DATA CENTER FABRIC

Best Practices Guide: Cabling the Data Center

A process overview for incorporating cabling in a typical data center; includes best practices for managing the cables, tips on selecting cabling components, a section on data transmission media, a discussion of 10 Gbit/sec cabling, and a glossary

BROCADE

Contents

INTRODUCTION

Today's data centers house a large number of diverse bandwidth-intensive devices, including bladed servers, clustered storage systems, virtualization appliances, and backup devices—all interconnected by networking equipment. These devices require physical cabling with an increasing demand for higher performance and flexibility, all of which require a reliable, scalable, and manageable cabling infrastructure.

Challenges arise not only with trying to research emerging data center cabling offerings in order to determine what you need for today and for future growth, but also with evolving cabling industry guidance, which sometimes lags in the race to deliver standards for deploying technologies such as 10 Gbit/sec data transmissions and beyond.

This paper takes you, briefly, through the process of effectively incorporating and managing the cabling in a typical data center, which involves:

- Planning the cabling infrastructure
- Selecting cabling components
- Implementing the cabling & testing cables
- Building a cable routing framework for equipment racks
- Managing the cabling infrastructure

Appendices cover the following topics:

- Data transmission media basics
- Common challenges faced with 10 Gbit/sec cabling

NOTE: Consult the glossary at the end of this paper for cabling terms and definitions.

Planning Is Key

Your task may involve wiring a new data center or upgrading the cabling in an existing data center.

- You are advised to review the common media used for data transmission and the cable types available (see "Appendix A: Data Transmission Media Basics").
- If you are upgrading an existing data center, you must evaluate, capture, and understand the present cabling infrastructure thoroughly.
- Document the current (if any) and projected network topologies using an application such as Microsoft Visio. Focus on the physical aspects, especially equipment interfaces. Document the various cable types present and proposed, present and projected cable counts, approximate routed distances to distribution areas and equipment, present and anticipated equipment port counts. Additionally, document any areas of concern, and any established internal cabling standards.
- Plan to accommodate both copper and fiber media, since each media has its unique place in the cabling segment. Build in flexibility, so that the patching structure will allow a device to connect to any other device in the data center. This will permit devices to be located anywhere within the data center.

Using a Structured Approach

The structured approach to cabling involves designing cable runs and connections to facilitate identifying cables, troubleshooting, and planning for future changes. In contrast, spontaneous or reactive deployment of cables to suit immediate needs often makes it difficult to diagnose problems and to verify proper connectivity.

Using a structured approach means establishing a Main Distribution Area (MDA), one or several Horizontal Distribution Areas (HDAs), and two-post racks for better access and cable management. The components selected for building the MDA and the HDA should be of good quality and able to handle anticipated and future loads, as this area will house the bulk of the cabling. Include horizontal and vertical cable managers in the layout. The MDA will house the main cross-connects as well as the core networking equipment. The HDA will house the cross-connects for distributing cables to the Equipment Distribution Areas (EDAs). Patch cables will be used to connect equipment such as servers and storage using the patch panels at their designated EDA.

Plan the layout of the equipment racks within the data center. Cables will be distributed from the HDA to the EDA using horizontal cabling. Dynamic data center environments call for a great deal of flexibility in connectivity, and the objective is to implement a cabling system with copper and fiber media capable of transmitting Ethernet, Fiber Channel, and any other protocols specific for the environment. Ensure that you address both current and future port counts and applications needs.

Plan for growth and for changes in technology, and implement the projected ports and cabling now while the tiles are off and other cables are being run. It will cost a lot more in labor and downtime to perform an upgrade later.

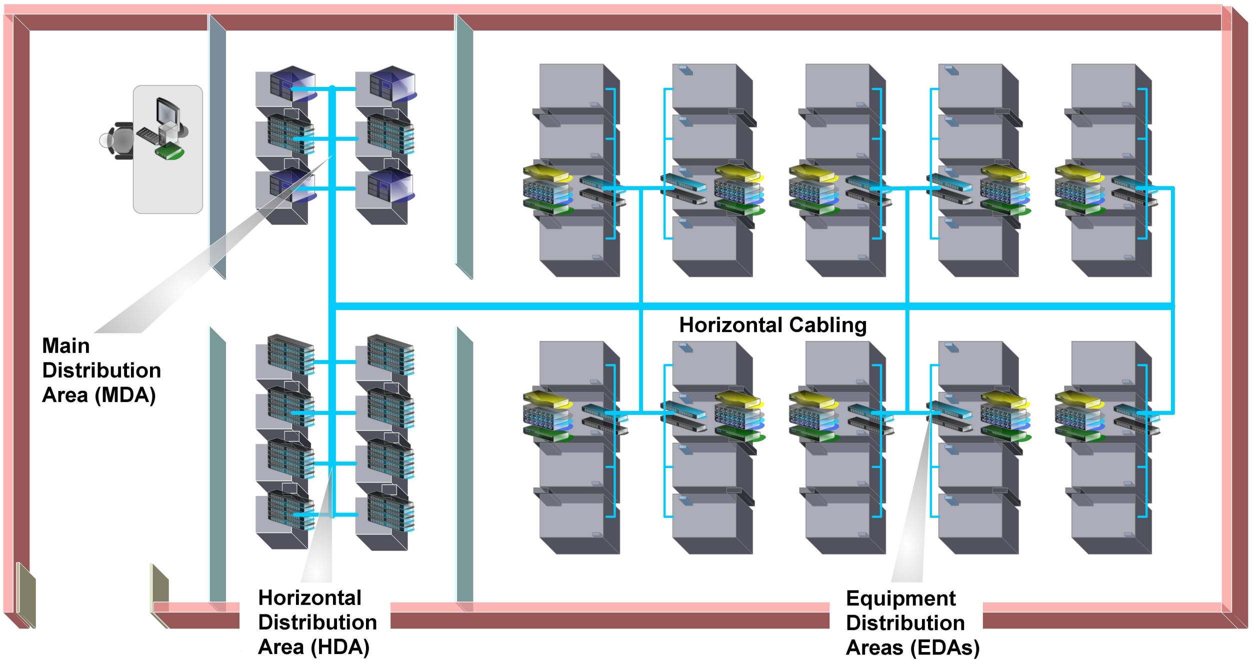

Figure 1. Top view of a data center layout showing a Main Distribution Area (MDA), a Horizontal Distribution Area (HAD) and several Equipment Distribution Areas (EDA).

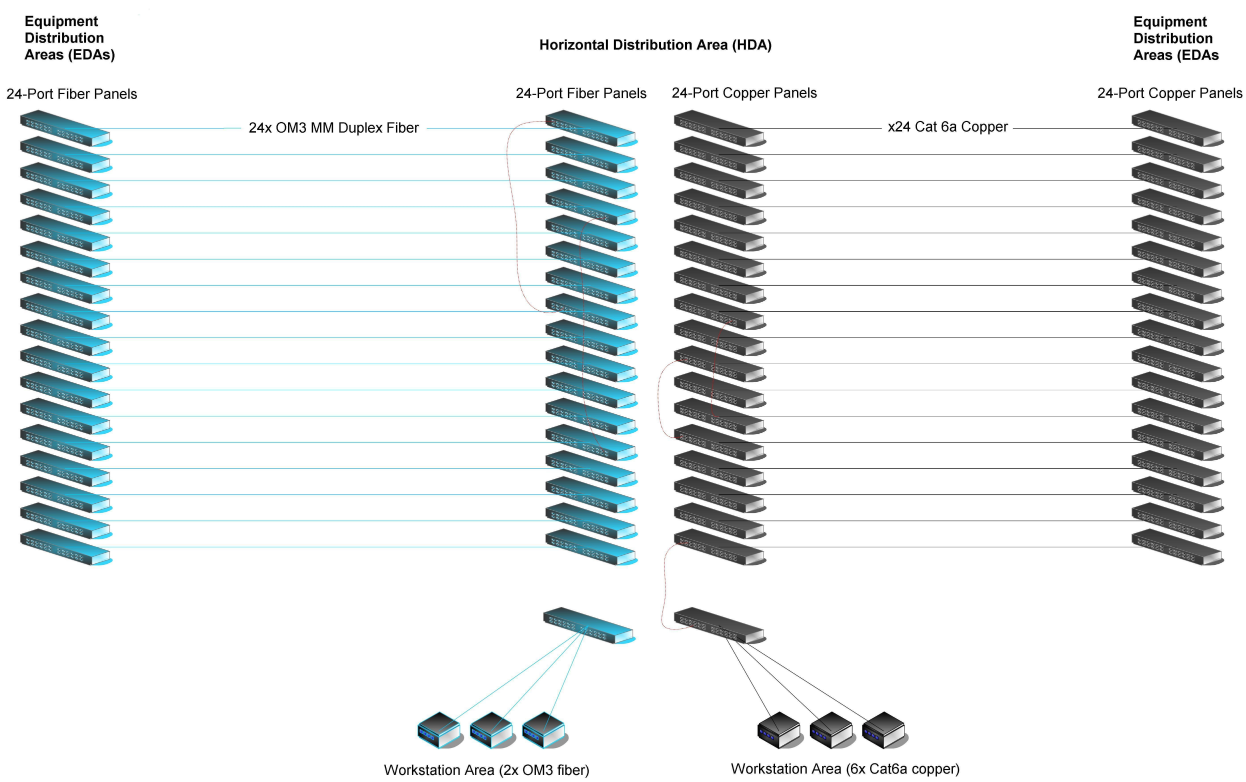

Figure 2. Sample logical diagram of the cable distribution between an HDA and several EDAs using horizontal cables.

Each scenario brings about its own challenges and customization requirements. It is important to digest the TIA-942 and the TIA/EIA-568 industry guidelines and to establish the cabling into some sort of structure. Each cabling component has an important role in the overall infrastructure and the trick is to carefully select and apply the right mix.

