the capacitance of a condenser with dielectric between the electrodes to the capacitance when air is between the electrodes; also called Permittivity and Specific Inductive Capacity

**Dielectric Strength** the voltage which an insulation can withstand before breakdown occurs; usually expressed as a voltage gradient (such as volts per mil)

**Differential Mode Delay (DMD)** the measurement of the difference between the leading edge of the fastest path and the trailing edge of the slowest path of light through a multimode fiber; this measurement is a type of modal dispersion within multimode fibers; DMD testing of fiber becomes more important with higher bandwidth requirements

**Diffraction** bending of radio, sound or lightwaves around an object, barrier or aperture edge
Digital  a signal having a limited number of discrete values, such as two (a binary system)
Direct Current Resistance (DCR)  the resistance offered by any circuit to the flow of direct current
Dispersion  the cause of bandwidth limitations in a fiber; dispersion causes a broadening of input pulses along the length of the fiber; three major types are: (1) modal dispersion caused by differential optical path lengths in a multimode fiber; (2) chromatic dispersion caused by a differential delay of various wavelengths of light in a waveguide material; and (3) waveguide dispersion caused by light traveling in both the core and cladding materials in single-mode fibers
Dissipation Factor  the tangent of the loss angle of the insulation material; also referred to as loss tangent, tan, and approximate power factor
Distributed Backbone  a star topology that connects desktop devices to the equipment room through horizontal crossconnects in the telecommunications room (TR)
Distribution Frame  a structure with terminations for connecting the permanent cabling of a facility in such a manner that interconnection or crossconnection may be readily made
Drain Wire  in a cable, the uninsulated wire laid over the component(s), used as a common connection
Duct  a single enclosed raceway for wires or cables; a single enclosed raceway for wires or cables usually in soil or concrete; an enclosure in which air is moved
Duct Bank  an arrangement of ducts in tiers or groups
Duplex  simultaneous two-way independent transmission
ELFEXT  see Equal Level Far End Crosstalk
EMI  see Electromagnetic Interference
ER  see Equipment Rooms
Eccentricity  like concentricity, a measure of the center of a conductor’s location with respect to the circular cross section of the insulation; expressed as a percentage of displacement of one circle within the other
EIA  Electronic Industries Association
ELFEXT  (Equal Level For End Crosstalk)  a method to mathematically subtract out the cable’s attenuation in order to accurately compare FEXT values from one cable to another; see FEXT
Electromagnetic Interference (EMI)  the interference in signal transmission resulting from the radiation of nearby electrical and/or magnetic fields; for U/UTP, EMI can be coupled onto a conducting pair and cause circuit noise; crosstalk is one type of EMI
Elongation  the fractional increase in length of a material stressed in tension
End User  someone who owns or uses the premises wiring system
Entrance Facility  an entrance to a building for both public and private network service cables; including the entrance point at the building wall and continuing to the entrance room or space
Equipment Cord  cable used to connect telecommunications equipment to horizontal or backbone cabling
Equipment Rooms (ER)  from ISO/IEC 11801: dedicated to housing distributors and specific equipment
ESCON  (Enterprise Systems Connection)  this refers to a proprietary parallel signal-processing transmission protocol as well as a data network architecture, which were developed and commercialized by IBM in the early 1990s; non-stop high bandwidth data transfer characterizes ESCON across distances up to 9 km with multimode technologies, and up to 60 km with single-mode technologies
Ethernet  this IEEE transmission protocol standard uses Carrier Sense Multiple Access/Collision Detection (CSMA/CD) to transmit data in a network; there are three different network topologies that support Ethernet transmissions: active ring, passive star and active star
Excess Length  the extra length of fiber contained in a cable; this extra length is present because the fiber does not lie parallel to the cable axis
FDDI  see Fiber Distributed Data Interface
FEP  Fluorinated Ethylene Propylene
FEXT  see Far End Crosstalk
FRP  see Fiber Reinforced Plastic
**Feeder** the segment of telecom networks that includes equipment, cable, and other hardware for transporting traffic from the switch location into the loop, usually to an outside plant equipment location where there is a passive cross-connect or an active demultiplex function; feeder cables can include high-count copper pair cables, where each pair supports one circuit, as well as cables carrying electronically derived circuits; such electronic feeder technologies include “pair gain” and “digital loop carrier”; “Fiber optic feeder equipment” usually refers to DLC or other access multiplexers.

**Ferrule** a mechanical fixture, usually a rigid tube, used to confine and align the stripped end of a fiber.

**FEXT (Far End Crosstalk)** crosstalk that occurs at the end opposite the location of the disturbed pair’s receiver; Normally, FEXT is only important in short links or full duplex transmission.

**FFEP** Foamed Fluorinated Ethylene Propylene.

**Fiber** thin filament of glass; an optical waveguide consisting of a core and a cladding that is capable of carrying information in the form of light.

