



## CommScope® Enterprise Data Center Design Guide

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# 1. Introduction

Today the Data Center is the heart of most companies' operations, pumping the lifeblood (i.e. data) to and from users, storage devices and the world wide web. The importance of effective management of increasingly large amounts of data is prompting many companies to significantly upgrade their current operations, or to create brand new data centers from greenfield. At the same time, economic conditions are forcing companies to focus on efficiency and simplification. As a result, Data Center optimization and/or consolidation may be on your agenda.

When considering a new Data Center or the consolidation of multiple sites, many questions arise:

1. Where should the Data Center be located?
2. How big should it be
3. How much power consumption can be expected?
4. What is the uptime target (what tier, how many 9's do you wish)?
5. What are the technologies to use?
6. How should the Data Center be laid out?
7. How long is the life span?

Upgrading current systems may at first seem easier, but this too will have its own set of questions

1. Should we continue to use the same exact products, or start utilizing higher grade options?
2. Space is already tight; what higher density options are available?
3. What are the distance limitations for expected applications?
4. What new standards do I need to be aware of?

This guide will examine all of these questions and more as we provide the information necessary to properly design a Data Center.

## How To Use This Guide

Data Center design can be significantly different than that of traditional structured cabling design for buildings and campuses. Even an experienced designer will need to familiarize themselves with Data Center specific standards and technologies. Integrating diverse technologies, combining different cabling types, matching capacity to traffic and, above all, making sure that the whole system performs reliably, creates a set of complex tasks. Critical issues that need to be addressed include:

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

The last question is of great importance. Your selection of architecture, capacity, media type and installed cost will all affect performance and reliability. CommScope is a leading manufacturer not only of fiber, twisted pair and coaxial cables, but of connectivity components that offer the highest levels of performance and reliability. CommScope integrates cable, connectivity and craft for systems with warranted capability. You can design and install networks from the entrance facility to the storage devices and be assured of the highest network speeds and reliability when utilizing CommScope solutions. While you work through the design process in this guide, 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.

## CommScope Connectivity Meets and Exceeds Networking Standards

TIA/EIA-942 *Telecommunications Infrastructure Standard for Data Centers* provides guidelines and requirements for the overall design and installation of a data center. TIA 942 often refers back to ANSI/TIA/EIA-568 *Commercial Building Telecommunications Cabling Standard*, for the component requirements. TIA-568 is the most comprehensive and authoritative standard for network performance, 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). This 550 meter fiber exceeds the requirements for OM4 fiber per the TIA standard released in 2009; CommScope's extended-range OM4 fibers met these requirements **6 years** before the Standard was completed. These fibers also allow a step up to even higher data rate applications like 40 and 100 gigabit Ethernet, with distances of 100 meters and greater.

CommScope was the first company to provide a loose-tube MPO trunk cable specifically for Data Center applications. While the industry was utilizing ribbon fiber technology primarily designed for outside plant applications, CommScope's innovative design provided a smaller and more flexible cable design to meet the specific requirements of data centers.

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.

In short, CommScope offers 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.

\*Standards may be reviewed or purchased at [www.tiaonline.org](http://www.tiaonline.org).

## CommScope Infrastructure Academy

For those interested in additional training in the Data Centers environment, the CommScope Infrastructure Academy offers certified training courses on network infrastructure solutions throughout the world. Training formats include instructor-led classroom training, as well as online training via webcast, video and self-paced assessments.

The CommScope Infrastructure Academy offers local language courses, in both high-quality conference facilities and online, and also offers customized training programs and consultancy relating to the latest development in structured cabling design and installation practices, ANSI's TIA, ISO/IEC or CENELEC standards, choice and selection of products, market trends, innovations and statistics - providing support, and competence assessment, for strategy and migration.

The SP8800 SYSTIMAX Data Center Design and Engineering Course provides in-depth training on data center design including standards, architecture and the appropriate media for high data rate applications. Available online, it can be taken individually or as part of the Passport Package, which provides access to a full array of training courses, covering installation and design, and including overall structured cabling solutions, as well as specialist training in optical fiber, intelligent solutions buildings, and more.

For more information, please visit the CommScope Infrastructure Academy online at [www.commscopetraining.com](http://www.commscopetraining.com).

## 2. Standards And Regulations

The best way to start the design of a new Data Center is by reviewing the codes and standards for Data Centers.

### Construction Codes Applicable to Data Centers

As our main focus is on the Structured Cabling System (SCS), a thorough discussion of the construction codes that affect the construction and installation of facilities such as Data Centers is outside the scope of this document. However, here is a list of the basic applicable codes. Contact your regional code body for more detailed information.

NFPA 13 Standard for the Installation of Sprinkler Systems

NFPA 70 (aka NEC) National Electrical Code

NFPA 75 – Standard for the Protection of Information Technology Equipment

For Canada:

CSA CEC C22.1 Canadian Electrical Code

### Standards Applicable to Data Centers

ANSI/TIA-942-2005 *Telecommunications Infrastructure Standard for Data Centers* is the North American Standard for design and implementation of Data Centers, providing requirements and guidelines for the design and installation of Data Centers and computer rooms.

The standard presents infrastructure topology for connecting various elements and cabling system configurations found in data centers. Also addressed are floor layouts related to achieving proper balance between rack density, manageability and security.

Data centers are categorized according to the domain they serve:

- private domain – enterprise (private corporations, institutions or government agencies)
- public domain – internet (traditional service providers, unregulated competitive providers and related commercial operators)
- co-location – multiuser

Standard TIA-942 specifies the minimum requirements for telecommunications infrastructure for single tenant enterprise centers and multi-tenant hosting centers. The topology recommended is applicable to any size data center.

TIA-942 is composed of 8 chapters and 9 informative annexes, covering all aspects of Data Center design and implementation.

1. Scope
2. Definition of Terms, Acronyms and Abbreviations, and Units of Measure
3. Data Center Design Overview
4. Data Center Cabling System Infrastructure
5. Data Center Telecommunication Spaces and Related Topologies
6. Data Center Cabling Systems
7. Data Center Cabling Pathways
8. Data Center Redundancy

- Annex A Cabling Design Considerations
- Annex B Telecommunications Infrastructure Administration
- Annex C Access Provider Information
- Annex D Coordination of Equipment Plans with Other Engineers
- Annex E Data Center Space Considerations
- Annex F Site Selection
- Annex G Data Center Infrastructure Tiers
- Annex H Data Center Design Examples
- Annex I Bibliography and References

One can see that the most significant aspects of design and implementation of the Data Center are covered by TIA-942. This includes a discussion of tiering, or redundancy, that will make a data center less susceptible to disruptions due to failure of active equipment, passive cabling or the service provider. Four tiering levels are discussed in **Chapter 13** Network Planning.

While TIA-942 covers data center design and installation, other standards can be referred for information about components and applications within the data center.

ANSI/TIA/EIA568-C Commercial Building Telecommunications Cabling Standard is composed of several sections related to both systems and components.

- 568-C.0 - LAN Topology, Grounding and Bonding, Cable Installation, Polarity of Fiber Systems, Cable Transmission and System Testing Requirements
- 568-C.2 - Balanced Twisted-Pair Telecommunications Cabling and Components Standards
- 568-C.3 - Optical Fiber Cabling Components Standard

The collection of IEEE 802.3 standards defines the Physical and Data Link layers' media access control (MAC) sub layer of wired Ethernet. Traditionally Ethernet has been utilized to support the LAN. Today, Ethernet is finding its way into data storage either directly or as part of Fibre Channel over Ethernet.

Examples of IEEE802.3 standards

- IEEE 802.3ab - 10G Ethernet Over Fiber
- IEEE 802.3an - 10G Ethernet Over Balanced Twisted Pair Cable
- IEEE 802.3ba - 40G & 100G Ethernet (July 2010)

Fibre Channel requirement are defined by the T11 Technical Committee of International Committee for Information Technology Standards (INCITS). Fibre Channel is heavily utilized in the SAN environment today.

The National Electric Code (NEC) is a US code for the proper installation of wiring and equipment and is primarily concerned with safety. Some of the codes that fall under the NEC and are applicable to data centers are:

NFPA 13 Standard for the Installation of Sprinkler Systems

NFPA 70 (aka NEC) National Electrical Code

NFPA 75 - Standard for the Protection of Information Technology Equipment

A code similar to the NEC, the Canadian Electrical Code CSA CEC C22.1 is also concerned with safe installation and maintenance of electrical equipment.

ASHRAE (The American Society of Heating, Refrigerating and Air Conditioning Engineers) is a technical society for all those interested in heating, ventilation, air-conditioning and refrigeration. Some of the ASHRAE standards of interest to data center design are:

- Standard 34 - Designation and Safety Classification of Refrigerants
- Standard 55 - Thermal Environmental Conditions for Human Occupancy
- Standard 62.1 - Ventilation for Acceptable Indoor Air Quality
- Standard 90.1 - Energy Standard for Buildings Except Low-Rise Residential Buildings - The IESNA is a joint sponsor of this standard.
- Standard 135 – BACnet - A Data Communication Protocol for Building Automation and Control Networks

## Other Resources

The Uptime Institute provides education, publications, consulting, certifications, conferences and seminars, independent research and thought leadership for the enterprise data center industry and for data center professionals. Institute research focuses on data center facilities, the IT and facilities interface, and how both functions affect the cost, reliability and energy consumption of computing. ([www.uptimeinstitute.org](http://www.uptimeinstitute.org) April 2010) The institute develops best practices, including the tiering approach to data center redundancy.

The Green Grid is a global consortium of IT companies and professionals seeking to improve energy efficiency in data centers and business computing ecosystems around the globe. The organization seeks to unite global industry efforts to standardize on a common set of metrics, processes, methods and new technologies to further its common goals. ([www.thegreengrid.org](http://www.thegreengrid.org) April 2010)

US Green Building Council is a non-profit organization working to make green buildings available to the masses. Their Leadership in Energy and Environmental Design (LEED) program provides third-party verification that a building (or community) was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO<sub>2</sub> emissions reduction, improved indoor environmental quality and stewardship of resources and sensitivity to their impacts. ([www.usgbc.org](http://www.usgbc.org) April 2010) As data centers consume a significant percentage of the energy within the United States, they are naturally a focal point for those interested in the USGBC and the LEED process.

## Data Center Categories

The Standards may outline how to design a data center, but they don't define their purpose and functionality. Data centers tend to fall into 2 basic categories – Enterprise and Collocation.

The majority of data centers are privately owned and operated, as each company develops a data center to support their commercial needs. These Enterprise Data Centers are typically treated as a cost center, controlled by the companies IT department, and are likely to be highly customized to the needs of that company. This higher level of customization will likely provide improved functionality and control, but may lead to an overall higher level of cost. For larger companies, the data center may run as a shared services organization that has service level agreements (SLAs) and chargeback mechanisms. However, the data center is still owned and operated within the same company.

Some companies may prefer to have some or all of their networking capabilities run by a third party. Collocation or Managed Data Centers are businesses that generate revenue by providing data center capabilities to Enterprise customers. These data centers can provide a secure public facility to offer power, cooling, rack space and infrastructure. Their customers may own their own active equipment or this can also be provided by the data center operator. Included within the collocation/managed data center category are Hosted Data Centers that over various levels of IT systems support. This can include web hosting, disaster recovery, and other typical data center operations.

Because collocation data centers are operated for profit and may support multiple customers, customization will be more limited than what is seen in private enterprise centers. A focus will be made to use off-the-shelf products that are lower in cost, easy to order and scalable to easily integrate into running systems.

As would be expected, there are advantages to utilizing both private and collocated centers, companies may choose to utilize both internal and third party data centers. For example, they may choose to maintain their own primary networks, but utilize a collocation partner for emergency backup. Or a company may want to lower costs by utilizing a third party, but may maintain internal control over functions it considers most critical to its business.

## Features of Enterprise and Collocated Data Centers

### **Enterprise:**

Company maintains control over network and data  
Optimize to business needs  
Maintain business flexibility  
No competition for priority of service

### **Collocation:**

Controlled costs  
Frees company to focus on business operations  
Provide backup and redundancy  
Simplifies process of increasing/decreasing network capacity

There is a hybrid of these two center types where a third party provides a data center that is dedicated to a single customer. This is an attempt to maintain the benefits of a private Enterprise center, while allowing a third party to maintain the physical facility.

Another twist on data center types concerns companies whose business are their networks and data managed within the data centers. Online catalog, search and social networking sites are good examples of this. IDC terms these as Web 2.0 or Mega Data Centers (IDC, 2008). These data centers are typically "mega" in size as an online company is fully dependent on the speed and capacity of their network to provide customers with instant access to information and transaction capability. The business model for Mega Data Centers forces these companies to focus on low overall costs and they have to factor in power, real estate, taxes and network costs when determining which locations to set their facilities (IDC, 2008).

# 3. Network Topology

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, called topologies.

The discussion of cabling topology covers two types of topologies: physical and logical.

**Physical topology** is the way cabling or media is installed and connected to the devices.

**Logical topology** is the way information travels on the cabling or media.

A network's logical topology is not necessarily the same as its physical topology. For example, twisted pair Ethernet is a logical bus topology in a physical star topology layout. While IBM's Token Ring is a logical ring topology, it is physically set up in a star topology.

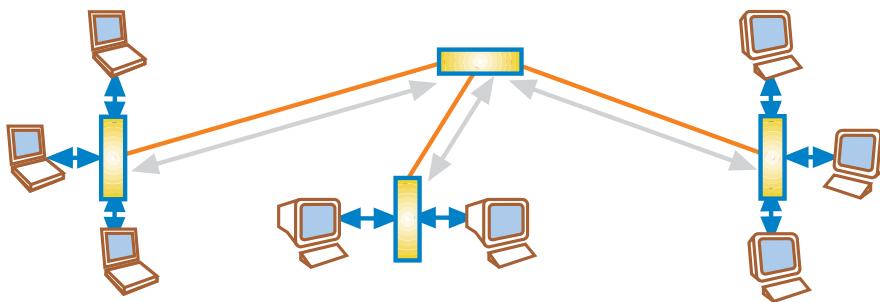
The best physical topology, as recommended by the standards, is a star configuration. Using a physical star, it is possible to implement any logical topology.

## Network Physical Topologies

### Star Topologies

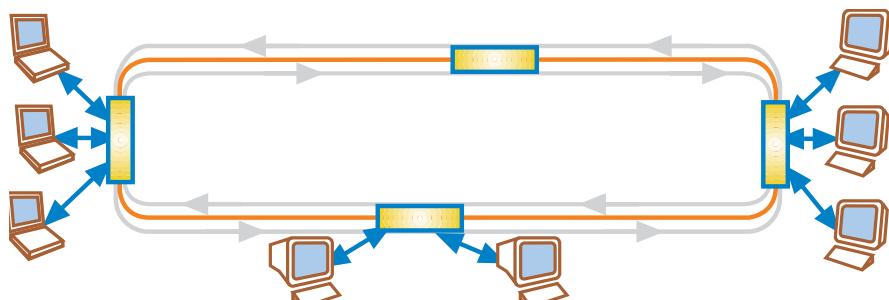
In a physical star topology, network devices are cabled to meet at a point of concentration, usually a piece of active electronics called a hub, router, switch or node. These actives are then connected to an intermediate point of concentration, and so on, until all traffic meets at a central point.

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 easily by a physical connection at any of the collection points. TIA and other standards typically recommend a physical star topology within buildings.



## Ring Topologies

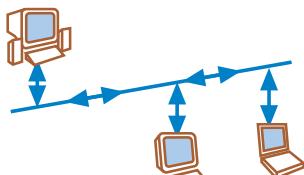
In a physical ring topology, the nodes of a network are all connected in a closed loop. Instead of running back and forth between nodes, the signal travels in one direction around the ring. In some networks, active and stand-by parallel circuits operate in both directions simultaneously (a counter-rotating 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.



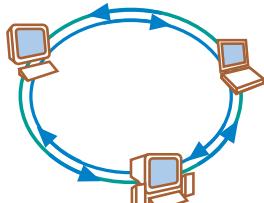
## Mesh Topologies

In a physical mesh topology, every device or node is connected to every other device or node in the network. Adding a device or node requires multiple connections.

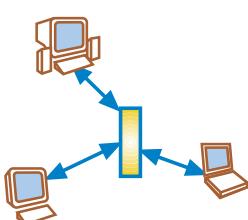
### Bus



### Ring (also called Token Ring)



### Star



### Point-to-point



## Network Logical Topologies

### 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 fails 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 star topologies as well.

### Mesh Topology

Devices are connected to every other device in the network. In a true mesh topology every device has a connection to every other device in the network.

### 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.

# 4. Network Architecture

Network architecture is the layout of the cabling infrastructure and the way the various switches are connected. We will first discuss the switching methods.

## Switches

There are three different types of switches commonly used: edge, core and distribution.

### Access Switch

An access switch (also called an edge switch), according to Newton's Telecom Dictionary, is a Broadband Switching System (BSS) located at the edge of the network. An edge switch is the first point of user access (and the final point of exit) for a network. Also known as the access switch, an edge switch will allow the servers to connect to the network. Multimode optical fiber is the typical media that connects the edge devices to the servers within the data center. Edge switches are interconnected by core switches.

### Core Switch

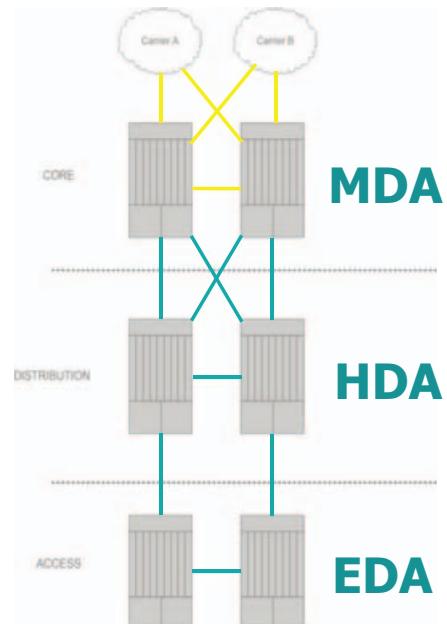
A core switch is located in the core of the network and serves to interconnect edge switches. The core layer routes traffic from the outside world to the distribution layer and vice versa. Data in the form of ATM, SONET and/or DS1/DS3 will be converted into Ethernet in order to enter the Data Center network. Data will be converted from Ethernet to the carrier protocol before leaving the data center.

### Distribution Switch

Distribution switches are placed between the core and edge devices. Adding a third layer of switching adds flexibility to the solution. Firewalls, load balancing and content switching, and subnet monitoring take place, aggregating the VLANs below them. Multimode optical fiber will be the typical media running from the distribution layer to the core and edge devices.

Not every data center will have all three layers of switching. In smaller Data Centers the core and distribution layer are likely to be one and the same.

**Figure 1: Layers of Switching and Routing**



## Data Center Network Architectures

Today, there are three primary approaches in Data Centers for server networking:

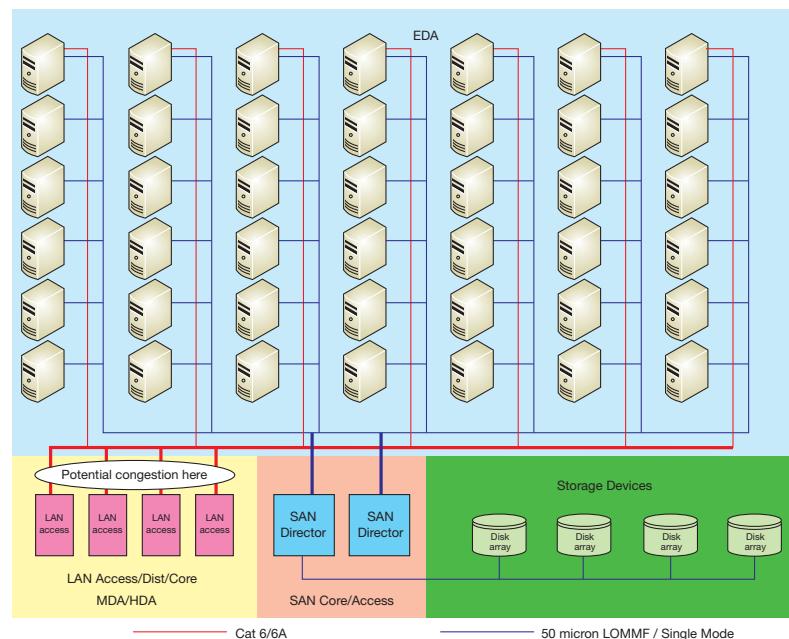
- Direct Connect (Centralized)
- Zone Distribution (including End-of-Row, Middle-of-Row, etc)
- Top-of-Rack (Distributed Electronics)

Which approach you choose is largely determined by the server being deployed and operational objectives. Each design has its advantages and trade-offs and frequently larger data centers will house at least two, if not all three approaches to network architecture.

### Centralized Direct Connect

The approach requires each server to be cabled back to the core switches. This provides a very efficient utilization of port switches and is easy to manage and add FOR SMALL SIZE data centers.

**Figure 2: Centralized Direct Connect Architecture**



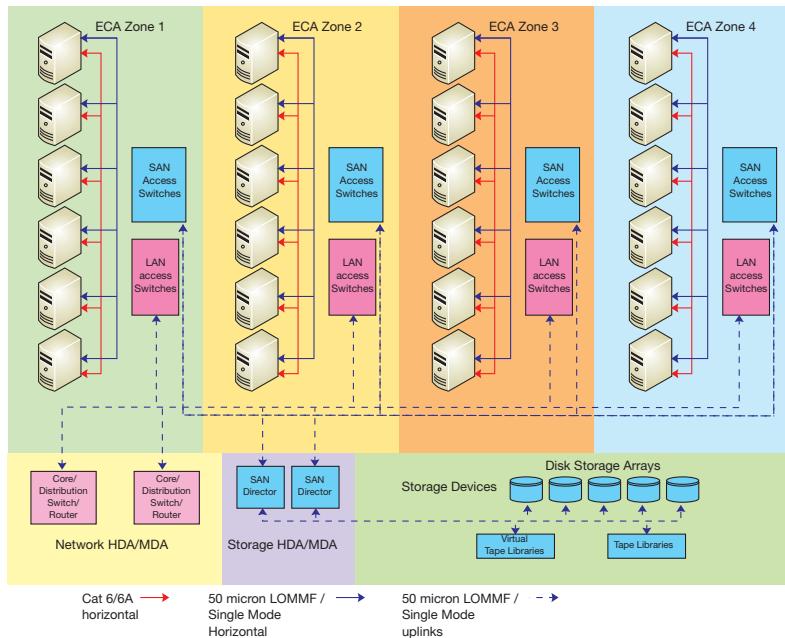
A drawback for larger size data centers is that the high number of extended length cable runs could fill up the pathways and increase the solution cost. The centralized direct connect works well and the best for small sized data centers.

### Zone Distribution

This solution can be implemented as end-of-row or middle-of-row, where a single large chassis-based switch is used to support one or more racks containing the servers. This approach is usually the most cost-effective, as it provides the highest level of switch and port utilization, especially when coupled with the rich set of network virtualization services available. This can be a significant advantage from a compliance and security perspective.

The distributed solution is the recommended cable architecture of TIA-942 Data Center Standards and is very scalable, repeatable and predictable. A common approach is to create a single bill of materials for each "zone" or "pod" design that contains the requirements for electronics, cabling and apparatus required to add capacity in set increments.

**Figure 3: Distributed Architect**



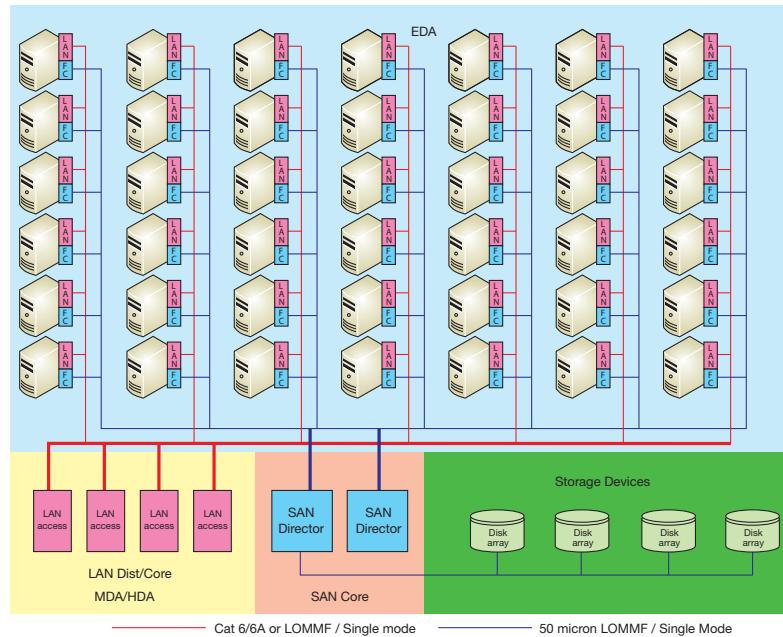
The zone distribution approach is also the most server-independent, so it provides maximum flexibility to support a broad range of servers. In certain scenarios, end-of-row switching can provide performance advantages, because two servers that exchange large volumes of information can be placed on the same line card to take advantage of the low latency of port-to-port switching (as opposed to card-to-card or switch-to-switch, which will be slower).

A potential disadvantage of end-of-row switching is the need to run cable back to the switch. Assuming every server is connected to redundant switches, this cabling can exceed what is required in top-of-rack architecture.

### Top-of-Rack

Top-of-Rack switching is a newer architecture and a viable choice for dense one rack unit (1RU) server environments. In this approach the 1RU Switch is placed at the top of the rack and all the servers in the rack are cabled to this switch, which then has one uplink. In some instances a pair of switches is used for high-availability purposes. This approach significantly simplifies cable management and avoids the rack space and cooling issues of end-of-row switching. This approach also provides some architectural advantages such as fast port-to-port switching for servers within the rack, predictable oversubscription of the uplink and smaller switching domains (one per rack) to aid in fault isolation and containment.

**Figure 4: Top-of-Rack Architecture**

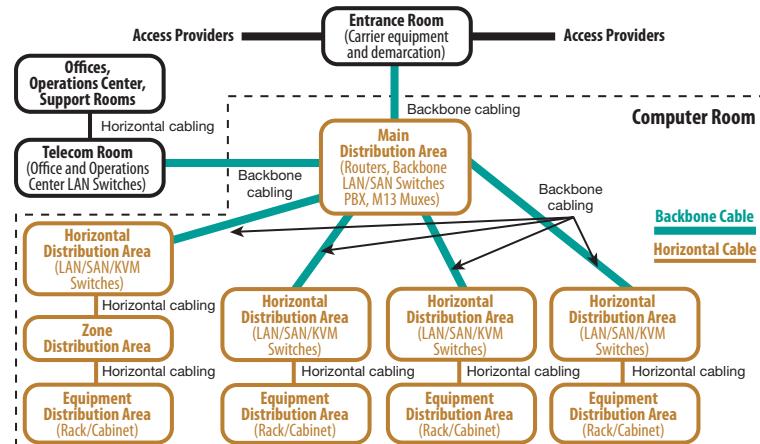


Although cabling is utilized more efficiently in the top-of-rack scenario, there can be an increase in the cost of switches. The common challenge with the top-of-rack approach is under-utilization of ports, where there are not enough servers to fill the switch. One solution is to put one top-of-rack switch server in adjacent racks: this preserves the advantages of the top-of-rack switch while increasing port utilization. However this approach can create the same problems as end-of-row switching when it comes to cabling and cooling issues. Top-of-rack switching may be difficult to manage in large deployments, and you also have the potential for overheating of LAN/SAN switch gear in server racks. Finally, with a top-of-rack approach, attention must be paid to ensure that commonly used or high-volume data pathways do not end up spanning multiple racks and thus multiple switches.

### TIA-942 Data Center Structured Cabling Layout

Let's take a look at the basic structured cabling layout of the Data Center and the various areas which are included.

**Figure 5: Example of Basic Data Center Topology**



\* TIA-942 is currently under revision and it is expected that an Intermediate Distribution Area (IDA) will be defined within TIA-942A. The IDA would connect between the MDA and an HDA.

## Data Center Areas

The **Entrance Room** is where the cabling from an outside service provider (i.e. telco, internet, CATV) enters the building. It should be large enough to accommodate more than one provider and have room for growth. The primary entrance facility would likely be located close to the Main Distribution Area within the computer room. Larger Data Centers may have multiple entrance facilities for redundancy and emergency restoration. A secondary entrance facility would likely be on the opposite side of the building and utilize a different access provider or cabling from the primary entrance facility.

The Entrance Room serves as a demarcation point to separate the service providers' networks from the Data Center. The service providers usually equip this space and control the cabling and apparatus, while the Data Center operator controls the rack or cabinet used to house the cross connection.

The LAN (Local Area Network) **Telecom Room** supports the enterprise capabilities required for Data Center operation. It connects the offices and cubicles – the LAN – to the main distribution area of the data center computer room. It would typically run on a different protocol (Ethernet) than the data center as they have different application requirements.

The **Computer Room** is the main focus of the Data Center. It houses everything required for data storage and access. This includes the switches and servers to control data access and flow, as well as storage devices such as disc and tape arrays.

The **Main Distribution Area** is the space where the main cross-connect is located, along with the core switches. This is the central point for the data center structured cabling system.

The **Horizontal Distribution Area** is the space where the horizontal cross-connect is located, along with the switches for the storage area and local area networks.

The **Equipment Distribution Area** is the space occupied by the equipment (server) racks and cabinets.

The **Zone Distribution Area** is the space where a zone outlet or consolidation point is located. The ZDA typically only includes passive devices.

## Cross-Connect vs. Interconnect

There are two typical methods used to connect electronics to the backbone cabling: cross-connection or inter-connection.

**Cross-connection** is a connection scheme between cabling runs, subsystems and equipment using patch cords or jumpers that attach to connecting hardware at each end. The advantage of a cross-connect is you do not have to directly disturb the electronic ports or backbone cabling in order to make the connection. Although there is more flexibility, it is more expensive to implement as it requires more cabling and apparatus.

**Interconnection** brings a patch cord directly from the electronics port to connect to the backbone cabling. This solution requires fewer components and is therefore less expensive; however, it does reduce flexibility and adds risk, as users have to directly access the electronics ports in order to make the connection.

There is a third option, which is to directly connect the backbone cabling to the electronics, but this has many significant problems. There is limited flexibility to make changes, it is difficult to manage connections, and there is a constant risk to the cabling and electronics ports during reconfiguration.

CommScope generally recommends utilizing cross-connections for maximum solution flexibility.

## Network Types: SAN and LAN

One of a Data Center's primary focuses is the storage of data; as such, the Storage Area Network (SAN) is of prime importance. Fibre Channel is the typical protocol used within a SAN to bring data to and from tape and disk arrays to the edge switches. The Data Center will also have a local area network (LAN) for operational purposes, and Ethernet is the most common protocol utilized here. As shown in some of the prior figures, the LAN and SAN equipment often lie within the same areas of the data center, and therefore the cable pathways are often parallel.

# 5. Pathways And Spaces

Compared to power and cooling, Data Center cabling pathways and spaces are often overlooked until late in the design process; however, careful and early planning can save time and frustration later.

Underfloor and overhead are the two most common ways to handle the cabling between cabinets and areas within the Data Center. We will discuss the pros and cons of both methods, as well as the need for cable management in cabinets and racks.

## Underfloor

Underfloor cable routing, where cable is installed in a cable tray under a raised floor and essentially left alone, has been the defacto standard. This method seems simple and the tray and cabling are "out of sight," creating a visually pleasing Data Center. However, good underfloor cable routing requires careful planning and implementation. It is important to plan for properly sized tray and routing, as well as power routing if the power will also be under the floor. Routing must also be carefully planned to avoid blocking the underfloor flow of cold air.

Long term maintenance of the cable plant can be complicated, as cable additions or removal requires opening the floor and removing floor tiles. Changes to the cable plant must be planned in the off hours to minimize the risk presented by holes in the floor and the instability of a floor surface with multiple missing tiles.

## Overhead

Overhead cable routing is frequently used in telecommunications rooms, and some have carried this practice into the Data Center, installing ladder tray above the racks and cabinets. One practice is to install multiple layers of tray to accommodate copper and fiber in separate trays.