- Start with the proposed network topology that includes the network components in the data center.
- Next, identify common cable distribution points in the cable layout diagram such as network switches, server concentration areas, and workstation areas—and their locations. These will help identify the required cabling distribution areas (for example, MDA) and cabling components within these distribution areas.
- The logical cabling should eventually map to a physical map of the cabling for the data center. Plan your current and future port counts and cable media, and use that information to calculate quantities.
- Work with a reputable cabling contractor to survey the data center environment and to establish the exact locations for the proposed cable distribution points. Start with the Main Distribution Area and gradually expand out to the Equipment Distribution Areas.

NOTE: According to TIA-942 recommendations, there must one Main Distribution Area, one or more Horizontal Distribution Areas, and one or more Equipment Distribution Areas within a data center.

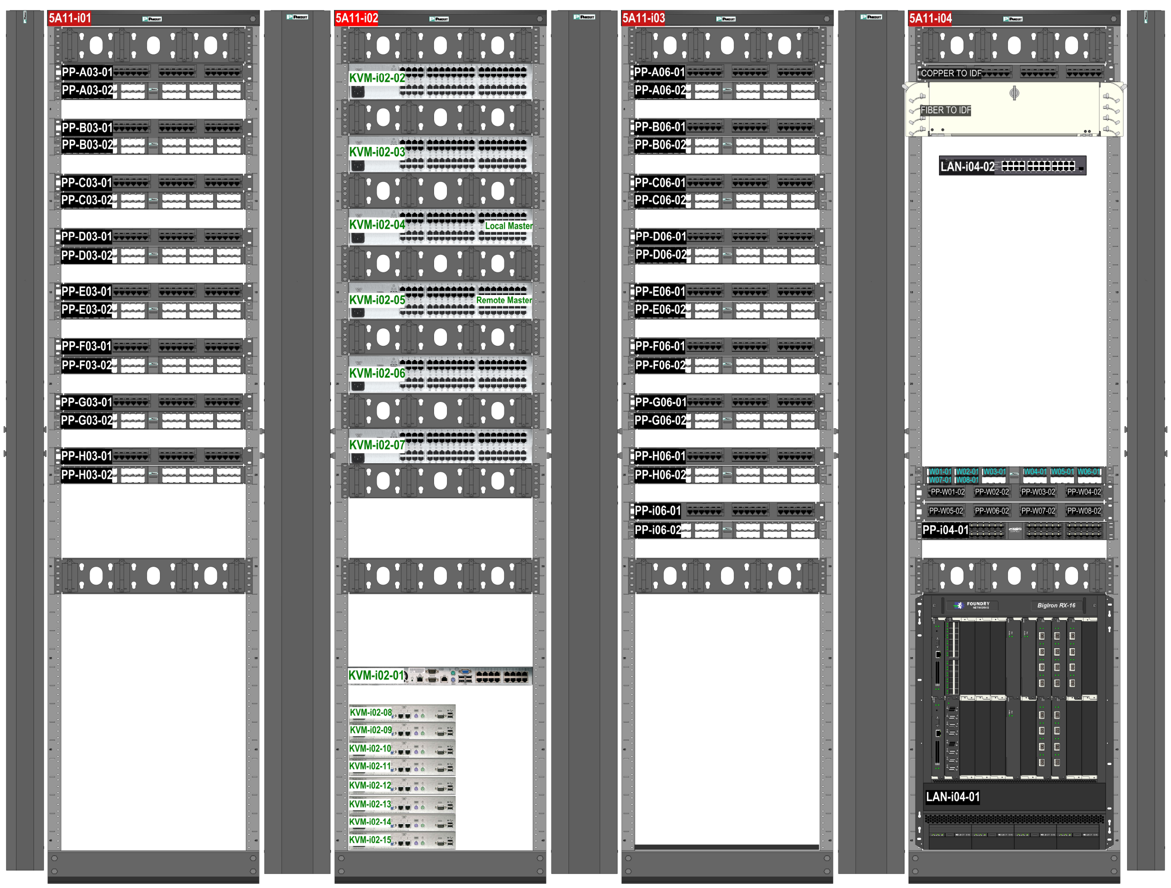

Figure 3. Layout of a Horizontal Distribution Area that includes patch panels, cable managers, and network equipment.

If you require further customization of cabling components, cabling contractors and manufacturers are usually willing to cooperate to modify products to suit your needs.

Structuring the cabling has many benefits, and since manufacturers strive to conform to standards, compatibility should not be a major issue. A structured infrastructure provides you with some of the following benefits:

- Simplifies cable identification and fault isolation
- Consistent current cabling shapes the foundation for future cabling
- Additions and modifications are easier to accommodate
- Can mix-and-match multi vendor components (be sure they comply with the same standards)
- Provides flexibility in connections

Modular Data Cabling

Modular cabling systems for fiber and copper connectivity are gaining in popularity. Modular cabling introduces the concept of plug-and-play, simplifying the installation of cables and drastically reducing labor time and costs. Cables are usually pre-terminated and tested at the factory.

As equipment prices continue to drop, vendors continue to build better options. The main difference to consider currently is the cost of modular components versus the cost of labor for a non-modular but structured offering. Although modular cabling saves you time and money when you want to modify the infrastructure yourself, the tradeoff is less flexibility and a potential commitment to stay with the chosen vendor for continued compatibility.

Cabling High Density, High Port Count Fiber Equipment

As networking equipment becomes denser and port counts in the data center increase to several hundred ports, managing cables connected to these devices becomes a difficult challenge. Traditionally, connecting cables directly to individual ports on low port-count equipment was considered manageable. Applying the same principles to high-density and high-port-count equipment makes the task more tedious, and it is nearly impossible to add or remove cables connected directly to the equipment ports.

Using fiber cable assemblies that have a single connector at one end of the cable and multiple duplex breakout cables at the other end is an alternative to alleviate cable management. Multifiber Push-On (MPO) cable assemblies are designed to do just that. The idea is to pre-connect the high-density, high-port-count Lucent Connector (LC) equipment with LC-MPO fan-out cable (shown in Figure 4) to dedicated MPO modules within a dedicated patch panel. Once fully cabled, this patch panel functions as if it were “remote” ports for the equipment. These dedicated patch panels ideally should be located above the equipment whose cabling they handle for easier access to overhead cabling. Using this strategy drastically reduces equipment cabling clutter and improves cable management.

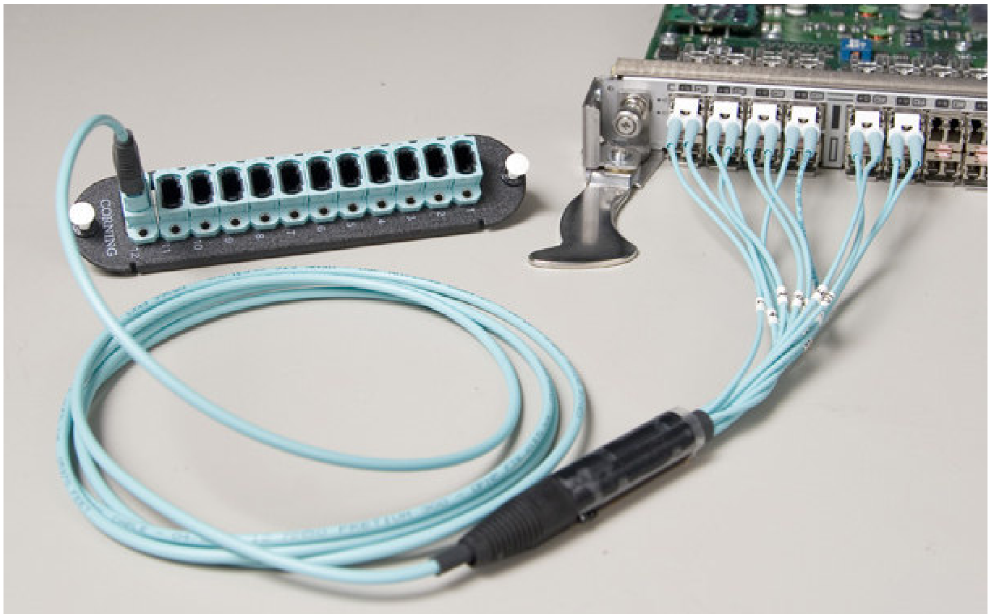

Figure 4. LC-MPO fan-out cable consolidates six duplex LC ports into one MPO connection.

As an example, the MPO module shown in Figure 4 is housed into a modular patch panel installed above a Fiber Channel director switch at the EDA. MPO trunk cables are used to link this patch panel to another modular patch panel located at the HDA. The patch panel at the HDA converts the MPO interface back to the LC interfaces using MPO-to-LC cassettes. MPO trunk cables can accommodate up to 72 individual fibers in one assembly; providing 36 duplex connections.