**Fiber Bend Radius** radius a fiber can bend before the risk of breakage or increase in attenuation occurs.

**Fiber Distributed Data Interface (FDDI)** refers to a 100Mbs LAN standard that was developed specifically for fiber; the standards organization is ANSI; the standard’s specifications at the physical layer include the optoelectronic component footprint and interfaces.

**Fiber Optics** thin filaments of glass or plastic through which light beams are transmitted over long distances and which can carry enormous amounts of voice and data traffic; benefits include high capacity, relatively low cost, low power consumption, small space needs, insensitivity to electromagnetic interference (EMI) and improved privacy.

**Fiber-Reinforced Plastic (FRP)** a material used as an alternative to aramid yarns for strength members in some cables, either as central strength members or other strengthening elements; the material with filament filaments of fiberglass (not optical fiber); it is also known as glass-reinforced plastic (GRP).

**Fibre Channel** an interface standard for serial data transmission developed for communications between workstations and file servers, between computers and storage systems, and between other hosts and peripherals; the standard defines bi-directional point-to-point channels so that the communications path or medium is not shared between multiple modes; a circuit or packet switching technology can be used to achieve multimode networking; the standard defines a hierarchy of serial data transfer bit rates and several families of transmission media and sources; the lowest speeds can be implemented on twisted pair, coax, and multimode fiber; the highest speeds can be implemented on multimode and single-mode fiber; the bit rates range from 132 Mbps to 1.06 Gbps.

**Figure-Eight** a type of aerial cable where the messenger strand and the communications cable are encased in a single extruded sheath; when viewed in cross-section, the cable/messenger arrangement resembles a figure eight.

**Firestop** a material, device or assembly of parts installed within a cable system in a fire-rated wall or floor to prevent the passage of flame, smoke or gases through the rated barrier.

**Flame Resistance** the ability of a material not to propagate flame once the heat source is removed.

**Flex Life** the measurement of the ability of a conductor or cable to withstand repeated bending.

**Flooded Launch** a condition in which the light source exceeds the NA of the fiber.

**Forward Path** transmission from the headed toward the subscriber, also known as “downstream”.

**FR-1** a flammability rating established by Underwriters Laboratories for wires and cables that pass a specially designed vertical flame test; this designation has been replaced by VW-1.

**Frequency** of a periodic wave, the number of identical cycles per second.

**Fresnel Reflection Losses** reflection losses that are incurred at the input and output of optical fibers due to the differences in refraction index between the core glass and immersion medium.

**Full Duplex** simultaneous two-way independent transmission; a method used to increase transmission throughput e.g. gigabit Ethernet where 250 Mb/s is sent bidirectionally across each of the four pairs.
Fusion Splice  a permanent joint accomplished by applying localized heat sufficient to fuse or melt the ends of optical fiber, forming a single continuous fiber

F/UTP  a 100 ohm cable with an overall foil shield and drain wire; formerly called Screened Twisted Pair (ScTP)

GHz  see GigaHertz

GRP  see Glass Reinforced Plastic

Gauge  a term used to denote the physical size of a wire

GbE  Gigabit Ethernet

Gb/s  millions of bits per second

General Purpose Cable  this type of cable meets specifications for general-purpose ratings (UL-1581), and is one of three types installed in premises networks; multimode general-purpose cables usually have loose-tube construction and are suitable for outdoor installation in campus network segments

Giga  numerical prefix denoting one billion

GigaHertz (GHz)  a unit of frequency that is equal to one billion cycles per second

Glass-Reinforced Plastic (GRP)  a strength member material, see FRP

Graded-Index Fiber  a fiber design where the refractive index of the fiber is lower toward the outside of the fiber core

Ground  a connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth

Grounding  see bonding

HC  see Horizontal Crossconnect

HVAC  Heating, Ventilating and Air Conditioning

Hz  Hertz, cycle per second

IC  see Intermediate Crossconnect or Integrated Circuit

ISDN  see Integrated Services Digital Network

ICEA  Insulated Cable Engineers Association

IEC  International Electrotechnical Commission

IEEE  Institute for Electrical and Electronics Engineers; this refers to a standards writing organization that organizes committees and oversees the development and publication of standards, including standards for network interfaces, communications protocols, and other communication technologies

Harmonic  full multiple of a base frequency

Headend  facility in a CATV network where the broadcast video signals are transmitted into the feeder and distribution network; headends are linked together with supertrunks and are linked to satellite downlink facilities with supertrunks

Helical Stranding  a stranding method in which the elements are stranded in one continuous direction

Home Run  a common term used to describe telecommunications cabling run in a star topology; e.g. direct from outlet to the telecommunications room

Horizontal Cable  from ISO/IEC 11801: Connects the floor distributor to the telecommunication(s) outlet; the cabling between and including the telecommunications outlet/connector and the horizontal cross-connect

Horizontal Cross-connect (HC)  a cross-connect of horizontal cabling to other cabling