Properly implemented, overhead cable routing can also be visually pleasing. In addition, overhead cable routing minimizes airflow blockage underfloor. If the power cabling is routed underfloor and data cabling is routed overhead, problems of routing data and power are also eliminated.

There are, however, negatives associated with overhead cable routing. Changes to the cable plant require that the installer use a ladder. Also the cabinets must accommodate top cable entry. Overall room height could be an issue, and cabinets must be able to accommodate top cable entry. In addition, it is important that the cabling be protected in the "waterfall" transition from the tray to the racks and cabinets.

## Rack and Cabinet Cable Management

It is absolutely necessary to plan for cable management in cabinets and racks. This management must be sized to handle both the fixed cable and the patch cables which will be installed. It's also important to remember that copper cables are getting larger in diameter; Category 6A is larger than Category 6, which is larger than Category 5e. (Of course, Category 5e cable should not be considered for use in a Data Center.)

During the cabinet selection process, be sure that your choice of cabinet includes adequate interior cable management. CommScope recommends that double-sided vertical cable managers should be installed between all racks and on all ends. Also verify that the cabinet will accommodate the desired entry method(s) – underfloor, overhead or both.

When installing cable in the cable tray, ensure that the cable is installed in a manner that doesn't cause damage. Install the heavier cables first; segregate copper and fiber to prevent damage to either; and avoid stacking bundle upon bundle, as this leads to crushing of the bottom bundles.

# 6. Electronics

## Network Equipment

The Data Center is basically a large computer room which houses a mixture of active and passive equipment.

A **server** is a combination of hardware and software that provides applications, such as corporate e-mail and webhosting, to client computers. Although a server has much of the functionality of a laptop computer, advanced in CPU and memory technology allow servers to be significantly more powerful, running multiple operating systems and applications. The traditional server is often described as a "pizza box" because of its shape; it is 1U in height and is mounted into a rack. These are also known as "rack optimized" servers, as they were originally compared to tower servers, which were not optimized for racks.

A blade server is designed to minimize space by stripping redundant components common to most servers, such as the power source, network ports and management interfaces. A server blade can be mounted into a chassis backplane that will have a consolidated group of all the components that each individual blade server is missing, leaving only the raw computer and memory in a fraction of the space. In addition to reduced cost per server, blade servers are modular and can be added one blade at a time. They also draw less power per physical server, and in turn generate less heat overall.

Traditionally, each server has been used to run a single application. This has proved somewhat inefficient, as a server is capable of running multiple applications simultaneously without loss of performance. Running two applications on one server could reduce the number of servers needed by 50%, and running a higher number of applications per server could reduce the physical devices needed even further. Running multiple operating systems on one physical server is known as virtualization, where a new application can be added onto a virtual "machine" instead of adding a new physical device.

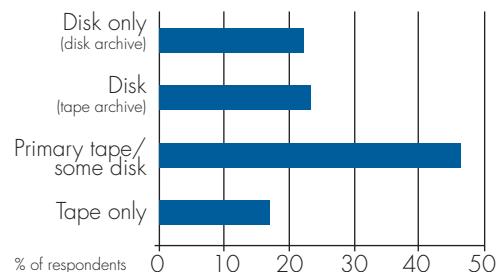
The benefits of virtualization include reducing the energy, heat dissipation, and required cabling, as well as a potential reduction in management and maintenance costs. Putting more "eggs in one basket" does make operation and connection to the remaining servers more critical. Virtualization is leading to the use of higher grade cabling to handle the increased expectations for data traffic to and from that server.

A **switch** is a networking device that connects multiple segments together and typically operates at Layer 2 (data link layer) of the Open Systems Interconnect (OSI) model. A switch not only creates a network to transfer data between individual components, but it can also be used to segregate the data in transport to create separate collision domains called virtual LANs, or VLANs. For example, the switch can connect a grouping of equipment running at 1 gigabit Ethernet to the backbone network operating at 10G speeds and differentiate between these two networks as it handles traffic. If the switch has additional functionality to process data, then it may also operate at Layer 3 (network layer).

A **router** is a device that connectors multiple networks together, typically at Layer 3 (network layer) of the OSI model. Acting as a gateway, a router can connect networks of different protocols, such as ATM to Ethernet at the core routing area of the data center. Because of their position at the edge of each network, routers often have firewalls and other complimentary capabilities integrated within them.

Access to **storage** can be organized in several ways. Legacy systems used Direct Attached Storage (DAS) before storage devices became attached to a network. DAS is simply configured where there was a direct cable link between the server and one (or more) storage devices. The main protocols used for DAS connections are ATA, SATA, SCSI, SAS and Fibre Channel. This network may be easy to configure, but lacked scalability and redundancy, and is now typically reserved for legacy systems or areas of limited expected need or growth.

Which best described your current backup and recovery infrastructure?



**Figure 6: Backup and Recovery Infrastructure, InforStor Annual Reader Survey, Published March 2009**

For a more dynamic and scalable architecture, a Storage Area Network (SAN) can be created which will allow servers to access data from multiple storage devices, running over multiple paths for redundancy and speed. About 90% of the networked storage within the data center is run over a SAN. In this architecture, remote computer storage devices (such as disk arrays, tape libraries and optical jukeboxes) are attached to servers in such a way that the devices appear as locally attached hard drives to the operating system. Fibre Channel is the typical protocol used in the SAN and optical fiber is the typical cable media.

Less common than SANs, Network-attached storage (NAS) is used on the LAN side for file storage and operates over IP-based Ethernet; copper cabling is the typical media. NAS is utilized in networked storage environments that do not require the service level parameters of FC such as networked home directories or department file-sharing. NAS in essence is a large file server, usually having backend SAN fiber connections and translating FC storage to IP traffic.

Tape storage devices were introduced almost 60 years ago and they have continued to improve over time with regards to size, cost and reliability. Data transfer speeds of up to 120MB/s are available today. Disk technology is newer and often perceived as having higher performance, as disks devices are available for fast access. Tapes are generally stored inert after data has been transferred to them, and have to be loaded when data access is required. Tape storage has maintained a cost advantage over disk, and is therefore often the choice for back-up, recovery infrastructure or data with low-access requirements. Both types of storage are widely used today, often within the same data center.

There are many options for the storage devices themselves. These devices may come preassembled in their own housing or cabinet. This saves time and installation headaches, but there may be better cabinet options for power and cooling if ordered separately.

Servers are typically housed in **cabinets** that are 600 - 800 mm wide by 800 - 1000 mm deep, although it is not uncommon to find 1200mm deep cabinets to support high-density server applications that exhaust higher heat loads. Within the cabinet is a 19 inch wide rack that the servers can be mounted to. Although a rack may have the physical capacity to support up to 44 (or more) 1U servers, there are many practical limitations to consider, such as weight, power supply, heat dissipation and cable management. A typical cabinet will house 10-15 servers; while a cabinet prepared for high density may house 20-25 servers. Server cabinet density is typically measured in terms of watts per rack. This allows Data Center designers to adequately allocate proper power and cooling for short-term needs and long-term growth.

**Network cabinets** are expected to hold more of the passive patching and are offered in widths of 600 mm to 1000 mm with a depth of 800 mm to 1200 mm. Network cabinets are capable of supporting a mix of patching and electronics with a weight capacity of 1100 lbs (compared to 2200 lbs for a typical server cabinet). LAN & SAN switches can weigh 200 to 300 lbs each with a typical density of 2 per cabinet. This weight, plus that of the copper and/or fiber cabling, will typically not exceed that 1100 lb limitation.

The chassis for a blade server will take up much more space than the typical 1U server. Configurations differ, but as an example, a single chassis that can hold 16 blade servers may take up 10U of space, allowing for a total of four chassis and 64 blades servers within one cabinet. When filled out, this is a higher density than available with 1U servers. However, the 10U for each blade server is lost space, even if the chassis is not filled out.

In an IBM **mainframe** solution, a director (switch) is commonly its own separate entity, thus taking all the guesswork out of filling a cabinet. However, it is important to note that the power and cooling capacity can support a fixed number of mainframes in a given area, thus dictating their placement.

From a cabling point of view, mainframes are generally wired from under floor. They usually don't have any suitable locations within their cabinets to mount structured cabling panels or shelves, so floor box consolidation boxes are popular in such environments. Another approach is to use a cable consolidation cabinet in proximity to the mainframe cabinets to facilitate the same sort of cabling support.

## Common Port Counts

It is helpful to understand the typical number of ports per device, as this will provide the designer information about the size of the cables needed to be installed between electronic components. Each port will have transmit and receive components. For copper cabling, one connector handles both the transmit and receive, while for optical fiber connectivity, two connectors are typically required. These connectors are often duplexed together to act as one unit; for example, a duplex LC patch cord (2-fibers) would be needed per port on a server.

A server will have a minimum of two ports typically, although only one is required. The upper and lower limits are determined by specific server Input/Output (I/O) design, and larger servers can have well over a dozen interfaces. Some of the ports may be active, while others may be there for when the network is unavailable, or when an active port is having issues.

A SAN switch for a fibre channel solution may come in many different configurations with varying port counts. There are "stackable" SAN switches with at least 80 ports and chassis based "directors" can have port counts in the hundreds. A current configuration allows two SAN chassis to be hooked together to form one logical switch with up to 1024 ports of 8 Gig FC ports.

A switch will typically have 48 ports on a card, with a capacity for 8 cards per switch. At two switches per cabinet, this totals 768 ports per cabinet. The ports are most likely to be optical fiber on the SAN side and UTP on the LAN side, but it could also be a mixture of each in a converged network.

## Optical Sources

Regardless of what kind of data is represented in a signal, that signal has to be transmitted along the cable as either electrical signal for copper cabling, or as light for optical cabling. This section will focus on the different optical sources available today and the appropriate application for each.

### Light Emitting Diodes

The Light Emitting Diode (LED) was developed in the 1920s and was first introduced in the United States as a practical electronics component in 1962. However, it was not until the mid 1970s that optical fibers were developed specifically to take advantage of LED's transmission capabilities. An LED puts out a fairly large spot size of light, with a diameter well over 100 µm. A larger core fiber (50 or 62.5 µm) was needed to capture as much of that light as possible. Advantages of LEDs include that they are much less expensive than lasers and they do have a highly symmetric output and tend to fill all available modes (optical paths) within a fiber.

The diode is made up of two semiconducting regions that vary by the amount of electrons in place. The "p" region has fewer electrons than atoms, leaving "holes", while the "n" region has more electrons than atoms. Applying a positive voltage to the "p" region and a negative voltage to the "n" region causes the electrons to flow towards the junction of the two regions. The flowing electrons drop into the holes, releasing energy in the form of light for gallium arsenide diodes.

Historically, LEDs have been the preferred choice for short distance/multimode fiber systems and have operated at data rates of 10 and 100 megabits per second for the commonly used Ethernet protocols. Fibre Channel, ATM and ESCON can also operate with LEDs over multimode fiber at low data rates. LEDs have a significant limitation, however, in that their maximum data rate output is limited to 622 Mb/s, requiring the use of more expensive electronics to run data rates of 1 Gb/s or higher. Although single-mode lasers could be utilized, the additional cost made research into a new option desirable.

### Lasers

A Laser (Light Amplification by the Stimulated Emission of Radiation) generates light by a process called stimulated emission, where an outside source is required to activate the process. With semiconductor lasers, an electric current is passed through the laser material to excite the atoms into a higher energy state. As the atoms drop back into the lower state, they release their energy as photons, or light.

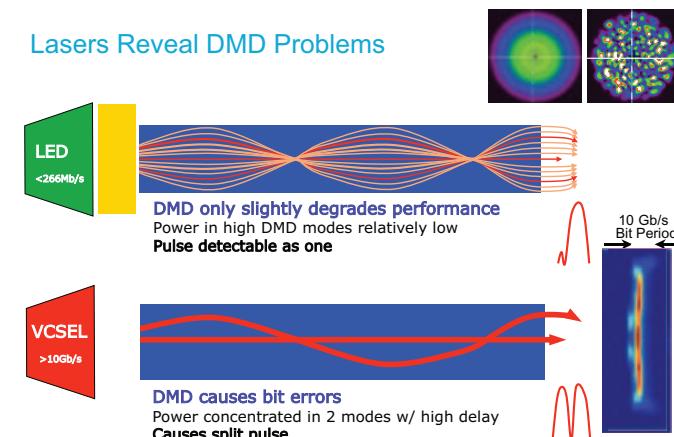
The laser is a diode, similar to the description of LEDs above, with "p" and "n" regions, but the laser requires stimulated emission, not spontaneous. Light energy must be extracted from the recombining electrons before they can spontaneously emit light. This requires a laser resonator, higher drive currents than those used in LEDs and confinement of both the excitation and the generated light.

Fabry-Perot (FP), also known as edge-emitting, lasers are relatively simple and low cost to make. Hence they are commonly used for short range applications. A FP laser cavity is designed as a set of parallel mirrors on opposite ends of the semiconductor chip that the light can resonate (bounce) between to stimulate light emission from excited atoms. One edge has a coating that will reflect most of the light back into the semiconductor. The other edge is left without the coating, to allow only one place for the light to exit as the laser beam; hence the name edge-emitting. There are other lasers on the market, typically used for long-reach applications, well beyond distances seen within the data center.

Edge-emitters cannot be tested until the end of the production process. If the edge-emitter does not work, whether due to bad contacts or poor material growth quality, the production time and the processing materials have been wasted. Although the manufacturing costs of lasers are low, the waste rate can cause unpredictable manufacturing yield.

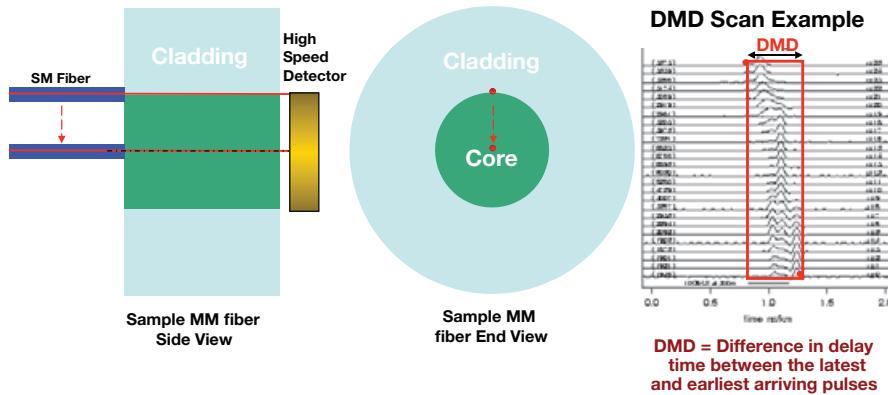
### Vertical Cavity Surface Emitting Lasers

Developed in the late 1980s, Vertical Cavity Surface Emitting Lasers (VCSELS) have several advantages during production when compared with the production process of edge-emitting lasers. Operating at the 850 nanometer (nm) wavelength, VCSELS emit energy in spikes that tend to inject light into a small subset of available modes within a fiber, and these spikes can be somewhat unpredictable and variable over time. The output profile can vary greatly between manufacturers, and from VCSEL to VCSEL within the same manufacturing lot. This has created the need for new testing procedures to evaluate the bandwidth of optical fibers when using a VCSEL as the source.



Fortunately, VCSELs can be tested at several stages throughout the process to check for material quality and processing issues. For instance, if the vias have not been completely cleared of dielectric material during the etch, an interim testing process will flag that the top metal layer is not making contact to the initial metal layer. Additionally, because VCSELs emit the beam perpendicular to the active region of the laser as opposed to parallel as with an edge emitter, tens of thousands of VCSELs can be processed simultaneously on a three inch Gallium Arsenide wafer. Furthermore, even though the VCSEL production process is more labor and material intensive, the yield can be controlled to a more predictable outcome. These manufacturing efficiencies allow for a much lower cost transmitting device.

Current standards define a DMD (differential mode delay) testing procedure to evaluate the bandwidth of optical fibers operating at 10G/s. A single-mode laser is used to input a light pulse into the core of a multimode fiber and to step from the edge of the core to the very center. The time it takes for each pulse to reach the end of the fiber is measured and compared to the flight time for all of the pulses. The difference in time is called the differential mode delay. In general, the lower the bandwidth and the longer the distance to be tested, the higher the DMD will be.



This process was developed when the maximum distance available utilizing multimode fiber was with the use of OM3 fiber to 300 meters. OM4 fiber allows a 550 meter distance today, almost twice the distance of OM3. CommScope has found that the standard OM3 test is not sufficient to evaluate DMD over this longer distance. Therefore, CommScope has developed a high resolution DMD test method that has several advantages over the current standard:

- Evaluates four quadrants of the fiber vs. the standard requirement of only one
- Shorter pulse widths are used to highlight issues faster
- 1 μm steps vs. 2 μm order to evaluate twice as many modes

CommScope was the first and is still one of the only cabling manufacturers to have their DMD testing capabilities certified by Underwriter's Laboratories (UL)

VCSELs are used in 1 and 10 gigabit Ethernet applications as well as 1, 2, 4, and 8G Fibre Channel today. Developing 40 and 100 Gigabit Ethernet applications are also employing VCSELs in arrays, where each VCSEL only needs to transmit 10G individually, with aggregation to occur at the electronics.

## Applications

We have tried to provide a brief overview of how different optical sources operate, but there is obviously much more to study to have a true understanding of these sources. This guide will focus more on specifically when each source is used with typical data center application.

LEDs are capped at speeds of 622 Mb/s and this has limited their use to slower 10 and 100 Mb/s ethernet solutions. There are some higher data rate applications like ESCON (200 Mb/s) and the slowest speeds of fibre channel and ATM that could be run with LEDs over multimode fiber. Lasers do offer a high data throughput and are required for most long haul applications, but the extra cost is prohibitive for most of the short length applications found within the data center. The VCSEL hits the sweet spot of high bandwidth over a distance that covers most applications paired with a much lower component cost compared to lasers.

TABLE 1: OPTICAL SOURCE APPLICATIONS

Source	Application Speed (Ethernet)	Relative costs	Optimal Fiber type
LED	10 & 100 Mb/s	low	MM
VCSEL	1G & 10G, and higher*	medium	MM
LASER	1G, 10G, and higher**	high	SM

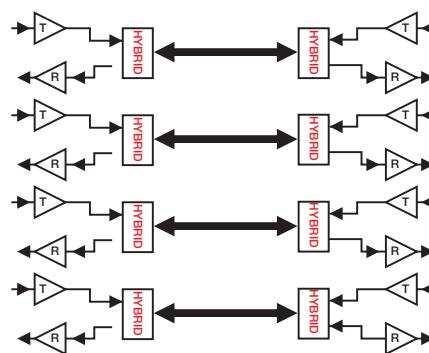
\* VCSELS will be used for 40 and 100G applications using parallel optics, where each VCSEL will support a data rate of 10 G/s or less

\*\* Lasers will be used for 40 and 100G applications using parallel optics or WDM. Each laser may provide a stream of data much higher than 10 G/s for WDM applications.

## Balanced Twisted Pair Applications

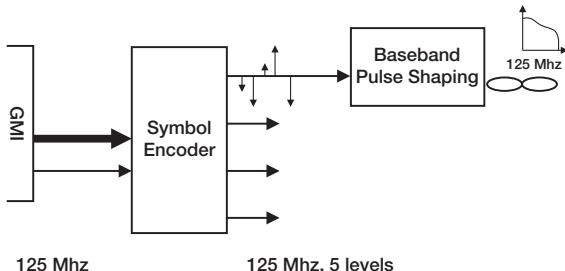
In the data center, both optical and copper solutions are utilized, and the electronics for UPT solutions operate on a much different process. For 1000Base-T ports, the electrical signal operates over 4 copper pairs with full-duplex operation 5-Level Phase Amplitude Modulation (PAM) signaling. This is utilized to increase the amount of data transmitted with each code point. Copper ports have chips assigned to them that control the power output.

Figure 7: Balanced Twisted Pair Signals



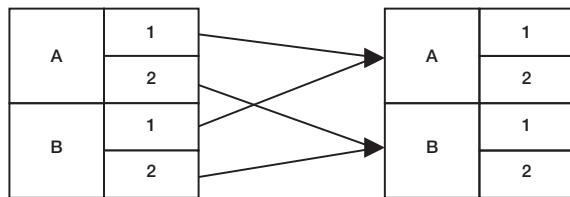
The signal is shaped into a 1000Base-T format. Forward error correction and DSP-based (digital signal processing) adaptive filtering are used to reduce the effects of echo, cross-talk and noise.

**Figure 8: Digital Signal Processing**



There is redundancy within the signal and each arriving code point is organized to define the subset membership of the next point.

**Figure 9: Built-in Redundancies**



10GBase-T standards were developed after 1000Base-T, but use much of the same terminology and physical architecture. 10G requires a higher crystal speed (250 MHz for 10G vs. 125 MHz for 1G) and more complex coding mechanisms.

### Transceiver Types

Along with the source options, there are also several transceiver types of ports to consider. Small Form factor Pluggable (SFP) transceivers connect a network motherboard to a cable (fiber or copper) and may support Ethernet, Fibre Channel and other applications. The available speeds for SFP transceivers are up to 8 gigabits for Fibre Channel and 1 gigabit for Ethernet.

For higher data rate applications, SFP+ transceivers refer specifically to 10G transmission. New QSFP (Quad SFP) transceivers are available that pack four channels into one module that offers improved density and cost.

# 7. Data Center Networking Protocols

## Introduction

Although this guide is focused on the structured cabling system, it is helpful to have a basic understanding of the data protocols running over this passive infrastructure. We will discuss the more common protocols and evaluate how each can affect the cabling requirements within the data center.

The OSI 7-layer model was developed to help standardize communication about computer networking, and is provided here for reference. Data Cabling fits squarely within layer 1, or the physical layer, and is required as the communication channel pathway for data to flow through network devices. This chapter, however, focuses primarily on the data link layer. At Layer 2, a received signal from the physical layer is interpreted before being passed up to Layer 3. Or data from Layer 3 is translated into a physical format that can be sent out across Physical Layer media.

## Ethernet

Ethernet is a set of frame-based computer networking technologies designed for local area networks (LANs). It defines a number of wiring and signaling standards for the Physical Layer of the OSI networking model, through means of network access at the Media Access Control (MAC) or Data Link Layer, and a common addressing format. IEEE 802.3 addresses the requirements for all Ethernet data rates.

As shown below, Ethernet protocols range in data rate from 10 Mb/s to 10 Gb/s TODAY and can run over a range of media types.

"Slow" Ethernet	10 Mb/s
"Fast" Ethernet	100 Mb/s
Gigabit Ethernet	1,000 Mb/s
10 Gigabit Ethernet	10,000 Mb/s

Gigabit Ethernet (GbE or 1 GigE) is a term for Ethernet transmission at a rate of 1 gigabit per second, as defined by IEEE 802.3z. Although half-duplex links (one-way data transmission) connected through hubs are allowed by the specification for lower data rate applications, the marketplace has basically settled on full-duplex applications for 1 Gbe and higher. The 10 Gigabit Ethernet (or 10 GE or 10 GbE or 10 GigE) Standard is published as IEEE Std 802.3ae and defines a data rate that is 10 times that of Gigabit Ethernet. 10 GbE supports only full duplex links which can be connected by switches. Half Duplex operation and CSMA/CD (carrier sense multiple access with collision detect) are not supported in 10 GbE.

10 GbE is no longer the highest speed that is planned for and system designers are trying to ensure that networks installed today can support speeds of 40 and 100 GbE. It is expected that the media required for data rates higher than 10G will be optical fiber. This will include multimode fiber (OM3 or OM4) to 100 meters or more, and single-mode fiber for links of significant length. Refer to Chapter 8 Transmission Media for more detail on the different fiber types.

Let's examine how the structured cabling for a 40 G/s Ethernet system could be configured using today's OM3 fiber. To be able to use today's 10 G/s VCSEL sources, the 40 G/s transmit signal is required to be broken down into four lower data rate channels. Each individual channel is now 10 G/s, which also matches the bandwidth of OM3 fibers, requiring four fiber pairs to carry the four 10 G/s channels. As Ethernet is a duplex operation, we must account for the receive path as well. At the electronics, the four channels are recombined into the 40G signal. This solution of breaking up a high data rate signal into multiple lower data rate signals for transmission is known as Parallel Optics.

Instead of utilizing many single-fiber connectors, the market is migrating towards the use of a 12-fiber MPO connection to make the space taken up by the port as small as possible. With this configuration, a single 12-fiber cable can carry both transmit and receive signals for 40 GbE. The transmit signal would be split over 4 fibers and the receive signal would utilize another four fibers, leaving four fibers dark.

**Figure 10: 40G Ethernet System Diagram**



With 100 G/s systems, it is also advantageous to utilize available VCSEL and fiber technology and divide the transmit signal into 10 10 Gb/s channels. Now 24-fiber trunk cabling is required, with two 12-fiber MPO (or one 24-fiber MPO) connections on each end. This provides 10 transmit fibers, 10 receive fibers, and 4 that are dark.

**Figure 11: 100G Ethernet Example with a 24F Trunk and 12F MPOs**



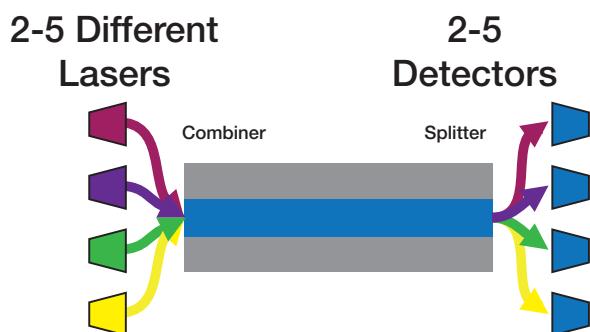
Today the 12-fiber MPO is the most common connector type for preterminated trunks, and will support 40 and 100G applications well. A 24-fiber MPO option is also expected to gain acceptance in the marketplace. The configuration would be the same, except that a single MPO connector takes the place of dual 12-fiber connectors.

As a side note, MPO connectivity is widely utilized today to provide lower density solutions within the cabling tray, as well as at the cross-connection points. Today there is a breakout from the 12-fiber connector to LC duplex or SC duplex before connecting to the 10G, 1G or lower ports. Installing a 12-fiber cable plant today provides a great future upgrade path to parallel optics. One would simply remove the breakouts and replace with MPO patch cords. For more detail, see Chapter 9 Passive Solutions.

The whole scenario of parallel optics has been described with 40 and 100G Ethernet as the baseline example; however the same structured cabling solutions will be required for high data rate Fibre Channel applications. Another benefit of utilizing a 12-fiber cable plant using MPO connectors within the data center is that it will function well for many applications.

Single-mode optical fiber is also a consideration for high speed applications, specifically when the distances preclude the use of multimode fiber. Single-mode fiber has a much higher bandwidth and therefore probable scenarios will not require parallel optics. Although one fiber can carry the higher bandwidth, it is still more cost effective to use multiple lower data rate lasers instead of one that is high powered.

**Figure 12: Wave Division Multiplexing Over Single-mode Fiber**



## Fibre Channel

Fibre Channel (FC) is the primary high-speed network technology for storage networking due to the protocol's quality of service, reliable transport (lossless nature) and speed of data transfer. A fibre channel system can be set up as point-to-point, as an arbitrated loop, or in its most useful and common configuration, a switched fabric. In a fabric network, the switches manage the state of the fabric, providing optimized interconnections, and allow multiple pairs of ports to communicate simultaneously. A high availability (HA) configuration allows for a failure of one port to be "failed over" to a redundant path, and should not affect operation to the host or storage devices.

Optical fiber is the typical media utilized for Fibre Channel, although a twisted pair option is allowed within the standard over shorter distances. FC is commonly available in speeds of 1, 2, 4 and 8 gigabits. Although implementation of 1G speed is trending down, there may be some need of this lower speed to connect to mainframe storage using 1G ESCON networks.

The industry is moving towards higher data rates now, with 16G speeds in development and 32G speeds on the horizon. Although still in draft form, 16G speeds will likely be capable with OM3 fiber to distances of 100M, with a potential longer distance option utilizing OM4.

## Fibre Channel over Ethernet

Fibre Channel over Ethernet (FCoE) is an attempt to simplify and converge the SAN and LAN networks at the data link layer. As Ethernet is becoming prevalent in the LAN and even moving out into the WAN or MAN space, it makes sense to consider a protocol that routes the SAN over the Ethernet. The FCoE standard was developed by INCITS T11 – The InterNational Committer for Information Technology Standards and completed in June 2009. FCoE recognizes that FC will continue to be a dominant storage protocol in the data center, while also providing for a simplified, consolidated I/O solution.

To implement FCoE, the FC frame has to be encapsulated into an Ethernet frame. Using the layering models, the top layers of the FC, along with a new mapping layer, are stacked on top of the Ethernet MAC and physical layers to create the FCoE Frame. To preserve the lossless nature of FC, the optional PAUSE capability allowed by IEEE 802.3x Ethernet must be used to allow a busy receive port to send a control frame to the transmit port asking for it to pause transmission as well. Use of this feature circumvents the traditional Ethernet allowance of dropped packets. There are other requirements besides the "pause" mechanism required to make Ethernet lossless. These are part of the Data Center Bridging group of standards under development in IEEE. Finally the traditional point-to-point addressing of FC is not sufficient, as Ethernet does not form the same point-to-point connection. A MAC address has to be added as the first 2 fields of the FCoE frame in order to point to its Ethernet destination. This method of CEE – Converged Enhanced Ethernet – allows FCoE to exist and its lossless nature differentiates this from traditional Ethernet.

FCoE is seen as complimentary to the movement towards virtualization. Hypervisors (platform allowing multiple operating systems to run on a host computer) need to provide guest operating systems with virtualized storage through a FC network infrastructure. Today it is cumbersome to move virtual servers to new equipment not just during initial deployment, but over the lifetime of the system for optimization and maintenance purposes. IT managers often use 4, 6 or 8 network adapters in critical applications to cover both Host Bus Adapters (HBA) and Network Interface Cards (NIC). FCoE enables the consolidation of both SANs and Ethernet traffic onto a single Converged Network Adapter (CNA), reducing the ever growing number of adapters required at the server level. FCoE combined with the advent of 10 Gigabit Ethernet (10 GE) fabrics grants companies the ability to consolidate their I/O, cables and adapters while at the same time increase the utilization of their servers through virtualization.

One of the main issues to consider is that the current FCoE solution is focused on running over 10 gigabit Ethernet specifically. And of this 10 Gbps link capacity, only 4 Gbps is allowed for Fibre Channel traffic by specification. Although this speed seems fast today, 16 and 32 gigabit FC is coming quickly, and it may not be advantageous to limit your network capacity to gain this flexibility. The lower speed of 100 Mbps or 1 Gigabit Ethernet is also not an option. Because 10 Gbps Converged Network Adapters are not backward compatible to lower speeds (by specification), this adapter cannot operate on server standby power. This means that a server connected by this mean cannot be put into a hibernate mode and later restarted with a Wake on LAN signal through this CNA interface. This makes sense as most networks are being designed for 10 gigabit speeds or higher today, but it is a limitation to understand and consider. Also it is important to understand that current activity in the IEEE for Energy Efficient Ethernet (EEE) will lower the power consumption levels of 1 G/s and 10 G/s Base-T transceivers, but will not apply to 10 G/s CNA based interfaces. This is due to the nature of CNA being a single speed only interface.

### InfiniBand

InfiniBand is an industry standard interconnect technology for data centers and high performance computing (HPC). It is a switched fabric I/O technology that ties together servers, storage devices and network devices. InfiniBand channels are created by attaching host channel adapters (HCAs) and target channel adapters (TCAs) through InfiniBand switches. HCAs are I/O engines located within a server. TCAs enable remote storage and network connectivity into the InfiniBand interconnect infrastructure, called a fabric.

Each channel has a raw throughput of 2.5 G/s with a data throughput of 2 G/s (typically). The InfiniBand Architecture currently offers three levels of link performance as shown in Table 2 below.

TABLE 2: INFINIBAND LINK PERFORMANCE

	Single Data Rate (SDR)	Double Data Rate (DDR)	Quad Data rate (QDR)
1X	2 Gbit/s	4 Gbit/s	8 Gbit/s
4X	8 Gbit/s	16 Gbit/s	32 Gbit/s
12X	24 Gbit/s	48 Gbit/s	96 Gbit/s

Higher data rate channels are starting to appear in commercial use, which will allow an increase in the throughput discussed above.