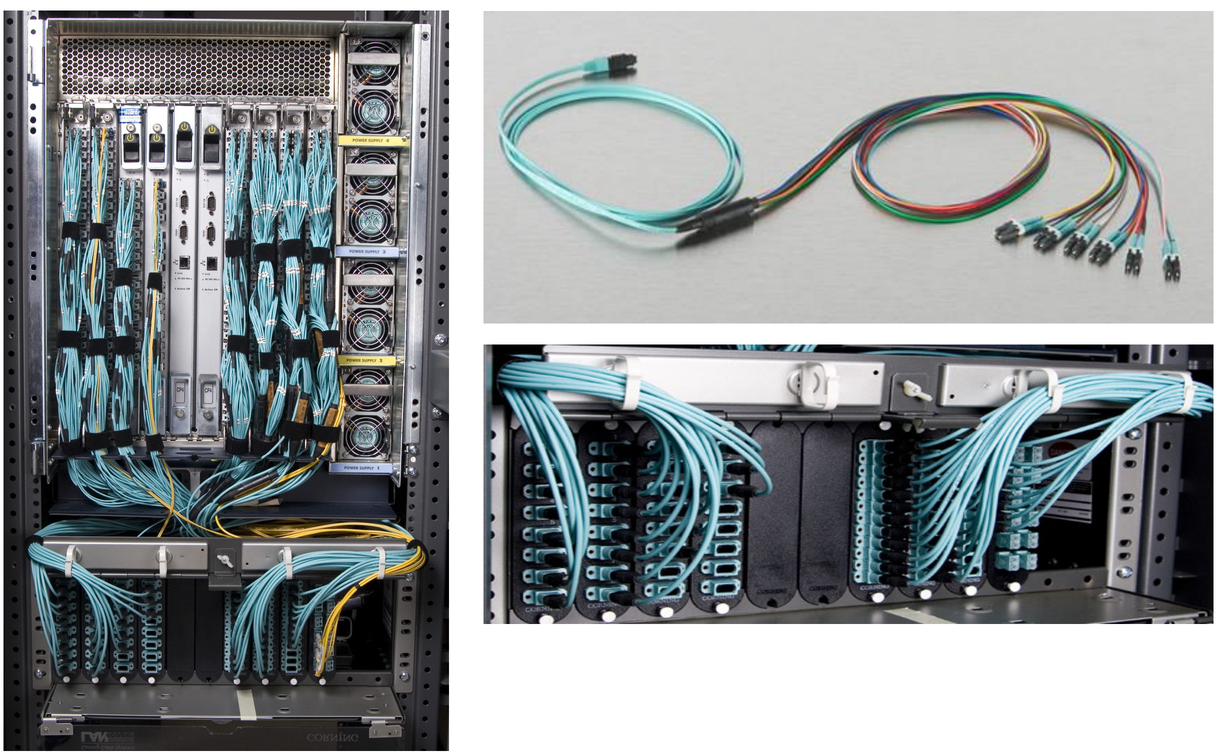

Figure 5. Director-class switch using MPO fan-out cabling structure.

Trusting the Standards

Industry cabling standards are designed to protect the end user. Whether these standards are in draft or ratified state, they provide a firm foundation for establishing a coherent infrastructure, and guidelines for maintaining high levels of cable performance. Cabling standards define cabling specifications looking out to the next several years, thus supporting future desires for higher speed transmissions. Standards enable vendors to use common media, connectors, test methodologies, and topologies, and allow planners to design a cabling layout in the data center without worrying about compatibility issues.

There are a number of standards organizations and standards. The three best-known cabling standards organization are listed below:

- United States ANSI/TIA/EIA-568 from the Telecommunications Industry Association (TIA)
- International ISO/IEC IS 11801 (also referred to as Generic Customer Premises Cabling)
- International TIA-942 from the TIA

NOTE: Cabling standards are reviewed and changed every five to ten years, which allows them to keep pace with technology advances and future requirements. Know and trust the standards, and apply common sense when designing, implementing, testing, and maintaining data center cabling.

Using Color to Identify Cables

Color provides quick visual identification. Color coding simplifies management and can save you hours when you need to trace cables. Color coding can be applied to ports on a patch panel: patch panels themselves come with different color jacks or have colored inserts that surround the jack. Cables are available in many colors (the color palette depends on the cable manufacturer). Apply these colors to identify the role/function of a cable or the type of connection.

Below is an example color scheme for patch cables.

Color	Type	Application (connections may by through patch panels)
Aqua	**OM3 fiber**	**LAN/SAN device to device**
Yellow	Single Mode Fiber	LAN/SAN device to device over long distance
Orange	OM1 or OM2 fiber	LAN/SAN device to device
Blue	Copper	LAN device to device
Green	Copper	KVM host to KVM switch, KVM switch to LAN switch, KVM switch to KVM switch
Yellow	Copper	Serial host to Terminal Server, Terminal Server to LAN switch
White	Copper	Power strip to LAN switch

In addition to cable colors, you can expand the color scheme by using different 1” color bands at each end of the cable, different color sleeves, and different color ports on the patch panel.

NOTE: If you use colors to identify cable functions or connections, be sure to build in redundancy to accommodate individuals with color blindness or color vision deficiency.

Establishing a Naming Scheme

Once the logical and physical layouts for the cabling are defined, apply logical naming that will uniquely and easily identify each cabling component. Effective labeling promotes better communications and eliminates confusion when someone is trying to locate a component. Labeling is a key part of the process and should not be skipped. A suggested naming scheme for labeling and documenting cable components is suggested below (examples appear in parentheses):

- Building (**SJ01**)
- Room (SJ01-**5D11**)
- Rack or Grid Cell: Can be a grid allocation within the room (SJ01-5D11-**A03**)
- Patch Panel: instance in the rack or area (SJ01-5D11-A03-**PP02**)
- Workstation Outlet: Instance in the racks or area (SJ01-5D11-A01-**WS02**)
- Port: Instance in the patch panel or workstation outlet (SJ01-5D11-A03-PP02**_01**)
- Cable (each end labeled with the destination port)

(You can exclude Building and Room if there is only one instance of this entity in your environment.)

Once the naming scheme is approved, you can start labeling the components. Be sure to create a reference document that will become part of the training for new data center administrators.

TIPS ON SELECTING CABLING COMPONENTS

Narrowing down and selecting the right combination of cabling components can quickly become overwhelming, especially when you consider the hundreds of comparable components available on the market. Each component has its own advantages and disadvantages, cost variations, and compatibility levels. This is your best chance to get the right equipment purchased and deployed and to avoid future cabling issues. As you make purchasing decisions, look for compatibility, ease of installation, cost, density, durability, aesthetics, accessibility, flexibility, and delivery times.

The components that make up the cabling structure range from data ports to patch cables to panels to cable managers. You will find a large selection, and as a general rule you should be able to mix and match vendor equipment, as long as they comply with the same standards.

Patch Cables

Patch cables are used to connect end devices to patch panel ports and to connect ports between two local patch panels. A big issue with patch cables is the design and quality of the terminations. This is especially true for RJ45 copper terminations. Keep in mind that the patch cable is a cabling component that will experience the most wear and tear.

Review cables from a number of different manufacturers and consider the following:

- √ Specification of the cable; avoid cheap, low-quality cables
- √ Compliance to EIA/TIA/IEEE standards
- √ Thickness of the copper cable; thicker is better
- √ Flexibility of the cable; the less cable memory the better
- √ Connector design and quality; this is a matter of personal preference. Ensure that you have exercised several similar cables with your network equipment and other cabling components
- √ Availability of colors and categories, since you will want to standardize for current and future needs
- √ Support for future applications

Patch Panels

Patch panels allow easy management of patch cables and link the cabling distribution areas. Multimedia patch panels, which allow several different cable connectors to be used in the same patch panel, are ideal. The main types of connectors that should be considered are LC for fiber and RJ-45 for copper. Although mixing cable types within the same patch panel is not best practice, it is good to have this flexibility for housing ad-hoc cable types. The best practice is to separate the fiber cabling from the copper cabling, using separate patch panels.

Colored jacks or bezels in the patch panel allow easy identification of the ports and the applications they are intended for. Patch panels also come in modular styles, for example, for an MPO structured system. The tradeoff for the higher cost of materials is this: some of this cost is recovered from faster installation and thus lower labor cost.

Figure 6. Angled patch panels allow cables to be routed directly into the vertical cable managers.

Angled patch panels, such as those shown in Figure 6, are ideal for high-density areas, as they do not require additional cable managers to be installed above and below the patch panel. They also allow for higher concentration of cables. When selecting patch panels, consider the following:

√ Spacing between ports aids insertion and removal of cables

√ Sturdy connectors: some panels have loose connectors and tend to fall out during cable installation and removal

√ Orientation of ports in the panel: the top row and bottom row cable clips should face outward. Test these connections with your patch cables.

√ One-piece dust covers for ports (recommended for high traffic areas)

√ Density supported (24 ports or 48 ports per 1U panel)

√ Compatibility with your racks

√ Space for labeling on the front of the panel

√ Compatibility with Industry standard connectors and racks

√ Added cable support for the intended cable types on the back of the panel. This is critical and overlooked by many manufacturers.

Horizontal and Backbone Cables

Choose the fire-rated plenum type. These cables may not be as flexible as the patch cords, because they are meant for fairly static placements, for example, between the EDA and the HDA. There are no high-density copper solutions, but you can choose a modular cabling system such as the MRJ21 connector system. For fiber, high density involving 24-strand to 96-strand cables is adequate. Fiber breakout cables provide additional protection, but add to the diameter of the overall cable bundle. For fiber, MPO trunk cables (up to 72 fiber strands can be housed in one MPO connection) can be installed if you are using MPO style cabling.

Evaluate the cost of materials and labor for terminating connections into patch panels. These cables will most likely end up under raised floors, or over the ceiling, or in overhead cable pathways—out of view and touch from end users.

Horizontal Cable Managers

Horizontal cable managers (shown in Figure 7) allow neat and proper routing of the patch cables from equipment in racks and protect cables from damage. These cable managers take up the much-needed space in racks, so a careful balance between cable manager height and cable density supported is important. 1U and 2U horizontal cable managers are the most common varieties. The density supported varies with the height and depth of the manager. Horizontal cable managers come in metal and flexible plastic—choose the ones that work best for you. The ideal cable manager has a big enough lip to easily position and remove cables, and has sufficient depth to accommodate the quantity of cables planned for that area. Note that you should allow 30% space in the cable managers for future growth.

Choose these cable managers carefully so that cable bend radius is accommodated. Make sure that certain parts of the horizontal cable manager are not obstructing equipment in the racks, and that those individual cables are easy to add and remove. Some cable managers come with dust covers. For dynamic environments, however, dust covers can be an obstacle when quick cable changes are required.

