Designing a Scalable Network Infrastructure

This chapter discusses the Data Center's structured cabling and outlines the importance of a well-organized physical hierarchy. The chapter explains the differences between common cabling media, suggests which are most appropriate in various scenarios, and presents best practices for installation and testing.

Importance of the Physical Network

Arguably, the most intricate part of the server environment's design, from an infrastructure standpoint, is its structured cabling system. While a Data Center's electrical infrastructure is crucial for keeping servers and networking devices running, it is the physical network—cable runs and their terminations—that dictates how (and if) these items communicate with one another and the outside world. Your network's structured cabling must be abundant in order to provide ample connectivity, employ various media to accommodate different machines, and be well organized so that the entire system is easy to learn, and simple to manage. All of this also needs to be done in tight spaces, terminating in multimedia boxes, data faceplates, four-post network cabinets, or two-post relay racks.

A Data Center's usability is greatly affected by the following:

- Cabling media choices
- How many connections are provided
- How cable terminations are organized

These are all key decisions that need to be made during the initial design of a server environment. Space constraints and the presence of running servers make it very difficult to reconfigure cabling infrastructure once a Data Center is online. Design your physical network well and you have a scalable infrastructure that can meet your company's needs for years. Design it poorly and you will likely incur downtime to reconfigure or expand that infrastructure to address shortcomings in the original design.

Following are a few tips to keep in mind as you design your Data Center's physical cabling network:

- **Build the entire structured cabling system during initial construction**—Some companies try to save on the initial cost of their Data Center by installing cabling to only certain server cabinet locations, with the intention of adding more later when additional equipment arrives. This is understandable, but not recommended—for the same reasons as for the installation of the room's electrical infrastructure. Running cable to all cabinet locations during initial construction makes the room easier to manage and avoids subjecting servers to potential downtime later when additional cabling is run. An up-front installation is also ultimately less expensive than adding cabling piecemeal since labor costs invariably rise over time.

- **Use shorter cable runs whenever possible**—Lay out Data Center cabinets so that devices can be connected with shorter rather than longer runs of cable. Shorter cables are less expensive and provide better performance. Abbreviated cable runs also reduce the potential for outages, since they provide less cabling in the Data Center to be affected by an incident.

- **Choose the right cabling media for the right connection**—What type of structured cabling to install into a Data Center isn't always as obvious as it seems. For instance, some cable solutions are cheaper to install, but require more expensive components (i.e., network cards) to be installed into servers, possibly resulting in a higher overall cost to your company. Choosing the most appropriate cabling also requires anticipating future needs, since you don't want to equip your Data Center with media that will quickly become outdated.
Cabling Hierarchy

There are essentially two ways to lay out your Data Center's physical network. Both approaches begin by creating a row to house the server environment's major networking devices. There are many terms used for this row:

- Room distributor
- Special distribution framework
- Home row
- Main street
- Network hub

It is simply referred to in this book as the network row. From the network row, structured cabling needs to be run to server rows.

One approach is structured cable runs routed directly to each server cabinet location. This works moderately well in a smaller server environment, say a room with fewer than 25 server cabinet locations. The cabling travels a relatively short distance and can be managed to stay fairly neat and organized. This approach doesn't work very well for large Data Centers, however. Cable bundles overlap and become tangled, making it very difficult to manage, trace, or remove them in the future.

A second approach is a network substation established at strategic locations in the Data Center—say at the end of each row—and then cable from the network row to the server cabinet locations by way of the substation. This substation, sometimes called a row distributor or zonal cabinet, serves the same purpose that end-of-row circuit panels do for the electrical infrastructure. Not only do network substations keep structured cabling better organized, but they also provide a level of distribution and redundancy for the Data Center network. By installing a highly available network device into each substation instead of consolidating them within the network row, each row of servers can be supported by a different networking device rather than having them all connect to one or two in the network row. This arrangement also limits the scope of downtime—in the event that a network device fails—to a single server row. Similarly, if an infrastructure problem arises at one cabinet location, you can immediately relocate servers to another row supported by identical infrastructure and networking devices.

Using networking devices at each server row also enables server connections to be aggregated and cable runs back to the network row to be greatly reduced. Fewer cable runs can, in turn, lead to improved airflow below the raised floor.

This approach does come with its own set of challenges, however. For one, data connections must pass through an additional patching field at the network substation. Every additional connection point along a cable run causes a slight degradation in the signal. So, passing through fewer termination points generally means better performance. Network substations in a Data Center also occupy floor space that can otherwise be used as server cabinet locations.