The cabling media for InfiniBand may be either optical fiber or copper cabling. HPC clusters typically keep the electronics very close together, and copper cabling is able to be used over these short distances – typically less than 15 meters – at a very high bandwidth. For longer distances, optical fiber cabling will be used.

Timing is very critical in InfiniBand, Ethernet and other applications, especially when there are parallel channels delivering information along different physical paths (different copper pairs or fibers). All of the information for a particular signal needs to arrive at basically the same time in order to be correctly deciphered by the electronics. But there is margin, and the receiver can store incoming streams until skewed bits are in buffer memory. In order to make sure that timing is not an issue, InfiniBand, Ethernet and other applications have a skew requirement, setting a liberal maximum deviation to signal arrival.

Skew can be caused by 3 basic reasons: timing differences between the optical transmitters, differences in speed that the light signal travels down one fiber compared to other fibers in that cable or differences in the lengths of each fiber within the cable. The manufacturing process of today's fibers and cables are uniform enough that skew will not be an issue. Research models [developed by CommScope and Nortel, and accepted by the IEEE 802.3ba Task Force committee] have shown that for 10 GbE, as an example, there would have to be at least 15 meters of difference in fiber length over a 100 meter nominal cable length to cause any issues. For MPO trunk cables, the actual difference in fiber length within the same cable and 12-fiber bundle would be insignificant, only be around a tenth of a meter over a 100 meter length.

For more information on skew, review the CommScope white paper *What to do About Fiber Skew, 2008*.

### Other Protocols

**iSCSI** (Internet Small Computer System Interface) is an Internet Protocol (IP)-based storage networking standard for linking data storage facilities. By carrying SCSI commands over IP networks, iSCSI is used to facilitate data transfers over intranets and to manage storage over long distances. iSCSI can be used to transmit data over local area networks (LANs), wide area networks (WANs) or the Internet and can enable location-independent data storage and retrieval. The protocol allows clients (called initiators) to send SCSI commands (CDBs) to SCSI storage devices (targets) on remote servers. It is a popular storage area network (SAN) protocol, allowing organizations to consolidate storage into data center storage arrays while providing hosts (such as database and web servers) with the illusion of locally-attached disks.

iSCSI uses TCP/IP (typically TCP ports 860 and 3260). In essence, iSCSI simply allows two hosts to negotiate and then exchange SCSI commands using IP networks. By doing this, iSCSI takes a popular high-performance local storage bus and emulates it over wide-area networks, creating a storage area network (SAN). Unlike some SAN protocols, iSCSI requires no dedicated cabling; it can be run over existing switching and IP infrastructure.

So iSCSI is an alternative SAN transport protocol, and at this time, 10GbE iSCSI appears to be a very inexpensive alternative to 8G FC, which requires a dedicated infrastructure. Applications for iSCSI are limited, however, because it is IP based and carries higher overhead than FC.

Although Fibre Channel is the leader, iSCSI is playing an important role in today's systems. About 55% of the new server virtualization environments out there are being attached to Fibre Channel and about 30% are being attached to iSCSI. (Nexsan Technology, July 2009)

**ESCON** (Enterprise Systems Connection) is a data connection created by IBM, and is commonly used to connect their mainframe computers to peripheral devices such as disk storage and tape drives. ESCON is an optical fiber, half-duplex, serial interface. Although SC connectors are also utilized, an ESCON optical fiber connector is the interface developed specifically for this application. This 2-fiber connector did not provide higher density, but it did control the fiber positioning well, as the duplex patch cords were used to connect equipment with ESCON ports to the cabling with ST, SC or other connector styles.

**FICON** (Fibre Connectivity) is the IBM proprietary name for the ANSI FC-SB-3 Single-Byte Command Code Sets-3 Mapping Protocol for Fibre Channel (FC) protocol. It is a FC layer four protocol used to map both IBM's antecedent (either ESCON or parallel) channel-to-control-unit cabling infrastructure and protocol onto standard FC services and infrastructure. The topology is fabric utilizing FC switches or directors. Valid data rates include 1, 2 and 4 Gigabit/s. Today's FICON has become similar to Fibre Channel and there are many ways it can interoperate with Fibre Channel devices and switches. FICON utilizes SC and LC optical connections.

Other protocols exist for WAN and MAN applications, such as ATM and SONET. These applications typically do not penetrate far into the Data Center. They would likely be translated at the Core routing into an Ethernet Protocol before continuing into the data center.

## Application Distances

TIA/EIA-568C.0 summarizes the distances for many applications within convenient tables. A table showing distances for applications utilizing balanced twisted pair is shown here.

TABLE 3: UTP APPLICATION DISTANCES

Application	Media	Distance (m)	Comments
Ethernet 10BASE-T	Category 3, 5e, 6, 6A	100	
Ethernet 100BASE-T	Category 5e, 6, 6A	100	
Ethernet 1000BASE-T	Category 5e, 6, 6A	100	
Ethernet 10GBASE-T	Category 6A	100	
ADSL	Category 3, 5e, 6, 6A	5,000	1.5 Mb/s to 9 Mb/s
VDSL	Category 3, 5e, 6, 6A	5,000	1500 m (4900 ft for 12.9 Mb/s; 300 m (1000 ft for 52.8 Mb/s;
Analog Phone	Category 3, 5e, 6, 6A	800	
FAX	Category 3, 5e, 6, 6A	5,000	
ATM 25.6	Category 3, 5e, 6, 6A	100	
ATM 51.84	Category 3, 5e, 6, 6A	100	
ATM 155.52	Category 5e, 6, 6A	100	
ATM 1.2G	Category 6, 6A	100	
ISDN BRI	Category 3, 5e, 6, 6A	5,000	128 kb/s
ISDN PRI	Category 3, 5e, 6, 6A	5,000	1.472 Mb/s

## Copper distances

Table 3 above can be used to determine what media is useful for the application and maximum distance of your system. For example, if a system is running 1000Base T (1 gigabit) Ethernet then Category 5e, 6, or 6A could be used to provide that data rate out to distances of 100 meters. For data rates of 10GBase-T (10 Gigabit) Ethernet only Category 6A twisted pair cabling would support that data rate to 100 meters. If a data center was planned to be running 1 Gb/s today and 10 Gb/s in 5 years, then Category 6A should be installed now to avoid a retrofit of the cabling system. TIA 568C.0 provides table 4, a similar table, for optical fiber media.

TABLE 4: TIA SUPPORTABLE DISTANCES

		Multi-mode				Single-mode		
		62.5/125 µm		50/125 µm		850 nm laser- optimized 50/125 µm		TIA 492CAAA (OS1)
		TIA 492AAAA (OM1)		TIA 492AAAB (OM2)		TIA 492AAAC (OM3)		TIA 492CAAB (OS2)
Application	Parameter Nominal wavelength (nm)	850	1300	850	1300	850	1300	1310 1550
Ethernet 10/100BASE-SX	Channel attenuation (dB)	4.0	-	4.0	-	4.0	-	- - -
	Supportable distance m (ft)	300 (984)	-	300 (984)	-	300 (984)	-	- - -
Ethernet 100BASE-FX	Channel attenuation (dB)	-	11.0	-	6.0	-	6.0	- - -
	Supportable distance m (ft)	-	2000 (6560)	-	2000 (984)	-	2000 (984)	- - -
Ethernet 1000BASE-SX	Channel attenuation (dB)	2.6	-	3.6	-	4.5	-	- - -
	Supportable distance m (ft)	275 (900)	-	550 (1804)	-	800 (2625)	-	- - -
Ethernet 1000BASE-LX	Channel attenuation (dB)	-	2.3	-	2.3	-	2.3	4.5 -
	Supportable distance m (ft)	-	550 (1804)	-	550 (1804)	-	550 (1804)	5000 (16405) -
Ethernet 10GBASE-S	Channel attenuation (dB)	2.4	-	2.3	-	2.6	-	- - -
	Supportable distance m (ft)	33 (108)	-	82 (269)	-	300 (984)	-	- - -
Ethernet 10GBASE-LX4	Channel attenuation (dB)	-	2.5	-	2.0	-	2.0	6.3 -
	Supportable distance m (ft)	-	300 (984)	-	300 (984)	-	300 (984)	10000 (32810) -
Ethernet 10GBASE-L	Channel attenuation (dB)	-	-	-	-	-	-	6.2 -
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810) -
Ethernet 10GBASE-LRM	Channel attenuation (dB)	-	1.9	-	1.9	-	1.9	- - -
	Supportable distance m (ft)	-	220 (720)	-	300 (984)	-	300 (984)	- - -
Fibre Channel 100-MX-SNH (1062 Mbaud)	Channel attenuation (dB)	3.0	-	3.9	-	4.6	-	- - -
	Supportable distance m (ft)	300 (984)	-	500 (1640)	-	860 (2822)	-	- - -

### Optical distances

Optical components that meet TIA standards should be able to meet the distances given within Table 4. There are a few key points to highlight though. There are 3 types of multimode fiber described 62.5 µm (OM1), 50 µm and laser-optimized 50 µm (OM3). So one cannot simply ask what is the distance for "multimode" fiber when evaluating a solutions capability. In most data center applications today, OM3 fiber will be required for its capability to provide 10 G/s speeds over a 300 meter distance. Additionally, an "enhanced" OM4 fiber, not shown in this table, is commonly available today and will provide longer 10G distances, out to 550 meters.

The standards offer a convenient look at the capability of the media, but this "one-number" has great limitations. On the copper side, the table does not provide an estimate of the available bandwidth performance headroom. If a high-bandwidth Category 6 cable is utilized, there may be headroom to spare, but Category 5e cabling may be barely sufficient.

On the fiber side, the distances are provided with the assumption that the distance is point to point. This means that there are no interconnects, cross-connects or splices within the link. Most systems are more complicated than this, however, and the extra loss associated with a cross-connect must be accounted for as a potentially shortened distance.

Another assumption that the standard makes is that all products are "worst case." The electronics have the worst case source characteristics, the optical fiber has the worst dB/km attenuation and the connectors have the worst case insertion loss at 0.75 dB per connector pair. This worst case planning methodology ensures that any mix of standards-compliant components will work at the distance denoted, but it does limit the potential length and/or configuration of the system. Although you can follow the standard recommended distances for a point to point or 2 connection system, one is left to calculate what the distance and loss budgets would be for links for more than 2 connections.

CommScope can supply derating tables that provide the distance that can be achieved based on a specific system's characteristics. These tables can be found at [www.mycommscope.com](http://www.mycommscope.com) and are broken out into three Performance Specifications Guides:

1. Copper
2. Optical Fiber
3. MPO / InstaPATCH® solutions.

These guides provide information on a multitude of systems, including Ethernet, Fibre Channel, InfiniBand and more. Let's look at one example to see how to use these guides.

*A data center is utilizing MPO trunks with OM3 fiber to connect a Server to a LAN switch; both of the electronics are located in separate EDAs and link through a cross-connect at the MDA. LC/MPO modules are utilized at all locations, with LC patch cords connecting to the equipment and also used for the cross-connect point.*

- Step 1: The application is 10 Gigabit Ethernet. Because the application includes MPO connections, the InstaPATCH® solutions document would be used for reference.
- Step 2: Within that guide, find the table corresponding to  
 10G-SX Ethernet  
 LC connections  
 OM3 (LazrSPEED® 300) fiber
- Step 3: Add up the number of LC and MPO connections. Within the cross-connect included, there will be four LC and four MPO connections. (Ignore connectors that are plugged directly into the electronics ports.)
- Step 4: From the table, choose the value that intercepts the column for four LC connections and the row for four MPO connections. In this case, the distance is 260 meters. If this distance is greater than the design requires, then you have confirmed that this solution will work well for the application. If this distance is too short, go to Step 5.

TABLE 5: 10G ETHERNET OVER LAZRSPEED® 300 WITH LC CONNECTIONS

# LC Connections with:	1 MPO	2 MPOs	3 MPOs	4 MPOs	5 MPOs
0	980 (300)	980 (300)	940 (285)	890 (270)	840 (255)
1	980 (300)	980 (300)	940 (285)	890 (270)	790 (240)
2	980 (300)	940 (285)	890 (270)	840 (255)	790 (240)
3	980 (300)	940 (285)	890 (270)	790 (240)	740 (225)
4	940 (285)	890 (270)	840 (255)	790 (240)	690 (210)
5	940 (285)	890 (270)	790 (240)	740 (225)	690 (210)
6	890 (270)	840 (255)	790 (240)	690 (210)	640 (195)

Step 5: If this distance is shorter than required by the design, consider the following alternatives

- Choose a higher grade LazrSPEED 550 fiber or
- Choose a low loss LazrSPEED 300 or LasrSPEED 550 solution.  
Please note that CommScope 360 pre-terminated solutions contain all low loss components as standard.

If neither of these two options provide a working solution, there are further steps to consider:

- Choose single-mode fiber
- Reconfigure the solution to eliminate the cross-connect and reduce overall link loss

This example shows how to determine that maximum distance given a set of system requirements. It can be used in several different ways, such as to determine the number of connector pairs allowable provided a set distance, or to determine if the proposed fiber type will allow an upgrade to a higher bandwidth.

# 8. Transmission Media

The media used for data transmission in a data center setting will generally be twisted pair copper (Category 5e, 6 or 6A) or fiber (OM1, 2, 3, 4 or OS2). Other media types include coax and wireless. Each media offers specific benefits for the different network subsystems. They differ most in how they carry (or propagate) communication signals.

## Network Cable Performance Criteria

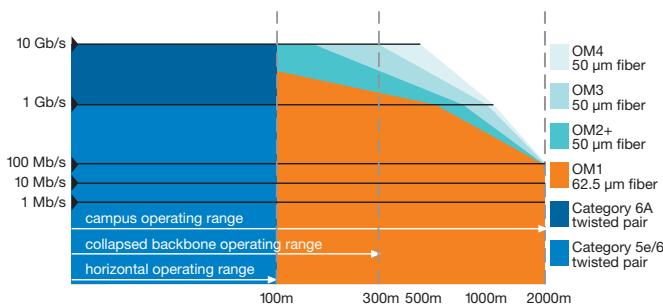
Before discussing individual media types, we will look briefly at media performance criteria. Two critical factors in measuring data cable performance are insertion loss (also called attenuation) and bandwidth.

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. 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.

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.

TIA-568 standards state the maximum operating distance is 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.

**Figure 13: Supportable Distances by Application and Media Type**



## Twisted pair copper

Twisted pair copper cabling is essentially two strands of thin (22 to 24 AWG) insulated copper wire twisted together into a pair at a precise lay; the twist helps to reduce crosstalk and electromagnetic interference (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.

Although CommScope is able to support F/UTP solutions, we strongly recommend the use of Class E<sub>A</sub> (Category 6A) UTP cabling. UTP has the benefits of a smaller cable diameter, a tighter allowed bend radius and can operate over a wide frequency range while still being easy to install and maintain over the life of the infrastructure. UTP systems avoid issues with earthing/ grounding and bonding, power supply requirements, the extra termination steps and shield maintenance procedures required in FTP systems. For a full discussion on the benefits of UTP cable, reference the CommScope white paper titled: *UTP vs. FTP for IEEE 802.3an 10GBASE-T Applications: From the User's Perspective*.

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).

With advancements in construction and materials, twisted pair cables are now produced with exceptional bandwidth that can 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-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.

**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 [-]10 dB).

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

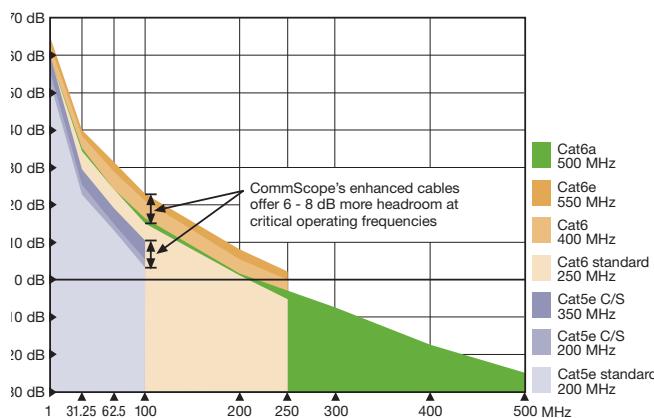
**Delay Skew** is the difference in propagation delay of the two conductors with the most/least delay.

### **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.

**Figure 14: PSACR for U/UTP Channels**



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.

## Fiber optics

Fiber optic cables are essentially very thin (125 microns or  $\mu\text{m}$ ) strands of glass that propagate light in an even smaller diameter core. Multimode fibers have (relatively) larger diameter cores (50 and 62.5  $\mu\text{m}$ ) that permit light to travel over hundreds of (or multiple) modes, or paths. The smaller core of single-mode fiber 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.

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

## Bandwidth

In a multimode fiber, 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 higher bandwidth. Bandwidth will be specified and will be a limiting factor in the data rate and distance used with this media.

Single-mode fiber has only one mode and does not experience the modal dispersion seen with multimode fiber. The bandwidth for single-mode fiber is not normally specified as it is not stressed by today’s electronics. 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 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. The typical laser-optimized fibers of today have a lower attenuation than the TIA minimum.

Single-mode fiber has much lower attenuation than multimode fiber. 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). Again, today's fibers typically improve upon this requirement.

#### 40 and 100G for Fiber

Most data centers recently built or under construction today are likely to be using speeds of 10Gb/s initially, but must also be prepared for new technologies and higher speeds in order to provide an expected lifespan of 1.5+ years. Similarly, existing data centers planning upgrades or expansion must also consider the needs for higher speeds.

If anything remains the same, it's the need for higher and higher data rates over time. 40 and 100 Gigabit Ethernet solutions are available within the standards today and the first commercial deployments are coming soon. This will require infrastructure that can support these speeds.

Standard optical fibers, like 62.5 µm OM1 and 50 µm OM2, have carried us a long way, but their limitations are finally being reached. We have seen at speeds of 10 Gb/s, the distances for OM1 and OM2 are too limited and laser-optimized 50 µm fiber is required for most applications. It is likely the standards for 40 and 100G will NOT include OM1, OM2 or OM2+ fibers for any distance, no matter how short.

Therefore, when preparing for data rates above 10G, OM3 fiber is the absolute minimum grade of fiber that should be installed. The draft standard shows a distance of 100 meters using OM3 for both 40G and 100G Ethernet applications. This distance covers an overwhelming percentage of data center applications. However, the 100 meter distance is given as a point to point solution. With typical systems that have 4, 6 or even 8 connector pairs within a link, that extra loss will shorten the allowable distance.

Extended-range OM3 fibers are available today, with specified distances of 550 meters as a minimum for 10 gigabit Ethernet performance. These type fibers are now represented within the Standards and have an OM4 designation. Completed in late 2009, TIA-492AAAD outlines the requirements for an OM4 fiber that also supports 40 and 100 GbE. The use of OM4 fiber will allow extended range and/or an increase in the number of connection points for very high data rate applications. Note that some of the 550 meter rated fibers sold before TIA-492AAAD was completed may not meet the bandwidth of the requirements and may not be true OM4 fiber. All CommScope LazerSPEED 550 fiber sold has met the requirements of TIA-492AAAD.

Correct fiber counts will also help eliminate the need to pull new backbone cabling every time a new application is available. 40 and 100G applications will likely run over "parallel optics," which is simply the process of breaking up a high speed data stream over multiple fibers, sending them over the passive system, and recombining these signals at the end.

Standards organizations (Both United States and international) are looking at various options utilizing MPO array connectors; a likely scenario for 100 gigabit Ethernet transmission includes having 10-fibers (of a 12-fiber bundle) act as a transmit channel, and another 10-fibers (also of a 12-fiber bundle) acting as the receive channel. For the system designer, this means that having 24 fibers going to many locations within the data center would be a minimum requirement to ensuring the capability to run parallel optics applications in the future.

At the same time that Ethernet is pushing the limits of data throughput, Fibre Channel is on a similar track. 8 Gigabit speeds are in wide use today, and speeds of 16 and 32G are being developed within the standards. To achieve these speeds, a similar approach should be taken with the choice of optical fiber. Avoid OM1 and OM2, using OM3 fiber as the minimum grade of glass throughout the system and strongly consider the use of OM4 fiber to allow for added distance and/or connector pairs within a link.

For optical fiber with a higher bandwidth to transmit at these high data rates, specify single-mode fiber. The cost associated with single-mode fiber electronics will likely continue to be twice that of multimode, and therefore not the best choice for the distances seen in the average data center. However, single-mode fiber is a great option for connecting data centers, for unusually long runs or future-proofing. There will be single-mode options within the standards for 40 and 100G and some data centers can make use of its high bandwidth.

It has been estimated that approximately 70% of data center operators replace their cabling after 4 years (BSRIA 2007 survey). Installing the proper cabling today will extend the expected life of the cabling, reduce upgrade costs over time, reduce material disposal in the future and limit the hassles and cost associated of cable replacement.

OM3	100 meters
OM4	150 meters
High Performance Low Loss OM4 Solution	170 meters*
OM1	NA
OM2	NA
OM2+	NA

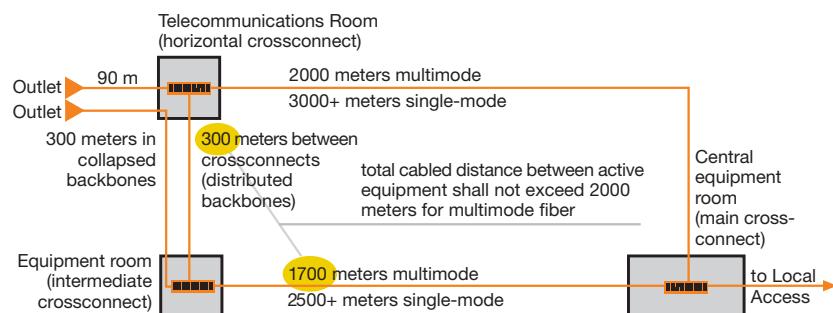
Available from CommScope Enterprise Solutions

## Fiber Optic Performance

### Fiber Optic Cable Distances for 100 Mb/s Networks

TIA-568 distance standards were initially written for a 'FDDI (Fiber Distributed Data Interface) grade' 62.5  $\mu\text{m}$  multimode 160/500 MHz/km bandwidth fiber powered by 850  $\mu\text{m}$  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.

**Figure 15: TIA 568 Distance Recommendations**



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 6: 100MB/S ETHERNET PERFORMANCE**

Fiber Description	Bandwidth (MHz•km) 850/1300 nm	1 Gb/s Range with 850 nm VCSEL	1 Gb/s Range with 1300 nm LASER
50 $\mu\text{m}$ OM4	4700*/500	1100 m	600 m
50 $\mu\text{m}$ OM3	2000*/500	1000 m	600 m
50 $\mu\text{m}$ OM2+	950*/500	800 m	600 m
50 $\mu\text{m}$ OM2	500/500	550 m	550 m
62.5 $\mu\text{m}$ OM1	200/500	275 m	550 m
8.3 $\mu\text{m}$ single-mode	NA	2 km and up**	2 km and up**

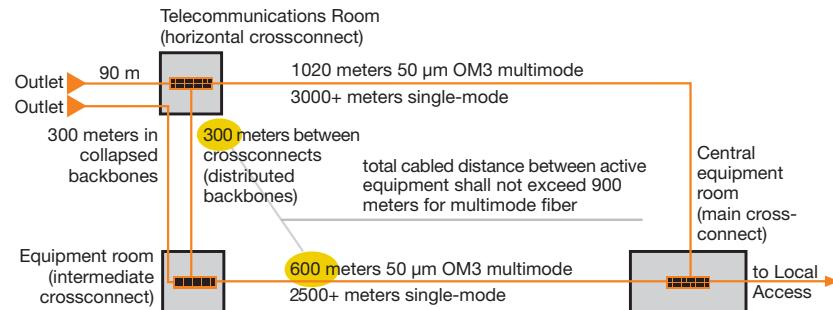
\* Effective Modal Bandwidth (EMB)

\*\* 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  $\mu\text{m}$  fiber can be used for the 300 meter backbone. When planning a future link of 300 - 1000 meters, consider using high bandwidth 50  $\mu\text{m}$  multimode fiber or single-mode fiber.

**Figure 16: TIA 568C Recommendations for 1Gb/s Ethernet**



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

**TABLE 7: 1G/S ETHERNET PERFORMANCE**

Fiber Description	Bandwidth (MHz•km) 850/1300 nm	1 Gb/s Range with 850 nm VCSEL	1 Gb/s Range with 1300 nm LASER
50 $\mu\text{m}$ OM4	4700*/500	1100 m	600 m
50 $\mu\text{m}$ OM3	2000*/500	1000 m	600 m
50 $\mu\text{m}$ OM2+	950*/500	800 m	600 m
50 $\mu\text{m}$ OM2	500/500	550 m	550 m
62.5 $\mu\text{m}$ OM1	200/500	275 m	550 m
8.3 $\mu\text{m}$ single-mode	NA	2 km and up**	2 km and up**

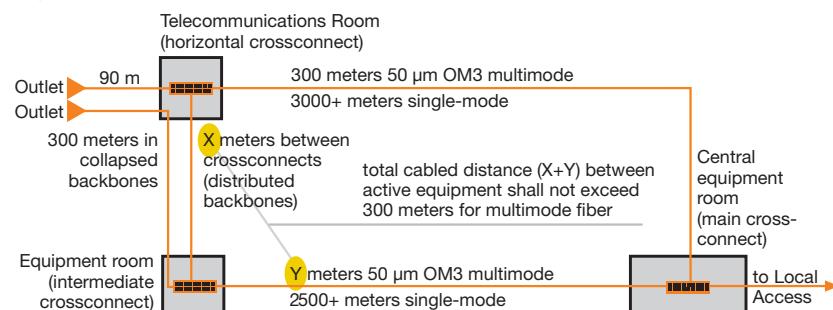
\* Effective Modal Bandwidth (EMB)

\*\* 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  $\mu\text{m}$  multimode fibers.

**Figure 17: TIA 568C Recommended Distance for 10Gb/s Ethernet**



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  $\mu\text{m}$  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  $\mu\text{m}$  fiber (at these operating distances, pay special attention to loss budgets). Distances beyond that require the use of single-mode transmission systems.

TABLE 8: 10GB/S ETHERNET PERFORMANCE

Fiber Description	Bandwidth (MHz•km) 850/1300 nm	10 Gb/s Range with 850 nm VCSEL
50 $\mu\text{m}$ OM4	4700*/500	550 m
50 $\mu\text{m}$ OM3	2000*/500	300 m
50 $\mu\text{m}$ OM2+	950*/500	150 m
50 $\mu\text{m}$ OM2	500/500	82 m
62.5 $\mu\text{m}$ OM1	200/500	33 m - very limited distance
8.3 $\mu\text{m}$ Single-mode	NA	2 km and up**

\* 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  $\mu\text{m}$  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  $\mu\text{m}$  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 manufacturers use an even tighter mask profile to really minimize the effects of DMD.

DMD testing is performed because VCSELs from various manufacturers 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  $\mu\text{m}$  fibers will support 10 Gb/s at longer distances or with less connector loss.

In Table 9, fibers are listed by TIA's LOMMF (Laser Optimized Multimode Fiber) and ISO's OM (Optical Multimode) performance standards.

TABLE 9: TIA 568C LOMMF AND ISO'S OM PERFORMANCE STANDARDS

Fiber Type or Name (ISO OM designation)	Bandwidth (MHz•km) 850/1300 nm	1 Gb/s Range	10 Gb/s Range
OM4 50 µm	4700*/500	1100 m	550 m
OM3 50 µm	2000*/500	1000 m	300 m
OM2+ 50 µm	950*/500	800 m	150 m
OM2 50 µm	500/500	600 m	82 m
OM1 62.5 µm	200/500	300 m	33 m
OS2 8.3 µm Single-mode	NA	40 km**	40 km**

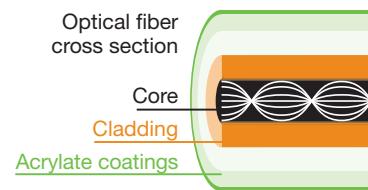
\* OFL bandwidth

\*\* 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.

**Figure 18: Optical Fiber Cross Section**



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 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.

#### Outside plant

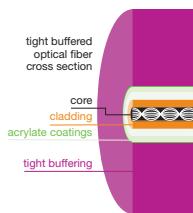
Outside plant cables are designed specifically for outdoor usage. They do not carry NEC listings and are not intended for indoor use except when placed in rigid or intermediate metal conduit (check local codes). Outdoor plant cables come in specialized constructions (armored, multiple jackets, special 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.

### Tight Buffered Fiber Optic Cable Construction

Tight buffered fibers have an additional plastic coating (900  $\mu\text{m}$  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.

**Figure 19: Tight Buffered Optical Fiber Cross Section**



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 patch cord. It is usually plenum or riser rated.

#### Breakout Cables

Breakout cable consists of several individually jacketed tight-buffered fibers (basically simplex cordage) cabled together. It is usually plenum or riser rated.

#### 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 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.

#### Coaxial Cable

Coaxial cable is made up of a conductor surrounded by a dielectric, which is covered with one or more shields (copper or aluminum tubes, aluminum tape and/or braided wire) and 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, its merits of fairly low attenuation and excellent protection from RF interference have been superseded by twisted pair and fiber.

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 ControlNetTM and MAP specify coaxial media.

### **Wireless Connections**

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 (SEAs) that are wired to the network.

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.

# 9. Passive Cabling Products

The design and quality of the passive cabling components can have a major impact on the performance and reliability of your Data Center and network. This chapter will review the various components that make up the passive cabling infrastructure, as well as performance and best practices to ensure you get the most out of your installation.

## Copper Cables and Components

### 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 effect 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 also 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 standards for performance.

#### **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.

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

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

#### **Shielded Twisted Pair (F/STP)**

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.

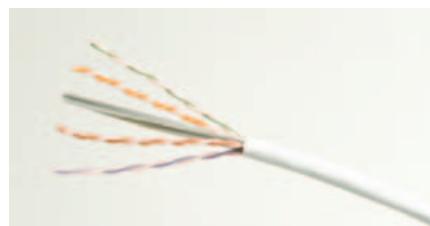
### Twisted Pair Channel Performance

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.

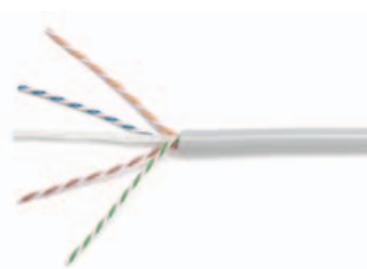
By definition, all Category 6 and 5e twisted pair cables support gigabit Ethernet. In a real world application, a cable with higher bandwidth will support it better. Network transmission depends on a signal with as little noise as possible; a noisy signal increases bit-error thus causing retransmission 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.



**Category 5e UTP**



**Category 6 UTP**



**Category 6A UTP**



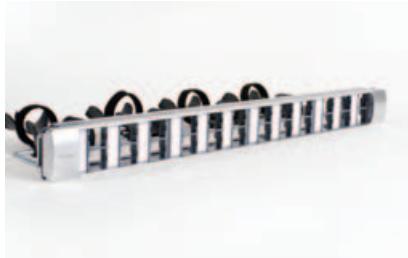
**FTP**



**Information Outlet**



**Patch Cord**



**Modular Panel**



**110 Wiring Block**

TABLE 10: TWISTED PAIR CHANNEL PERFORMANCE

All values in dB @ 100 MHz	Insertion Loss (attenuation)	NEXT	ACR	P\$um NEXT	P\$um ACR	ELFEXT*	P\$um	ELFEXT**	Return Loss
Category 6A (500 MHz)	19.1	44.3	25.2	42.3	24.8	27.8	24.8	20.1	
Category 6e (550 MHz)	19.6	42.9	23.3	42.1	22.5	29.3	27.3	16.0	
Category 6 (400 MHz)	20.2	41.9	21.7	41.1	20.9	27.3	27.3	15.0	
Category 6 (250 MHz)	21.3	39.9	18.6	37.1	15.8	23.3	20.3	12.0	
Category 5e (350 MHz)	22.1	34.1	12.0	32.6	10.5	22.9	19.9	13.0	
Category 5e (200 MHz)	23.5	32.1	8.6	29.1	5.2	19.4	16.4	12.0	

\* Called ACRF in the Category 6A standard

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

Consult local codes as to what type (plenum or non-plenum) of cable to install.