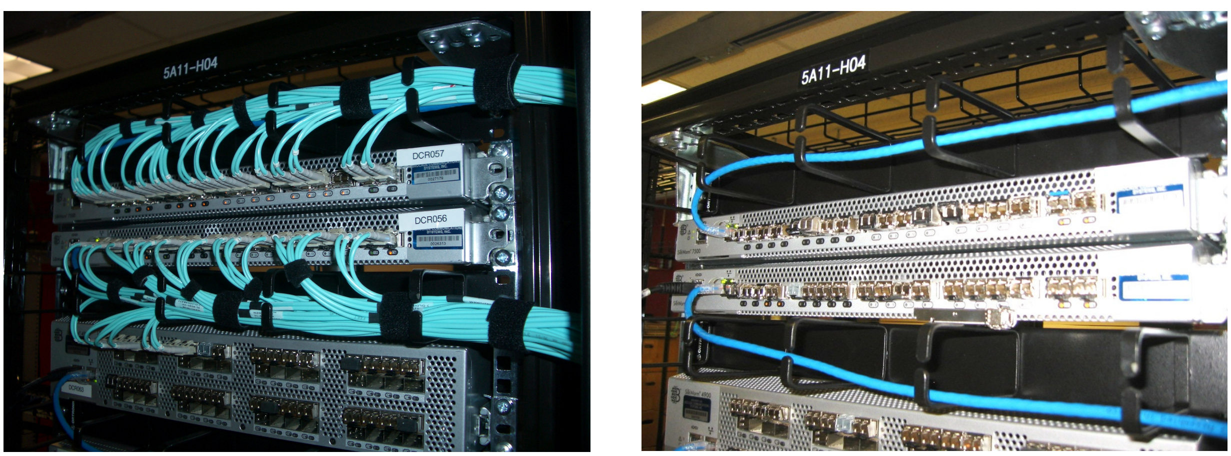

Figure 7. Cables from devices are routed through the horizontal cable managers.

Vertical Cable Managers

For vertical cable managers, look for the additional space required to manage the slack from patch cords, and ensure that they can easily route the largest cable diameter in your plan. The most convenient managers available on the market have hinged doors on both sides of the manager for pivoting the door from either side, and allow complete removal of the doors for unobstructed access. Allow for 50 percent growth of cables when planning the width (4" width for edge racks and 6" width for distribution racks are typical) and depth (6" depth is typical) of the vertical cable manager. Additionally, use d-rings type cable managers to manage cables on the back side of the racks in dynamic environments. For static environments, you can consider installing another vertical cable manager behind the racks, which does not block access to components in the space between the racks.

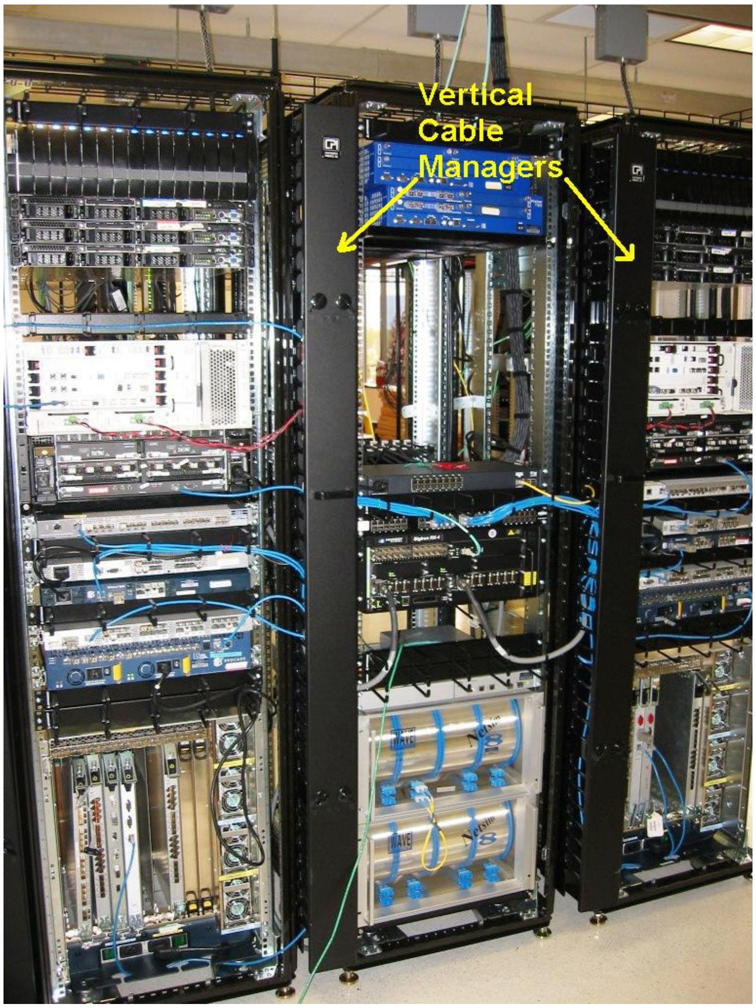

Figure 8. Vertical cable managers are installed between racks. Cables are routed from the horizontal cable manager into the vertical cable managers.

Overhead Cable Pathways

Overhead cable pathways or trays allow placement of additional cables for interconnecting devices between racks on an ad-hoc basis. Check support for cable bend radius, weight allowance, sagging points for cables, and flexibility in installing the pathways. In addition, ensure that pathways allow cable drop points where needed. These trays should be easy to install and to customize.

Figure 9. Overhead cable pathways used for routing cables between distribution areas or for ad-hoc cabling between distant racks.

Cable Ties

Use cable ties to hold a group of cables together or to fasten cables to other components. Choose Velcro-based cable ties versus zip ties, as there is a tendency for users to over-tighten zip ties. Over-tightening can crush the cables and impact performance. Velcro cable ties come in a roll or in pre-determined lengths. Bundle groups of relevant cables with ties *as you install*, which will help you identify cables later and facilitate better overall cable management.

Labelers

Labelers are used to print sticky labels for devices and cables. Here are some considerations when you choose a hand-held labeler:

- √ Should be capable of operating using batteries
- √ Can print labels on smooth, textured, flat, and curved surfaces
- √ The actual label material should resist solvents, chemicals, and moisture
- √ Labels are durable and resist fading
- √ Adhesive should be long-lasting

If you choose a labeler with bundled software, install it on a client workstation. You can then customize labels, print labels in batches, and store the formats for future printing.

IMPLEMENTING THE CABLING INFRASTRUCTURE

The cabling infrastructure will be under a raised floor or overhead—or both. This is where the bulk of the horizontal cabling will be installed. Most likely you will hire a reputable cabling contractor to survey the environment, plan out the cabling routes, and install the horizontal runs. Ensure that copper and fiber runs are separated, because the weight of copper cables can damage the fiber.

Also, ensure that the cabling contractor:

- Allows room for future growth
- Is careful about cable bend stress
- Uses plenum-rated cable where needed
- Is aware of and bases installation on industry standards (see the next section on standards)
- Tests the cabling consistently during installation

Testing the Links

Testing cables throughout the installation stage is imperative. Any cables that are relocated or terminated after testing should be retested. Although testing is usually carried out by an authorized cabling implementer, you should obtain a test report for each cable installed as part of the implementation task. For 10 Gbit/sec testing over copper, a new parameter called "alien crosstalk" has been introduced.

NOTE: In a twisted-pair system, the actual measured length will be greater than the physical length due to the twists in the cable. Also note that the maximum supported distance for a cable specifies the total end-to-end length (these include patch cables) and not just the individual cables.

Building a Common Framework for the Racks

The goal of this step is to stage a layout that can be mirrored *across all racks in the data center* for consistency, management, and convenience. Starting with an empty 4-post rack or two, build out and establish an internal standard for placing patch panels, horizontal cable managers, vertical cable managers, power strips, KVM switch, serial console switch, and any other devices that are planned for placement into racks or a group of racks. The idea is to fully cable up the common components while monitoring the cooling, power, equipment access, and growth for the main components in the racks (such as servers and network switches).