Hub  a device which connects to several other devices, usually in a star topology or refers to the facilities where all customer facilities are terminated for purposes if interconnection to trunks and/or cross-connection to distant ends

Hybrid Cable  an assembly of one or more cables, of the same or different types or categories, covered by one overall sheath

Hz  Hertz, cycle per second

IC  see Intermediate Crossconnect or Integrated Circuit

ISDN  see Integrated Services Digital Network

ICEA  Insulated Cable Engineers Association

IEC  International Electrotechnical Commission

IEEE  Institute for Electrical and Electronics Engineers; this refers to a standards writing organization that organizes committees and oversees the development and publication of standards, including standards for network interfaces, communications protocols, and other communication technologies

Hard Drawn Copper Wire  copper wire that has not been annealed after drawing; sometimes called HD wire
Impedance  The total opposition that a circuit offers to the flow of alternating current or any other varying current at a particular frequency; it is a combination of resistance $R$ and reactance $X$, measured in ohms

Index-Matching Fluid or Gel  a fluid with an index of refraction close to that of glass that reduces reflections caused by refractive-index differences

Index of Refraction  ratio of velocity of light in a vacuum to the velocity of light within a given transmitting medium

Indoor Cable  cable designed for use indoors; these cables typically have a flame resistance rating and are not suitable for the environmental conditions experienced by outdoor cables

Indoor /Outdoor Cable  cable rated for use indoors and suitable for outdoor environmental conditions

Inductance  the property of a circuit or circuit element that opposes a change in current flow, thus causing current changes to lag behind voltage changes; it is measured in henrys

Infrared  the range of the electromagnetic spectrum from 780 nm to 1 mm; optical signal transmission takes place within the infrared portion of the spectrum

Infrastructure  a collection of components, excluding equipment, that provides the basic support for the distribution of all information within a building or campus

Innerduct  additional duct work (conduit) placed within a larger diameter duct (conduit), also known as subduct

Insertion Loss  attenuation caused by insertion of a component into a transmission route/ channel

Insulating Joint  a splice in a cable sheath where the continuity of the sheath and shield are deliberately interrupted to prevent the flow of electrolytic currents which may cause corrosion

Insulation  a material having high resistance to the flow of electric current, often called a dielectric in radio frequency cable

Insulation Displacement Connection  the type of connection required by ANSI/TIA/EIA 568 for twisted pair

Insulation Resistance  the ratio of the applied voltage to the total current between two electrodes in contact with a specific insulation, usually expressed in megaohms-M feet

Integrated Circuit  A complex set of electronic components and their interconnections that are etched or imprinted on a chip.

Integrated Messenger Cable  aerial plant communications cable with a messenger support cable within the outer cable jacket, also known as figure-eight or self-support

Interconnection  a connection scheme that provides for the direct connection of a cable to the other cable without a patch cord or patchcord

Intermediate Cross-connect (IC)  a cross-connect between first and second level backbone cabling

Integrated Services Digital Network (ISDN)  a public switched network which provides end-to-end digital connections; refers to a standard for the simultaneous transmission of voice and data, including digital video, over telecom networks

ISO/IEC 11801  International standard for generic cabling system

Jacket  an outer non-metallic protective covering applied over an insulated wire or cable

Kb/s  Kilobits per second, one thousand bits per second

Kevlar  a registered (DuPont) trade name for aramid fiber yarn, which is typically used as a non-conducting strength member in fiber optic cable

KHz  Kilohertz, 1,000 cycles per second

Kilo  numerical prefix denoting one thousand

Kilometer  one thousand meters or approximately 3,281 feet; the kilometer is a standard unit of length measurement in fiber optics

kpsi  a unit of force per area expressed in thousands of pounds per square inch; usually used as the specification for fiber proof test

LAN  see Local Area Network

LC  see Lucent Connector

LEC  see Local Exchange Carrier

LED  see Light Emitting Diode
LID  see Local Injection and Detection
LT  see Loose Tube
LSZH  see Low Smoke Zero Halogen
LASER Diode  Light Amplification by Stimulated Emission of Radiation; an electro-optic device that produces coherent light with a narrow range of wavelengths, typically centered around 780 nm, 1310 nm, or 1550 nm; lasers with wavelengths centered around 780 nm are commonly referred to as CD lasers
Lashing  attaching a cable to a supporting strand or cable using a steel or dielectric filament around both cable and support
Lay  the length measured along the axis of a wire or cable required for a single strand (in stranded wire) or conductor (in cable) to make one complete turn about the axis of the conductor or cable
Lucent Connector (LC)  a type of fiber optic connector pioneered by Lucent
Light Emitting Diode (LED)  a semiconductor light source without the coherent properties of a laser diode; typically used for less than 1 Gb/s transmission
LID (Local Injection and Detection)  a method of measurement used for alignment of optical fibers, typically used for optimizing splice performance
Line Cord  see work area cable
Link  a transmission path between two points, not including terminal equipment, work area cables or equipment cables
Listed  equipment included in a list published by an organization that maintains periodic inspection of production of listed equipment, and whose listing states either that the equipment meets appropriate standards or has been tested and found suitable for use
Local Access Network  a term used to refer to that part of that connects the exchanges with the customers
Local Access Provider  operator of facility used to convey telecommunications signals to and from a customer premises
Local Area Network (LAN)  refers to an on-premises data communications network, usually for linking PCs together or linking PCs to a file server and other data processing equipment