### 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 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 and/or 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.

## Fiber Optic Cables and Components

### 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

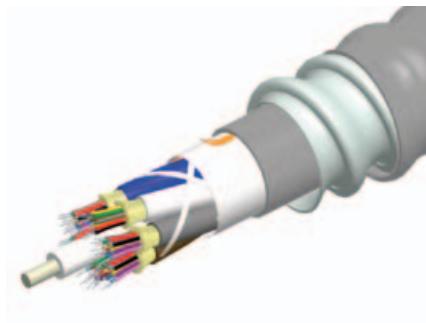
Distribution cables are a compact solution for transporting up to 144 tight buffered fibers (bundled in 12 fiber subunits) over a long distance. Aramid yarn provides tensile strength while a dielectric strength member gives support for pulling and for long riser installations. Distribution cables are 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 distribution cables 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.

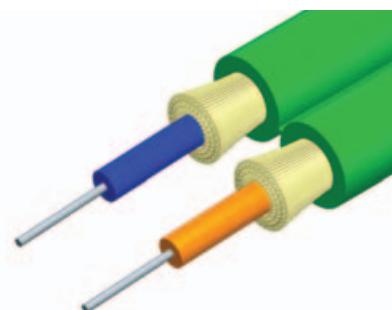
Distribution cables are available plenum and riser-rated versions.



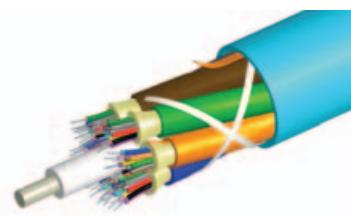
**Distribution Armored**



**Simplex**



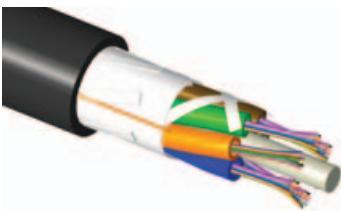
**Zipcord**



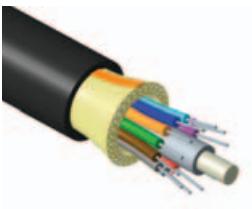
**Distribution**



**Interlocking Armored Cable**



**Loose Tube Cable**



**Tight Buffered**

#### **Trunk Cables**

Trunk cables are a subset of distribution cables that run in the data center between the Entrance Facility, MDA, HDA and EDA. Commonly trunk cables are factory-terminated with MPO or LC connectors. Although trunk cables could contain tight-buffered or ribbon fibers, today the best option is to use loose-tube fibers. Loose tube fibers typically have the lowest attenuation because they are not encumbered by an over-coating (900 µm) or stressed due to their attachment to the other fibers within a ribbon. Loose tube cable designs also provide the lowest density for the fiber counts most commonly seen in today's data centers runs (12 – 144 fibers).

#### **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.

#### **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 are 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.

## 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  $\mu\text{m}$  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 patch-cord. Pre-terminated patch cords and pigtailed 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. The LC connector is the connector used in network switches.



**LC Connector**

### 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-568 to illustrate fiber systems.



**SC Connector**

### 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 patch cords. STs offer slightly more insertion loss than other connector types, but have a large installed base from years of use.



**ST Connector**

Most connectors and adapters are color-coded as specified in TIA-568 for easy recognition:

- Blue - Single-mode components.
- Green - SM/APC (Single-Mode Angled Polish Contact) components.
- Beige - Multimode components.
- Aqua - Designate 50  $\mu\text{m}$  laser optimized components.



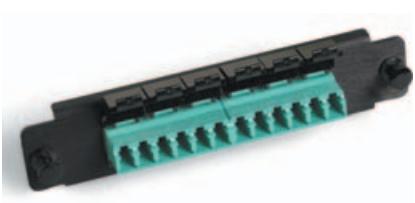
**MPO Connector**

### MPO Connector

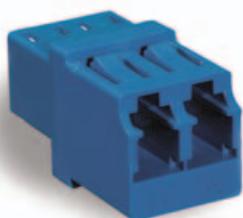
The MPO connector is significantly different from the previous discussed connectors in that 12 fibers are contained within each connector ferrule. This provides a high density solution that is very fast to install. Today, MPO connectors are typically the pre-terminated ends of trunk cables. As 40 and 100G applications take off, we will start to see electronics with MPO ports. CommScope MPO connectors mate key-up to key-up and have 12-fibers per connectors. MPOs are aligned by the use of 2 metal pins and a pinned connector is always mated into a pinless connector.

With CommScope solutions, the MPO connector on both ends of a standard trunk is pinless, while the MPO inside the module is pinned. If MPO trunks are to be interconnected, then a standard trunk would be mated to an extender trunk (different part numbers). The extender trunk would have one pinned MPO connector, which is mated to the standard trunk, and one pinless connector which plugs into the module.

Other solutions may have a different keying convention and therefore not interconnect properly with CommScope MPO solutions.



**LC Adapter Panel**



**LC Adapter**



**Enclosure**



**Entrance Enclosure**

## 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.

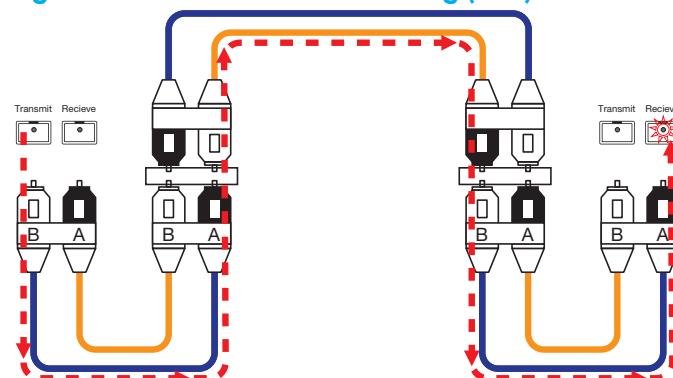
## Optical Fiber Polarity

### Optical Fiber Polarity with Duplex Systems

With most electronics within the data center, the port is configured as a transmit/receive pair, requiring 2-fibers to connect into that port. Within the cabling system, therefore, it is critical that the fibers are organized so that the transmitted signal at one end of the system arrives at the receive port at the other end of the system. TIA/EIA-568B.1 allows for two different methods to align the fibers – Consecutive Fiber Positioning and Reverse Pair Positioning. Each method works well, provided that the chosen convention is followed throughout the system. Reverse Pair Positioning (RPP) is described here as an example.

With RPP, the fiber or connector that is in the first position at one end of a link is “reversed” to the second position at the other end of the system. This is repeated for every link within the system. As shown in the figure, this reversal allows the signal that was transmitted at one end of the system to reach the receiver at the other end. As fibers are typically color-coded, a good example can be seen in the figure with the blue and orange fiber pairs. Within any link, the blue fiber is in the first position (right side) at one end of the link and switches to the second position (left side) at the other end of the link. RPP works for any number of cross-connects and interconnects.

**Figure 20: Reverse Pair Positioning (RPP)**



Note that a TIA568B.1 compliant patch cord is built by RPP and are known as A-to-B patch cords. These patch cords fit into the system without need for reconfiguration. If the links are installed with the proper polarity, there should be no need for patch cord reconfiguration i.e. undoing the duplex connectors on one end of the cord and flipping in the field.

#### **Optical Fiber Polarity with Array Systems**

Density requirements within the data center have pushed manufacturers into developing high density trunk cables segregated into 12-fiber subunits and terminated with MPO connectors.

At the patch panel, the 12-fiber groupings are broken out into the traditional 2-fiber pairs that are patched into today's electronics. This breakout is either done through a module or with an array patch cord.

A complicating factor is the need to design for future applications, which will run over parallel optics, which is simply the process of breaking up a high speed data stream over multiple fibers, sending them over the passive system and recombining these signals at the end.

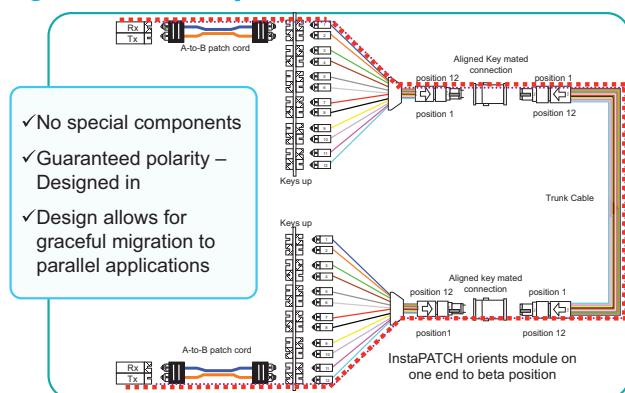
These systems will utilize fibers within a 12-fiber subunit, with an MPO connection directly to the electronics port. Therefore the system polarity has to be designed to both meet the needs of today's electronics ports utilizing fiber pairs, and tomorrow's ports utilizing a 12-fiber connection directly into the electronics.

TIA and international standards have tried to address this issue early on and have incorporated some standardized methods within TIA/EIA568 C.1 and draft IEC documents. Unfortunately, there are currently 3 methods described within C.1 without a specific recommendation given. Of the 3 methods, only method B provides the proper polarity for duplex solutions without the need of polarity correcting components AND also allows for the migration to parallel optics without replacing the backbone cabling. Therefore method B is the solution recommended and utilized by CommScope.

Method B utilizes a trunk cable that has NO pair-wise and NO array flips. This is achieved by utilizing a MPO connection where both connectors are inserted into an adapter "key-up." The polarity is controlled within the trunk and modules, leaving no extra configuration on the user side.

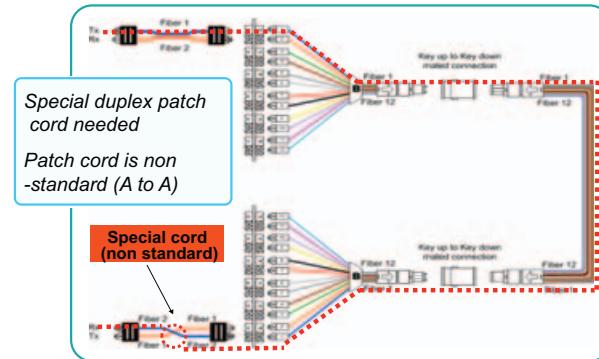
To upgrade to parallel optics, the MPO to single-fiber connector modules are replaced with an MPO adapter and MPO patch cord that can be connected into the new electronics. No replacement of the trunk cable is required.

**Figure 21: Polarity Method B**



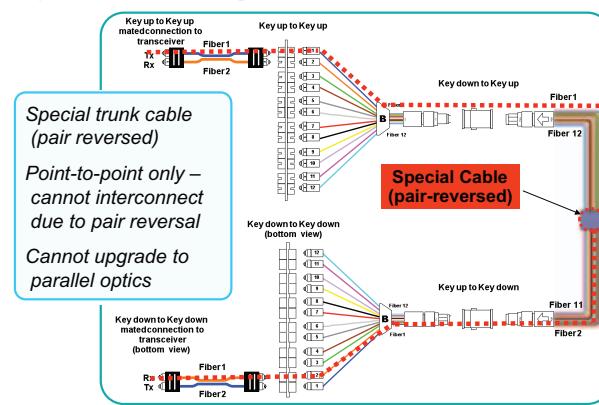
Method A utilizes MPO connections that mate key-up to key-down. This causes a flip in the system that is resolved by a ribbon flip within the trunk cable. Looking at drawings of this solution, one may not actually see a flip in the ribbon shown. However the connectors are shown with one MPO in the key-up position and MPO on the other end of the trunk in the key-down position. When inserted into an MPO adapter, one of those will have to be flipped, causing the flip to occur. The real negative of this solution is that a non-standard patch cord is required at the electronics on one end of the system. A system operator would have to reconfigure the patch cord on one end of the system every time a patch or connection is made.

**Figure 22: Polarity Method A**



Method C utilizes fiber pair flips within the cable trunk as well as key-up to key-down MPO matings. This method does work successfully for 2-fiber polarity. However the pair flips within the trunk make it unsuitable for upgrading to parallel optics. With no upgrade path to high data rate applications, this solution is not very appealing.

**Figure 23: Polarity Method C**



There are proprietary methods on the market with various positives and negatives. With any proprietary solution, however, one always runs the risk that the vendor will change or obsolete that technology, leaving the customer with no path to the future. Note also that because each method, both standardized and proprietary, are so different, one may not be able to mix components from each solution. Choosing the best solution is critical.

To summarize array polarity, Method B is the only option that is standards compliant, works with today's transmit/receive fiber pairs without requiring polarity correcting components AND allows a clear upgrade path to high data rate parallel optics applications without replacing the trunk. Array polarity method B is the clear winner and should be utilized for all array applications.

## **Preterminated solutions in the data center**

To help data center managers achieve faster and better performing installations with less troubleshooting, many manufacturers are providing pre-terminated fiber and copper solutions. Pre-terminated solutions are beneficial because they:

- are built to preconfigured lengths
- are terminated at the factory in carefully controlled conditions
- come with pulling grips and mounting pre-installed
- provide consistent test results
- reduce time spent in restricted data center areas
- reduce time spent testing and troubleshooting
- simplify planning due to less variability in installation time and fewer redo's
- increases team capacity to take on more work
- eliminates the need for termination training, toolkits and consumables

The base cost of pre-terminated components is typically more expensive than purchasing the raw materials; however, these costs can be greatly offset by the lower expenses for consumables, labor and overall hassle.

## **Enclosures**

### **Racks, Cabinets and Cable Management**

All Data Centers 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 1U 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 also an important consideration if the installation includes active equipment.

### **Wall Mount 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.



**4 Post Rack**



**3" Two Post Rack**



**6" Two Post Rack**

### ***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, cabinets 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. Since heat can degrade the performance of active electronics, 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.

### ***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, 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 patch cord management. They have greater depth between the closed doors and rails to allow more room for patch cord 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 hundreds of patch cords. The consequences of improperly routed circuits can be hours of downtime and a crippling loss of productivity.

Intelligent infrastructure can help solve 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 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 patch cords.

### ***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 is instantly conveyed to the network manager.

## **Data Center in a Box**

The goal of the Data Center in a Box (DCB) idea is to reduce the time and expertise it takes to set up additional capacity. The DCB can be thought of as a “mega cabinet” built into a 20 or 40 foot shipping container. The DCB includes electronics, HVAC, cabling and more, all delivered to the customer in a ready-to-go package. This package may make sense in places where deployment speed and simplification are paramount. With a hardened structure, applications could include military or disaster recovery.

As with any developing technology, there are some considerations to review. These packages will be expensive compared to in-building applications and come in set packages that are not easily customizable. The server platform selection or network configuration options may be limited and greatly dependant upon the vendor offering the DCB. There will be limited I/O connectivity inside and especially outside the container, which may greatly limit network and storage flexibility. The DCB will require infrastructure components such as power, communication links and chilled water for operation, and if used for a long term period, it may be necessary for security reasons to place brick and mortar around the container, adding to the total cost.

This application is not suggested as a replacement for the traditional data center model because of the discussed limitations; however the DCB may be advantageous for niche applications.

# 10. Building Automation Systems

## What are Building Automation Systems Designed For?

Every building, particularly data centers, has to meet basic requirements including security, ventilation, lighting, fire-life-safety (FLS), health and comfort.

Security needs, for the protection of property, content and personnel, include:

- identifying vehicles
- controlling access
- taking precautions against terrorist threats, robberies and burglaries

All these needs may require closed-circuit television (CCTV) and access control.

Ventilation and lighting requirements, for the comfort of occupants and energy conservation, include:

- managing heating, ventilation and air conditioning (HVAC) systems
- managing lighting controls
- managing global health and safety regulations
- monitoring and regulating building pollution
- producing efficient and 'greener' buildings

These needs may require building-wide efficient system management and electrical demand monitoring.

Fire and safety requirements include:

- rapidly locating and containing the fire source
- quickly locating missing personnel
- managing access control

These needs require fire monitoring and sprinkler systems, lift and access control systems, a public address system and a personnel database.

The systems designed to handle all these requirements are collectively referred to as a Building Automation System (BAS). No longer are these systems only for monitoring purposes. Standard today are graphical user interfaces that display detailed systems flow and equipment control diagrams. A newer BAS can communicate the important parameters of a data center in real time and at a high resolution, enabling the operator to fully visualize a system's performance over any operating period.

The programming capabilities, processing speeds and response times of today's BAS make implementing some of the control strategies presented here possible in the legacy data center. These systems can gather a multitude of central plant and electrical distribution system parameters, from raised floor temperatures, pressures at precise points and the computer floor's total energy use on a constant basis. From the operator's workstation, these readings can be used to calculate power usage effectiveness (PUE) and perform iterative adjustments over time to tune the mechanical systems to operate most efficiently. Using the BAS to log and trend power consumption, equipment runtimes and current cooling capacities will help facility managers understand the present state of operations, discover where energy is being wasted and determine optimal systems settings to operate the data center as efficiently as possible.

Whether in the Data Center or building-wide, a BAS can be implemented in new buildings or retrofit into existing structures to gain the benefits. Over half of all buildings in the U.S. that are larger than 100,000 square feet utilize BAS today, and are able to reduce their overall energy consumption by 5 to 15%. Buildings that consume a lot of energy, such as a data center, or older, poorly maintained buildings that do not have the latest in energy efficient equipment may see even greater savings.

## Intelligent Buildings

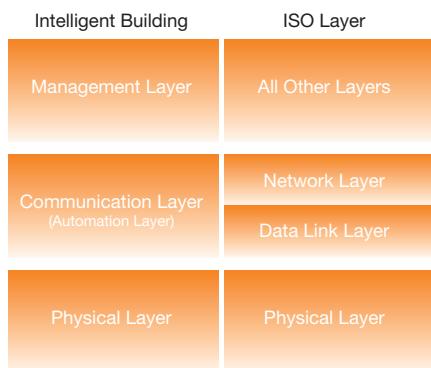
Building Automation Systems can be implemented to help achieve what is known as an intelligent building. An intelligent building incorporates the best available concepts, materials, systems and technologies to optimize its structure, systems and management, creating a productive and cost-effective environment.

An intelligent building can be divided into three layers:

- **Integration of the control and management of all the building services** such as HVAC, lighting, fire-life-safety, security and access control, environmental control and monitoring. This can be achieved via software and hardware designs. This is done at the management layer.
- Convergence of Information and Communication Technology (ICT) systems and BAS onto **a single IP (Internet Protocol) platform** at the communication or automation layer.
- Implementation of ICT systems and BAS under **one uniform network infrastructure** at the physical layer.

Since operation and maintenance account for 75% of the costs for a typical 30 or 40 year building lifespan, infrastructure decisions, such as intelligent building and BAS implementation, can have far-reaching financial and operational advantages.

**Figure 24: Intelligent Building Conceptual Layers**



**Figure 25: Building Lifecycle**



CommScope's Intelligent Building Information System (IBIS) is a modular, flexible cabling infrastructure system that supports building automation devices and systems by providing cost effective connectivity for intelligent building control and management. It supports ICT systems and BAS using twisted pair and fiber optic cables to provide connectivity in an open architecture environment.

CommScope IBIS design became the blueprint for the ANSI/TIA-862 Building Automation Cabling Standard which was published in 2002. This standard specifies a generic cabling system for BAS to support a multi-vendor environment, establishing performance, topology and technical criteria for various cabling system configurations for connecting BAS equipment and devices.

In the standard, the space served by one BAS device is referred to as the coverage area. Each coverage area will have one outlet for each building control application (e.g. HVAC, security, FLS, lighting control). TIA-862 defines the coverage areas for several LAN locations, but neither it nor TIA-942 specifically address data center coverage areas today.

The standard calls for horizontal cabling based on a star topology, but due to the nature of BAS equipment, the standard also permits optional topologies such as bridge connection, chain connection, multipoint bus and multipoint ring. The transmission media, cords and associated connecting hardware must comply with ANSI/TIA-568-B. The maximum horizontal distance is 90 meters, independent of the media type; the maximum channel distance – the cabling between a controller and a BAS device – is application dependent.

CommScope promotes a uniform cabling infrastructure IBIS concept to support voice, data, video and BAS applications, with the same cable and connecting hardware used throughout. Furthermore, equipment for supporting these applications should ideally be collocated in the Entrance Rooms and Telecom Rooms to ensure maximum flexibility and ease of maintenance.

However, some end-users will prefer demarcation between data services and BAS. One simple method of providing this demarcation is to use different color cables and different connecting hardware types for these applications (e.g., 8-pin modular patch panels for communication systems and 110, or VisiPatch panels for BAS). Also, some BAS installers may prefer hardwiring rather than using patch cords.

## IBIS Benefits

A well-designed IBIS solution will protect your infrastructure investment by:

- Reducing installation costs: cables for voice, data and BAS applications can be pulled in tandem, reducing installation labor cost. The cable pathways can also be consolidated, reducing cost even further. (However, for ease of maintenance, avoid intermixing the BAS and ICT cables within the same cable tray. Instead, place different cable types on opposite sides of the tray, and use differentiating colors.)
- Reducing commissioning time: there is only one installation team (at most two since some FLS systems require special circuit integrity cables) to deal with. This will minimize scheduling conflicts between installation teams, speeding the installation. Clear demarcation can now be provided between the accredited cabling installer and the BAS equipment suppliers. The installer will normally test the cabling for continuity, DC resistance, crosstalk, return loss and attenuation before handling the installation over. The BAS suppliers will typically pre-test their equipment off-site before installation. Clear demarcation will reduce commission time.
- Reducing construction financing cost: since commissioning time is reduced, the building can be occupied sooner, allowing the owner to start earning revenue faster and paying off loans earlier.
- Reducing equipment cost: with a preset architecture, the locations of the equipment rooms can be optimized to centralize BAS equipment and use equipment ports more efficiently.
- Reducing operational and maintenance costs over the building life cycle: CommScope's IBIS enhanced "Plug and Play" concept means last minute design changes to the fit-out areas can occur with minimum disruption and cost. Newer systems and technologies such as Ethernet/IP-based equipment can also be implemented with minimal loss of productivity and disruption, delaying functional obsolescence of the building. The move to Ethernet/IP based equipment will also reduce WAN (wide area network) connection cost by eliminating expensive leased lines for remote monitoring and maintenance, utilizing web-based controls instead. Moves, adds, and changes can be accomplished in less time with minimal disruption and cost.
- Allowing for technology growth: traditional BAS cabling may have insufficient cable pair counts to handle new BAS technologies, requiring the installation of new cabling. For example, many BAS controllers/devices operate on 1-pair cabling. If these controllers/devices are replaced with Ethernet/IP-based ones, then the cabling will have to be replaced as well. However, CommScope IBIS uses 4-pair cable to each outlet location and very few BAS will require more than 4-pair to communicate. Furthermore, Category 5e/6/6A cabling has better transmission characteristics than traditional BAS cabling and hence has the capability to support future technology advances in BAS applications, thereby increasing overall return on investment.

## BAS Design Guidelines

### Above Layer 1

Open communications systems are based on published protocols that are available to all manufacturers. For building automation, BACnet is a primary choice for open communications. BACnet was created by ASHRAE (the American Society of Heating, Refrigerating and Air-Conditioning Engineers) to provide a standard protocol that all manufacturers could use. BACnet runs at a level on par with IP and appears to be the dominating open protocol in the building automation market. There are several other manufacturers of both open and proprietary systems. To compare the advantages of each open protocol standard for a given system design, seek assistance from a building controls designer.

The operator interface may be a specific control panel, but today it is as likely to be a web browser that can be opened on any computer. The browser not only allows access through the internet, but allows the BAS system to be connected to applications that can be very useful to its operation, such as current temperatures and humidity. Future applications could include procurement of energy at the right price, or resource adjustment based on costs for a "price sensitive" building.

### General BAS Subsystems

**Figure 26: BAS Architecture**

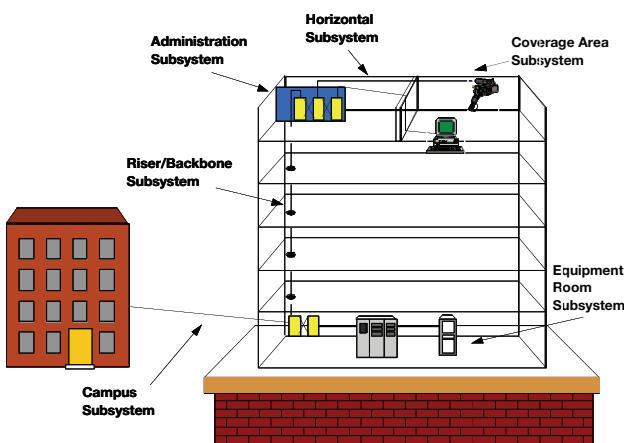
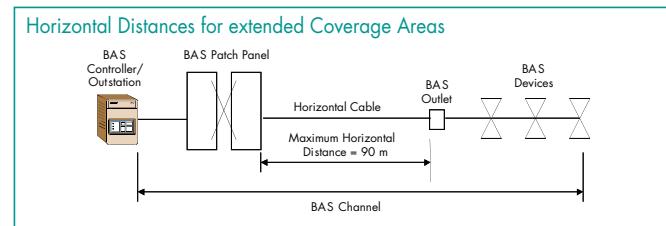
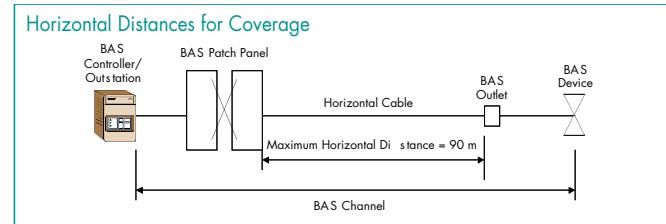


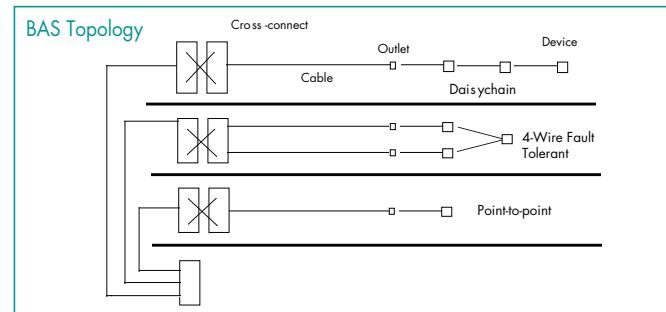
Figure 26 shows the various subsystems for supporting BAS. The architecture is similar to that used for supporting communication systems except that, for BAS applications, a coverage area is used instead of a work area. Building control devices and BAS information outlets (IOs) are typically mounted in different physical places than voice and data IOs; most of them are on walls, in the ceiling and in other building structures.

The BAS architecture, topology and these general design guidelines are in compliance with ANSI/TIA/EIA-8621. The maximum horizontal distance is 90 m (see Figure 27). A BAS channel is defined as the cabling between a BAS controller/outstation in the floor distributor (FD) or telecommunication room (TR) to the furthest BAS device in the (extended) coverage area(s). It may include both horizontal and backbone cabling. Cross-connect jumpers and patch cords in the cross-connect facilities, including horizontal cross-connects, jumpers and patch cords that connect horizontal cabling with equipment or backbone cabling, should not exceed 5 m in length. If a BAS channel includes horizontal and backbone sub-systems, then the backbone distance requirements specified in ANSI/TIA/EIA-568-C or ISO/IEC IS 11801:2002 or CENELEC EN 50173-1 (whichever is shorter) shall be met. Due to the nature of building control devices, the BAS topology permits chained circuits, T-tapped circuits and redundant path fault tolerant circuits in addition to the point-to-point star wiring circuits. This is shown in Figure 27.

**Figure 27: BAS Architectures and Topologies**



### BAS Horizontal Distances



TIA-862 defines several types of branches and connections. Detailed descriptions of these can be found in the CommScope Guide titled **General Design Guidelines For Building Automation Systems (BAS)**. This guide also provides addition detail on the following BAS planning and design topics:

- Coverage area size and outlet density
- Mechanical plant rooms and electrical rooms
- Power feeding BAS devices (circuit current capacity)
- Resistance circuits
- Voltage drop circuits
- Power support
- Current limiting devices and fusing requirements
- Sheath sharing
- Endpoint device connections
- Generic pin assignments for building control services

### BAS and IEEE 802.3af Power-over-Ethernet Standard

Many BAS field devices such as sensors, actuators, card readers and security cameras require power to function. These devices could be powered via Power-over-Ethernet (PoE), as defined in the IEEE 802.3af standard, if they are IP-based. The advantages offered by PoE are:

- No need for separate power cabling to the field devices. One can create a building that is more sustainable and “green” since fewer natural resources are being consumed.
- The ability to provide redundant power supplies and UPS (Uninterrupted Power Supply) for more critical services.

One BAS application where IP-based PoE devices are readily available is security applications such as video surveillance and access control. The traditional way of supporting analog cameras was to use coaxial cables with the cameras being powered locally. Furthermore, if analog PTZ (Pan, Tilt and Zoom) cameras are required, the telemetry signals (for controlling the PTZ) have traditionally been transported over shielded twisted pair cables, requiring a composite coaxial-twisted pair cable.

However, using CommScope IBIS, the analog cameras can either be locally or remotely powered depending on the types of cameras and the powering requirements. This arrangement can simplify the cable and containment requirements, as well as eliminate ground loop noise on the cabling. CommScope IBIS also provides for easy migration to digital video surveillance technologies.

## BAS Applications

### *Security Surveillance and Access Control Systems*

Security functions in a Building Automation System cover a wide range of applications. Some functions operate independently; others are usually integrated with those of other systems. For example, in case of a fire, all doors must be unlocked automatically once a fire is detected. Table 11 provides a list of security system functions and typical devices:

TABLE 11: TYPICAL DEVICES CONNECTED TO A SECURITY SYSTEM

Function	Device Types	Location
Surveillance	CCTV	Parking areas, exits, entrances, restricted areas, ceiling or hidden areas
	Guard tour stations	Mounted to monitor guard during guard tour
Detection	Metallic or magnetic contact closures (digital input devices)	Doors and window openings, and mounted on equipment to activate signal tampering.
	Motion/PIR, sound, vibration, and glass breaking detectors	Door, window, floor or ceiling areas as required.
Alarms	Manual switches for initiating alarms (e.g. panic buttons, etc.)	Secure areas such as bank teller positions, payroll offices, etc.
	Audio and visual alarm indicators (e.g. siren, lights, speakers, computer console, etc.)	Visual indicators in hidden areas such as behind counter. Audio devices in ceiling, security center, etc. Computer console may be located in security center.
Access control	Card access with magnetic strip, barcode, proximity or smart card	Secure areas and outside entrances
	Keypad and signature pad access	Secure areas and outside entrances
	Biometric verification (e.g. fingerprint reader, retinal/iris scanner, etc.)	Secure areas and outside entrances
Elevator control	Elevator control relay	Usually mounted at top of elevator shaft. Control from security center
Clock control	Master clock control relay	Mounted on wall, near ceiling, or as required
	Time and attendance system	Near exits
Communication and information management	Telephone, intercom, modem	Communications facilities are usually in the security center. Telephones and intercom units are mounted at strategic locations.

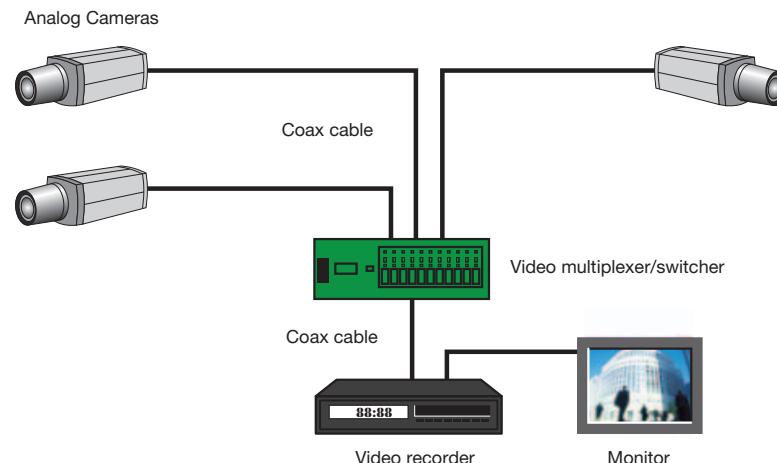
### CCTV Overview

The surveillance function, one of the main applications for security, makes heavy use of CCTV. The CCTV components are connected directly, as opposed to broadcast television, where any correctly tuned receiver can pick up the signal from the airwaves.