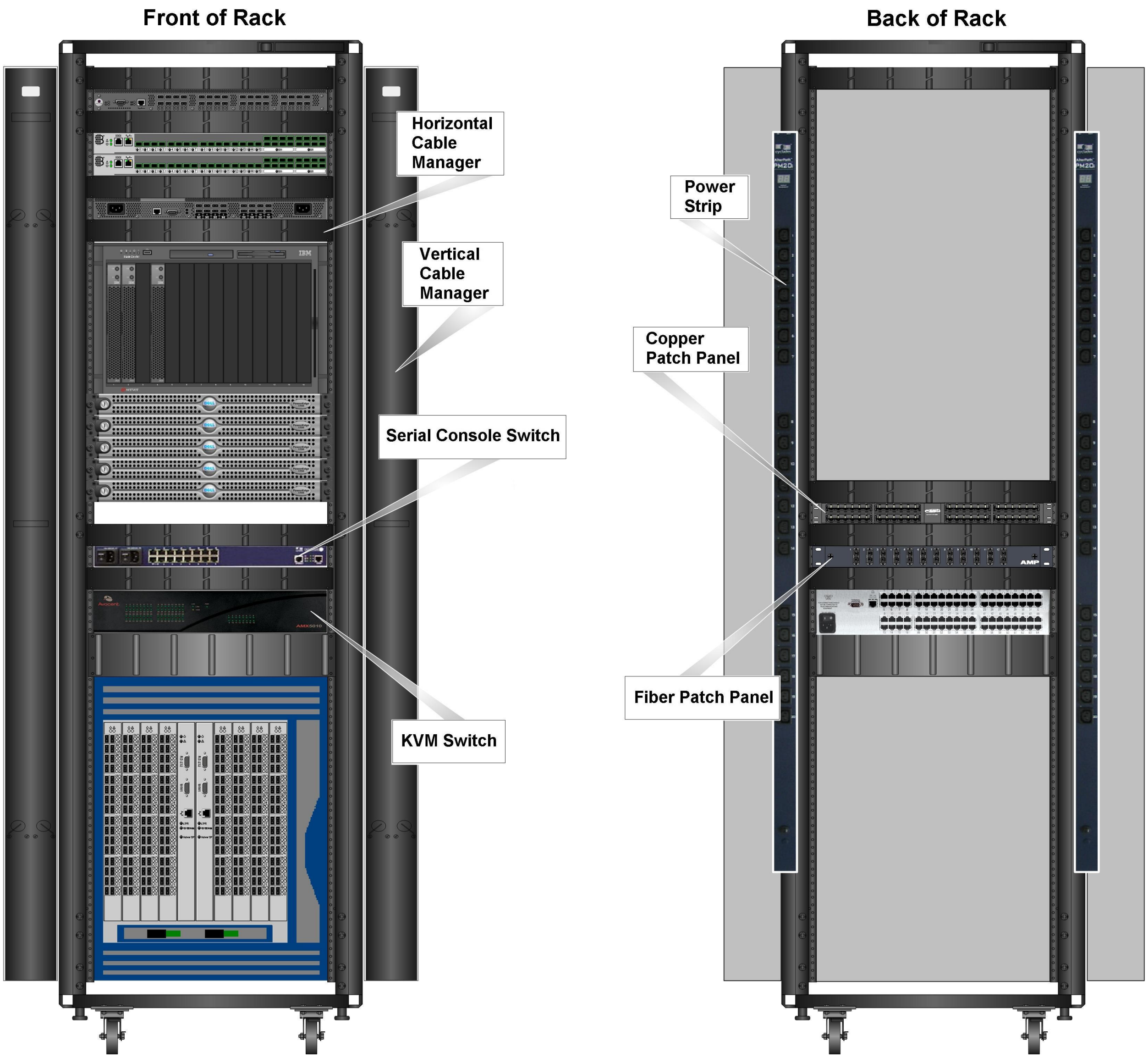

Figure 10. Front and back view of a rack showing placements of common cabling components.

A good layout discourages cabling in between racks due to lack of available data ports or power supply ports. Allow more power outlets and network ports than you need. This will save you money in the long run as rack density increases, calling for more power and network connectivity. Using correct length cables, route patch cables up or down through horizontal patch panels, avoiding overlapping other ports. Some cable slack may be needed to enable easy removal of racked equipment.

Once you are satisfied that the rack is populated and cabled efficiently, label, document and establish this as an internal standard for your data center. Once you have created the ideal layout of a rack, you will be able to get an idea of cable density, power consumption, weight, and the heat generated per rack—for the entire data center. The actual figures will vary from rack to rack, but this will establish baseline metrics.

Vertical cable managers should be mounted between racks. The outermost rack may not need a vertical cable manager if you decide to route cables using the between-rack vertical cable managers only. Also, ensure that the front of the vertical cable manager is flush with the front of the horizontal cable manager to provide better routing and management of the cables.

Placement of horizontal cable managers is important too. Use one horizontal cable manager to route cables between two adjacent 1U switches that have a single row of ports. For switches and equipment that have two rows of ports, route the cables from the top row of the equipment to a horizontal cable manager placed above this equipment; route the cables from the bottom row of the equipment to a horizontal cable manager placed below the equipment. Bladed systems, especially ones with high port counts, usually come with recommended cable routing guidelines—ensure that are addressed in your layout.

Preserving the Composition

Physically, the cabling infrastructure is at its “peak” immediately following a clean installation or upgrade. Even when you have hired a cabling contractor to install, label, dress, and test the cabling; when the contractor walks away, it will be your task to manage and maintain the conventions you set up initially.

Regular inspections of the cabling layout will go a long way toward maintaining consistency. It will also help you identify problem areas for improvement and give you ideas for future enhancements to accommodate newer devices.

Documentation

Perhaps the most critical task in cable management is to document the complete infrastructure: including diagrams, cable types, patching information, and cable counts.

Keep this information easily accessible to data center staff on a share drive or intranet Web site. Assign updates to one or more staff members and make sure it is part of their job assignment to keep the documentation up-to-date. Furthermore, create a Training Guide, which documents guidelines for installing new cables, cable management components, and routing cables. Take digital photographs as reference points to support your guiding principles.

NOTE: The cabling contractor should provide this documentation, so be sure that it is included in the Statement of Work (SOW) and that it is delivered in a timely manner once the cabling is complete.

Stocking Spare Cables

Where do you go when you need the correct type and correct length patch cable right away? Unless you are very good with cable terminating tools, buy a small stock of cables in multiple lengths and colors. The most frequently used patch cable lengths are 3 ft, 5 ft, and 7 ft. The types and colors will vary per implementation. The variation that is most common to your environment will be self-evident once you have fully cabled two to three racks in the data center. Although in an emergency there is a human tendency to “cannibalize” existing equipment that is not being used, *this is not good practice*.

Maintaining an approximate count on the installed cabling and port count usage will give you an idea of what spares you need to keep on hand.

Paradoxically, managing spare cables has its own challenges. How do you effectively store and easily identify recoiled cables, and keep a count of the spares? Again, discipline is the key, with whatever guidelines you have put in place.

Best Practices for Managing the Cabling

Whether implementing, upgrading, or maintaining cabling in the data center, establish a set of guidelines that are thoroughly understood and supported by the staff. Here are some pointers for managing your cabling.

During Installation

√ Avoid over-bundling the cables or placing multiple bundles on top of each other, which can degrade performance of the cables underneath. Additionally, keep fiber and copper runs separated, because the weight of the copper cables can crush any fiber cables that are placed underneath.

√ Avoid mounting cabling components in locations that block access to other equipment inside and outside the racks.

√ Keep all cable runs under 90 percent of the maximum distance supported for each media type as specified in the relevant standard. This extra headroom is for the additional patch cables that will be included in the end-to-end connection.

√ For backbone and horizontal runs, install additional cables as spares.

√ Install higher cabling categories that will meet application requirements for the foreseeable future.

√ Cabling installations and components should be compliant with industry standards.

√ Don’t stress the cable by doing any of the following:

- Applying additional twists
- Pulling or stretching beyond its specified pulling load rating
- Bending it beyond its specified bend radius, and certainly not beyond 90º
- Creating tension in suspended runs
- Stapling or applying pressure with cable ties

√ Avoid placing copper cables near equipment that may generate high levels of electromagnetic interference. Generally avoid locations near power cords, fluorescent lights, building electrical cables, and fire prevention components.

√ Avoid routing cables through pipes and holes. This may limit additional future cable runs.

√ Label cables with their destination at every termination point (this means labeling both ends of the cable).

√ Test every cable as it is installed and terminated. It will be difficult to identify problem cables later.

√ Locate the main cabling distribution area nearer the center of the data center to limit cable distances.

- √ For horizontal and backbone twisted-pair cabling, preserve the same density of twists in the cable pairs up to its termination.
- √ Use thin and high-density cables wherever possible, allowing more cable runs in tight spaces. Ensure the selected cables meet standard specifications.
- √ Dedicate outlets for terminating horizontal cables, that is, allocate a port in the patch panel for each horizontal run.
- √ Include sufficient vertical and horizontal managers in your design; future changes may involve downtime as cables are removed during the changes.
- √ Use angled patch panels within high-density areas, such as the cable distribution area. Use straight patch panels at the distribution racks.
- √ Utilize modular cabling systems to map ports from equipment with high density port counts; as described in the earlier section titled “The Structured Approach”.

Daily Practices

- √ Avoid leaving loose cables on the floor; this is a major safety hazard. Use the horizontal, vertical, or overhead cable managers.
- √ Avoid exposing cables to direct sunlight and areas of condensation.
- √ Do not mix 50-micron cables with 62.5-micron cables on a link.
- √ Remove abandoned cables that can restrict air flow and potentially fuel a fire.
- √ Keep some spare patch cables. The types and quantity can be determined from the installation and projected growth. Try to keep all unused cables bagged and capped when not in use.
- √ Use horizontal and vertical cable guides to route cables within and between racks. Use “cable spool” devices in cable managers to avoid kinks and sharp bends in the cable.
- √ Document all cabling components and their linkage between components and make sure that this information is updated on a regular basis. The installation, labeling, and documentation should always match.
- √ Use the correct length patch cable, leaving some slack at each end for end device movements.
- √ Bundle cables together in groups of relevance (for example, ISL cables and uplinks to core devices), as this will ease management and troubleshooting.
- √ When bundling or securing cables, use Velcro-based ties every 12” to 24”. Avoid using zip ties as these apply pressure on the cables.
- √ Avoid routing cables over equipment and other patch panel ports. Route below or above and into the horizontal cable manager for every cable.
- √ Maintain the cabling documentation, labeling, and logical/physical cabling diagrams.
- √ Maintain a small stock of the most commonly used patch cables.

SUMMARY

Although cabling represents less than 10 percent of the overall data center network investment, expect it to outlive most other network components and expect it to be the most difficult and potentially costly component to replace. When purchasing the cabling infrastructure, consider not only the initial implementation costs, but subsequent costs as well. Understand the full lifecycle and study local industry trends to arrive at the right decision for your environment.

Choose the strongest foundation to support your present and future network technology needs—comply with TIA/ISO cabling standards. The cabling itself calls for the right knowledge, the right tools, patience, a structured approach, and most of all, discipline. Without discipline, it is common to see complex cabling "masterpieces" quickly get out of control, leading to chaos.

Since each environment is different, unfortunately, there is no single solution that will meet all of your cable management needs. Following the guidelines and best practices in this paper will go a long way to providing you with the information required for the successful deployment of a cabling infrastructure in your data center.

Appendix A: Data Transmission Media Basics

There are two common types of data transmission media found in data centers: fiber optics and twisted-pair copper. These types are available in different grades of performance and are constructed to fulfill specific application needs.

Fiber Optics

Fiber optic cables are made of a glass core covered by several protective and strengthening layers. These layers contain cladding, stranded fibers, and a jacket. This media is designed to transmit light signals, allowing movement of data at faster speeds and at greater distances than twisted-pair copper cables. Light waves propagate through the core and are confined to the core until they reach the other end of the cable. Fiber optics cabling is commonly referred to as MultiMode Fiber (MMF), which is designed for short distances and Single Mode Fiber (SMF), which is designed to cover long distances.