Local Exchange Carrier (LEC)  the local phone companies, which can be either a regional Bell Operating Company (RBOC), or an independent (e.g., GTE) which traditionally has the exclusive, franchised right and responsibility to provide local transmission and switching services; with the advent of deregulation and competition, LECs are now known as ILECs (Incumbent Local Exchange Carriers)
Longitudinal Shield  a tape shield, flat or corrugated, applied longitudinally with the axis of the core being shielded
Loop Resistance  sum of conductor resistance and shield resistance (DCR)
Loose Buffered Fiber  buffered optical fiber in which the buffer material is applied such that the fiber is not in contact with the buffer material; typically, a gel is used to decouple the fiber from the buffer tube
Loose Tube (LT)  refers to cable type with an oversized buffer tube that typically holds up to 12 fibers, with multiple tubes stranded around the center axis; in OSP cables, the buffer tubes usually are stranded around a central strength member
Loss  energy dissipated without accomplishing useful work
Low Loss Dielectric  an insulating material that has a relatively low dielectric loss, such as polyethylene or Teflon
Low Smoke Zero Halogen (LSZH)  a class of cables made without halogens (i.e. chlorine and fluorine) to meet specific and strict fire safety codes
MAN  see Metropolitan Area Network
MUTOA  see Multi-User Telecommunications Outlet Assembly
MUX  see Multiplexer
Macrobending  relatively large deviations in the waveguide that can result in increased attenuation, or loss due to bend radius
Main Cross-connect (MC)  a cross-connect for first level backbone cables, entrance cables and equipment cables
**Material Dispersion** dispersion caused by differential delay of various wavelengths of light in a waveguide material

**Mechanical Splicing** joining two fibers together by permanent or temporary mechanical means (vs. fusion splicing or connectors) to enable a continuous signal

**Media** telecommunications wire, cable or conductors used for telecommunications

**Medium-Density Polyethylene (MDPE)** a type of plastic material used to make cable jacketing

**Meg or Mega** a numerical prefix denoting 1,000,000 (10^6)

**Megabits per second (Mb/s)** million bits per second

**Megahertz (MHz)** a unit of frequency that is equal to one million cycles per second

**Messenger** a support strand, typically constructed of steel or Kevlar cable, used for attachment of communications cable for aerial plant

**Metropolitan Area Network (MAN)** a citywide or regional public access data and telecommunication network

**Micro** numerical prefix denoting one-millionth

**Micron** one-millionth of a meter

**Microbending** bends that take place on a microscopic level, which can result in increased attenuation, or loss due to local

**Micrometer (µm) or micron** one millionth of a meter; typically used to express the geometric dimension of fibers

**Microwave** portion of the electromagnetic spectrum above 760 MHz

**Modal Dispersion** propagation delay between modes within a multimode fiber; this will cause a change in shape (broadening) of a pulse traveling within a multimode fiber

**Mode** light path through a fiber, as in multimode or single mode

**Mode Field Diameter** a measure of the width of the energy distribution for optical fiber at 37% of the maximum energy level; the effective diameter of a single-mode fiber, taking into account the fact that some light travels within the cladding; accordingly, the mode field diameter is larger than the core diameter

**Modulation** a process where certain characteristics of a wave, which is often called the carrier, are varied or selected in accordance with a modulating function

**Modulus of Elasticity** the ratio of stress to strain in an elastic material

**Modular Plastic Duct** a type of telecommunications duct. Available in molded formations of 4, 6, or 9 ducts in lengths of 36 in.; can be direct buried

**Multimedia** a system or a service, or a set of services characterized by two-way communications, interactive services, and the ability to combine data, voice, and video

**Multimode** an optical fiber that will allow many bound modes to propagate; may be graded-index or step-index; this refers to the propagation quality of transverse electromagnetic waves in a medium; inside an optical fiber, multimode refers to the simultaneous transmission of several electromagnetic waves that interact with each other; emerging from an active device, multimode refers to the multiple wavefront spatial quality of the electromagnetic beam

**Multiplexer (MUX)** equipment used to combine multiple signals for transmission on a single channel

**Multiplexing** combination of independent signals for transmission within one waveguide

**Multi-User Outlet** a telecommunications outlet used to serve more than one work area, typically in open-systems furniture applications

**Multi-User Telecommunications Outlet Assembly (MUTOA)** an easily-reconfigured mid-channel consolidation point

**Mutual Capacitance** capacitance between two conductors when all other conductors including ground are connected together and then regarded as an ignored ground