The starting point for any CCTV system is the camera, either analog or digital. The CCTV cameras can be divided into two main categories: analog and digital versions. The camera converts light into electrical signal that is then processed by the camera electronics and converted to a video signal output. This output is either recorded or displayed on a monitor, normally using a dedicated communications link between cameras and monitors. Remote monitoring and recording may also be required along with access to PTZ (Pan, Tilt and Zoom) capabilities for a better look at what may be happening at remote sites (see Figure 28).

Some CCTV installations will also provide an audio message, via a loudspeaker, when an intruder sets off a detection sensor. Research has shown that although people will only obey a written notice to leave in 7% of cases, they will obey an audible command 92% of the time.

**Figure 28: Traditional Analog CCTV System**

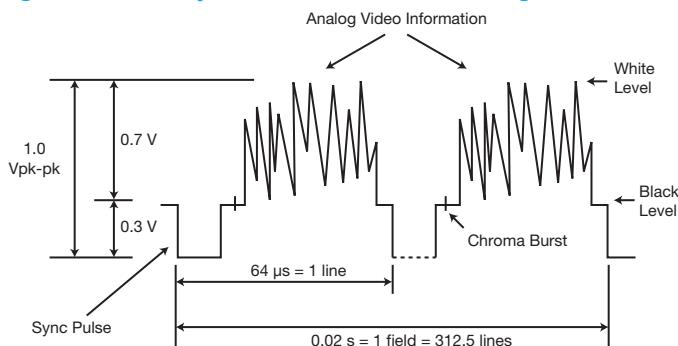


Proper grounding of video equipment is important. Visible interference such as "hum bars" (rolling horizontal lines travelling from the top to the bottom of a monitor) are due to noise currents on the shield of a video connector. This interference is a common concern with baseband video transmission since the frequency spectrum of the noise often lies within the bandwidth of the video signal. An example would be 50/60 Hz noise due to ground potential differences between power receptacles or between the shield of the video connector and the case of the video equipment. This type of interference can occur with coaxial as well as balanced cabling.

### CCTV Video Signal

Figure 29 shows a typical CCTV analog video signal. This is commonly known as the composite baseband video signal because the synchronising and video information are combined into a single signal without a modulated radio frequency carrier. Maximum light will produce a maximum voltage and therefore a white level. No light will produce no voltage and therefore a black level. In between these will be shades of grey, and this is the luminance information of a video signal. In the case of a color camera, the chrominance and color burst signals are superimposed onto the luminance signal to carry the color information.

**Figure 29: Composite Baseband Video Signal**



The total voltage produced is 1 volt peak-to-peak (Vpk-pk), from the bottom of the sync pulse to the top of the white level. The luminance portion of the signal is from 0.3 volt to 1 volt (0.7 volt maximum). The bandwidth required to transmit this signal ranges from DC to 8 MHz for the three main video standards: NTSC (National Television System Committee), developed in the U.S.; PAL (Phase Alternate Line), developed in Europe; and SECAM (Sequential Colour and Memory), developed in France.

**TABLE 12: MAIN TV VIDEO STANDARDS**

Format	Where used	Scanning lines (lines/frame)	Frame rate (fields/sec)	Channel bandwidth (MHz)
NTSC	North/South/Central America, Japan, Korea, Taiwan, Philippines	525	50 or 60	6
PAL	Europe (most), Asia (most), Africa	625	50	7 (< 300 MHz) 8 (> 300 MHz)
SECAM	France, Bulgaria, Czech Republic, Hungary	625	50	8

#### CCTV PTZ Signal

In addition to providing composite baseband video, some CCTV cameras require baseband digital telemetry signal in order to control PTZ functions. Control data signaling formats include EIA-RS422, EIA-RS232, 20 mA current loop or Manchester. These PTZ signals have traditionally been sent on shielded twisted pair cables separate from the video signal, which is transported over coaxial cable.

Some CCTV camera manufacturers superimpose the PTZ control signaling within the vertical blanking interval, i.e. lines 1 to 21 of a 525-lines/frame picture so that the combined video and PTZ signal can be transported over one coaxial cable. Examples of such equipment include

- Panasonic System 200 WV-CU254 controller with WV-CS304 unitized camera
- PELCO CM6700-MXB video matrix switcher/controller with SD5 SpectraDome camera
- PELCO CM9760-MXB video matrix switcher with CM-9760-CXT coaxitron translator and SD5 SpectraDome camera

#### Analog CCTV System (Traditional Approach)

An analog system using a VCR (video cassette recorder) represents a fully analog system, consisting of analog cameras with coax output, connected to the VCR for recording. The VCR uses the same type of cassette as a home VCR and uncompressed video. In larger systems, a multiplexer/switcher can be connected in between the camera and the VCR. The multiplexer makes it possible to record several cameras to one VCR, but at the cost of a lower frame rate. To monitor the video, an analog monitor is used.

An analog system can also use a DVR (digital video recorder) for the video recording. In a DVR, the videotape is replaced with hard drives, which requires the video to be digitized and compressed in order to store as many days' worth of video as possible. An analog DVR system offers the following advantages over a traditional analog system:

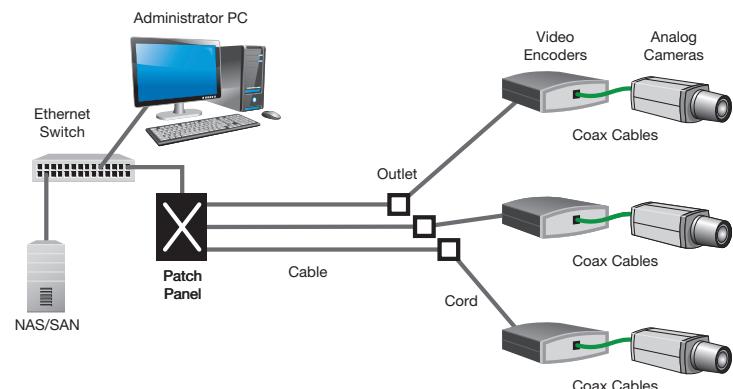
- No need to change tapes
- Consistent image quality

#### **Hybrid CCTV System (IP-Enabled Approach)**

In a hybrid CCTV system (see Figure 30), the analog cameras are connected to an IP network using video encoders (sometimes referred to as video servers). A video encoder digitizes and compresses the video. The encoder then connects to an IP network and transports the video via a network Ethernet switch to a PC with video management software, a NAS (Network Attached Storage) device or a SAN (Storage Area Network) where it is stored digitally. A hybrid system offers the following advantages:

- Use of IP network and PC server hardware for video recording and management
- A scalable system, in steps of one camera at a time
- Off-site recording
- Easy expansion by incorporating network cameras or upgrading to a true IP system

**Figure 30: Hybrid CCTV System**



#### **Digital CCTV System (True IP Approach)**

With the advent of IP or Network cameras, the method of installing CCTV system changes dramatically. These IP cameras are plug-and-play devices and are easy to integrate into corporate LANs or WANs (see Figure 31).

An IP camera compresses the video and sends it over the LAN to a PC with video management software, a NAS device or a SAN. An IP camera is always streaming video across the network, and therefore, is always using bandwidth. Hence a separate or segmented LAN is recommended to avoid bottleneck issues on the main corporate network. However, some IP cameras now incorporate both storage and DVR functions and this helps to limit some of the bandwidth impact. The connection to the LAN is via 10/100/1000 Mbps Ethernet. In addition, many of these IP cameras are IEEE 802.3af compliant, meaning they are PoE enabled. By connecting them to PoE switches, additional saving can be obtained by eliminating the need for main electrical sockets and main cabling.

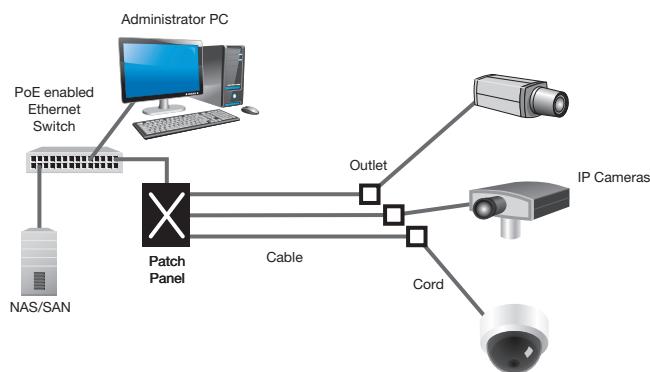
Pictures from an IP camera can be viewed and the PTZ movement (if so equipped) can be controlled using a PC with video management software. Additional features include built-in activity detection function that triggers an alarm or switch. For example, when the camera senses movement, it could turn on an alarm or lamp, or send a signal to lock a door. In addition, the captured image at the time the alarm was triggered can be sent to an email address or FTP server.

There are many different compression methods that an IP camera can utilize. These include JPEG (Joint Photographic Expert Group), MJPEG (Motion JPEG), H.263, MPEG (Motion Picture Expert Group), Fractal and Wavelet. The main difference between these are their bandwidth consumption.

A digital CCTV system using IP cameras offers the following additional advantages:

- High resolution cameras
- Consistent image quality
- Power-over-Ethernet and wireless functionality
- Pan/tilt/zoom, audio, digital inputs and outputs over IP along with video
- Full flexibility and scalability

**Figure 31: Digital CCTV Systems**



#### **Access Control Applications**

The access control function is one of the other main security applications. Access control can be used to:

- deny access to restricted areas to unauthorized persons
- improve employee productivity by preventing unrestricted traffic to different areas of a building
- monitor entrances and exits
- recall access information at a later date

The security industry utilizes a vast array of card and reader technologies, ranging from the very basic (barcode) to the most sophisticated (biometric). Most access control applications can be integrated with CCTV surveillance systems, paging systems, energy management systems and fire-life-safety systems.

A typical access control system consists of a controller (sometimes referred to as the control panel) connected to several card or biometric readers, keypads or signature pads, badge printer, a motion/PIR (passive infrared) detection system, optional guard tour readers and an optional photo identification system (see Figure 32).

Card types include:

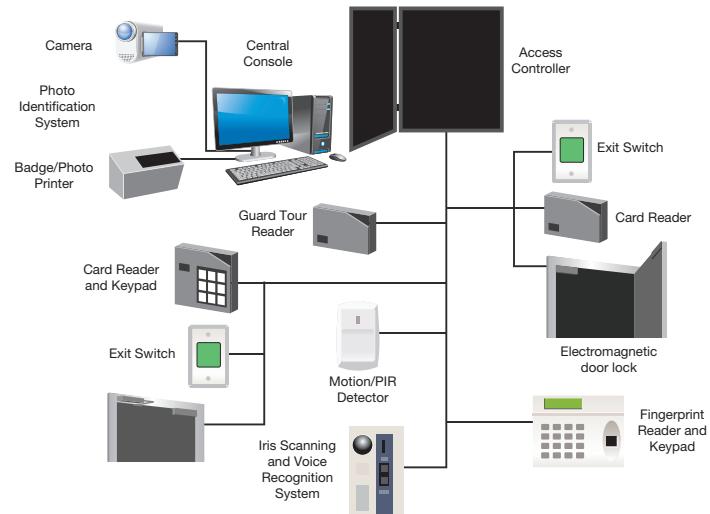
- Traditional proximity cards using 125 kHz frequency
- Wiegand cards, which use a code strip containing specially treated vicalloy wires
- Smart cards, using 13.56 MHz contactless technology with read/write capabilities. Some cards are compliant to either ISO 14443 (proximity card - e.g. MIFARE developed by Philips) or ISO/IEC 15693 (vicinity card)

Biometrics are automated methods of recognizing a person based on physiological or behavioral characteristics. Features measured include face, fingerprints, handwriting, iris, retina and voice. Biometric measurement is highly secure and considerably more accurate than methods such as passwords or PINs. Since biometric scans link an event to a particular individual, they overcome the insecurity of a password or token being used by someone other than the authorized user.

Biometric access is convenient because there is nothing to carry or remember and it provides positive identification with an available audit trail. These security methods are becoming increasingly socially acceptable and affordable.

An Access Control system can sound alarms when abnormal events trigger the system. It is also capable of recording all of the personnel In/Out transactions for reference or for monitoring purposes. Other features include door prop monitoring with digitally recorded voice messages, infrared sensor beams to detect tailgating, guard tour tools to help manage the security guards by defining the sequence and timing of tour points, RFID key tags, and multiple door mantraps/security interlocks.

**Figure 32: Typical Access Control System**



Most of the traditional Access Control systems utilize RS-232, RS-422, RS-485 or Wiegand signalling between the controller and the card readers. The distances supported will depend on the vendor's equipment. The Wiegand signalling is a 3-to 6-wire interface that provides 26- or 34-bit code format.

However, newer IP-based Access Control systems are starting to enter the market.

The communication protocol between the controller and the central console server is usually 10/100/1000 Mbps Ethernet but MS/TP (master-slave token passing) protocol may be used by some existing legacy systems. Most Access Control systems also provide remote monitoring capabilities using modems and are usually linked to police control centers. In some countries, installers of these remote systems may require accreditation from certain national associations.

A typical security door will require the following connectivity:

- Connection from controller to a card reader (some card readers may require more than 4-pair connectivity)
- Connection from the controller to the door lock
  - Door strike (usually solenoid operated) for electric strike locks
  - Door electromagnet for electromagnetic door locks
- Connection from the controller to the exit push or request-to-exit (RTE) button
- Optional connection from the controller to (break glass) emergency door release button

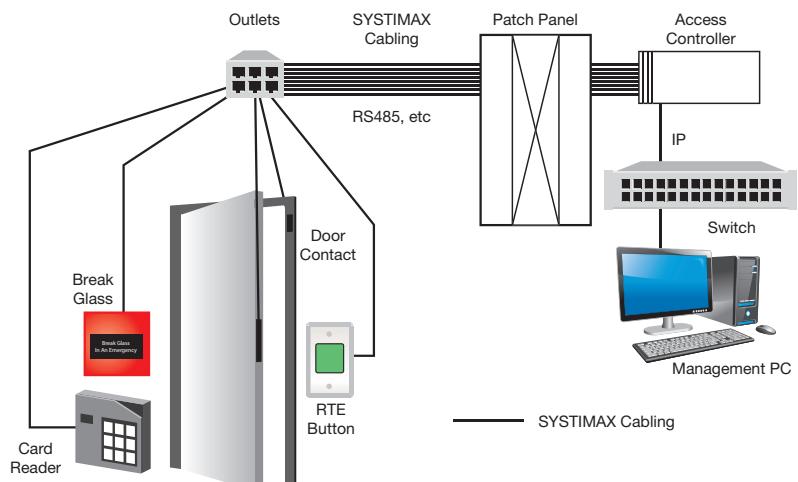
#### **Non-IP Access Control Application over CommScope IBIS**

Figures 33 and Figure 34 show how an access control application can be configured with cabling. A minimum of 4 outlets are required for connecting a security door to the controller if all the signals are to be connected via cabling with the access controller located in the wiring closet. This is shown as Option 1 in Figure 33. If the access controller is located on the floor, then Option 2 in Figure 34 can be used. A typical configuration will have several card readers connected in a multipoint bus topology to a controller. There should be no more than 5 BAS devices in a multipoint bus for each branch as per ANSI/TIA-862 requirements.

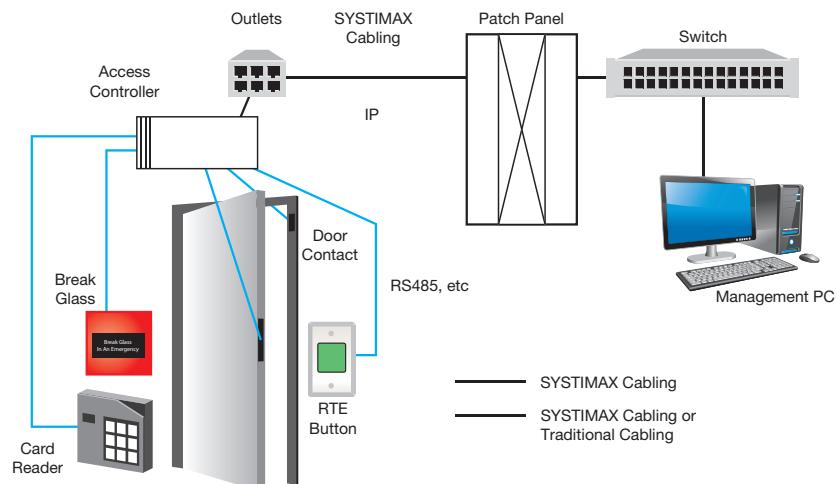
The mapping of access control signals to the 8-pin modular jack pinouts is important in order to ensure consistency and ease of problem troubleshooting/resolution. CommScope IBIS recommends the use of ANSI/TIA-568B T568B pin assignment. The allocation of access control signals to the 8-pin modular jack pinouts is shown in Table 13. It should be noted that some vendor equipment might require additional signaling, such as compensation signals. These signals should therefore be assigned to the appropriate unused pairs/pins.

The distances supported will depend on the vendor equipment. Please refer to CommScope IBIS test configuration template and building control devices templates and guidelines for guidance.

**Figure 33: Access Control Option 1**



**Figure 34: Access Control Option 2**



**TABLE 13: ACCESS CONTROL APPLICATIONS AND ACTIVE PAIR**

Pair	1	2	3	4
Wire	W-BL	BL	W-O	O
Pin	5	4	1	2
Data 0 (Clock)	X			
Data 1 (Card Information)		X		
LED			X	
+ Power				X
GND (Ground)				X
Door Strike Power				X
Door Strike Common				X

For additional design guidelines, please refer to the latest issues of following documents:

- **COMMSCOPE IBIS GENERAL DESIGN GUIDELINES**
- **COMMSCOPE IBIS TEST CONFIGURATION TEMPLATE AND BUILDING CONTROL DEVICES TEMPLATES AND GUIDELINES**

#### ***Energy Saving Control Strategies with BAS***

One of the benefits of a BAS solution is the ability to control your energy costs without affecting the operation of your building, limiting the use of energy when it is not needed. A properly configured BAS system will enable energy savings through:

**Scheduling:** Turning equipment off or on, depending on a key variable, such as time of day, day of week, outside temperature, etc.

**Lockouts:** Prevent equipment from turning on during certain calendar dates. Locking out a chiller during winter months would prevent it from turning on inadvertently.

**Resets:** Keeping the operating equipment parameters matched to the current conditions within the building. Raising the temperature (limiting the HVAC system efforts) of the chilled water when the outside temperature is low is an example of a reset. Other parameters that can be reset include the temperatures for supply-air and discharge-air, hot-deck and cold-deck and the heating-water supply.

**Direct Digital Control (DDC):** The sensors and controllers that control valves, operate compressed air and other system components. DDC systems with advanced control algorithms can reliably maintain the set temperature.

**Demand Limiting:** Setting limits on the amount of load (energy) that a piece of equipment or system can utilize at one time. The strategy here is to both limit overall consumption and encourage energy usage to be spread out into lower cost time periods. For example staging the heat to start with colder sections of building first and delay the heat to naturally warmer sections can limit and stagger electricity usage without impacting operations.

**Diagnostics:** Monitoring equipment operation – temperature, airflow, positions, speed – to determine efficiency. Monitoring diagnostics provides the data to maintain and/or upgrade equipment when and only when needed.

#### ***Other BAS Applications***

Other important BAS applications, including FLS, HVAC and lighting controls, tend to be more vendor specific. CommScope can provide application documents for a variety of vendor specific applications.

# 11. Power In The Data Center

When designing a new Data Center, it is necessary to calculate the complete power requirements to be certain there will be enough energy to power all the equipment, cooling and lighting. It is also important to plan for future growth in the calculations.

A rough rule of thumb for budgeting power is that a Data Center will devote half of the energy requirements to power IT equipment and the other half to support the infrastructure. For every watt that goes to power the equipment, another watt goes to support systems such as cooling and lighting, as well as to losses in power distribution and UPS inefficiencies.

## ***Watts per Square Foot***

Designers first used watts per square foot as an architectural term to calculate the power consumption, assuming uniform cooling. A Data Center could average 150 watts per square foot ( $\text{W}/\text{ft}^2$ ) of power consumption, but only be able to support 2 kW per rack because of how the cooling system was designed. This is equivalent to cooling only 60  $\text{W}/\text{ft}^2$ , therefore wasting energy.

## ***Watts per Cabinet***

A much more accurate metric that provides more realistic power requirements is watts per rack (or cabinet). This computation identifies the heat load in the space and is not dependent on the room shape, square footage or equipment. It gives the ability to control cooling at the micro level, decreasing costs and increasing efficiencies. An industry average is 4-5 kW per rack. However, requirements can vary from 1 to more than 30 kW per rack.

The measurement of kW per cabinet is simply the sum of the power used by all servers and any other active electronic gear in a cabinet (such as LAN or SAN switches), expressed in Watts. However determining that power usage can be complicated.

Most server and switch manufacturers publish a "sticker" power level that usually is not indicative of true running conditions; the published numbers are actually typically higher than actual usage, reflecting a worst-case scenario. Installed options on a server can cause power levels to vary by a large amount, depending on the amount of configured memory and attached storage, for example. When attempting to compute the power consumption of a server, a good guideline to use is to "de-rate" the stated power consumption by multiplying by 0.6 or 0.7.

Here's a power calculation example:

- 5 MW of power allows 2.5 MW to be used for IT equipment including servers, storage and networking
- Goal: support a current use of 4 kW per rack with headroom to move to 8 kW per rack
- Result: 312 racks can be supported by this hypothetical amount of power ( $312 \times 8 = 2496 \text{ kW}$ , or 2.5 MW)

## ***Planning for Cooling***

A modular, flexible data center must be able to handle equipment and racks with physically different power and cooling configurations. Some equipment is built with front-to-back cooling so that data centers can be configured with alternating hot and cold aisles. Some use a 'chimney' cooling model, where cold air is brought up from the floor, through the cabinet and exhausted at the top. A data center's cooling strategy must be able to accommodate the different types of equipment that will be required by the business.

## ***Blade Servers and Power Requirements***

Blade servers are designed to maximize computing power density and can condense the amount of space required by 50% by sharing (or eliminating) redundant components between server blades. A significant benefit of this component sharing is that power requirements are reduced by 35% or more (IBM 2007). As a result, overall power requirements – watts per square footage – for a data center utilizing blade servers are reduced.

However, as noted above, required watts per cabinet is as important as average wattage per square foot. Server density may be limited by ability to provide enough power to the cabinet, as well as available space to house the server blades.

## **Power Standards in the Data Center**

Following are the various standards bodies that have issued standards, codes or guidelines that affect power in the Data Center, as well as relevant codes or standards numbers. Contact each organization for more specific detail.

### **TIA – Telecommunication Industry Association**

- TIA-942 the Data Center Standard

### **IEEE – Institute of Electric and Electronic Engineers**

- IEEE SCC-22: Power Quality Standards Coordinating Committee
- IEEE 1159: Monitoring Electric Power Quality
  - IEEE 1159.1: Guide For Recorder and Data Acquisition Requirements
  - IEEE 1159.2: Power Quality Event Characterization
  - IEEE 1159.3: Data File Format for Power Quality Data Interchange
- IEEE P1564: Voltage Sag Indices
- IEEE 1346: Power System Compatibility with Process Equipment
- IEEE P1100: Power and Grounding Electronic Equipment (Emerald Book)
- IEEE 1433: Power Quality Definitions
- IEEE P1453: Voltage Flicker
- IEEE 519: Harmonic Control in Electrical Power Systems
- IEEE P446: Emergency and Standby Power
- IEEE P1409: Distribution Custom Power
- IEEE P1547: Distributed Resources and Electric Power Systems Interconnection

### **IEC – International Electrotechnical Commission**

- IEC 61000-4-11 - Voltage Sag Immunity - 16 amps or less
- IEC 61000-4-34 - Voltage Sag Immunity - more than 16 amps
- IEC 61000-4-30 - Power Quality Measurement Methods
- General IEC power quality standards
  - 61000-1-X - Definitions and Methodology
  - 61000-2-X - Environment (e.g. 61000-2-4 is Compatibility Levels in Industrial Plants)
  - 61000-3-X - Limits (e.g. 61000-3-4 is limits on Harmonics Emissions)
  - 61000-4-X - Tests and Measurements (e.g. 61000-4-30 is Power Quality Measurements)
  - 61000-5-X - Installation and Mitigation
  - 61000-6-X - Generic Immunity & Emissions Standards
- IEC SC77A: Low frequency EMC Phenomena – Essentially Equivalent of "Power Quality" in American Terminology
  - TC 77/WG 1: Terminology (Part of the Parent Technical Committee)
  - SC 77A/WG 1: Harmonics and other Low-Frequency Disturbances
  - SC 77A/WG 6: Low Frequency Immunity Tests
  - SC 77A/WG 2: Voltage Fluctuations and other Low-Frequency Disturbances
  - SC 77A/WG 8: Electromagnetic Interference Related to the Network Frequency
  - SC 77A/WG 9: Power Quality Measurement Methods
  - SC 77A/PT 61000-3-1: Electromagnetic Compatibility (EMC) - Part 3-1: Limits - Overview of Emission Standards and Guides. Technical Report

### **Industry-specific power quality standards**

- SEMI F42 – Voltage Sag Standards
- SEMI F47 – Voltage Sag Standards
- SEMI E6

#### ***U.S. military power quality standards***

- MIL-STD-1399  
"Interface Standard for Shipboard Systems" covers the design and testing of electric power systems and user equipment. It applies only to shipboard power.
- MIL-STD-704E  
"Interface Standard: Aircraft Electric Power Characteristics" specifications for aircraft power quality, including DC, single-phase, and three-phase systems. It provides specifications on sags, interruptions, impulses, unbalance, and harmonics.
- MIL-E-917E(NAVY)  
"Electric Power Equipment: Basic Requirements"
- MIL-PRF-28800F(SH)  
"Test Equipment for use with Electrical and Electronic Equipment" discusses all aspects of test equipment for this purpose: safety, calibration, accuracy, etc.
- MIL-M-24116B(SH)  
"Monitors, Voltage and Frequency, 400 Hz Electric Power" covers trip levels and durations of voltage and frequency monitors. It applies only to shipboard installations.

#### ***Other power quality standards***

- UIE: International Union for Electricity Applications
- CENELEC: European Committee for Electrotechnical Standardization
- UNIPEDE: International Union of Producers and Distributors of Electrical Energy
- ANSI: American National Standards Institute
- ANSI C62: Guides and standards on surge protection
- ANSI C84.1: Voltage ratings for equipment and power systems
- ANSI C57.110: Transformer derating for supplying non-linear loads
- CIGRE: International Council on Large Electric Systems
- CIRED: International Conference on Electricity Distribution
- CBEMA / ITIC curve

#### **Power Distribution Units**

A power distribution unit (PDU) is a device that steps down the data center voltage to a value used by the end equipment (servers, switches, storage, etc.), normally 110VAC or 208VAC, depending on the region. Typically in US Data Centers, the PDU input is 480VAC, with an output of 208VAC three-phase power. Different voltages are used globally, and some large data centers will have much higher voltage supplies than the 480VAC level, requiring equipment to bring the voltage to 480VAC.



**Figure 35: Example of Power Distribution Units:**

PDU types include:

- a simple outlet strip
- total power monitored
- phase power monitored
- individual outlet power monitored
- remote individually port switched

The monitored varieties are either local monitored only, or both local and remotely monitored. As features increase, so will the purchase price. The big power manufacturers refer to the panel in the service cabinet as an equipment PDU, or ePDU.

There's a large PDU category that have heavy transformers and control and monitoring electronics located inside a large box, approximately the size of a CRAC or CRAH unit. It is becoming more common for these to be located outside of the data center white space and connected with permanent cables to a remote power panel (RPP). The RPP is typically a 2'x2'x5' cabinet containing individual breakers that feed the power cables to each equipment cabinet.

#### **Basic PDUs**

Basic PDUs are essentially power strips that are constructed out of high-quality components for use in critical environments. They generally support distributing correct voltage and current to several outlets.

- **Pros:** Basic, affordable, proven technology.
- **Cons:** Lack instrumentation and are not manageable on any level.

#### **Metered PDUs**

Metered rack devices meter the power at the PDU level, e.g., RMS volts, current, etc. and display it locally. Typically, the meter displays information for the entire PDU. More sophisticated models have user-defined alarming capabilities and the ability to remotely understand PDU-level metering data over a serial or network port.

- **Pros:** Provide real-time remote monitoring of connected loads. User-defined alarms alert IT staff of potential circuit overloads before they occur.
- **Cons:** Most only provide information locally. They also don't offer outlet-level switching or critical environmental data.

#### **Switched PDUs**

Switched PDUs provide controlled on/off switching of individual outlets and load metering (see metered PDUs above) at the PDU level. They allow users to power cycle devices remotely, apply delay for power sequencing and provide some outlet use management.

- **Pros:** Remote power on/off capabilities, outlet level switching and sequential power-up.
- **Cons:** Lack temperature and humidity monitoring. The information provided and functions supported are limited.

#### **Intelligent PDUs**

An intelligent rack PDU can be controlled remotely via a Web browser or command line interface (CLI). It meters power at both the PDU level and the individual outlet level; supports alerts based on user-defined thresholds; provides security in the form of passwords, authentication, authorization and encryption; and incorporates rich environmental management capabilities. Models are usually highly customizable and integrate seamlessly within existing corporate infrastructures.

- **Pros:** Remotely accessible via Web browser or CLI. Models include all the features of switched PDUs, plus offer real-time environmental data, standards-based management, integration with existing directory servers, enhanced security and rich customization.
- **Cons:** Higher cost relative to basic and metered PDUs due to their greatly enhanced feature set.

**Vertical Power Distribution Strip**



**Vertical PDU Mounting Bracket**



**Horizontal Power Distribution Unit**

## Data Center Electrical Efficiency

For both cost and environmental reasons, it is important that IT professionals have the right tools to monitor the energy efficiency of their Data Centers. The Green Grid, an industry group focused on Data Center energy efficiency, has proposed two methods to measure efficiency:

- Data Center infrastructure Efficiency (DCiE)
- Power Utilization Effectiveness (PUE), also known as Site Infrastructure Power Overhead Multiplier (SI-POM)

### *DCiE - Data Center infrastructure Efficiency*

DCiE is the only metric that is compliant with the August 2007 U.S. Environmental Protection Agency report to Congress on Data Center efficiency. DCiE is determined by dividing IT equipment power by total Data Center input power, to arrive at a percentage of efficiency.

IT Equipment Power

$$DCiE = \frac{\text{IT Equipment Power}}{\text{Total DC Input Power}} \times 100$$

Total DC Input Power

75% DCiE means 25% of energy wasted; the ideal DCiE value is 100%.

### *PUE - Power Utilization Effectiveness*

PUE (or SI-POM) is determined by dividing the total Data Center input power by the IT equipment power.

Total DC Input Power

$$PUE = \frac{\text{Total DC Input Power}}{\text{IT Equipment Power}}$$

IT Equipment Power

The output is the opposite of DCiE. A PUE of 1.5 indicates 50% more power than the IT equipment requires. An ideal PUE value is 1.

Both results are plotted on a grid and given an efficiency rating.

TABLE 14: EFFICIENCY RATINGS

PUE	DCiE	Level of Efficiency
3.0	33%	Very Inefficient
2.5	40%	Inefficient
2.0	50%	Average
1.5	67%	Efficient
1.2	83%	Very Efficient

Source: Green Grid

#### *DCiE Example:*

A facility uses 100,000 kW of total power.  
90,000 kW is used to power the IT equipment.  
The DCiE is 90%, or "Very Efficient."

#### *PUE Example:*

A facility uses 100,000 kW of total power.  
80,000 kW is used to power the IT equipment.  
The PUE is 1.25, which is nearly in the "Very Efficient" category.