Twisted-Pair Copper

This media consists of several copper wires surrounded by insulators and is designed to transmit electronic signals. Two insulated wires are twisted together to form a pair, and the pair forms a balanced circuit. The twisting of the wires protects against Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI). A typical cable consists of multiple twisted pairs housed within a protective jacket.

Copper cables are available in Unshielded Twisted-Pair (UTP) and Shielded Twisted-Pair (STP). Unshielded cables are easier to implement, slightly cheaper, and more widely used than their shielded counterparts. Shielded cabling is less susceptible to EMI and RFI, which is achieved by using a thin foil wrapper around each pair of twisted wires. Shielded cable types are commonly termed as “foil shielded,” “screened,” or “shielded.”

Cable Personalities

Cables are graded and categorized according to their performance (industry standards define the boundaries for this performance) and vary greatly from manufacturer to manufacturer. Cables also have well-defined characteristics, such as pulling load rating, fire rating, bend radius, maximum supported length, and maximum supported bandwidth.

Two of the most important performance measurements for cables are attenuation and alien crosstalk.

Attenuation

Attenuation is the loss or reduction in signal strength over distance. Apart from distance, attenuation can be exacerbated by damaged or bad cables, higher temperatures, or metal conduits. Weak signals cause the receiving equipment to interpret signals incorrectly and data to be discarded, thus forcing retransmissions—which leads to performance degradation. Attenuation in copper cables increases with frequency, so the higher the speed the greater the attenuation. Attenuation in fiber optic cables decreases with frequency and the lowest attenuation is found at 1550 nm.

Alien Crosstalk (AXT)

Twisted-pair copper cables are susceptible to signals from other surrounding components. Unwanted signal coupling from one component to another is known as “alien crosstalk.” Alien crosstalk can compromise the integrity of high-speed transmissions over copper cables such as 10GBase-T Ethernet, requiring special handling of such cables during installation, testing, and use. Optical fiber does not experience AXT.

Comparison of Cable Types

The following table compares fiber optic and copper cables.

Fiber						
Medium	**Standard**	**Maximum Rate**	**Maximum Distance**	**Maximum Bandwidth**	**Common Connectors**	**Common Applications**
MMF (62.5/125 microns)	OM1	1 Gbit/sec	300 m[2]	200 MHz[2]	LC, SC, ST, MPO	FDDI, Ethernet
MMF (50/125 microns)	OM2	1 Gbit/sec	500 m[2]	500 MHz[2]	LC, SC, ST, MPO	SANs, High Speed Ethernet
MMF Laser Optimized (50/125 microns)	OM3	10 Gbit/sec	300 m[2]	2000 MHz[2]	LC, SC, ST, MPO	SANs, High Speed Ethernet
MMF Laser Optimized (50/125 microns)	OM3E	10 Gbit/sec	550 m[2]	4700 MHz[2]	LC, SC, ST, MPO	SANs, High Speed Ethernet
SMF (9/125 microns)	OS1	10 Gbit/sec	40 km	Infinite	LC, SC, ST, FC, FJ, MPO	SANs, WANs, Telco

Copper [1]						
Medium	**Standard**	**Maximum Rate**	**Maximum Distance**	**Maximum Bandwidth**	**Common Connectors**	**Common Applications**
UTP	Cat 1	1Mb/sec		1 MHz		Analog voice ISDN Doorbell wiring
UTP	Cat 2	4 Mb/sec		4 MHz		IBM Token Ring
UTP, S/STP, S/UTP	Cat 3	10 Mb/sec	100 m	16 MHz		Voice/Data on 10BASE-T Ethernet
UTP, S/STP, S/UTP	Cat 4	16 Mb/sec	100 m	20 MHz		Token Ring
UTP, S/STP, S/UTP	Cat 5	100 Mb/sec	100m	100 MHz	RJ-45	100 Mbps Networks 155 Mbps ATM
UTP, S/STP, S/UTP	Cat 5e/ Class D	1 Gbit/sec	100 m	100 MHz	RJ-45	100 Mbps Networks 155 Mbps ATM
UTP, S/STP, S/UTP	Cat 6/ Class E	10 Gbit/sec	55 m	250 MHz	RJ-45	Broadband Most popular for new installs
UTP, S/STP, S/UTP	Cat 6a/ Class Ea	10 Gbit/sec	100 m	500 MHz	RJ-45	10GBASE-T
S/STP	Cat 7/ Class F	10 Gbit/sec		600 MHz	Vary by Manufacturer	Full-motion video Government/ Industrial environments
S/STP	Cat 7a/ Class Fa	10 Gbit/sec		1,000 MHz	Vary by Manufacturer	Full-motion video Government/ Industrial environments

[1] For copper cabling, only Cat 5e or greater is relevant in today's data centers

[2] Rating for 850 nm laser sources

APPPENDIX B: FIBRE CHANNEL CABLING SPECIFICATIONS

The following table and charts show distances supported for Fibre Channel cabling.

Maximum Fiber Cabling Lengths for FC

The following table summarizes the maximum distances supported when using different fiber cable types. The table assumes a 1.5 dB connection loss and an 850nm laser source in the calculations.

FC-0	**OM1 (M6) Standard 62.5/125 µm**	**OM2 (M5) Standard 50/125 µm**	**OM3 (M5E) Laser-optimized 50/125 µm -300**
2 Gbit/sec FC	150 m	300 m	500 m
4 Gbit/sec FC	70 m	150 m	380 m
8 Gbit/sec FC limiting	21 m	50 m	150 m
10 Gbit/sec FC	33 m	82 m	300 m

Mixing Fiber Types

The following graphs show the distances supported when a link contains both OM2 and OM3 fiber for a given Fibre Channel speed and connector loss. These graphs are from T11, Annex D of FC-PI-4 and can be used to determine if the mixed link is within Fibre Channel specifications.