The largest effect of all, though, is that the more network substations you include in a Data Center design, the more networking equipment you must purchase. Because networking devices can be expensive, weigh the benefits of this distributed design against their price tag. If costs become prohibitive, consider using a smaller ratio of substations to server cabinet locations—perhaps one substation to support two server rows instead of one, for example.

### Designing for Physical Versus Logical Network Topology

As this book deals with the physical infrastructure of your Data Center, I recommend the distributed model. Using network substations follows good principles of Data Center infrastructure design because the substations make the server environment more robust, modular, flexible, and standardized.

I work in both models of Data Center, some with direct-connect structured cabling and others with distributed structured cabling. As someone who manages physical infrastructure, I find the distributed design much easier to deal with due to its redundancy and organizational benefits. I consider the network substations an effective use of floor space, much like setting aside cabinet space for much-needed wire management, and I have seen no drop in performance because of the substations.

You will find many Data Center network designers who call for a direct-connect approach, however. That is because their designs focus on the logical topology of a network and pay little attention to the physical topology. That is, their designs streamline the paths that data travels from one point of the network to another but don't address the structured cabling that must be installed to enable the logical functions to occur.

These competing priorities are one of the toughest challenges facing a Data Center designer—more distribution points make the physical network easier to manage and the logical network more complex. Fewer distribution points make the physical network more complicated and the logical network simpler. You must decide upon which network elements are most critical for your Data Center, and design your cabling hierarchy accordingly.
Figure 7-1 shows structured cabling running directly from a network row to multiple server cabinet locations, while Figure 7-2 shows the same number of connections made by way of a network substation at the end of each server row.

The cabling hierarchies in Figures 7-1 and 7-2 should look familiar. They are similar to the power distribution models outlined in Chapter 6, "Creating a Robust Electrical System," except that they involve data cabling instead of electrical conduits. In addition to the other benefits that a distributed design provides, employing it for both your power and data provides consistency and makes your server environment easier for users to work in. Once a user understands the concept for one system, the user understands it for both.

Assuming you use the distributed design for your Data Center, orient the server rows perpendicular to the network row when designing the room. Then place each server row's network substation at the end closest to the network row. This makes the cable run between the network row and the network substations as short as possible, which is less expensive to install. The shorter runs also provide marginally better performance.
Cable Characteristics

Data Center connectivity is provided by two broad types of cabling media—copper and fiber—and they in turn come in different configurations that offer various levels of performance.

NOTE

This chapter focuses primarily on copper- and fiber-structured cabling that is initially installed in a server environment. Patch cords, which are smaller lengths of pre-terminated cable used to connect into these structured cabling systems, are discussed in Chapter 12, "Stocking and Standardizing."

To assess the capabilities of each cable type and configuration and make an informed decision about what to install in your server environment, it is necessary to first understand how cable performance is measured.

The speed at which data can travel across a cable is measured in kilobits per second (Kbps), megabits per second (Mbps), or gigabits per second (Gbps). The capacity of information that a cable can carry, its bandwidth or frequency, is measured in megahertz (MHz).

Bandwidth and speed are sometimes discussed interchangeably, but really shouldn't be. They represent two different qualities of a cable. Imagine that your physical cabling network is a highway. The higher its Mbps rating, the more cars that can drive along the road. The higher its MHz rating, the more lanes the road has. Greater bandwidth won't increase the speed at which information is passed along a cable, but it is necessary in order to accommodate high-end demands such as video broadcasts. Another apt comparison is a water pipe. A larger pipe, enabling a greater volume of water to pass through, equates to greater bandwidth (MHz). More water pressure equates to higher speed (Mbps).

Copper Cabling

Copper cabling has been used for decades in office buildings, Data Centers, and other installations to provide connectivity. Copper is a reliable medium for transmitting information over shorter distances; its performance is only guaranteed up to 109.4 yards (100 meters) between devices.

NOTE

Technically, that distance limitation includes 98.4 yards (90 meters) of structured cabling and a total of 10.9 yards (10 meters) of patch cords on either end.

Copper cabling that is used for data network connectivity contains four pairs of wires, which are twisted along the length of the cable. The twist is crucial to the correct operation of the cable—if the wires unravel, the cable becomes more susceptible to interference.

Copper cables come in two configurations:

- **Solid cables**— Provide better performance and are less susceptible to interference, making them the preferred choice for use in a server environment.
- **Stranded cables**— More flexible and less expensive, and typically only used in patch cord construction.