#### **Efficiency Benefits:**

If a Data Center uses all 5 MW of power it has available, at 8 cents per kWh, this Data Center will use \$3.5 million worth of power over 1 year.

If, however, the same Data Center is designed to a PUE of 1.6, the power draw becomes only 4MW. The 20% efficiency gain will result in over \$700,000 in savings a year.

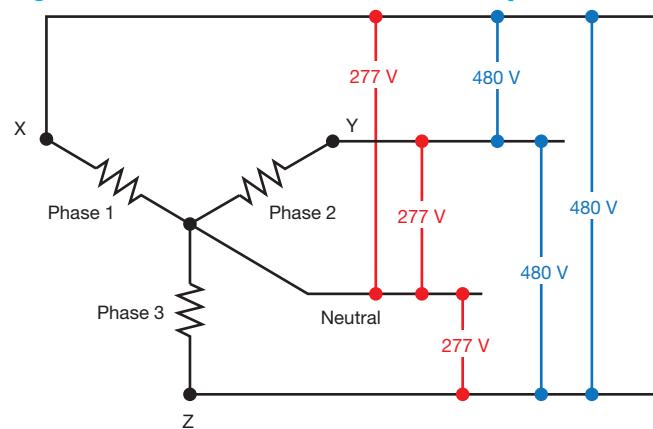
From another perspective, reducing your PUE gives your organization more freedom to grow without incurring the immense expense of upgrading the mechanical and electrical infrastructure.

#### **Power Conversion Efficiency**

The power path from the building entrance to the Data Center loads contains several power converters and transformers for each conversion. Each conversion and transformation can cause inefficiencies and power losses; reducing the number of transformers and operating at a higher voltage will improve efficiency and reduce electrical costs.

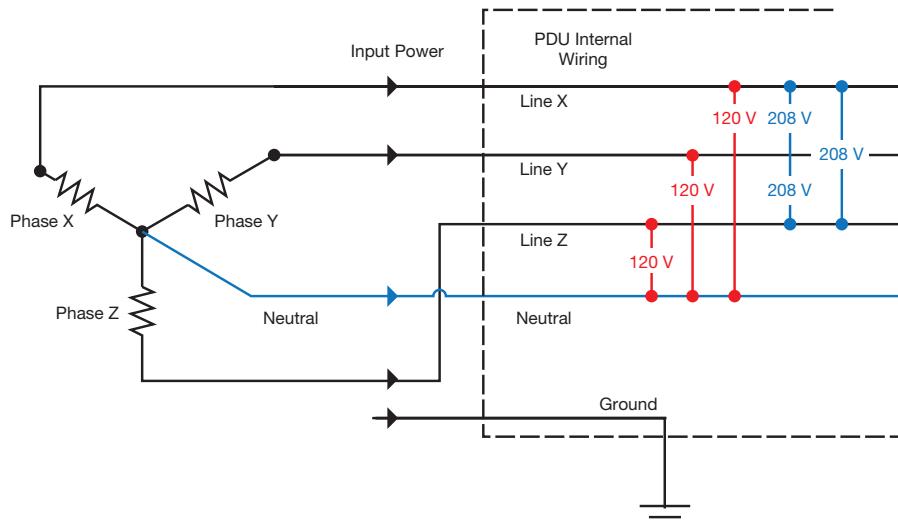
In North America power is delivered to commercial building via 277/480 VAC 3-phase Line to neutral = 277, and line to line = 480VAC (see diagram below).

**Figure 36: North America Power Delivery via 277/480 VAC 3-Phase Line**



Most IT equipment operates at 100 to 240VAC; therefore, an isolated step-down transformer must be used to reduce the power. This is normally achieved by routing the power through a PDU transformer, where it is stepped down from 480VAC 3-phase to 208VAC 3-phase.

**Figure 37: Step Down Process**



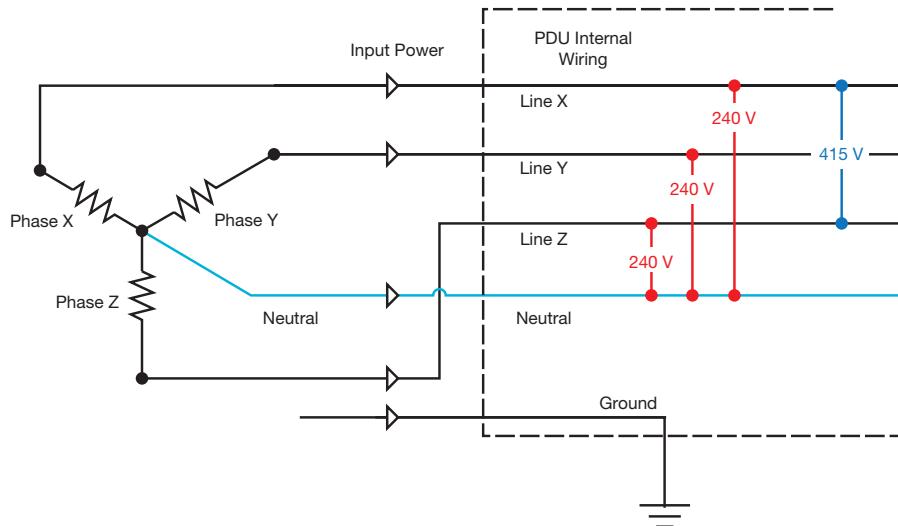
From the primary PDU, power is typically distributed in three ways by remote power panels (RPP) or cabinet-level power distribution units (CDU):

- 120VAC single-phase (measured line-to-neutral)
- 208VAC single-phase (measured line-to-line)
- 208VAC 3-phase (in a Delta or Wye configuration).

Most IT devices have automatic switching power supplies that will accept both low-line voltages, 100-120VAC; and high-line voltages, 200-240 VAC. Running devices at the higher voltages (240VAC) will increase efficiencies approximately 2 to 3.5 percent.

415VAC 3-phase can be achieved by reducing the number of power transformers and converting the UPS output from 277/480VAC to 240/415VAC. This is done by replacing the PDU transformer with an auto-transformer. This will double the power capacity, increase efficiency and reduce cost.

**Figure 38: UPS Power Conversion**



For additional discussions in far more depth about ways to measure, monitor and increase efficiencies in the Data Center, consult the papers published by The Green Grid, The Uptime Institute, PG&E, Lawrence Berkeley Laboratories and others on this topic.

# 12. Cooling The Data Center

Cooling, next to power, is one of the most important areas of concern in Data Center design. Providing cooling for the computer room is one of the highest costs of running a Data Center while delivering adequate cooling to exactly where it's needed can be a major challenge for Data Center managers.

Data suggests that the typical Data Center uses only 30% of available cooling effectively. In other words, three times more cooling is provided than is truly necessary; the cool air is not being delivered efficiently to the electronics that need it.

It is important when planning cooling capacity to allow for expansion. A 2007 report by the EPA showed that over 1,000,000 servers are added annually to data centers. This results in a 14% annual growth rate in energy consumption, requiring additional cooling. Also keep in mind that the power consumed by each server has also increased as more processors are included. A general rule of thumb when planning cooling capacity is to allow one watt of power for cooling for every watt of power used (or planned to be used) by IT equipment.

## Cooling methods

The traditional method of providing cooling in the computer room is with Computer Room Air Conditioners (CRACs) located along the computer room perimeter. These units also may be called Computer Room Air Handlers (CRAHs). A dedicated chilled water plant provides the cooling energy for the CRAC units.

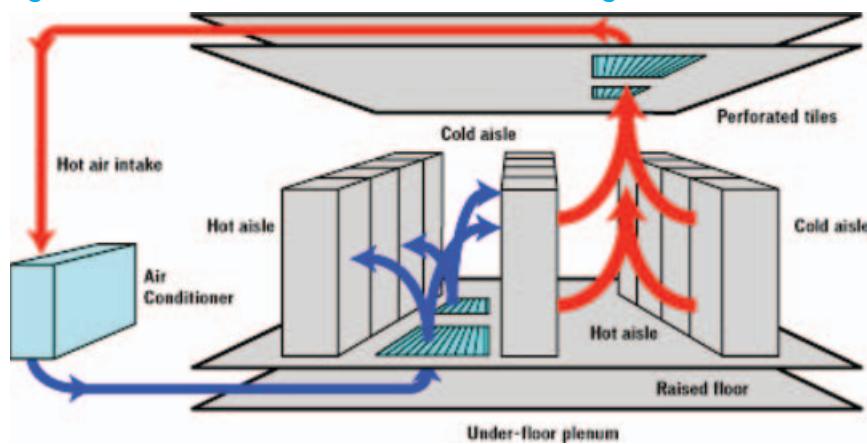
Portable spot cooling units to supplement the CRACs are used when necessary to cool particularly hot areas.

Usually the computer room is on a raised floor (access flooring) and the space beneath the floor is used as a positive pressure air supply plenum. The CRACs supply air to the underfloor space and perforated floor tiles are used in front of equipment cabinets to allow cool air to flow up through the floor and into the fronts of the equipment cabinets. The cooling fans inside the switches and servers mounted inside the equipment cabinets draw the cool air through the cabinet and exhausts it out the rear of the cabinet.

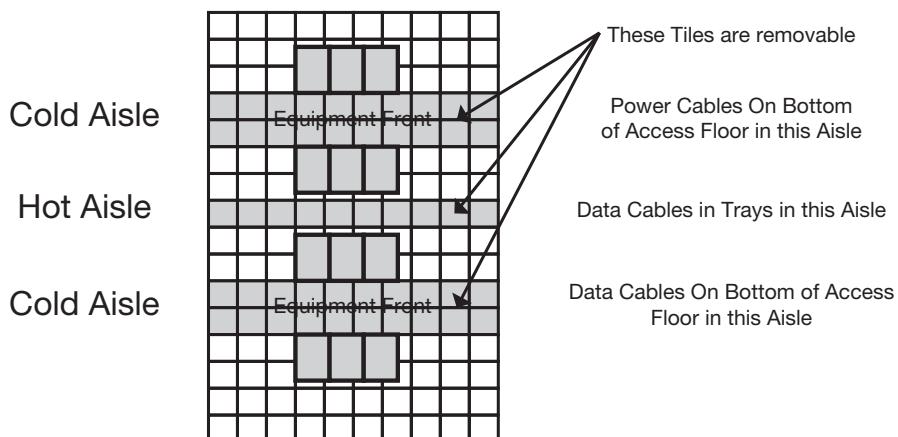
Rows of cabinets and racks are then arranged in an alternating pattern, with fronts of the cabinets/racks facing each other to create "hot" and "cold" aisles. The hot exhaust air that exits the rear of the cabinets rises to the ceiling where it is drawn into the CRAC for cooling and recirculation.

Power distribution cables are run along the cold aisle in the space below the access floor. They may be placed on the slab under the removable tiles between the two rows of cabinets/racks. Telecommunications cabling is run in the hot aisle, supported in raceway or cable tray. It is not advisable to place these telecommunication cables directly on the slab.

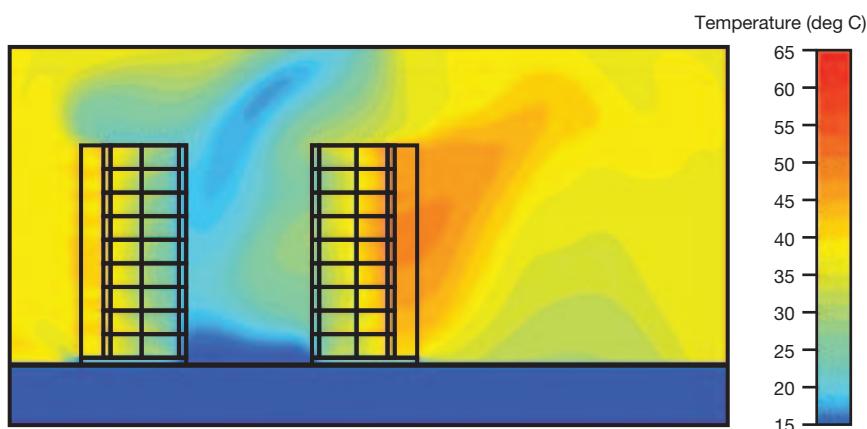
**Figure 39: Hot Aisle / Cold Aisle Cabinet Arrangement**



**Figure 40: Location of Power and Data Cabling to Facilitate Cooling**



**Figure 41: Thermogram Showing Cold Aisle / Hot Aisle Temperature Striations**



Perforated floor tiles are only used in the cold aisle, directly in front of cabinets/racks that contain active equipment. Perforated tiles should not be used within 5m (15 feet) of CRACs in order to prevent air recirculation, in hot aisles or where there is no active equipment installed.

There are many variations on this theme where channeling devices are used above and below the access floor to improve control of the cool air and hot air.

The use of variable speed fans in the CRAC units and variable speed pumps in the chilled water system can take advantage of less energy usage for off-peak loads and more precisely match the cooling supply with the load.

#### Applicable Temperature/Moisture Standards

Many of the standards bodies have issued guidelines that apply to cooling the Data Center.

**TIA-942 Telecommunications Infrastructure Standard for Data Centers** is the primary standard used in North America for data centers. It states that HVAC must be provided 24 hours per day, 365 days per year to the computer room. In addition, the HVAC system should be supported by the standby power supply, ie, emergency generator or UPS. Recommended temperature and humidity ranges to be maintained in the data center are:

- dry bulb temperature: 20° - 25°C (68° - 77°F)
- relative humidity: 40% to 55%
- maximum dew point: 21°C (69.8°F)
- maximum rate of change: 5°C (9°F) per hour

Measurements should be made after equipment has been in operation and temperatures are stabilized. Measurements should be made 1.5 m (5 ft) above the floor every 3-6 m (10-30 ft) along the centerlines of the cold aisles.

**2008 ASHRAE guidelines** list various temperature and moisture-related limits for Data Centers:

- temperature range: 18° - 27°C (64° - 81°F)
- dew point range: 5.5° - 15°C (42° - 59°F)
- max. rate of change, temperature: 5°C (9°F) dry bulb per hour
- max. rate of change, temperature: 5% relative humidity per hour

Hot spots are defined as inlet air conditions that exceed the maximum temperature of 27°C (81°F) or minimum dew point of 5.5°C (42°F).

**The European Union's** *Code of Conduct on Data Centres Efficiency and Best Practices* for the EU Code of Conduct on Data Centres give temperature and humidity guidelines that match the ASHRAE guidelines. In addition, they state that, in 2012:

New IT equipment should be able to withstand the extended air inlet temperature and relative humidity ranges of 5 to 40°C and 5 to 80% RH, non-condensing respectively, and under exceptional conditions up to +45°C. The current relevant standard is described in ETSI EN 300 019 Class 3.1.

### **Calculating the Cooling Load**

The intent here is not to provide the detailed calculations needed to accurately size the HVAC system for a particular Data Center, but help to calculate a quick estimate of the cooling load.

As you can imagine, with computer rooms full of servers, switches, routers, tape and disc arrays, etc., calculating the cooling load can be a daunting task.

### **Managing Airflow**

Having enough cooling available for the computer room is only half the battle; the other half is delivering the cool air to the electronics and removing the hot exhaust air in an efficient manner.

Usually there is plenty of total cooling capacity and airflow available in a data center; the challenge is delivering the cool air efficiently to the electronics air inlets. Blockages under the access floor, too much bypass air, too much hot air recirculation and too high a heat density all contribute to hot spots.

When trying to optimize cooling, the first step to take is to remove unused servers from service. Studies show that 5-15% of data center servers are not being used. Yet, they are still turned on, generating heat and consuming electricity. Removing unused electronics from the computer room not only reduces the power consumption and resulting heat load, but it also either frees up real estate or reduces the real estate needed.

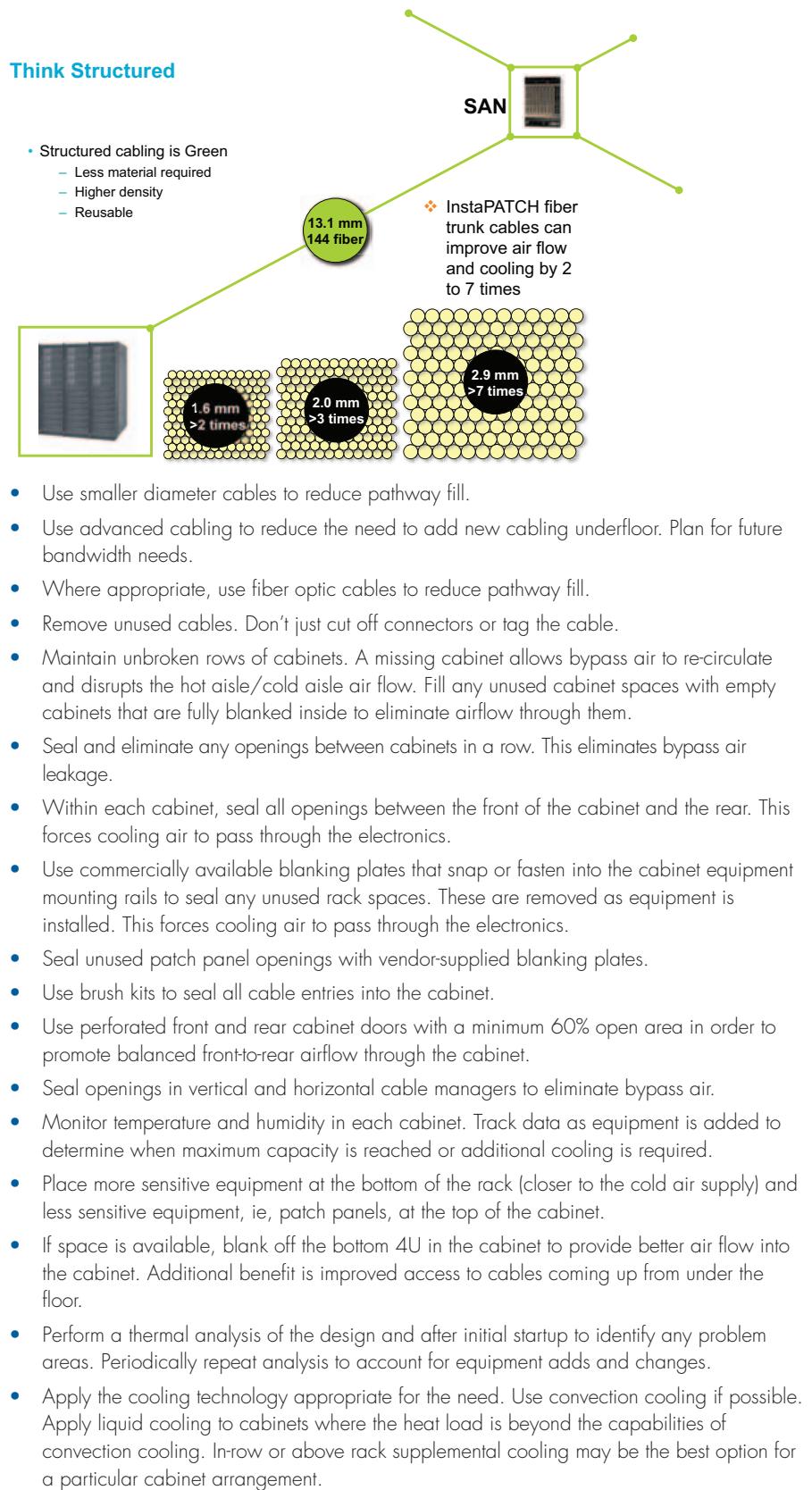
Another step to consider is virtualization of servers. The standard practice of using one server for each application results in servers that are often only 7-10% utilized. By combining multiple applications onto one server, each server runs at a much higher utilization, and the other servers can then be decommissioned and removed. Since not all applications can reside on a shared server, total utilization can never be achieved; however, significant improvements can be made.

After reducing the number of servers that need to be cooled, other steps can be taken to improve cooling. The intent of these changes is to avoid recirculation of hot air without it first passing through the cooling machinery. These steps are listed below.

(Before implementing any changes to an existing data center, contact the local power provider to find out if any incentive programs are available that reward efficiency improvements. If so, they will want to baseline current performance to determine the magnitude of the improvements. Payments here can offset the cost of efficiency improvements.)

- Implementing the TIA-942 hot aisle/cold aisle cabinet arrangement channels the cold and hot air.
- Place multiple CRAC units throughout the data center instead of a few large units. If a unit fails, the others can maintain the room temperature, rather than requiring a shut down while a large unit is repaired.
- Use management software to control CRAC units. In many data centers the CRAC units battle each other as they try to maintain their individual settings. Install humidistats on building columns and use these as inputs to the building management system to run the CRAC units.
- Calibrate temperature and humidity sensors to make sure they are operating correctly.
- Use management software to analyze and optimize computing workloads. Some workloads can be delayed to non-peak compute times, which balances the power and cooling load in the data center.
- Utilize servers that can go into ‘sleep’ mode when not being utilized.
- Use equipment with variable speed cooling fans that adjust fan speed to the heat load.
- Utilize access flooring (aka “raised floor”) as the supply plenum of cold air. The height of the floor should be sized to maintain clear air paths after cabling and piping is installed. Access floor height should be a minimum of 18 inches; more is better.
- Maintain positive pressure under the access floor. This can be checked with the business card test. Place a business card onto a perforated floor tile. If the card floats above the floor positive pressure exists. If the card is sucked down onto the tile then there is negative pressure or the tile is located too close to the CRAC unit. If the card blows up into the air you may have too much pressure and need more perforated floor tiles or slower fan speed. Lack of positive pressure indicates too many perforated tiles or other openings in the floor, or not enough CRAC units.
- Install perforated floor tiles only as needed, and only in front of each occupied cabinet and only in the cold aisle. Do not install perforated floor tiles in front of empty cabinets or in open floor areas. Do not install them in the hot aisle either, no matter how hot the air is, as this reduces the efficiency of the CRAC unit by lowering the return air inlet temperature, making the CRAC think that the room air is cooler than it really is. Often in existing data centers, cooling problems can be resolved by removing up to half of the installed perforated floor tiles.
- Install perforated floor tiles no less than 15 feet from the CRAC unit to avoid recirculation of cold air that hasn’t been used to cool electronics.
- Install perforated baffles and/or solid barriers underfloor to guide and control cold supply air. Do not block off zones with one zone per CRAC; instead use underfloor barriers to address supply air problems based on design analysis. Perforated barriers are used to balance supply flow rates and pressures so as to maintain good flow rates and pressures to all points in the computer room.
- Limit removal of floor tiles for service work. The positive pressure in the underfloor plenum disappears when floor tiles are removed and air flow to the perforated floor tiles is reduced.
- Seal areas between floor tiles and walls.
- Seal cable, pathway, and piping wall penetrations in the underfloor area.
- Seal cable openings in the floor tiles. Brush kits are available for this that allow easy re-entry and changes.
- Locate underfloor power cables along the cold aisle and data cabling along the hot aisle. These help form natural channels for supply air. An alternative is to place data cables in overhead pathways if the access floor plenum is of insufficient height.
- Ensure underfloor cabling pathways are sized appropriately to handle the volume of initial and future cabling needs, and that they do not block airflow across the pathway.
- Install a structured cabling system to reduce the need to add new cabling underfloor.

**Figure 42: Reusable Trunk Cabling is Green**



Separation of supply and exhaust air can be improved by using methods generally referred to as air containment. Using any or all of the following methods reduces air bypass and recirculation of air and improves the efficiency of the air conditioning equipment. Each has tradeoffs in cost, aesthetics and space requirements that need to be considered.

- Use a hot air plenum above the cabinets. Install a false ceiling with duct openings over each hot aisle to collect and channel hot air back to the CRAC units.
- Use hot air containment. Install curtains above the rows of cabinets and at both ends of each hot aisle to contain hot exhaust air. This air is free convected or ducted back to the CRAC units or other HVAC units for cooling. Used with a hot air false ceiling plenum, hot air is efficiently captured and returned to the CRAC units and is kept separate from the cold supply air.
- Install a complete hot aisle containment system, utilizing cabinet-level ceiling and doors at the ends of the hot aisle. In-row cooling modules cool the air in the hot aisle and return cold air to the cold aisle. It is important to consider hot aisle lighting requirements and placement, as well as fire detection and suppression requirements; consult the local authority having jurisdiction and/or the fire marshal before installing this system.
- Install cold aisle containment. Similar to hot aisle containment, this method seals the cold aisle from the rest of the data center to ensure that all the cold air flows through the equipment.
- Use contained rack return. This method utilizes chimneys or other ducting to channel the hot exhaust air back to the air handler. The ducting may exit the top of the cabinet or out the rear door.
- Use liquid cooling in the cabinet. Several technologies exist for this, using water, refrigerant, or dielectric fluid as the fluid. The cabinet can be self-contained with the cooling unit being either an internal module, located nearby, or installed as the back door. Alternatively, the data center can be plumbed with a network of piping using quick disconnects, eliminating the need for a plumber each time a change occurs. The entire data center is not cooled using these methods; they are generally reserved for high-heat cabinets only. One of the downsides to this is the introduction of liquids in the computer room. While the systems are generally reliable, some IT managers are adverse to the presence of liquids around their critical electronics.

### **Maintaining Cooling Efficiency**

Optimizing cooling efficiency is not just about the initial design and installation. Once the data center is up and running, equipment and cabling is changing constantly. This requires that cooling audits and ongoing maintenance occur. This includes the cleaning and replacement of air filters and intake grilles in the CRAC units and any other air handlers. The area under the access floor must be kept clean and all clutter removed. Remember that dust and debris here quickly ends up in the switches and servers, clogging those air passages and reducing cooling efficiency. Abandoned cables should be removed. Continue to run cables only in the pathways designated for cabling.

Above the floor, remove cartons, furniture and non-operational equipment from the computer room. These only add to the dust and dirt loading on the air filters.

The chilled water systems must be maintained for optimum efficiency. Clean and lubricate all components as called for by the manufacturer's preventive maintenance guidelines.

Remember that cooling problems are not solved by simply turning down the CRAC thermostats; this only aggravates the problem and uses extra energy. The source of the cooling problem must be identified and the appropriate solution implemented. With proper planning and maintenance, and utilizing the steps in this chapter, efficient and accurate delivery of necessary Data Center cooling is possible.

# 13. Network Planning

After examining the various component technologies that make up a Data Center, the task becomes combining them to make a functional area. While TIA-942 does a nice job of identifying the elements that could be included in a Data Center, there is no master template. It's important to weigh information, desires and constraints to design the most functional, cost-effective, efficient and future-proof Data Center possible.

## Planning for the Future

"Expected useful life" is the first guidepost to consider. While planning for the ultimate demise of a new Data Center may seem counterintuitive, this process helps frame what may be very difficult product and technology decisions down the road.

A real-life example is a television broadcast studio in New York City that has had to build concrete support structures within their existing broadcast cable pathways just to support the weight all of the old and abandoned copper that have accumulated over the years. The original designers - decades ago - probably did a great job anticipating current, and even seemed like future, needs. But as is all too often the case the asset has far outlived the original designed use.

At this point in the Data Center design process, you can use best design practices to anticipate and plan for some possible future uses for your design. Some generally accepted guidelines for expected lifetimes of various components within a data center are:

<b>Component</b>	<b>Useful Life</b>
Building/Pathways	50+ years
Cabling	20+ years
Hardware	3 to 5 years

Short-sighted decisions regarding building, pathways and cabling can severely limit the overall long-term value of a Data Center design if it cannot support multiple technology evolutions associated with the hardware.

As an example, an organization with a Data Center that is currently required to only handle 1U servers, with a tolerance for both planned and unplanned downtime, may be content with a single-source 120V power supply. However, this organization should consider if their business model over the next decade will still require only that level of availability. If their model could require less downtime and higher density server deployments, that same 120V power supply that serves their current needs will be almost impossible to upgrade. Unless the long-term plan anticipates building a new Data Center, the cost for additional unplanned renovations may prove to be prohibitive.

Future planning can be as simple as stating some basic assumptions and getting the approval of the customer or management before diving into a design. Good planning can include simple steps such as placing underground feeder lines in locations that do not preclude expansion of a building in a certain direction, or ensuring that there is sufficient property for expansion. Future growth planning will result in minimal costs for demolition, reconstruction and/or duplication in the future.

## Data Center Availability

The TIA-942 standard uses four tiers to rank the availability of a Data Center. TIA-942 goes far beyond planned and unplanned equipment downtime due to maintenance or failure; it also factors in partial or total operational failure due to unintended human interaction, natural disasters such as flooding, earthquakes, hurricanes, criminal activity, terrorism and acts of war. TIA-942 says, for example, that a Tier 4 Data Center:

*"Has considered all potential physical events, either intentional or accidental, natural or man made, which could cause the data center to fail. A tier 4 data center has provided specific and in some cases redundant protections against such events. Tier 4 data centers consider the potential problems with natural disasters such as seismic events, floods, fire, hurricanes, and storms, as well as potential problems with terrorism and disgruntled employees. Tier 4 data centers have control over all aspects of their facility."*

The typical maximum annual downtime allowed by TIA-942, by tier is:

Tier 1: 28.8 hours

Tier 2: 22.0 hours

Tier 3: 1.6 hours

Tier 4: .4 hours

TABLE 15: COST OF DOWNTIME

Application	Industry	Hourly Cost
Brokerage Operations	Finance	\$6.45 million
Credit Card-Sales Authorizations	Finance	\$2.6 million
Pay-per-view	Media	\$150K
Home Shopping (TV)	Retail	\$113K
Catalogue Sales	Retail	\$90K
Airline Reservations	Transportation	\$89.5K
Tele-Ticket Sales	Media	\$69K
Package Shipping	Transportation	\$28K
ATM Fees	Finance	\$14.5K

Source: Contingency Research Planning

When you consider the hourly cost of many common industries (see Table 15), you can quickly see how critical even a few moments of downtime could be.

When planning a Data Center, it is important to weigh what the maximum allowable downtime could be for your application. TIA-942 goes into great detail what minimum level of performance each system requires for each Tier; for the sake of brevity, we will provide a general overview here.

### Tier 1 - Basic

A Tier 1 installation is the most basic and least expensive design scenario. In this design there is no planning for contingencies; the equipment installed is all that is needed for operation. This is represented by "N", for Need, in most documentation. Any planned maintenance of any critical system or any unplanned failure will require the Data Center to either be taken fully or partially offline. While it is obvious that a financial or other data-centric organization needs far more than this degree of availability, other non-mission critical applications may be able to tolerate this level of performance.

Since there is no redundancy, it is important that the best design and installation practices are followed in this type of installation.

### **Tier 2 - Redundant Components**

A Tier 2 installation anticipates that there will have to be some level of maintenance on the systems, so it provides for "spare" critical components. This is represented by a "**N+1**" (Need plus 1) in the documentation. Planned maintenance, or the failure of a single critical system component, will not reduce the operation of the Data Center. However, more than one planned or unplanned event will result in reduced performance or failure.

This is by far the most common tier classification obtained by most Data Centers, as designing for Tiers 3 and 4 becomes increasingly expensive. Some Data Centers will use Tier 3 design guidelines on more mission-critical systems, such as power, backup and cooling, while using Tier 2 rules for other more expensive systems.

### **Tier 3 - Concurrently Maintainable**

A Tier 3 Data Center is designed with fully parallel systems, thus allowing for one full system to be affected by a planned or unplanned outage without interruption of the Data Center performance. It is typically referred to as a "**2N**" (Need times 2) design, where there is fully redundant power, cooling (including all of the piping), power supplies, servers, network hardware etc. Essentially the designer will have to design two mirror-image systems at the same time. A Tier 3 Data Center can handle multiple critical system component failures, but cannot withstand more than one full critical system failure. Multiple UPS or power supplies can fail without affecting Data Center performance, but failure of more than one entire electrical feed, or one electrical feed along with some critical system components on the backup system, will affect performance.

It is at this level where more structural and security requirements come into play for the building and site. For instance, the design must now exceed building code standards for some walls and ceilings, exterior windows must be excluded from the computer room, specific security requirements exist, etc.

### **Tier 4 - Fault Tolerant**

A Tier 4 Data Center provides the highest level of protection, allowing less than 30 minutes downtime per year. In order to provide this level of assurance, the design relies on a "**2(N+1)**" (redundant Need plus 1) design where there are not only two mirrored, redundant systems, but each of those systems has spare critical components. This design has the ability to withstand a full planned downtime or failure of one entire side of the system, as well as some planned or unplanned downtime of system components on the remaining active side of the system, without degrading the performance of the Data Center as a whole.