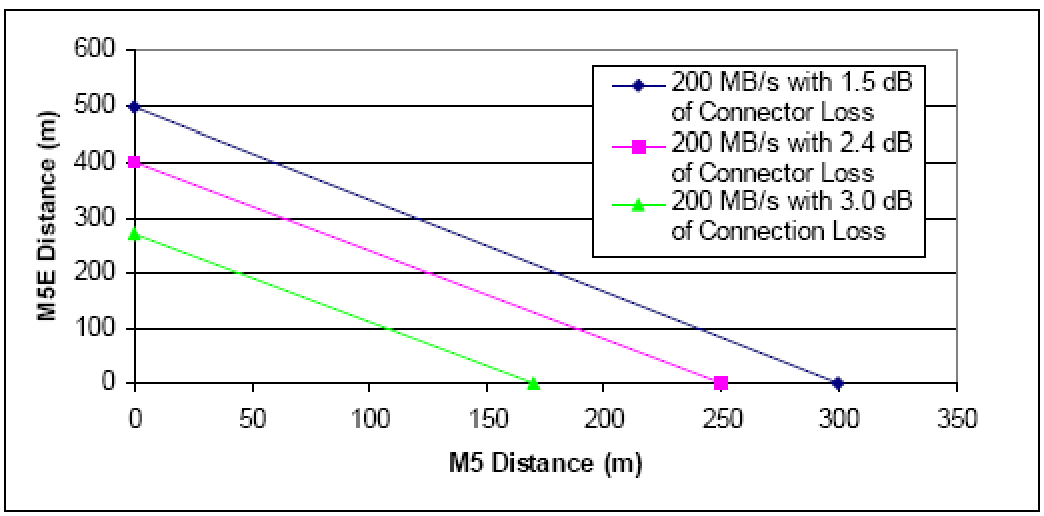

Figure 11. Distances on mixed 2 Gbit/sec link

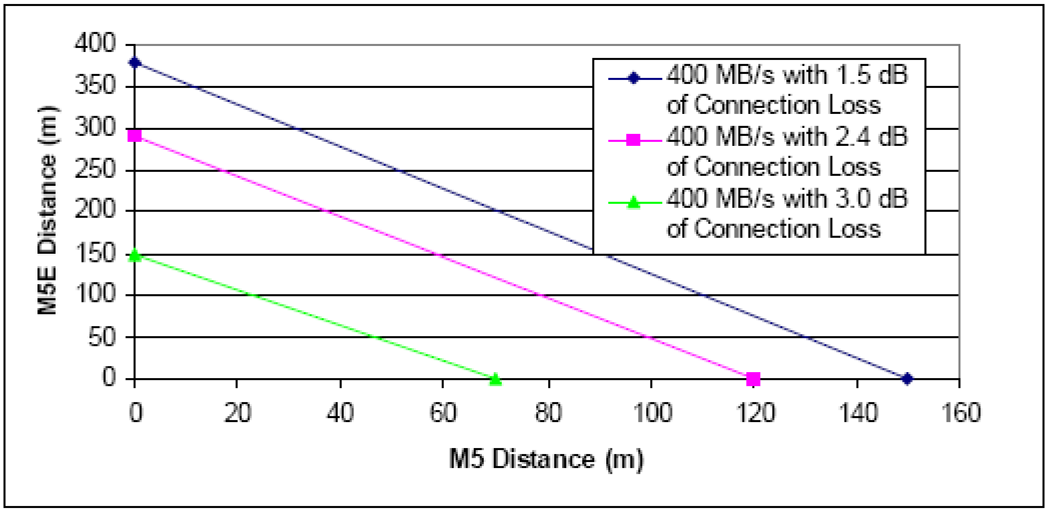

Figure 12. Distances on mixed 4 Gbit/sec link

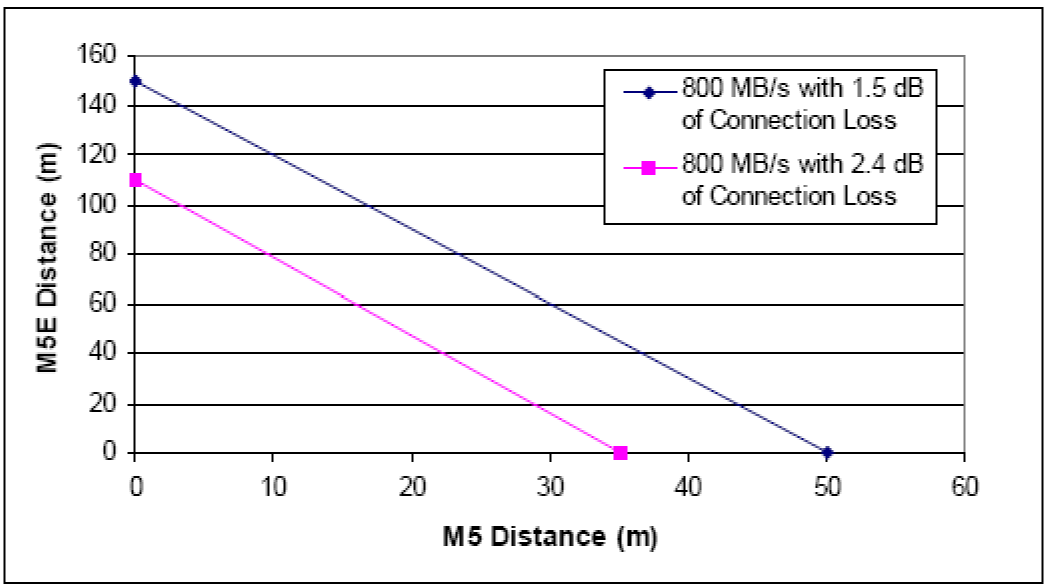

Figure 13. Distances on mixed 8 Gbit/sec link

For example, if you have a 400 MB/sec link composed of 100 m of M5 fiber and 80 m of M5E fiber, you can follow this procedure to see the possible ways to extend the link:

1. Draw a line on each axis that represents the current distance of the link for each fiber type.
2. The intersection of the lines shows the operating point of the link as seen in Figure 13. If the intersection of the lines is under a given connection loss line, the link length is supported by the standard.

In this example, the *link* is above the 2.4 dB and 3.0 dB connection loss line, so the link is not supported with these high connection losses. The *intersection of the lines* is below the 1.5 dB connection loss line, so the link can be extended if the connection loss does not exceed 1.5dB.

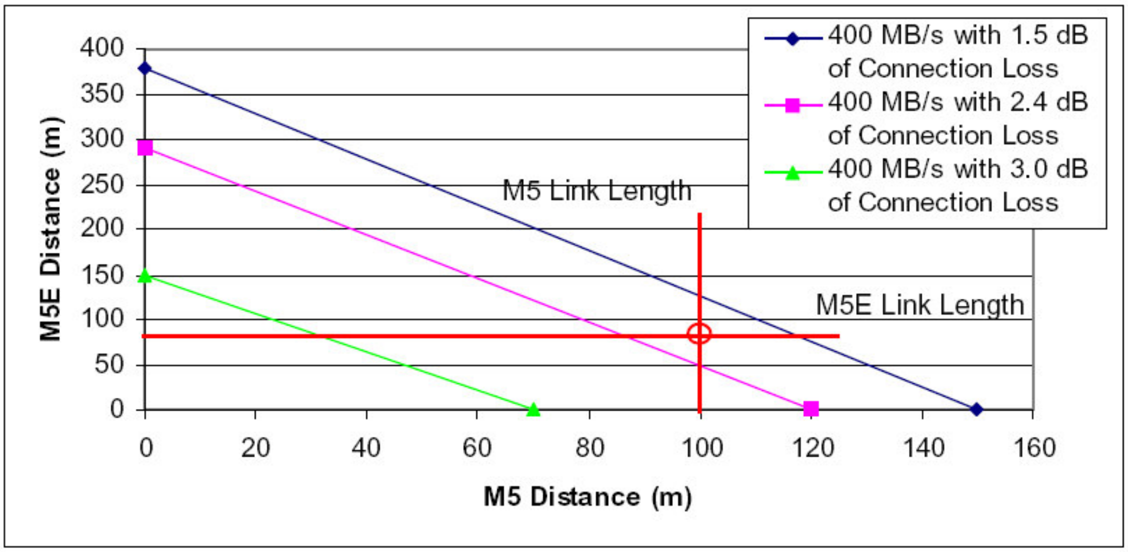

Figure 13. Example of graph showing how to extend the link

APPENDIX C: 10 GBIT/SEC DISCUSSION

This appendix discusses support for 10 Gbit/sec transmissions and highlights the most common areas of uncertainty and discrepancy in the industry today.

Fiber or Copper?

The decision to deploy fiber or copper really depends on several factors. First is the length of time you think the data center will remain in the same physical location. Fiber-only or copper-only implementations are rare in comparison to mixed fiber and copper. Fiber will remain the medium of choice for backbone (vertical) applications and increasingly for horizontal applications alongside copper. This is mainly due to the distance support, size of cable, high bandwidth, high density, immunity to EMI/RFI, security, and reliability of fiber. Fiber has been the medium of choice for Storage Area Network (SAN) implementations for many years and is thus a proven cabling component.

Copper, on the other hand, is currently being challenged with the recent ratification of 10GBASE-T. Companies are currently racing to market their “unique” copper-based structured cabling solutions for 10 Gbit/sec devices. Cat6a copper cables made for 10 Gbit/sec transmissions are approximately 50 percent thicker than Cat6 copper cables and certainly a lot thicker than fiber cables; the space available for the cable runs may influence the type of cable you deploy. Copper cabling is more suited for horizontal runs, but of course limited to 100 meters distance. It is advisable to install a higher category of cable if you plan to be at the same facility for a while.

Until recently, copper was the clear winner in a straight cost comparison. However, recent technology advances are closing the cost gap, especially in the high-performance arena. Fiber-based solutions are dropping in cost, but the main differentiation is in the cost of the active electronic components, and not in the actual cabling. In parallel, the cost for copper-based solutions is on the rise, due primarily to the stringent implementation and testing requirements imposed by TIA/ISO for 10 Gbit/sec transmissions. Note also that in support of “Greener” data center environments, certain vendors are choosing, designing, and promoting active cabling components and media that consume the least power without compromising performance. 10GBASE-T consumes about 5 to 10 times more electrical power than optical solutions.

Another area that plays an important role in cable selection is the network components that are planned in the data center. Is their interface fiber or copper? And do they support 10 Gbit/sec transmissions? Upgrading the cabling may include swapping out the connectors and other existing cabling components for the ones slated for 10 Gbit/sec.

If you want to deploy Power over Ethernet (PoE), then your choice is limited to copper—carrying power over fiber is not yet possible.

In most cases, the end result will be a combination of cable types for the different segments of the infrastructure. Most likely fiber for the backbone, fiber and/or twisted pair for the horizontal runs, and fiber and/or copper for the final patching (since this will be governed by the interface of the equipment that you will be connecting to). When selecting cabling consider the pros and cons for each cable type in each segment of the infrastructure using the following criteria:

- Existing implementation
- Installation difficulty
- Termination difficulty
- Reliability
- Distance required
- Compatibility

UTP or STP for Copper?

Believe it or not, there is no straightforward answer to this question. Most countries in Europe have been using STP cabling for a long time, whereas in the US and in Canada, UTP has maintained dominance with over 95 percent of the installed base using UTP instead of STP. A best practice is to stay with the industry trend for the country where the cabling is to be installed.

UTP and STP cabling types are commonly applied for horizontal segments and for patch cables. Installing STP cables takes more time than installing UTP cables, primarily due to the stringent grounding requirements for shielded systems. Badly grounded or ungrounded STP cables or components can perform worse than UTP cabling. An ungrounded cable can act like a magnet for attracting noise on the wire. Screening and shielding technologies are commonly available; many active electronics today use shielding.

The following table compares UTP and STP cables.

	Advantages	**Disadvantages**
UTP	Easier to implement	Requires more space due to a larger cable diameter
	Better performance for PoE plus	External noise suppression
	Better suited for dynamic environments	Category 6a is not a ratified standard yet
	Slightly cheaper	
STP (S/UTP, S/STP, STP)	Smaller diameter	Cost of labor is higher
	Better internal and eternal noise suppression	Low acceptance in North America
	Better suited for static or noisy (EMI/RFI) or secure environments	Installation has to be precise, more time consuming
	Some exceed performance	Strict grounding requirements
	AXT minimized by shielding rather than by space	
	Better resistance to EMI and RFI	

For copper, future speeds beyond 10 Gbit/sec may call for Category 7 variations, which means inclusion of STP. This type of cabling is expensive since it will involve new connectors. With the gradual drop in cost of fiber and its active components, it would not be surprising if fiber becomes a viable contender for Category 7.

Selection of UTP or STP depends on your environment and on your personal preference. Cabling systems usually are built to support applications for the next 10 years; after this period of time the cabling is outlived by technology demands, which will force you to replace your cabling infrastructure.

Beyond 10 Gbit/sec

While 10 Gbit/sec Ethernet has come into the mainstream, standards development for speeds beyond 10 Gbit/sec has not yet begun. The next leap could be to 40 Gbit/sec but even this level may not be sufficient to keep up with the bandwidth demands imposed on service providers. Service providers are looking into even higher transmission speeds that can travel longer distances to handle video and multimedia applications. While servers will not need more than 40 Gbit/sec for several years, the core network may need 100 Gbit/sec in the WAN space. However, due to its high cost, the actual implementation for speeds greater than 10 Gbit/sec is expected to be limited.

NOTE: IEEE is planning to support both 40Gbit/sec and 100 Gbit/sec for the next step in Ethernet. These higher speeds will not be standardized until 2010, but pre-standard parts should begin to appear in 2009. Fiber is the media expected to carry this speed by using MMF up to 100 meters and SMF up to 10 kilometers.