**NEC** see National Electric Code

**NESC** see National Electrical Safety Code

**NEXT** see Near End Crosstalk
Nano  numerical prefix denoting one-billionth
Nanometer  unit of measurement equal to one billionth of a meter
National Electrical Code (NEC)  identifies the construction techniques and materials necessary in building wiring requirements and was developed by the National Fire Protection Association’s (NFPA’s) National Electric Code committee. Committee members are professionals from the electrical and insurance industries. The NEC has been adopted by the American National Standards Institute (ANSI).
National Electrical Safety Code (NESC)  are standards produced by the Institute of Electrical and Electronics Engineers (IEEE). The NESC relates to outside plant cabling as the NEC does to the inside of a building.
NESC Rated  cable that has been certified as plenum-rated, riser-rated or general cable by passing of flame propagation testing
NEMA  National Electrical Manufacturer’s Association
Near End Crosstalk (NEXT)  crosstalk that occurs at the same end as the disturbed pair’s receiver; normally, this is the largest contributor of noise because the disturbing pair’s transmitted signal is strongest at this point
NFPA  National Fire Protection Association
NID  Network Interface Device
Node  device in a hybrid fiber-coax (HFC) system which converts optical signals on fiber optic cable to electrical signals on coaxial cable to the subscribers’ premises; places at the end of the fiber optic cable in a local serving area, typically with 200 to 2,000 homes; also an addressable device attached to a computer network
Non-zero DS  refers to an improved type of dispersion-shifted fiber in which dispersion at 1,550 nm is substantially reduced compared with conventional single-mode fiber, but dispersion is not zero at 1,550 nm; this fiber was designed to overcome the possible risk of “four-wave mixing,” which is an effect that can degrade transmission quality in WDM systems having multiple channels in the 1,550-nm window
Numerical Aperture  measure, in radians, of the angle that expresses the light-gathering point of optical fiber
OSP  see Outside Plant
OTDR  see Optical Time Domain Reflectometer
OC-X (Optical Carrier - Level X)  refers to the basic line rate in the SONET hierarchy of line rates; all higher speed rates are integral multiples of OC-1, which is 51.84 Mbps (example: OC-12 is 12 x 51.84 or 622.08 Mbps)
Ohm  a unit of electrical resistance or impedance
Optical Receiver  an electronic device which converts optical signals to electrical signals
Optical Time Domain Reflectometer (OTDR)  an instrument for analyzing fiber links which may be used to locate faults and to assess splices and connector interfaces; it operates by launching a pulsed laser input into the fiber under test, then analyzing the return signal that results from reflections and backscattering phenomena
OSHA  Occupational Safety and Health Administration
Outdoor Cable  cable designed for use outdoors; these cables are suitable for the environmental conditions experienced by outdoor cables, but do not typically have a flame resistance requirement
Outside Plant (OSP)  refers to all cable and equipment located outside
PBX  see Private Branch Exchange
PC  see either Personal Computer or Positive Contact (for a fiber connector)
PE  see Polyethylene
PSumXT  see Power Sum Crosstalk
PVC  see Polyvinyl Chloride
Packet  a group of bits, including data and control elements, that are switched and transmitted together
Patchcord  a cable assembly with connectors at both ends, used to join telecommunications circuits or links at the cross-connect
Packet Switching  a communications method where packets (messages) are individually routed between hosts, with no previously established communications path
Pair-to-Pair Crosstalk  the crosstalk measurement of a single disturbing pair. It can be made for NEXT or FEXT
Passive Optical Components components, such as splitters, couplers and connectors, which do not require external power to perform their function

Patch Cable a length of cable with connectors on one or both ends to join telecommunications links

Patch Cord a length of cable with connectors on one or both ends used to join telecommunications circuits or links at the cross-connect

Patch Panel a cross-connect system of mateable connectors that facilitates administration

Pathway a facility for the placement of telecommunications cable

Periodicity the uniformly spaced variations in the insulation diameter of a transmission cable that result in reflections of a signal, when its wavelength or a multiple thereof is equal to the distance between two diameter variations

Personal Computer (PC) any general purpose computer whose size and capabilities make it useful for individuals and which is intended to be operated by an end user

Pico a numerical prefix denoting one-trillionth (10^-12)

Pigtail a length of fiber attached to a device so that it can be spliced into the network; the pigtails on some active devices also may have a connector interface; if one is comparing the cost of pigtailed devices, it is important to check the specifications to see if a connector is included, and if so what the connector specifications are

Plenum Cables this type of cable meets specifications for plenum ratings (NFPA-262), and is one of three types installed in premises networks;

Point-To-Point a connection established between two specific locations, as between two buildings

Poke-through an unlimited or random penetration through a fire resistive floor structure to permit the installation of electrical or communications cables; not covered within TIA/EIA-569

Polyethylene (PE) a type of plastic material used for outside plant cable jackets

Polyvinyl Chloride (PVC) a type of plastic material used for cable jacketing, typically used in flame-retardant cables