Tier 4 design goes far beyond just redundant and spare systems and components; it also specifies building design rules far beyond those of typical building, electrical, fire, security and safety codes. For example, not only do separate electrical and telecommunications feeds have to enter the building, they have to follow diverse paths to the site and be derived from geographically diverse sources. The electrical supply to the building has to be derived from two or more separate electrical grids to protect from downtime caused by an external system-wide electrical power outage.

Designers can also choose to implement higher level Tier requirements in a lower Tier Data Center in order to mitigate certain circumstances that may be more of a concern than others. For example, if network access to the outside world is considered a high-risk element, the designer may choose to utilize multiple providers entering the data center at multiple locations. Although this may offer Tier 4 availability to and from the outside world, less redundancy within the building will still restrict the Data Center to a lower-Tier rating overall.

Table 2 summarizes the benefits and costs of the various Tiers; this table can be used along with Tables 8 through 11 of TIA-942 to determine the appropriate design criteria for each Data Center.

**FIGURE 43: COMPARISONS OF EACH TIER LEVEL**

	TIER I	TIER II	TIER III	TIER IV
Number of delivery paths	Only 1	Only 1	1 active 1 passive	2 active
Redundant components	N	N+1	N+1	2 (N+1) or S+S
Support space to raised floor ratio	20%	30%	80-90%	100%
Initial watts/ft <sup>2</sup>	20-30	40-50	40-60	50-80
Ultimate watts/ft <sup>2</sup>	20-30	40-50	100-150	150+
Raised floor height	12"	18"	30-36"	30-36"
Floor loading pounds/ft <sup>2</sup>	85	100	150	150+
Utility voltage	208, 480	208, 480	12-15kV	12-15kV
Months to implement	3	3 to 6	15 to 20	15 to 20
Year first deployed	1965	1970	1985	1995
Construction \$/ft <sup>2</sup> raised floor*	\$450	\$600	\$900	\$1,100+
Annual IT downtime due to site	28.8 hrs	22.0 hrs	1.6 hrs	0.4 hrs
Site availability	99.671%	99.749%	99.962%	99.995%

\*Tiering Reference Guidelines from TIA942

### Site Selection

In addition to ensuring that the Data Center design conforms to all national, state and local codes, it is important to choose the site carefully. Local zoning and environmental laws regarding land use, fuel storage, hydrocarbon and sound emissions, among others, all may affect which sites would be suitable.

Site location should also take into account geographic access, as well as hazards. Sites that would be obvious targets for terrorism (i.e. cities, public arenas, airports, power generation facilities, military bases) should not be immediate neighbors. The Data Center should not be located in an area where there is an increased probability for an accident that may damage or destroy the Data Center or critical infrastructure (i.e. within the landing path of local airport, downhill from a dam or within a 100-year flood plain).

Conversely, the Data Center should not be located in an area so remote so as to not be able to economically provide services and personnel for the site. Employee concerns like ease and safety of access, as well as the local crime rate, should also be considered.

The site should have access to a stable, clean and affordable supply of electrical power. Locations that are on the same feeder as large industrial consumers of electricity should be avoided, as their processes may affect the quality of the power supplied. Also areas subject to significant power outages due to a susceptibility of the local grid to natural disturbances (i.e. wind, ice etc) should also be avoided. Generally, locations located close to hospitals tend to have cleaner power and also tend to have a higher priority when there is a service disruption. Underground utilities will also help to mitigate natural and human disturbance.

The telecommunication services should be provided by a diverse optical fiber path via geographically diverse service routes and central offices. In many cases, service providers utilize the same physical pathways, so the selection of two different service providers does not alone guarantee path diversity. One must also ensure that the telecommunications supplies are as isolated as possible from regional disruptions.

One other regional consideration is the cost of providing cooling. Locating a Data Center in an area where the ambient air temperature is lower will increase the efficiency of the cooling system. In some rare cases, outside filtered and conditioned air can be used directly for cooling during some seasons, thus reducing the cost of cooling even further.

### Architectural considerations

A Data Center should never be located in the basement of a building, due to the increased possibility of flooding due to natural events, plumbing failures or fire suppression located in the building above. Similarly a Data Center should not be located adjacent to or below rooms or walls that contain plumbing as they pose a risk of flooding should there be a failure of the system.

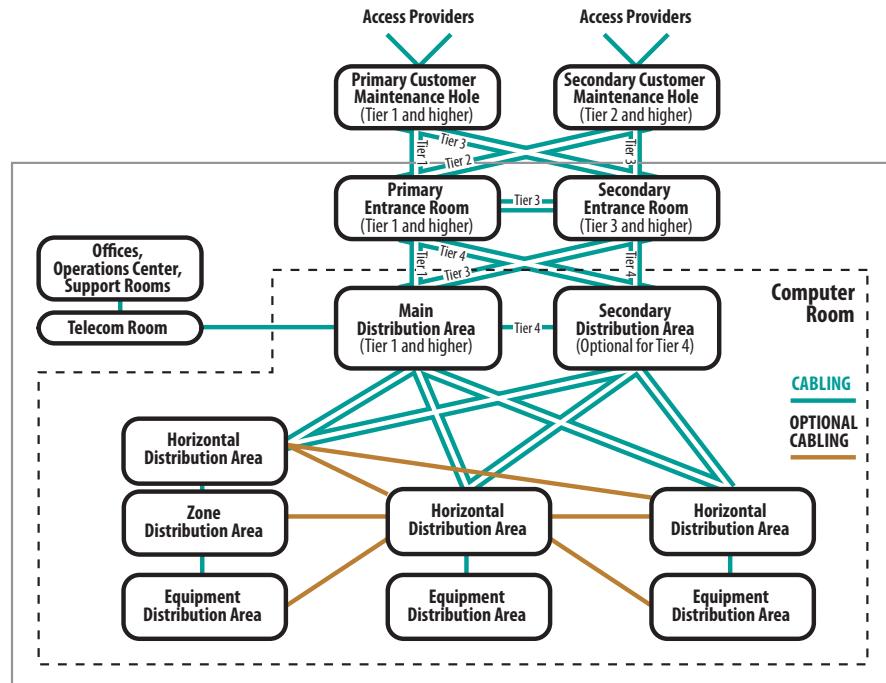
Where possible, a Data Center should be a single story building solely dedicated to the use as a Data Center. When it is not possible to provide dedicated space, shared space should be limited to office space or International Building Code type "B" space. Industrial, restaurant and cafeteria type uses should not be located in the same structure, due to the risk of fire and EMI effects.

When subordinate uses have to be co-located with a Data Center it is important that adequate space is allocated for backup generators, security, telecommunication pathways and spaces, and fire suppression. Loading docks should be easily accessible to the Data Center, and doors and hallways should be appropriately sized for tall network equipment to get through.

A Data Center room should have no exterior windows to minimize external security issues and solar heating. Exterior landscaping should be kept 60 feet from the building and exterior walls should be constructed of concrete or masonry.

Room height, floor to ceiling, should be 13ft or more, and a raised floor system should be planned for within the Data Center room itself. Floor loading should be between 150 lbf/sq ft to 250 lbf/sq ft for the Data Center room, and potentially much higher for each respective mechanical room.

**Figure 44: Example of a Basic Data Center Topology**



### **Computer Room Layout**

There is no hard rule for how to design the layout of a computer room. Ultimately the design will be a compromise between budgets, computing requirements and physical building constraints.

A computer room will consist of a combination of dedicated areas – some separate and distinct in larger installations, and some combined into single spaces in smaller installations. The terms TIA-942 uses to describe the zones and pathways in a Data Center are similar to the terms

TIA-568 uses to describe the telecommunication spaces and pathways in commercial buildings:

### **Customer Maintenance Hole (CMH)**

This is the location at the edge of the Customer Property where the Service Provider first enters the customer premises. Depending on the size of the project this could be a simple handhole where the Service Providers conduit meets the Customer's, or it could be a large structure that contains active equipment.

### **Entrance Room (ER)**

This is the location where the Customer interfaces with the outside world through various Service Provider connections. Protection devices to protect against external voltage surges are located on all copper conductors entering the facility in this room. Service Provider demarcation points and equipment are also located in this room. It is not uncommon for an Entrance Room to have a separate security protocol and for the various Service Provider equipment to be segregated via chain link fences.

### **Main Distribution Area (MDA)**

This is the core area within the data center and the center of the star from a network architecture point of view. Core LAN/SAN switches, routers, firewalls and load balancers are installed in this location, analogous to the Main Crossconnect (MC) in the TIA-568 description. Almost all of the cabling entering a MDA is backbone cable and will typically terminate in at least one more Distribution Area or Telecommunications Room.

This area will be the central hub of the entire Data Center design and should allow for expansion as the Data Center grows. It will have the highest density of cables, crossconnects, and interconnects, and will be the most sensitive to service disruption, as almost all signal pathways lead to and through the MDA.

### **Horizontal Distribution Area (HDA)**

This is final hub in the star configuration for the network wiring. It is the same as TIA-568's Horizontal Crossconnect (HC), and typically houses the Access LAN/SAN and KVM switches. Backbone cables from the MDA will terminate in the HDA and horizontal cabling out to the equipment will start here. Typically HDA's serve groups of equipment and therefore will require less room for expansion than the MDA. (While there may be some minor build out within an HDA, typically new HDAs and equipment are added when expansion is required.)

### **Zone Distribution Area (ZDA)**

This is an optional passive inter/cross connect located by the equipment served, allowing for additional cabling flexibility. It mirrors the purpose of the Multi User Telecommunications Outlet Assembly (MUTOA) in TIA-568, but not the limitations on number of ports served. There are no active components in a ZDA.

### **Equipment Distribution Area (EDA)**

This is where the active processing and storage equipment resides and may include some interconnect patching. The Horizontal cables from the HDA terminate in the EDA. This area is the same as the Telecommunication Outlet in TIA-568.

Not all Data Centers will have all of these areas, or to the same degree. For example, a Data Center that serves a large co-located call center may have few links to the outside world thus minimizing, but not eliminating, the roles of the Entrance Room (ER) as well as Customer Maintenance Hole. At the other extreme, a large remotely located Data Center whose sole purpose is providing computing power for remote users will have a significant ER but will probably have very little Telecommunications Room (TR) and office space.

## Modular Design Technique

While it's very tempting to start populating an empty Data Center with equipment and figure out how to connect it later, this approach wastes cabling and switch ports. In the long term, this will require difficult and expensive reconfiguration when expansion is necessary.

The most effective way to plan a Data Center space is to use a modular approach, where processors and storage are assembled into logical and physical modules that represent a single EDA. One or more EDAs can then be grouped into a single modular HDA area, and these can then be assembled to populate the entire Data Center area. The best approach groups the various pieces of equipment by type and/or usage. From this, the cabling, power, cooling and space requirements for each module can be determined. The module footprint is then designed using all of the racks, cabinets and patching, as well as associated pathways. Finally, the connectivity requirements, depending on module type, can be determined. Although modules can be re-used in multiple locations, if they utilize different cable/power routing, cooling or floor layout, different versions of that module may have to be developed that utilize common features.

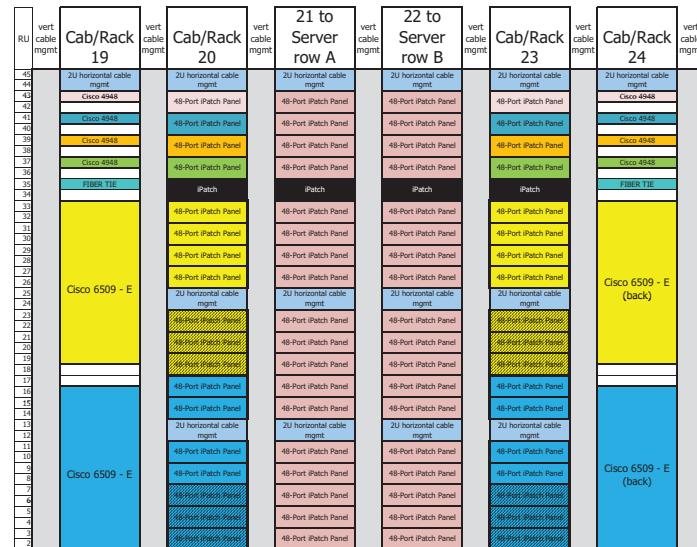
A modular design approach benefits ongoing operations and maintenance. Expansion and/or upgrades can occur in well-defined blocks that have understood resource requirements and performance characteristics. New module configurations can be pilot tested offline, exposing overall operations to fewer disruptions. Modules themselves can be replicated across sites to standardize operational and maintenance procedures.

## Rack and Cabinet Layout

There are some general design guides to follow when populating active cabinets. First ensure that the cabinets being specified can handle the weight of the equipment being placed into them. Many of the newer high density switches and blade servers pack a significant amount into the Rack Units (RU) they occupy. Also review the equipment manufacturer's specifications for cooling airflow. Some equipment has front to back airflow, while others utilize side to side. Mixing equipment with different types of airflow requirements within one cabinet is not suggested; even mixing different equipment within a row or between two adjacent rows can also cause cooling problems.

Cabling and connectivity must be accounted for in the cabinet and wire management selection. Generally there should be 1U of horizontal cable management for every 2U of patch field. As shown in Figure 45, while only two full racks house active equipment it takes another three racks to handle all of the equipment interconnects as well as horizontal/backbone connections. If this was a Category 6A installation, the horizontal managers shown would not be sufficient.

**Figure 45: Example Cabinet Layout**



The rack placement of hot or temperature-sensitive equipment is important. Since heat rises, the hottest location is at the top of a cabinet. Since patching has a higher tolerance to warmer temperatures, patching equipment can be placed at the top of a cabinet or rack, with equipment that generates greater heat at the bottom.

Once the equipment and connectivity has been determined, hardware should be built from the ground up. Select the appropriate equipment cabinets, paying close attention to load capacity and airflow. If the cabinet will use a front-to-back airflow pattern, make sure the doors have enough open area. Make sure the cabinets have the proper grounding, as well as power distribution units. Determine if cabling will exit or enter the cabinet. If cables will run horizontally between cabinets make sure there are cable brushes installed. If top or bottom entry is desired again make sure proper brushes are installed.

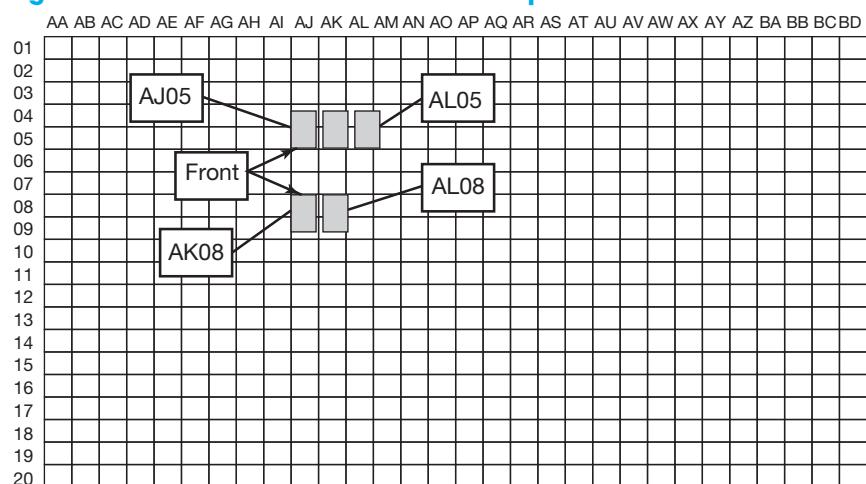
When designing the patching area, the most important factors are the ability to block airflow through the patch field, and the effectiveness of the cable management systems. Copper and fibers systems now have to coexist within the same rack environment and novel patching systems are available that reduce the amount of rack space required for patching. There are zero U solutions available that place the patching within the vertical cable management areas between cabinets or on the rear rails of cabinets populated with equipment. There are also underfloor and overhead wire-tray-mounted patching solutions for those installations that are tight for space.

## Room Layout

### *Floor Grid and Identification*

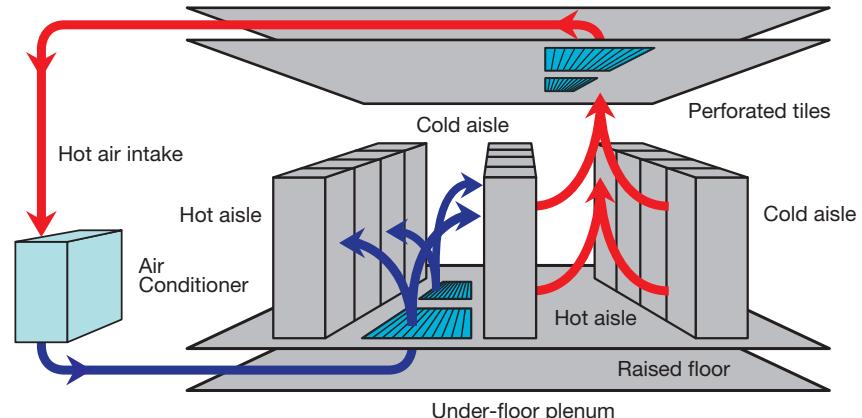
Generally, a Data Center that utilizes a typical 2 ft by 2 ft raised floor system should also utilize that same grid for rack and cabinet identification. This method may also be used for a Data Center that has other flooring systems by adjusting the lateral dimensions logically to fit the flooring system used. Starting in one corner of the room, orthogonal X and Y axis are identified and unique sequential identifiers are used to identify each X and Y column/row in the room.

**Figure 46: Floor Grid Identification Example**



Using the front right corner of the cabinet (if standing inside the cabinet) the tile the corner sits on can be used as the cabinet identifier. In the above example note that the top and bottom rows of cabinets do not start with the same column identifier (ie AK vs AJ) since the right front corners are on different floor tiles.

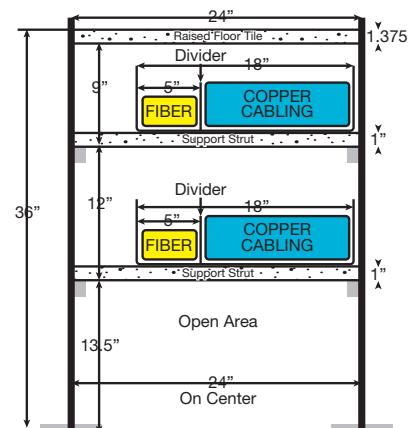
**Figure 47: Hot Aisle / Cold Aisle**



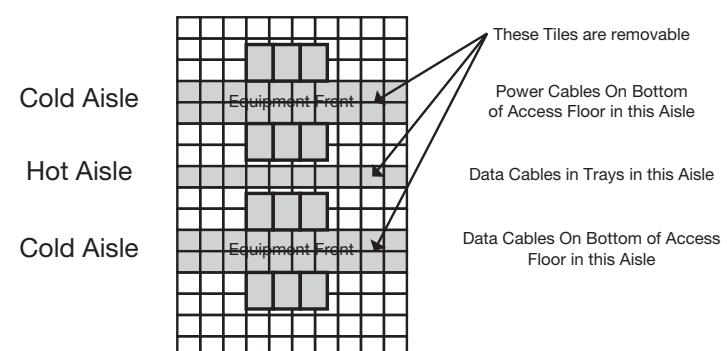
Heat management can be a significant issue in any size data center. While heat management techniques are covered extensively elsewhere in this design guide, room layout can have a significant impact on the effectiveness of any cooling technique chosen.

In general a Hot Aisle/Cold Aisle layout is suggested thus allowing the cool air to enter the fronts of the equipment in the cabinets while exhausting the hot air out the backs of the cabinets. Regardless of the use of a raised floor system, this allows cool conditioned air to be directed to the aisles that have all cabinet fronts and allows the hot air to be removed from the aisle that has all of the cabinet backs facing it. When using a raised floor system with underfloor cabling, you will typically run your power lines on the bottom of the raised floor under the cool aisles and you will run your data cables under the hot aisles in racks just below the tiles.

**Figure 48: Separation of Cables Under A Raised Floor, Side View**



**Figure 49: Separation of Cables Under A Raised Floor, Overhead View**

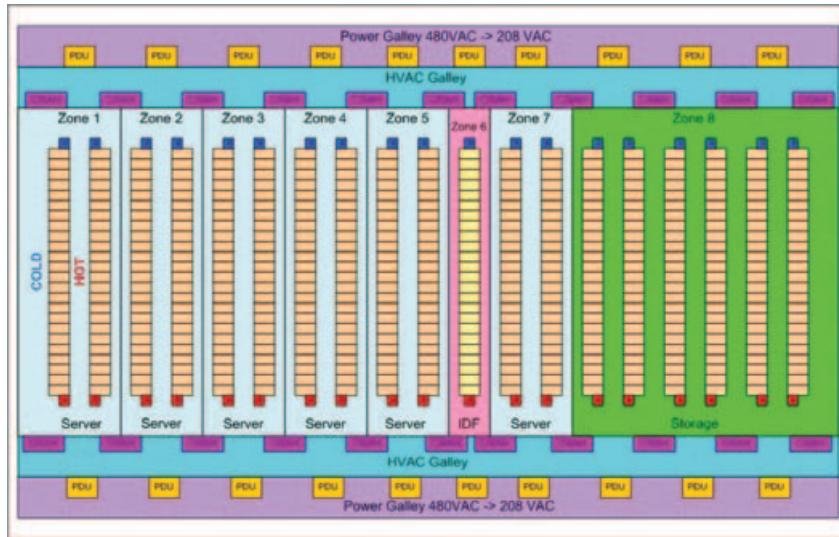


When using the raised floor as a cold air supply plenum, all perforated tiles should be placed in the cold aisle close to the equipment that requires cooling and not close enough to the conditioned air return so as to allow conditioned air to bypass the equipment to be cooled.

#### **Example Layout**

Below is an example modular layout that clearly separates the various modules within the Data Center by dashed boxes.

**Figure 50: Modular Data Center Layout Example**



This modular approach allowed the designer to copy and paste the design multiple times within this larger Data Center design.

# 14. Installation & Implementation

This chapter will examine the data center components in the computer room and explore best practices for installation and product handling. Of course, these guidelines are general in nature and each implementation step may not be covered in depth; refer to each manufacturer's installation procedures for specific instructions on how to handle each product.

Many of these guidelines may apply to areas outside the computer room as well. However, for implementations in the LAN, campus and outside plant, refer to the recommendations of TIA-568 as well as the CommScope Enterprise Design Guide.

We will first review a typical sequence for implementation:

1. Utility Power
2. Lighting
3. Access floor supports
4. Underfloor ground grid
5. Cooling
6. Install pathways
7. Install floor tiles
8. Install cabinets or racks
9. Computer power from floor serving PDUs
10. Install patch panels
11. Install cable
12. Terminate cables into patch panels
13. Test cabling infrastructure permanent link
14. Install electronics
15. Install patch cords
16. System test

This order may not be exactly the same for every Data Center therefore it is important to plan the process up front. The order of some items is obvious, such as installing the racks or cabinets before installing the patch panels that will be held within them. The sequence of other items may not be as straightforward. While we will touch on most steps in this list, we will devote far more time on the structured cabling items.

## **1. Utility Power**

Power is the lifeblood of a data center and nothing can run without it. Many data centers will require a high level of redundancy here, even if lower in other areas. (See the chapter on network planning for a thorough discussion of redundancy.) Within the building there will likely be redundant "A" and "B" fields as well going out to all critical locations.

The "A" and "B" fields are likely both utilized and run alternatively or together at low capacity for each. Each field would normally run at less than 50% capacity in order to be able to handle the entire load if the other field goes down.

## **2. Lighting**

Compared to power and data flow, lighting is of significantly less importance. In fact, many operators are hoping to reach a "lights out" data center, where technicians are rarely needed inside. As such, lighting systems are less likely to be fully redundant. Instead, emergency lights are utilized to illuminate emergency exits and main hallways.

## **3. Access floor supports**

A raised floor requires support for the expected weight of cabinets that will eventually be placed on the floor. This weight capacity should be based on the maximum expected utilization of the data center.

The amount of weight a raised floor can bear serves as a concern since too much weight can cause this type of flooring to buckle or sag. Subfloor cable installation also has advantages of hiding the data cabling out of view. Although in today's Data Centers, many wish to show off their cabling and disregard this as a real issue. Overhead cabling is often seen as the preferred choice since it eliminates the load issue and is easier to install given there are no floor components in the way.

A mix of overhead and raised floor could be used as well. Placing power cables underfloor would make sense as these are rarely moved after the initial installation. Putting the data cables overhead would allow more access for MACs.

#### **4. Underfloor ground grid**

#### **5. Cooling**

#### **6. Install pathways**

The preferred method would be to use ladder rack in the overhead spaces and basket tray in the underfloor spaces. Cable should not be installed directly on the slab.

#### **7. Install floor tiles**

After most of the components underneath the floor are in place, the tiles can be laid down over top to create the floor space. If the expected placement of cabling is well documented, then some tile areas can be left open for cabling to be installed. Depending on the planned placement of the cabinets and expected air flow needs, some of the tiles may need to be vented or have openings, brushed or not, to allow for cable and air flow exit requirements.

Tiles are designed to be easily configurable, so it is possible to rearrange the tile placement as additional componentry is added in the future.

#### **8. Install cabinets or racks**

#### **9. Computer power from floor serving PDUs**

#### **10. Install patch panels**

It's best to install patch panels before the equipment is installed. This reduces the risk of damage to the equipment that might occur while other work is being completed. If this is an MDA installation, install patch panels from bottom up. This configuration makes it easier to add cables and patch panels that don't need cooling.

If, however, this is not an MDA installation, patch panels can be installed in a top-of-rack configuration. Be sure to leave in (or install) blank panels for unused ports to properly direct cooling airflow.

#### **11. Install cable**

Ideally, it is best to place cable 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.

##### ***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.

##### ***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.

#### **Cable Layout**

Due to the nature of the Data Center, hundreds of cables may traverse and 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.

#### **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.

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 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.

#### **Cable Conveyance and Installation Tools**

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.

#### **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 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.

#### **Preparing to pull**

Plan to start with the longest route. 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). If several cables are being pulled to a single location, 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 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-606 standards require that the final labels be mechanically generated.

#### *Pulling the cable*

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 bends and sharp edges. Using helpers, place and pull the cable along the conveyance. 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.)

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.

#### *Housekeeping prior to termination*

After installation, organize the slack in the cabling 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.

## **12. Terminate cables into patch panels**

The connector is the "last inch" of cabling to be installed. A link may have many connections and/or splices in its journey; each one must be made as accurately as possible.

#### *Preterminated vs. field installable*

Within the Data Center, there is often a need for a speedy install. To minimize traffic within a secure area, limit the risk of disruption to service and keep the computer room neat, clean and uncluttered, we recommend using factory-terminated assemblies wherever possible.

Factory terminated assemblies are considered a higher quality since they are pre-tested in the factory and orderable to set lengths and sizes. Additionally, limited training and tooling is required to set these cables into place. Both optical fiber AND twisted pair copper cabling are available factory terminated. Some connectors, such as the optical fiber MPO, are very difficult to field install and therefore preterminated cables would always be recommended as the preferred option. Connectorized fiber cables are available for almost all cable and connector types.

Field-installation still has a place in many applications. Field-installable cabling allows the flexibility to choose exact cable lengths, may make up for imprecise initial planning or allow for changes if they occur during installation. With today's high quality cable and connector components, a trained installer can achieve loss performance that meets or exceeds the requirements of TIA and IEEE.

However, individually purchasing the cables, connectors, etc may cost less than pre-terminated cables, but remember these cost do not include labor.

## **Twisted pair**

### ***Twisted Pair Wiring Schemes***

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.

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 specific.

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).

### ***Twisted Pair Termination***

Twisted pair cables typically terminate in one of two TIA 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.

### ***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.

## **Optical Fiber**

### ***Fiber optic schemes***

Optical fibers can be either spliced together by fusion, mechanical methods or terminated with a connector.

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. The diagrams in chapter 9 show a typical duplex link with a transmit/receive fiber pair as well as the more complicated systems of today, with duplex solutions over an array cable or parallel optics.

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

### ***Loose tube preparation***

Prepare the cable end for termination. If the cable is loose tube buffered, furcate the fibers. 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 manufacture's procedure, using non-recommended materials or using out of date adhesives are not recommended. This 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. Some of these connectors recommend the use of a VFL (Visual Fault Locator) to provide a visual guide of success during termination.

### ***If splicing on a pigtail***

Remember that a pigtail is a length of fiber that has one end already terminated from the factory and the other end bare, waiting to be spliced (joined) to an incoming cable.

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. By splicing indoors, the harsh conditions are usually avoided but there may be dust and debris still within the computer room. Regardless of your splicing location, make sure to follow all appropriate OSHA procedures.

Before exposing cable components and working within the enclosure, the installer should consider how the cable and pigtail (or pigtail module) will lay when the process is finished. The fiber can be test-routed to make sure that it can fit into the location and that the fiber bend radius can be maintained.

### ***Cable preparation/jacket removal for splice***

Prior to splicing, secure the cable to the enclosure. 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. Carefully make a ring cut through the jacket at the choke point using the appropriate cable prep tool. DO NOT cut or nick the fibers within the cable jacket. Make a second cut about 15 cm (6 inches) from the cable end and remove that part of the jacket to access the ripcord.

### ***Removing non-fiber elements and securing***

Trim the aramid yarns and any strength element flush with the cable jacket. Review the manufacturer's instructions as to how the cable should be secured. If the pigtail is integrated within a module, unwrap several loops of fiber in order to have enough length to work with while splicing.

### ***Connector loss***

TIA 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. Pre-terminated single-fiber connectors typically provide loss of 0.5 dB or less.

### *Cleaning*

Finally, clean each connector before inserting into the patch panel. Keep dustcaps on any connectors reserved for future use.

### **Coaxial wiring**

Coaxial cable has a center conductor and an outer conductor which acts as a shield. Using BNC-style connectors is a popular method of termination for DS3/4 cable.

Specialized connectors exist for other coaxial cable types; contact CommScope Technical Support at [support@commscope.com](mailto:support@commscope.com) for more information.

### *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.

### **Labeling termination**

TIA standard 606-A calls 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.

## **13. Test cabling infrastructure permanent link**

The details of testing copper and optical links is discussed in Chapter 15. In general though, every link should be tested as installed. Up-front testing and fixing of troubled links will create a much smoother process when the system is brought online and will have additional benefits throughout the life of the system.

## **14. Install electronics**

It is common practice to activate and run, or "burn-in," electronics before placing into production. Review manufacturer's recommendations on the timing, but one week burn in should be sufficient to discover so called "infant mortality," or early failure of electronic gear. If there is no failure after that initial time, the device will likely run for years. Burn-in is typically done in a different room in order to keep separate room in order to keep separate from operational devices.

The electronics can be installed into the rack or cabinet frame using the flanges and screws that are supplied with the units. Electronics, especially heavier units, are typically installed from the bottom up for ease of handling and stability during the process.

## 15. Install patch cords

A patch cord is a relatively short length of cable connectorized at both ends and can be used to connect electronics to other electronics, electronics to a patch panel or connect two passive links together.

Unlike backbone or behind-the-wall cabling, patch cords are expected to be mated and unplugged frequently. Therefore a robust design is strongly desired, and CommScope recommends the use of factory terminated patch cords for both copper and fiber cabling to provide a robust, durable solution along with a consistent and low loss.

Note that patch cords are part of the cabling link and that their quality is of great importance, just like that of the backbone cabling. A system utilizing all Category 6A components must utilize Category 6A patch cords in order to achieve the expected performance.

Similarly, for fiber cabling, the cord fiber type needs to match the cabling in the backbone. For fiber cables trunk cable with 50 µm core fiber must be connected to patch cords that also have a 50 µm core size. Similarly, singlemode cabling must be connected with singlemode patch cords.

Matching fiber core sizes is standard practice. Today the challenge is making sure that the fiber patch cords meet or exceed the bandwidth of the cabling. Laser-optimized OM3 or OM4 fiber cabling must be connected to the electronics through laser-optimized fiber as well. For any 50 µm fiber application, CommScope recommends using patch cords that only contain OM4 50 µm fiber. These will match up well with OM4, OM3 or any lower grade 50 µm cabling. Having one 50 µm cabling type for your patch cords also limits excessive inventory or accidentally mixing fiber types within the system.