GLOSSARY

The following Web sites were consulted to create this glossary:

- http://www.siemon.com
- http://www.techfest.com/networking/cabling/cableglos.htm
- http://en.wikipedia.org
- http://www.brocade.com
- http://searchdatacenter.techtarget.com

Alien Crosstalk (AXT)	Electromagnetic noise that can occur in a copper cable that runs beside one or more other signal-carrying cables. The term "alien" arises from the fact that this form of crosstalk occurs between different cables in a group or bundle, rather than between individual wires or circuits within a single cable.
ANSI	American National Standards Institute.
Attenuation	The decrease in magnitude of a signal as it travels through any transmission medium, such as a cable or optical fiber. Measured in decibels per unit of length.
Backbone cabling	A cable connection between telecommunication or wiring closets, floor distribution terminals, entrance facilities, and equipment rooms—either within or between buildings. In star networks, the backbone cable interconnects hubs and similar devices, as opposed to cables running between hub and station. In a bus network, it is the bus cable.
Balanced cable	A cable with two identical conductors that carry voltages of opposite polarities and equal magnitude with respect to ground. The conductors are twisted to maintain balance over a distance.
Balanced transmission	A mode of signal transmission in which each conductor carries the signal of equal magnitude, but opposite polarity. A 5-volt signal for example, appears as a +2.5 volts on one conductor and -2.5 volts on the other.
Bandwidth	The range of frequencies required for proper transmission of a signal. Expressed in hertz (cycles per second). The higher the bandwidth, the more information that can be carried. A continuous range starting from zero is said to be "baseband," while a range starting substantially above zero is "broadband."
Bend loss	A form of increased attenuation in an optical fiber caused by an excessively small bend radius. The attenuation may be permanent if microfractures caused by the bend continue to affect transmission of the light signal.
Bend radius	Radius of curvature that a fiber optic or metallic cable can bend before the risk of breakage or increased attenuation.
Bonding	A method used to produce good electrical contact between metallic parts. Also refers to the grounding bars and straps used in buildings to bond equipment to an approved ground.

Cable	A group of insulated conductors enclosed within a common jacket.
Cable sheath	A covering over the conductor assembly, which may include one or more metallic members, strength members, or jackets.
Cabling	A combination of cables, wire, cords, and connecting hardware used in the telecommunications infrastructure.
Cladding	The material surrounding the core of a fiber optic cable that has an outer diameter of 125 um. The cladding must have a lower index of refraction than the core in order to contain the light in the core.
Coating	Material surrounding the cladding of the fiber for protection.
Cross connection	A connection scheme between cabling runs, subsystems, and equipment using patch cords or jumpers that attach to connecting hardware at each end.
Crosstalk	The coupling of unwanted signals from one pair within a cable to another pair. Crosstalk can be measured at the same (near) end or far end with respect to the signal source.
Decibel (dB)	A unit for measuring the relative strength of a signal. Usually expressed as the logarithmic ratio of the strength of a transmitted signal to the strength of the original signal. A decibel is one tenth of a bel.
Distribution frame	A structure with terminations for connecting the permanent cabling of a facility in a manner that interconnections or cross-connects may be readily made.
EDA	Equipment Distribution Area.
EIA	Electronic Industry Association (formerly RMA or RETMA). An association of manufacturers and users that establishes standards and publishes test methodologies.
Electromagnetic interference	An interfering electromagnetic signal. Network wiring and equipment may be susceptible to EMI as well as emit EMI.
Ethernet	A Local Area Network (LAN) protocol defined in the IEEE 802.3 standard in which computers access the network through a Carrier Sense Multiple Access/Collision Detect (CSMA/CD) protocol.
Far End Cross Talk (FEXT)	Crosstalk that is measured on the quiet line at the opposite end as the source of energy on the active line. FEXT is not typically measured in cabling, with Near End Cross Talk (NEXT) the preferred crosstalk measurement.
Fibre Channel (FC)	The primary protocol for building SANs. Unlike IP and Ethernet, Fibre Channel was designed to support the needs of storage devices of all types by providing a lossless network via flow control.
Frequency	The number of times a periodic action occurs in a unit of time. Expressed in hertz (Hz). One hertz equals one cycle per second.

Gbit/sec	Gigabits per second.
Ground	A common point of zero potential such as a metal chassis or ground rod.
Ground loop	A condition where an unintended connection to ground is made through an interfering electrical conductor.
HDA	Horizontal Distribution Area.
Hertz (Hz)	The unit of frequency, one cycle per second.
Horizontal cabling	Part of the cabling system that extends from the telecommunications outlet in the work area to the horizontal cross-connect in the telecommunications room. It includes the telecommunications outlet, an optional consolidation point or transition point connector, horizontal cable, and the mechanical terminations and patch cords (or jumpers) that make up the horizontal cross-connect.
Horizontal cross-connect	A cross-connect of horizontal cabling to other cabling for example, horizontal, backbone, or equipment.
IDF	Intermediate Distribution Frame. This is usually located on each floor within a building. It is tied directly to the Main Distribution Frame via cables.
IEC	International Electro technical Commission.
IEEE	Institute of Electrical and Electronics Engineers. A professional organization and standards body. The IEEE Project 802 is the group within IEEE responsible for LAN technology standards.
InfiniBand	A switched fabric communications link primarily used in High-Performance Computing (HPC). Its features include quality of service and failover.
Interconnection	A connection scheme that provides for the direct connection of a cable to another cable or to an equipment cable without a patch cord or jumper.
Intermediate cross-connect	A cross-connect between first-level and second-level backbone cabling.
Insertion loss	A measure of the attenuation of a device by determining the output of a system before and after the device is inserted into the system. For example, a connector causes insertion loss across the interconnection (in comparison to a continuous cable with no interconnection).
ISO	International Standards Organization.
Jacket	The outer protective covering of a cable.
Jitter	The slight movement of a transmission signal in time or phase that can introduce errors and loss of synchronization. More jitter is encountered in longer cables, cables with higher attenuation, and signals at higher data rates. Also, called “phase jitter,” “timing distortion,” or “intersymbol interference.”
MDA	Main Distribution Area.
Media	Wire, cable, or conductors used for transmission of signals.

MultiMode Fiber (MMF)	A fiber optic cable which supports the propagation of multiple modes. Multimode fiber may have a typical core diameter of 50 to 62.5 µm with a refractive index that is graded or stepped. It allows the use of inexpensive VCSEL light sources and connector alignment and coupling is less critical than single mode fiber. Distances of transmission and transmission bandwidth are less than with single mode fiber due to inter-modal dispersion.
Near-end crosstalk	Crosstalk between two twisted pairs measured at the same end of the cable as the disturbing signal source. NEXT is the measurement of interest for crosstalk specifications.
Network	An interconnection of computer systems, terminals or data communications facilities.
OM3 fiber	Laser Optimized MultiMode Fiber.
Optical fiber cable	An assembly consisting of one or more optical fibers.
Patch cable	A flexible piece of cable terminated at both ends with connectors. Used for interconnecting circuits on a patch panel or cross-connect.
Patch panel	A passive device, typically flat plate holding feed-through connectors, to allow circuit arrangements and rearrangements by simply plugging and unplugging patch cables.
Pathway	A facility for the placement of telecommunication or networking cables.
Plenum cable	A cable that is rated as having adequate fire resistance and low smoke producing characteristics for use in air handling spaces (plenum).
Raceway	Any channel designated for holding wires or cables. Raceways can be metallic or nonmetallic and can totally or partially enclose the wiring. (for example, conduit, cable trough, cellular floor, electrical metallic tubing, sleeves, slots, underfloor raceways, surface raceways, lighting fixture raceways, wireways, busways, auxiliary gutters, and ventilated flexible cableways).
Riser cable	A type of cable used in vertical building shafts, such as telecommunications and utility shafts. Riser cable typically has more mechanical strength than standard cable and has an intermediate fire protection rating.
Screened Twisted Pair (S/UTP)	Four pair UTP (also known as ScTP, F/UTP, and FTP), with a single foil or braided screen surrounding all four pairs in order to minimize EMI radiation or susceptibility. S/UTP can be thought of as a shielded version of the Category 3, 4, & 5 UTP cables.
Screened/Shielded Twisted Pair(S/STP)	Four pair cabling, with each pair having its own individual shield, in addition to an overall shield surrounding all four pairs. SSTP offers similar performance to Type 1 STP except with four pairs (rather than two) and in a 100 (rather than 150) ohm impedance.
Shield	A metallic foil or multiwire screen mesh used to prevent electromagnetic fields from penetrating or exiting a transmission cable. Also referred to as a screen.

Shielded Twisted Pair (STP) A type of twisted-pair cable in which the pairs are enclosed in an outer braided shield, although individual pairs may also be shielded. STP most often refers to the 150 ohm IBM Type 1, 2, 6, 8, and 9 cables used with Token Ring networks.

Single Mode Fiber (SMF) An optical fiber that will allow only one mode to propagate. The fiber has a very small core diameter of approximately 8 µm. It permits signal transmission at extremely high bandwidth and allows very long transmission distances.

Structured cabling Telecommunications cabling that is organized into a hierarchy of wiring termination and interconnection structures. The concept of structured wiring is used in the common standards from the TIA and EIA.

VCSEL Vertical-Cavity Surface-Emitting Laser. A light source for use in an infrared data-association data link device.

TIA Telecommunications Industry Association. Authored the TIA/EIA 568-A "Commercial Building Telecommunications Wiring Standard" in conjunction with EIA.

Topology The physical or logical interconnection pattern of a network.

Transmission media Anything used to carry a signal, such as wire, coaxial cable, fiber optics, air, or vacuum.

Twisted pair A multiple conductor cable whose component wires are paired together, twisted, and enclosed in a single jacket. Each pair consists of two insulated copper wires twisted together. When driven as a balanced line, the twisting reduces the susceptibility to external interference and the radiation of signal energy. Most twisted-pair cabling contains either 2, 4, or 25 pairs of wires.

Unbalanced line A transmission line in which voltages on the two conductors are unequal with respect to ground. Generally one of the conductors is connected to a ground point. An example of an unbalanced line is a coaxial cable.

Unshielded Twisted Pair (UTP) Twisted-pair cabling that includes no shielding. UTP most often refers to the 100 ohm Category 3, 4, and 5 cables specified in the TIA/EIA 568-A standard.