Positive Contact or Physical Contact (PC) surface-to-surface contact between fibers in a connector-to-connector interface

Power Sum Crosstalk (PSumXT) a crosstalk measurement where the crosstalk from all adjacent disturbing pairs in a cable are mathematically summed to give a combined crosstalk value; it simulates the effects of multiple signals in a multi-pair cable or parallel transmission in a 4 pair cable; it can be made for NEXT, FEXT, or ELFEXT

Premises Distribution System a cabling system as defined by ANSI/TIA/EIA 568 series

Prewiring cabling installed either before walls are enclosed or finished; or in anticipation of future use or need

Private Branch Exchange (PBX) a private phone system owned by a customer, which allows communication within a business and between the business and the outside world

Protocol set of rules for communicating

Pull Box device to access a raceway in order to facilitate placing of wires and cables

Pull Cord cord or wire placed within a raceway used to pull wire and cable through the raceway

Pull Strength maximum pulling force that can be safely applied to a cable or raceway

Pulling Tension the pulling force that can be applied to a cable without effecting the specified characteristics for the cable

Quad-shield four layers of shielding

RF see Radio Frequency

RFI see Radio Frequency Interference

RL see Return Loss

Raceway any channel designed for holding wires or cables

Radio Frequency (RF) refers to analog signal processing and transmission technology for applications that include CATV; the term “RF” is sometimes used to refer to electronic or coaxial part of hybrid-fiber coax systems in CATV and other broadband applications

Radio Frequency Interference (RFI) the unintentional transmission of radio signals
**Rated Temperature** the maximum temperature at which an electric component can operate for extended periods without loss of its basic properties.

**Rated Voltage** the maximum voltage at which an electric component can operate for extended periods without undue degradation or safety hazard.

**Receiver** an electronic package that converts optical signals to electrical signals.

**Reflectance** the ratio of power reflected to the incident power at a connector junction or other component or device, usually measured in decibels (dB); reflectance is stated as a negative value; a connector that has a better reflectance performance would be a -40 dB connector or a value less than -30 dB; the term return loss, back reflection, and reflectivity are also used synonymously in the industry to describe device reflections, but they are stated as positive values.

**Reflection Loss** the part of a signal which is lost due to reflection at a line discontinuity.

**Refraction** bending of oblique (non-normal) incident electromagnetic waves as they pass from a transmission medium of one refractive index into a medium of a different refractive index.

**Refractive Index** a ratio of the speed of light within the medium, as compared to the speed of light within a vacuum; refractive index is wavelength dependent and is important for accurate length measurement. Also the ratio of the sines of the incidence angle and the refraction angle of a media.

**Repeater** device consisting of a receiver and transmitter, used to regenerate a signal to increase the system length.

**Return Loss (RL)** a measure of standing waves independent of variation of input impedance, measured with a load equal to the desired characteristic impedance of the cable.

**Return Path** transmission from a node in the distribution network toward the head-end; also known as “upstream”.

**Ribbon** a parallel array of optical fibers, which can be used as an organizational unit within a cable; ribbons offer consistent geometry, required for mass splicing of product, and offer a higher packing density in large fiber count cables.

**Riser Cable** cable designed for use in elevator shafts, utilities columns, or other vertical shafts in multi-story buildings; because the cable connects different floors of multi-story buildings, it must be designed to meet safety codes that specify a low level of flammability; riser cables are also used in telephone company central offices to connect the equipment with the outside-plant cable, which enters a “vault”, which is usually below grade.

**Rope Lay Cable** a cable composed of a central core surrounded by one or more layers of helically laid groups of wires or buffer tubes.

**Router** a device that forwards traffic between networks or subnetworks; operates at the OSI Network Layer (Layer 3).

**SC** see Subscriber Connector.

**ScTP** see F/UTP.

**SONET** see Synchronous Optical Network.

**SRL** see Structural Return Loss.

**ST** see Straight Tip Connector.

**STP** see Shielded Twisted Pair, see S/FTP.

**Scattering** a property of glass that causes light to deflect from the fiber and contributes to optical attenuation.

**Screened Twisted Pair (ScTP)** see F/UTP.

**Self-Support** see figure-eight.

**S/FTP** a 100 ohm cable with foil shields over the individual pairs; formerly Shielded Twisted Pair (STP).

**Sheath** the outer covering or jacket of a multiconductor cable.

**Shield** a metallic layer placed around a conductor or group of conductors; may be the metallic sheath of the cable or a metallic layer inside a nonmetallic sheath.

**Shield Effectiveness** the relative ability of a shield to screen out undesirable radiation; frequently confused with the term shield percentage, which it is not.

**Side-Wall Pressure** the crushing force exerted on a cable during installation.

**Simplex** operation of a communications channel in one direction only with no capability of reversing.
**Single-mode Fiber**  optical fiber with a small core diameter, as compared to the wavelength of light guided, in which only one mode is propagated.