A good exercise for checking fiber consistency in active networks is to walk through the data center and run a patch cord "color check." Much of today's backbone and trunking cable within the data center will be aqua in color, to denote the high bandwidth laser optimized fibers. Any patch cords that are orange in color, which is the traditional color for standard multimode fiber, then there was likely no patch cords that match the bandwidth of your high bandwidth backbone cabling. Orange patch cords are likely standard 50 µm grade and may even be 62.5 µm fiber, which would be the wrong core size.

Fiber patch cords are typically cleaned in the factory after polishing is completed, but this does not mean that they arrive to the job site free of debris. It is important to clean the connector endfaces of the patch cord before inserting into the patching field. Connectors that are not patched should be left with their dust caps on to limit endface contamination. Similarly, optical ports should have their dust caps reinstalld immediately after patch cords are removed.

## 16. System test

Lastly, the system should be tested. Although individual links were evaluated earlier in the process, it is important to test the whole system for several reasons.

- to verify the cable connections are routed to the proper location
- to verify proper polarity is maintained (transmit goes to receive)
- to verify connections are properly mated into the adapters and free of debris

Testing is described in detail in the following chapter.

# 15. Testing & Documentation

When the design and installation of a data center is complete, testing of the installed cabling is the next important step.

A permanent link is considered to be all of the cabling and terminations within a cable run except for the patch cords, which are expected to be interchangeable over time. Cabling should be tested AFTER installation into the panels in order to evaluate the quality of the fully installed system. Found issues should be investigated and solved before commission of the system can be considered complete.

Testing of the passive system, whether copper or optical fiber, is typically completed on the passive links before connection to electronics. This is very important, because once a system is operational; end users typically do not want to disturb any of the cabling.

Consider, for example, an optical fiber run utilizing a 24-fiber MPO trunk cable connecting to a 24-fiber LC-MPO module on each end. A request comes in to connect one user quickly and therefore testing is bypassed in order to meet the request; the new user is patched in through fibers 1-2. Later it is determined that the trunk cable was damaged during installation and fibers 13&14 are dark. Although the active connection is only utilizing one pair of fibers, it is now impossible to replace or repair the link without taking down that active pair.

CommScope goes to extra lengths to ensure that our cables perform as promised. CommScope's unique WebTrak identifier printed on the cable allows customers and installers to enter this information online 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 such as cable bent 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 and helps trouble-shooting 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.

## Twisted Pair Cable Testing

All twisted pair cable permanent links should be tested and the results documented. Some warranty programs may require additional testing - see the warranty for details.

Permanent links and channels should be 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](http://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 and 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 and 6. Worst-case values for link and channels are shown in the following tables.

## Performance Standards

TABLE 16: CATEGORY 6A U/UTP PERFORMANCE STANDARDS (TIA 568 C.2)

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

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.

TABLE 17: CATEGORY 6 U/UTP PERFORMANCE STANDARDS (TIA 568 C.2)

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

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.

TABLE 18: CATEGORY 5E U/UTP PERFORMANCE STANDARDS (TIA 568 C.2)

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

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

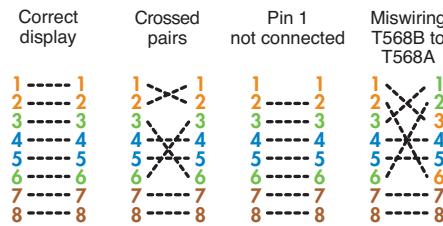
Document each channel's performance for the criteria listed above, the test date, the name(s) of the test personnel and the equipment used (manufacturer, model number and calibration date). Record (or download if the equipment has that function) the test results and store them with the as-built drawings. 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 Figure 52). Fix wiremap problems by inspecting and correcting miswired termination hardware.

Figure 52: Wiremap Test Set Display



#### Fail Length (test set $\pm 10\%$ )

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. 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.

#### ***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 "Fail Length").

#### ***Post-testing Problems***

Some problems appear 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 failure can have numerous causes; the most obvious is that the cabling cannot support the application. If the correct cable is being used, troubleshooting becomes more complex.

If installation testing rules out wiremap problems, 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.

### **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.

Take, for example, a link of 500 meters (1640 feet) with three connector pairs (crossconnect, patch panel and desktop). The TIA maximum loss allowance for a connector pair is .75 dB. Adding the fiber loss ( $3.0 \text{ dB/m} \times 0.5 \text{ km} = 1.5 \text{ dB}$ ) to the loss from three connector pairs ( $.75 \text{ dB max} \times 3 = 2.25 \text{ dB}$ ) establishes a calculated total loss of 3.75 dB ( $1.5 + 2.25$ ). 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.

While standards such as TIA/EIA568C.3 provide baseline performance level of components, there are many options in today's market that provide significantly higher performance levels in order to achieve high data rate performance with more connector pairs and/or at an extended distance. Therefore, one cannot simply refer to the standards for what should be expected in the field.

For example, a manufacturer may specify a 0.5 dB maximum (vs. 0.75 dB allowable by TIA) for factory terminated LC connectors. Therefore a point-to-point link should see a maximum loss of 1.0 dB for the two connector pairs, which is less than the 1.5 dB allowable by the Standards. This issue arises frequently in the data center when examining the expected loss of an MPO to LC module. Although the module creates a situation with 2 connector pairs, the loss is typically specified at well below the maximum allowable by the Standards.

Determining the expected loss can become complicated, and CommScope has a link loss calculator available to provide its business partners with expected loss based upon distance, fiber type and connectivity. A calculator can take into account statistical data to provide a more accurate picture of what the system test results should look like.

**Figure 53: www.myCommScope.com, Link Loss Calculation**

Enter Link Data below:		Rw3 1 Apr04
3	Cable type and test wavelength	LazSPEED Cable @ 850 nm
5	Total link length	365
6	TeraSPEED tight-buffered cable length	0
8	# of LC connections	2
9	# of ST or SC connections	0
10	# of MPO connections (InstaPATCH only)	0
11	# of splices	2
13	Loss test set uncertainty (dB)	0
16	Maximum Allowable Field-Measured Attenuation (dB):	2.12
21	Measurement Check List	
22	Did you remember to:	

Test equipment today has become very sophisticated and can often calculate expected loss values based upon standards' provided values. Although valuable, the allowable loss based upon the standards may be higher than what the system should actually experience based upon the product specifications. It is recommended to use a link loss calculator based upon the manufacturer's product performance beyond just the standards' baseline requirements.

During the testing process, you are very likely to have test results that initially are not passing. The good news is that an initial test failure does not guarantee that the product is faulty. With optical fiber testing, simply cleaning both the test cord and the behind-the-wall connector will ensure that dirt and dust will not adversely affect the test results. If a failing result is obtained, one should clean both the system connector and test lead before investigating further. Most issues can be resolved by cleaning the connectors.

There are many devices that can be used to clean connectors and adapters. It is very important to have the correct cleaning device for the component being cleaned. Dirt can be removed from the endface of connector utilizing a cleaning tape, often within a cassette that allows for automatic rotation of that tape to a clean each time it is used. Even connectors that are "behind-the-wall" are accessible with cleaning sticks that are sized for the appropriate ferrule diameter. Cleaning and inspection kits can be purchased that contain all of the cleaning supplies as well as a microscope to examine the endface of the connector for dirt and scratches.

**IMPORTANT: Before looking at the endface of a connector through a microscope always make sure that the link is unplugged from the transmitter and that no optical power can be directed towards your eye.**



Fiber optic links should be tested for continuity and attenuation. The methods for fiber testing are

1. using an OLTS (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)
3. using an Optical Time Domain Reflectometer (OTDR)

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 bidirectionally. 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 patch cord" method (OLTS)***

The power-meter-and-light-source method is the most accurate way to measure attenuation. TIA outlines testing procedures in documents 526-14A (multimode)\* and 526-7 (single-mode).

Hybrid patch cords can be used to connect the test equipment to the link. Thoroughly clean the patch cord 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.)



## CommScope Inspection Kit

Exact testing methods will differ with each power meter and its features, but this is the basic process for OLTS testing for one fiber at a time. Many OLTS 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) patch cord reference, Step 2) patch cord check and Step 3) system test.

**Step 1:** Connect the light source and the power meter with a test patch cord. 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 patch cord from the optical power meter; DO NOT detach the patch cord from the light source. Add the second patch cord to the test meter port and connect to the first patch cord. Measure the total loss. If greater than 0.5 dB, the patch cord connectors must be cleaned and retested. If cleaning does not produce a loss below 0.5 dB, than replace one or both patch cords until a passing value is obtained. Do NOT reference out again at this step.

**Step 3:** Disconnect the two test patch cords from each other and connect to the ends of the system link being tested. Use a previously tested and verified patch cord 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 patch cord five times around a mandrel (or smooth rod) of 25 mm diameter for 50  $\mu\text{m}$  fiber and 20 mm for 62.5  $\mu\text{m}$  fiber removes these losses. Be sure to unwrap the patch cord after testing. Refer to TIA/EIA 569 B.1 Section 11.3.3 for details.*

## Fiber Optic Performance Standards

### *Loss budgets*

TIA 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 19: TIA 568 C COMPONENT AND LINK PERFORMANCE

Network part	Loss
Splice	$\leq 0.3$ dB insertion loss at all wavelengths
Connector pair	$\leq 0.75$ dB insertion loss at all wavelengths
Horizontal link (100 meters max.) (maximum of 2 connector pairs)	$\leq 2.0$ dB insertion loss at 850/130 nm
Horizontal link (100 meters max.) w/consolidation point (splice or connector)	$\leq 2.75$ dB insertion loss at 850/130 nm
Collapsed backbone link (300 meters max.) (maximum of 3 connector pairs)	$\leq 3.3$ dB insertion loss at 850/130 nm

For example, if all the pairs in a three-connector-pair link with a consolidation point were tested at the permitted maximum of 0.75 dB, the loss would be an allowable  $0.75 \text{ dB} \times 3$  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 standards). The budgets above refer to TIA standard recommendations.

Many CommScope products offer performance tighter than the standard. Please refer to the specification guides 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.

## **Fiber Optic Troubleshooting**

#### ***Test equipment***

Improper calibration (also called improper baseline setup) is a common reason for a link to indicate high loss. Follow the instructions above to be certain 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 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 (VFL) 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 patch cord. OTDR testing can be used to determine the section of the link with the event (see the next section). 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

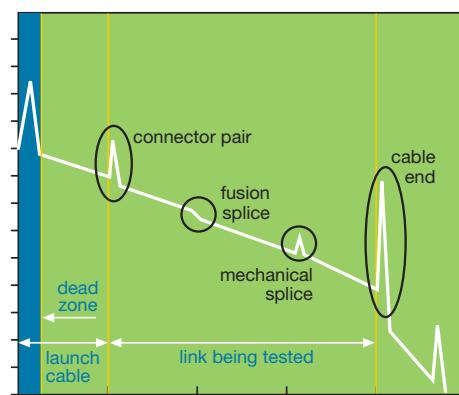
Exact operating methods and features will differ between OTDR manufacturers, but these procedures apply to most OTDRs. There are important settings within the OTDR that must be set according to fiber type before accurate testing can occur (i.e. index of refraction, backscatter coefficient). These can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

**Figure 54: Typical OTDR Trace and Events**



#### **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.

#### **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.

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.

#### **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 these units are 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.

# 16. GLOSSARY

**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

**Access Layer or Access Switch** allows the connected servers to access the network. Also known as Edge Switches

**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 "framing 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 ( $\alpha$  or  $\kappa$ )

**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.

<b>Backbone Raceway</b> 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	<b>Breakout Cable</b> a multifiber cable where each fiber is further protected by an additional jacket and optional strength elements
<b>Backfill</b> materials used to fill an excavation; may be crushed stone, sand or soil	<b>Brush or Brushed</b> A method to partially seal a cable entry way though a floor tile, cabinet top or bottom, or other enclosure. The brushes will block or control air flow while still allowing cables to enter or exit.
<b>Backscattering</b> the scattering of a fiber optic signal in the opposite direction from its intended course	<b>Buffering</b> 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
<b>Balanced Transmission</b> 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)	<b>Buffer Tubes</b> loose-fitting covers over optical fibers, used for protection and isolation
<b>Bandwidth or Bandwidth-Distance Product</b> 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	<b>Building Backbone</b> 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
<b>Barrier</b> a permanent partition installed in a raceway or cable tray to provide complete separation of the adjacent compartment	<b>Building Backbone Cable</b> from ISO/IEC 11801: connects the building distributor to the floor distributor, which may also connect floor distributors in the same building
<b>Building Automation System (BAS)</b> the functionality of the control systems of a building	<b>Building Distributor</b> 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
<b>Baud</b> 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	<b>Building Entrance Facilities</b> from ISO/IEC 11801: provides all necessary mechanical and electrical services for the entry of telecommunications cable into a building
<b>Beamsplitter</b> a device used to divide a optical beam into two or more beams	<b>Buried</b> communications cable that is installed in direct contact with the earth; common installation methods include trenching, plowing or boring
<b>Bend Radius</b> the radius a cable may be bent before the risk of breakage or an increase in attenuation, may also be called cable bend radius	<b>Buried Cable</b> a cable installed directly in the earth without use of underground conduit; also called "direct burial cable"
<b>Bend Radius, Minimum</b> the radius of curvature of the fiber or cable that will result in excessive signal loss or breakage	<b>Byte</b> one character of information, usually 8 bits
<b>Binder Groups</b> 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-white-red-black-yellow-violet-rose-aqua for fiber; for copper, group of 25 pairs identified by colored material	<b>CATV</b> see Cable Television (Community Antenna TV)
<b>Bit</b> basic unit of information in digital transmission	<b>CCTV</b> see Closed Circuit Television
<b>Blade</b> See Server Blade	<b>CPE</b> see Customer Premises Equipment
<b>Bonding Conductor for Telecommunications</b> the conductor interconnecting the telecommunications bonding infrastructure to the building's service equipment (electrical power) ground	<b>CSA</b> see Canadian Standards Association
<b>Braid</b> a fibrous or metallic group of filaments interwoven in cylindrical form to form a covering over one or more wires	<b>CO</b> see Central Office
<b>Braid Angle</b> the smaller of the two angles formed by the shielding strand and the axis of the cable being shielded	<b>CT</b> see Central Tube
<b>Branch for IBIS</b> a consolidation point, typically at the FD/TR, where multiple circuits connect at one point; referred to as connections in TIA/EIA-862	<b>Cable Assembly</b> a completed cable and its associated hardware ready to install
	<b>Cable Bend Radius</b> 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
	<b>Cable Element</b> 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
	<b>Cable Rack</b> vertical or horizontal open support attached to a ceiling or wall
	<b>Cable Sheath</b> a covering over the conductor assembly that may include one or more metallic members, strength members or jackets
	<b>Cable Television (CATV)</b> 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** 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 nonprofit, 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/IEC 11801

**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)** 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

**Chassis** a housing that holds multiple server blades

**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)** any security video system

**Coarse Wave Division Multiplexing** 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 in 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 lower-speed channels in 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 pre-installed 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

**Core Layer or Core Switch** a layer of the network that passes packets as quickly as possible, routing traffic from the outside world to and from the Distribution layer

<b>Count Loop Diversity</b> loop diversity that assigns circuits among different binder groups within one cable	<b>Diffraction</b> bending of radio, sound or lightwaves around an object, barrier or aperture edge
<b>Coverage</b> expressed in percent (%), represents the percent coverage by the braid of the underlying surface	<b>Digital</b> a signal having a limited number of discrete values, such as two (a binary system)
<b>Crossconnect</b> a facility enabling the termination of cable elements and their interconnection and/or cross-connection, usually by means of a patch cord or patch cord	<b>Direct Current Resistance (DCR)</b> the resistance offered by any circuit to the flow of direct current
<b>Crossconnection</b> a connection scheme between cabling runs, subsystems and equipment using patch cords or patch cords that attach to connecting hardware at each end	<b>Dispersion</b> 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
<b>Crosstalk</b> 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	<b>Dissipation Factor</b> the tangent of the loss angle of the insulation material; also referred to as loss tangent, tan, and approximate power factor
<b>CSMA/CA</b> Carrier Sense Multiple Access/Collision Avoidance	<b>Distributed Backbone</b> a star topology that connects desktop devices to the equipment room through horizontal crossconnects in the telecommunications room (TR)
<b>Customer Premises Equipment (CPE)</b> telephones, answering machines, or other terminal equipment located within the customer's premises	<b>Distribution Layer or Distribution Switches</b> used to aggregate multiple access switches as well as take care of routing, access lists, filtering, firewalls, and more
<b>Cut-Off Wavelength</b> the shortest wavelength at which the propagation of one path of light can occur	<b>Distribution Frame</b> a structure with terminations for connecting the permanent cabling of a facility in such a manner that interconnection or crossconnection may be readily made
<b>dB</b> see Decibel	<b>Drain Wire</b> in a cable, the uninsulated wire laid over the component(s), used as a common connection
<b>DCR</b> see Direct Current Resistance	<b>Duct</b> 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
<b>DMD</b> see Differential Mode Delay	<b>Duct Bank</b> an arrangement of ducts in tiers or groups
<b>DWDM</b> see Dense Wave Division Multiplexing	<b>Duplex</b> simultaneous two-way independent transmission
<b>Dark Fiber</b> 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	<b>ELFEXT</b> see Equal Level Far End Crosstalk
<b>Data Center</b> 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	<b>EMI</b> see Electromagnetic Interference
<b>Decibel (dB)</b> a unit for measuring the relative strength of a signal	<b>ER</b> see Equipment Rooms
<b>Demarcation Point</b> a point where operational control or ownership changes	<b>Eccentricity</b> 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
<b>Dense Wavelength Division Multiplexing (DWDM)</b> wavelength division multiplexing systems with very tight spacing in the same transmission window; see also WDM	<b>Edge Switch</b> see Access Layer
<b>Dielectric</b> a material that is nonmetallic and nonconductive; this term is typically used to describe a non-metallic cable	<b>EIA</b> Electronic Industries Association
<b>Dielectric Constant (K)</b> 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	<b>ELFEXT (Equal Level Far End Crosstalk)</b> a method to mathematically subtract out the cable's attenuation in order to accurately compare FEXT values from one cable to another; see FEXT
<b>Dielectric Strength</b> the voltage which an insulation can withstand before breakdown occurs; usually expressed as a voltage gradient (such as volts per mil)	<b>Electromagnetic Interference (EMI)</b> 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
<b>Differential Mode Delay (DMD)</b> 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	<b>Elongation</b> the fractional increase in length of a material stressed in tension
	<b>End User</b> 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

**EDA or Equipment Distribution Area** the TIA-942 defined space occupied by the equipment (servers), racks and cabinets.

**Equipment Rooms (ER)** from ISO/IEC 11801: dedicated to housing distributors and specific equipment

**ESCON (Enterprise Systems Connection)** 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

**Far End Crosstalk (FEXT)** 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)** a 100-Mbs 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 is a resin 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 bi-directionally 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

<b>F/UTP</b> a 100 ohm cable with an overall foil shield and drain wire; formerly called Screened Twisted Pair (ScTP)	<b>Hub</b> 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 of interconnection to trunks and/or cross-connection to distant ends
<b>GHz</b> see GigaHertz	
<b>GRP</b> see Glass Reinforced Plastic	
<b>Gauge</b> a term used to denote the physical size of a wire	
<b>GbE</b> Gigabit Ethernet	
<b>Gb/s</b> Billions of bits per second	
<b>General Purpose Cable</b> 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	
<b>Giga</b> numerical prefix denoting one billion	
<b>Gigahertz (GHz)</b> a unit of frequency that is equal to one billion cycles per second	
<b>Glass-Reinforced Plastic (GRP)</b> a strength member material, see FRP	
<b>Graded-Index Fiber</b> a fiber design where the refractive index of the fiber is lower toward the outside of the fiber core	
<b>Ground</b> 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	
<b>Grounding</b> see bonding	
<b>HC</b> see Horizontal Crossconnect	
<b>HVAC</b> Heating, Ventilating and Air Conditioning	
<b>Hz</b> see Hertz	
<b>Half Duplex</b> a method of transmitting or receiving signals in one direction at a time	
<b>Handhole</b> an access opening, provided in equipment or in a below-the-surface enclosure into which personnel reach, but do not enter to work with or place cable (also known as maintenance access handhole)	
<b>Hard Drawn Copper Wire</b> copper wire that has not been annealed after drawing; sometimes called HD wire	
<b>Harmonic</b> full multiple of a base frequency	
<b>Headend</b> 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	
<b>Helical Stranding</b> a stranding method in which the elements are stranded in one continuous direction	
<b>Home Run</b> a common term used to describe telecommunications cabling run in a star topology; e.g. direct from outlet to the telecommunications room	
<b>Horizontal Cable</b> 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	
<b>Horizontal Cross-connect (HC)</b> a cross-connect of horizontal cabling to other cabling	
<b>Horizontal Distribution Area (HDA)</b> the TIA-942 defined space where the horizontal cross-connect is located, along with the switches for the storage area and local area networks	
	<b>Heating, Ventilation, and Cooling (HVAC)</b> a system to control the climate by regulating the temperature and air flow
	<b>Hybrid Cable</b> an assembly of one or more cables, of the same or different types or categories, covered by one overall sheath
	<b>Hypervisor</b> a computer software/hardware platform virtualization software that allows multiple operating systems to run on a host computer concurrently
	<b>Hz</b> Hertz, cycle per second
	<b>IC</b> see Intermediate Crossconnect or Integrated Circuit
	<b>ICT</b> Information and Communication Technology
	<b>IDC</b> see Insulation Distributing Connector
	<b>ISDN</b> see Integrated Services Digital Network
	<b>ICEA</b> Insulated Cable Engineers Association
	<b>IEC</b> International Electrotechnical Commission
	<b>IEEE</b> Institute for Electrical and Electronics Engineers; 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
	<b>Impedance</b> 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
	<b>Index-Matching Fluid or Gel</b> a fluid with an index of refraction close to that of glass that reduces reflections caused by refractive-index differences
	<b>Index of Refraction</b> ratio of velocity of light in a vacuum to the velocity of light within a given transmitting medium
	<b>Indoor Cable</b> 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
	<b>Indoor /Outdoor Cable</b> cable rated for use indoors and suitable for outdoor environmental conditions
	<b>Inductance</b> 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
	<b>InfiniBand</b> an industry standard interconnect technology for data centers and high performance computing (HPC). It is a switched fabric I/O technology that ties together servers, storage devices, and network devices
	<b>Infrared</b> the range of the electromagnetic spectrum from 780 nm to 1 mm; optical signal transmission takes place within the infrared portion of the spectrum
	<b>Infrastructure</b> a collection of components, excluding equipment, that provides the basic support for the distribution of all information within a building or campus
	<b>Innerduct</b> 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; designed to be connected to the conductor of an insulated wire by a connection process which forces a blade or blades through the insulation, removing the need to strip the wire before connecting.
- 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 patch cord
- Intermediate Cross-connect (IC)** a crossconnect 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
- Intelligent Building** as defined by the IBI (Intelligent Buildings Institute) in the US, is one that provides a productive and cost-effective environment through optimization of its four basic components - structure, systems, services and management - and the interrelationships between them.
- 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** that part of the network 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)** 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

<b>Loss</b> energy dissipated without accomplishing useful work	<b>Mode</b> light path through a fiber, as in multimode or single mode
<b>Low Loss Dielectric</b> an insulating material that has a relatively low dielectric loss, such as polyethylene or Teflon	<b>Mode Field Diameter</b> 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
<b>Low Smoke Zero Halogen (LSZH)</b> a class of cables made without halogens (i.e. chlorine and fluorine) to meet specific and strict fire safety codes	<b>Modulation</b> a process where certain characteristics of a wave, which is often called the carrier, are varied or selected in accordance with a modulating function
<b>MAN</b> see Metropolitan Area Network	<b>Modulus of Elasticity</b> the ratio of stress to strain in an elastic material
<b>MUTOA</b> see Multi-User Telecommunications Outlet Assembly	<b>Modular Plastic Duct</b> a type of telecommunications duct. Available in molded formations of 4, 6, or 9 ducts in lengths of 36 in.; can be direct buried
<b>MUX</b> see Multiplexer	<b>MPO</b> an array connector that most commonly has a single-row of 12-fibers; provides high density and speed of connection for data center applications
<b>Macrobending</b> relatively large deviations in the waveguide that can result in increased attenuation or loss due to bend radius	<b>Multimedia</b> 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
<b>Main Cross-connect (MC)</b> a cross-connect for first level backbone cables, entrance cables and equipment cables	<b>Multimode</b> 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 waveform spatial quality of the electromagnetic beam
<b>Material Dispersion</b> dispersion caused by differential delay of various wavelengths of light in a waveguide material	<b>Multiplexer (MUX)</b> equipment used to combine multiple signals for transmission on a single channel
<b>Main Distribution Area (MDA)</b> the TIA-942 defined space where the main cross-connect is located along with the core switches; this is the central point for the data center structured cabling system.	<b>Multiplexing</b> combination of independent signals for transmission within one waveguide
<b>Mechanical Splicing</b> joining two fibers together by permanent or temporary mechanical means (vs. fusion splicing or connectors) to enable a continuous signal	<b>Multi-User Outlet</b> a telecommunications outlet used to serve more than one work area, typically in open-systems furniture applications
<b>Media</b> telecommunications wire, cable or conductors used for telecommunications	<b>Multi-User Telecommunications Outlet Assembly</b>
<b>Medium-Density Polyethylene (MDPE)</b> a type of plastic material used to make cable jacketing	<b>(MUTOA)</b> an easily-reconfigured midchannel consolidation point
<b>Meg or Mega</b> a numerical prefix denoting 1,000,000 (10 <sup>6</sup> )	<b>Mutual Capacitance</b> capacitance between two conductors when all other conductors including ground are connected together and then regarded as an ignored ground
<b>Megabits per second (Mb/s)</b> million bits per second	<b>NEC</b> see National Electric Code
<b>Megahertz (MHz)</b> a unit of frequency that is equal to one million cycles per second	<b>NESC</b> see National Electrical Safety Code
<b>Messenger</b> a support strand, typically constructed of steel or Kevlar cable, used for attachment of communications cable for aerial plant	<b>NEXT</b> see Near End Crosstalk
<b>Metropolitan Area Network (MAN)</b> a citywide or regional public access data and telecommunication network	<b>Nano</b> numerical prefix denoting one-billionth
<b>Micro</b> numerical prefix denoting one-millionth	<b>Nanometer</b> unit of measurement equal to one billionth of a meter
<b>Micron</b> one-millionth of a meter	<b>National Electrical Code (NEC)</b> 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).
<b>Microbending</b> bends that take place on a microscopic level, which can result in increased attenuation, or loss due to light loss at that specific point	<b>National Electrical Safety Code (NESC)</b> 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.
<b>Micrometer (<math>\mu\text{m}</math>) or micron</b> one millionth of a meter; typically used to express the geometric dimension of fibers	
<b>Microwave</b> portion of the electromagnetic spectrum above 760 MHz	
<b>Modal Dispersion</b> propagation delay between modes within a multimode fiber; this will cause a change in shape (broadening) of a pulse traveling within a multimode fiber	

<b>NEC Rated</b> cable that has been certified as plenum-rated, riser-rated or general cable by passing of flame propagation testing	<b>Patch cord</b> a cable assembly with connectors at both ends, used to join telecommunications circuits or links at the cross-connect
<b>NEMA</b> National Electrical Manufacturer's Association	<b>Packet Switching</b> a communications method where packets (messages) are individually routed between hosts, with no previously established communications path
<b>Near End Crosstalk (NEXT)</b> 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	<b>Pair-to-Pair Crosstalk</b> the crosstalk measurement of a single disturbing pair. It can be made for NEXT or FEXT
<b>NFPA</b> National Fire Protection Association	<b>Parallel Optics</b> the process of taking a high data signal and breaking it up into multiple lower-data rate signals before transmission across the physical media; this scenario is utilized for 40 and 100G Ethernet as well as high data rate Fibre Channel applications to allow the use of today's optical fibers as well as lower-cost VCSEL transmitter components
<b>NID</b> Network Interface Device	<b>Passive Optical Components</b> components, such as splitters, couplers and connectors, which do not require external power to perform their function
<b>Node</b> 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	<b>Patch Cable</b> a length of cable with connectors on one or both ends to join telecommunications links
<b>Non-zero DS</b> refers to an improved type of dispersion-shifted fiber in which dispersion at 1550 nm is substantially reduced compared with conventional single-mode fiber, but dispersion is not zero at 1550 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 1550-nm window	<b>Patch Cord</b> a length of cable with connectors on one or both ends used to join telecommunications circuits or links at the cross-connect
<b>Numerical Aperture</b> measure, in radians, of the angle that expresses the light-gathering point of optical fiber	<b>Patch Panel</b> a cross-connect system of mateable connectors that facilitates administration
<b>OSP</b> see Outside Plant	<b>Pathway</b> a facility for the placement of telecommunications cable
<b>OTDR</b> see Optical Time Domain Reflectometer	<b>Power Distribution Unit (PDU)</b> the device that steps down the data center voltage to a value used by the end equipment
<b>OC-X (Optical Carrier - Level X)</b> 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)	<b>Periodicity</b> 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
<b>Ohm</b> a unit of electrical resistance or impedance	<b>Personal Computer (PC)</b> any general purpose computer whose size and capabilities make it useful for individuals and which is intended to be operated by an end user
<b>Optical Receiver</b> an electronic device which converts optical signals to electrical signals	<b>Pico</b> a numerical prefix denoting one-trillionth (10-12)
<b>Optical Time Domain Reflectometer (OTDR)</b> 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	<b>Pigtail</b> a length of fiber attached to a device so that it can be spliced into the network; the pigtailed 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
<b>OSHA</b> Occupational Safety and Health Administration	<b>Plenum Cables</b> this type of cable meets specifications for plenum ratings (NFPA-262), and is one of three types installed in premises networks
<b>Outdoor Cable</b> 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	<b>Point-To-Point</b> a connection established between two specific locations, as between two buildings
<b>Outside Plant (OSP)</b> refers to all cable and equipment located outside	<b>Poke-through</b> 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
<b>PBX</b> see Private Branch Exchange	<b>Polyethylene (PE)</b> a type of plastic material used for outside plant cable jackets
<b>PC</b> see either Personal Computer or Positive Contact (for a fiber connector)	<b>Polyvinyl Chloride (PVC)</b> a type of plastic material used for cable jacketing; typically used in flame-retardant cables
<b>PE</b> see Polyethylene	
<b>PSumXT</b> see Power Sum Crosstalk	
<b>PVC</b> see Polyvinyl Chloride	
<b>Packet</b> a group of bits, including data and control elements, that are switched and transmitted together	

**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

**Power Usage Effectiveness (PUE)** a method for measuring Data Center efficiency, determined by dividing the total Data Center input power by the power used by the IT equipment

**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

**PUE** see Power Usage Effectiveness

**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)** an 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"

**RG/U** "RG" is the military designation for "Radio Grade" coaxial cable, and "U" stands for "general Utility"

**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)

**Rack Unit (RU)** a measure of how much vertical space is available on a rack of a given height or how much vertical space is required on that rack by a device. 1U is equivalent to 1.75"

**Storage Area Network (SAN)** connects storage devices to the network

**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

**Serial Transmission** a signal that is contained within one pathway. Gigabit Ethernet can be described as a serial transmission when 1G is sent over 1 fiber in each direction

- Self-Support** see figure-eight
- Server Blade** a server that is stripped of most of its components to leave only the computing function; must be inserted into a server chassis for operation
- 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
- 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 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 enter 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

**Top of Rack (ToR)** a network architecture that consolidates all of the cabling from a cabinet or rack into one device located on that rack that is linked elsewhere in the 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

**Vias** within printed circuit board design, the pads with plated holes that provide electrical connections between copper traces on different layers of the board

**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)** 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

**Zone Distribution Area (ZDA)** the TIA-942 defined space where a zone outlet or consolidation point is located; the ZDA typically only includes passive devices.

**Zero-Dispersion Wavelength** wavelength at which the chromatic dispersion of an optical fiber is zero; occurs when waveguide dispersion cancels out material dispersion



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