Copper cabling, patch cords, and connectors are classified based upon their performance characteristics and what applications they are typically used for. These ratings, called categories, are spelled out in the TIA/EIA 568 Commercial Building Telecommunications Wiring Standard. TIA is the Telecommunications Industry Association; EIA is the Electronics Industries Alliance. Both are trade organizations that develop industry technology standards for electronics, telecommunications, and information technology equipment.

NOTE

Consider TIA/EIA 568 and its addendums your bible for recommended Data Center cabling practices. Installation practices, performance standards, and testing procedures are all covered by it. Buy a copy and reference it liberally in your design documents. You can find this document online at [http://www.tiaonline.org/](http://www.tiaonline.org/).
The lowest rating of copper cable used in modern Data Centers is Category 5. Previous categories were used for telephone systems and, by today's standards, slower network connections. Technically, even Category 5 cable is considered obsolete by TIA/EIA in favor of Category 5E—the E stands for enhanced—but it can still be found in server environments built in recent years.

Table 7-1 outlines the minimum standards for copper cabling, by category. As of this writing, a definition for Category 7 is still under development, so the listed criteria are only projections.

<table>
<thead>
<tr>
<th>Category</th>
<th>Cat5</th>
<th>Cat5E</th>
<th>Cat6</th>
<th>Cat7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>250 MHz</td>
<td>600 MHz</td>
</tr>
<tr>
<td>Attenuation</td>
<td>22 dB</td>
<td>22 dB</td>
<td>19.8 dB</td>
<td>20.8 dB</td>
</tr>
<tr>
<td>Characteristic Impedance</td>
<td>100 ohms ±15%</td>
<td>100 ohms ±15%</td>
<td>100 ohms ±15%</td>
<td>100 ohms ±15%</td>
</tr>
<tr>
<td>NEXT</td>
<td>32.3 dB</td>
<td>35.3 dB</td>
<td>44.3 dB</td>
<td>62.1 dB</td>
</tr>
<tr>
<td>PS-NEXT</td>
<td>-</td>
<td>32.3 dB</td>
<td>42.3 dB</td>
<td>59.1 dB</td>
</tr>
<tr>
<td>ELFEXT</td>
<td>-</td>
<td>23.8 dB</td>
<td>27.8 dB</td>
<td>Not yet specified</td>
</tr>
<tr>
<td>PS-ELFEXT</td>
<td>-</td>
<td>20.8 dB</td>
<td>24.8 dB</td>
<td>Not yet specified</td>
</tr>
<tr>
<td>Return Loss</td>
<td>-</td>
<td>20.1 dB</td>
<td>20.1 dB</td>
<td>14.1 dB</td>
</tr>
<tr>
<td>Delay Skew</td>
<td>-</td>
<td>45 ns</td>
<td>45 ns</td>
<td>20 ns</td>
</tr>
</tbody>
</table>

The attenuation and all cross-talk requirements are at a minimum of 100 MHz, while the delay skew is at a maximum of 109.4 yards (100 meters).

So, what do all of these statistics mean? Following are definitions of each characteristic:

- **Attenuation, also called loss**—A reduction in signal strength during transmission. It is measured in decibels (dB) and normally occurs over long distances. The less attenuation, the more efficient a cable is.

- **Characteristic impedance**—The opposition that a cable or component gives to the flow of an alternating electrical current. This impedance can affect the performance of high-speed networks.

- **NEXT, PS-NEXT, ELFEXT, and PS-ELFEXT**—Refer to crosstalk, which is when a signal carried along one set of cable wires interferes with a signal on another nearby set. This is much like if you were talking on the telephone and began to hear a conversation from a nearby phone line. Crosstalk is measured in decibels (dB) and is typically caused by poorly twisted terminations at the connection points. The different types of crosstalk are defined as follows:
  - **NEXT**—When measured at the end closest to the transmitter, it is called near end cross talk (NEXT).
  - **FEXT**—When measured at the end farthest from the transmitter, it is called far end cross talk (FEXT).
  - **Power Sum (PS)**—All possible combinations of interference from adjacent cable pairs added up is the power sum (PS).
  - **ELFEXT**—The subtracted attenuation of a signal due to cable length is equal level far end cross talk (ELFEXT). The amount of crosstalk enabled on a copper cable actually increases with a higher category of cable because its better construction makes it more resistant to interference.