**Skin Effect**  the phenomenon in which the depth of penetration of electric currents into a conductor decreases as the frequency increases.

**Sleeve**  an opening, usually circular, through the wall, ceiling or floor to allow the passage of cables and wires.

**Slot**  an opening, usually rectangular, through the wall, ceiling or floor to allow the passage of cables and wires.

**Spiral Wrap**  the helical wrap of a tape or thread over a core.

**Splice**  a permanent joining of two fiber cables that cannot be easily disconnected; a splice will provide the lowest power loss for a connection of fibers.

**Splice Closure**  a device used to protect a cable or wire splice.

**Splice Tray**  device used within splice closures or cabinets to organize and protect spliced fibers.

**Star Coupler**  optical component which allows emulation of a bus topology in fiber optic systems.

**Star Topology**  a topology where each telecommunications outlet is directly cabled to the distribution device.

**Step-Index Fiber**  optical fiber which has an abrupt (or step) change in its refractive index due to a core and cladding that have different indices of refraction, typically single-mode fiber.

**Straight-tip Connector (ST)**  a type of fiber optic connector.

**Strand Vice**  a device that allows a stranded cable to enter it but grips it when pulled in the opposite direction.

**Stranded Cable**  multiple like units brought together; may be cable with an integral messenger support strand, see figure-eight or self-support.

**Stranded Conductor**  a conductor composed of groups of wires twisted together.

**Structural Return Loss (SRL)**  a measure of standing waves independent of variation of input impedance, measured with a load equal to the characteristic impedance of the cable at that frequency.

**Subscriber Connector (SC)**  a type of fiber optic connector.

**Support Strand**  a strong element used to carry the weight of the telecommunication cable and wiring; may be constructed of steel, aluminum or aramid fiber yarns, also known as messenger.

**Sweep Test**  pertaining to cable, checking frequency response by generation an rf voltage whose frequency is varied back and forth through a given frequency range at a rapid constant rate and observing the results of an oscilloscope.

**Synchronous Optical Network (SONET)**  a standard—or more specifically a set of standards—for synchronous transmission; the standards include signal rates, formats, and optical and electrical interface specifications; the standards organization is ASNI; the international counterpart of the SONET standards is SDH.

**SZ Stranding**  stranding methods in which the elements are stranded such that the direction of stranding changes intermittently down the length of the cable; this method of stranding offers advantages over helical stranding in mid-span access of cables where the core is not cut.

**TDM**  see Time Division Multiplexing.

**TO**  see Telecommunications Outlet.

**TR**  see Telecommunications Room.

**T1**  carries 24 pulse code modulation signals using time-division multiplexing at an overall rate of 1.544 million bits per second (Mbps); T1 lines use copper wire and span distances within and between major metropolitan areas (T2, 6.312 Mbps; T3, 44.756 Mbps; T4, 273 Mbps).

**Tape Wrap**  a spirally wound tape over an insulated or uninsulated wire.

**Tear Strength**  the force required to initiate or continue a tear in a material under specified conditions.

**Teflon®**  the Dupont® brand name for FEP resin.

**Telco**  a telephone company; a term from the telephone industry jargon; it usually refers to a local exchange carrier, but is not precise and also can refer to long-distance carriers; short for Telecommunications.

**Telecommunications Bonding Backbone**  the copper conductor extending from the telecommunications main grounding busbar to the farthest floor telecommunications grounding busbar.
Telecommunications Room (TR) from ISO/IEC 11801: a cross-connect point between the backbone and horizontal cabling subsystem; houses telecommunications equipment, cable terminations and cross-connect cabling; formerly known as the telecommunications closet

Telecommunications Grounding Busbar a common point of connection for the telecommunications system and bonding to ground

Telecommunications Outlet (TO) from Cenelec EN50173: a fixed connecting device where the horizontal cable terminates; provides the interface to the work-area cabling

Tensile Strength the pull stress required to break a given specimen

Terminal a point at which information enters or leaves a communication network; the input-output associated equipment; or a device which connects wires or cables together

Termination Hardware an outmoded term; see connecting hardware

TIA Telecommunications Industry Association

TIA/EIA-568 Commercial Building Telecommunications Standard; the standard concerning acceptable cabling and connecting hardware performance for telecommunications infrastructures; "C" is the latest revision; this standard now has four parts: 568 C.0 and C.1 cover general information, 568 C.2 covers 100 ohm twisted pair, and 568 C.3 covers fiber optics

TIA/EIA-569 Commercial Building Standards for Telecommunications Pathways and Spaces

TIA/EIA-606 the Administration Standard for the Telecommunications Infrastructure of Commercial Buildings, the standard concerning telecommunications numbering and labeling, identifiers and linkages between components of the system

TIA/EIA-607 Commercial Building Grounding and Bonding Requirements for Telecommunications; the standard concerning grounding systems, practices, labeling and requirements

TIA/EIA TSB 72 Centralized Optical Fiber Cabling Guidelines (October 1995)

Tight Buffer cable construction where each glass fiber is tightly buffered by a protective thermoplastic coating to a diameter of 900 microns

Tight Buffered Fiber buffered optical fiber in which the buffer material is directly applied to the fiber coating

Time-Division Multiplexing (TDM) signaling technology in which two or more signals can be transmitted over the same path by using different time slots or intervals for each signal; in telecommunications, this is done with digital signals so that packets from two or more lower-speed digital signals are interleaved into time slots on a higher-speed multiplexed signal; in TDM fiber optic systems, the digital signals are multiplexed electronically so that resulting aggregated or multiplexed high-bit-rate signal is transmitted over fiber as a single high-speed signal; after it is received and converted to an electronic signal, it is demultiplexed electronically into the two (or more) original signals

Token Ring a network protocol in which the stations circulate a token in sequential order; the next logical station is also the next physical station on the ring, used by IBM

Topology the physical or logical configuration of a telecommunications system

TSB Technical Systems Bulletin (issued by TIA/EIA)

Transceiver a module containing both transmitter and receiver; a "transceiver" is an example of a "transmitter/receiver pair" but other examples have separate packaging for the transmitter and the receiver

Transmitter electronic package which converts an electrical signal to an optical signal

Transmitter/Receiver Pair (Tx/Rx Pair) an abbreviation used to note the number of "transmitter/receiver pairs" in the market for a specific application or customer group; a transmitter/receiver pair consists of one transmitter (laser) plus one receiver (detector); they can be in a combined "transceiver" module or packaged separately

Tray a cable tray system is a unit or assembly of units or sections, and associated fittings, made of metal or other non-combustible materials forming a rigid structural system used to support cables; cable tray systems (previously termed continuous rigid cable supports) including ladders, troughs, channels, solid bottom trays, and similar structures
Triaxial Cable  a cable construction having three coincident axes, such as conductor, first shield and second shield all insulated from one another

Twisted Pair  any of a family of data cables with two conductors twisted together; the cabled pairs may be unshielded (U/UTP), shielded (S/FTP) or screened (F/UTP)

UHF  Ultra High Frequency (300 to 3,000 MHz)

Underfloor Raceways  raceway of various cross-sections placed within the floor from which wires and cables emerge within a specific floor area

Underground Plant  communications cable that is placed within a conduit or duct system

Underwriter’s Laboratories (UL)  a non-profit organization established by the insurance industry to test devices, materials and systems for safety

Upstream  transmission direction from the subscriber towards the central office or head-end

U/UTP or UTP  Unshielded Twisted Pair

VCSEL  see Vertical Cavity Surface-Emitting LASER

VSAT  see Very Small Aperture Terminal

VP  see Velocity of Propagation

Vault  a subsurface enclosure that personnel may enter to work with or place cable and/or equipment (also known as maintenance access hole or manhole)

Velocity of Propagation (VP)  the speed of transmission of electrical energy within a cable as compared to its speed in air; also known as NVP, or nominal velocity of propagation

Vertical Cavity Surface-Emitting LASER (VCSEL)  refers to a laser diode structure designed to emit the optical radiation in a vertical direction relative to the plane with the active region; most diode lasers emit from end facets in the plane of the active region; typically used for transmission speeds of 1 Gb/s and higher

Very Small Aperture Terminal (VSAT)  a satellite communications system for data

VHF  Very High Frequency (30 to 300 MHz)

Volt  a unit of electromotive force

VW-1  a flammability rating established by Underwriters Laboratories for wires and cables that pass a specially designed vertical flame test, formerly designed FR-1

WDM  see Wavelength-Division Multiplexing

WAN  see Wide Area Network

Water Migration  the act of water traveling through a breach in the outer jacket(s) of a telecommunications cable, moving along the conductors due to capillary action

Watt  a unit of electric power

Waveguide Dispersion  dispersion caused by light traveling in both the core and cladding materials in a single-mode fiber

Wavelength  the length of a wave measured from any point on a wave to the corresponding point on the next wave, such as from crest to crest

Wavelength-Division Multiplexing (WDM)  the simultaneous transmission of more than one optical signal through an optical fiber with each signal having a distinct wavelength; WDM technology is typically used to increase system capacity by adding channels onto a signal fiber and the demultiplexers that separate the signals of different wavelengths at the receive end; see also “DWDM”

Wide Area Network (WAN)  refers to a network that uses switched long-distance, dedicated, or leased facilities to link two or more locations in different cities for data or other applications

Wire  a conductor, either bare or insulated

Work-Area Cable  from ISO/IEC 11801; connects the telecommunications outlet to the terminal equipment

Work-Area Telecommunications Outlet  a connecting device located in a work area at which the horizontal cabling terminates and provides connectivity for work-area patch cords

Zero-Dispersion Wavelength  wavelength at which the chromatic dispersion of an optical fiber is zero; occurs when waveguide dispersion cancels out material dispersion