- **Return loss**—Noise that occurs when a signal travels down a cable and encounters a jack or other piece of connecting hardware. The greater the impedance difference between the two items, the more noise—return loss—that results. If the cable and connecting item have the same impedance, there is no return loss.

- **Delay skew**—Refers to the different amounts of time that it takes for a signal to travel down a copper cable's various internal wires. Because a copper cable contains four pairs of twisted wires, those wires can be slightly different in length from one another. The difference between the fastest and slowest pairs is the delay skew. Errors can occur if a cable's delay skew is too great.

When specifying structured cabling and connectors during the construction of a server environment or ordering of patch cords to support an existing room, be aware of what cabling standards have been adopted by industry organizations. Someone is stretching the truth in selling cables, connectors, or patch cords and claiming that they meet standards that haven't been ratified. Really, he or she is selling a cable exceeding existing standards, and assuming that it will meet the upcoming standard.
NOTE

In the years before Category 6 standards were recognized by TIA/EIA, I had several vendors offer to sell me patch cords purported to be Category 6. While the patch cords exceeded Category 5E standards and were fine for my needs, they weren’t Category 6, because technically it didn’t yet exist.

It is important to note that many cabling products on the market are made to significantly outperform the standards that have been adopted by the cabling industry. Many Category 5E cables are capable of performing well beyond 100 MHz, for example. Manufacturers make better cables and components to attract buyers to their brand of products, and competition drives them to make continual improvements. Therefore, your Data Center’s connectivity needs aren’t limited to the minimum capabilities associated with a particular rating of cable. If you need better performance and are willing to pay more, you can very likely obtain it.

Category 5, 5E, and 6 cabling materials are all compatible with one another. Mixing components along a connection provides performance that is somewhere in the middle of what the individual items normally offer. For example, terminating a Category 5 cable with a Category 6 jack is going to perform better than if the system consisted entirely of Category 5 components but not as well as if only Category 6 items were used.

**Fiber-Optic Cable**

Fiber-optic cable is another common medium for providing connectivity. Fiber cable consists of five elements. The center portion of the cable, known as the core, is a hair-thin strand of glass capable of carrying light. This core is surrounded by a thin layer of slightly purer glass, called cladding, that contains and refracts that light. Core and cladding glass are covered in a coating of plastic to protect them from dust or scratches. Strengthening fibers are then added to protect the core during installation. Finally, all of these materials are wrapped in plastic or other protective substance that is the cable’s jacket.

Figure 7-3 shows the components of a fiber optic cable.

Figure 7-3. Anatomy of a Fiber Cable

A light source, blinking billions of times per second, is used to transmit data along a fiber cable. Fiber optic components work by turning electronic signals into light signals and vice versa. Light travels down the interior of the glass, refracting off of the cladding and continuing onward until it arrives at the other end of the cable and is seen by receiving equipment.

When light passes from one transparent medium to another, like from air to water or in this case from the glass core to the cladding material, the light bends. A fiber cable’s cladding consists of a different material from the core—in technical terms, it has a different refraction index—that bends the light back toward the core. This phenomenon, known as total internal reflection, keeps the light moving along a fiber optic cable for great distances, even if that cable is curved. Without the cladding, light would leak out.
NOTE

To see refraction in action, fill a clear drinking glass with water and drop in a piece of silverware. When viewed from an angle, the utensil appears bent. This is because light waves bend as they pass from the denser water into the less dense air.

Fiber cabling can handle connections over a much greater distance than copper cabling, 50 miles (80.5 kilometers) or more in some configurations. Because light is used to transmit the signal, the upper limits of how far a signal can travel along a fiber cable is related not only to the properties of the cable but also to the capabilities and relative location of transmitters.

Besides distance, fiber cabling has several other advantages over copper:

- Fiber provides faster connection speeds.
- Fiber isn't prone to electrical interference or vibration.
- Fiber is thinner and lighter weight, so more cabling can fit in to the same size bundle or limited spaces.
- Signal loss over distance is less along optical fiber than copper wire.

Multimode Fiber

Multimode fiber is commonly used to provide connectivity over moderate distances, such as those in most Data Center environments or among rooms within a single building. A light-emitting diode (LED) is its standard light source. The term multimode refers to the several rays of light that proceed down the fiber.

Multimode fiber comes in multiple types, with the two most common listed as 62.5/125 mm and 50/125 mm. The first number represents the diameter of the cable's core; the second represents the size of the cladding. Both values are in microns, which is one millionth of a meter.

The cable with the smallest diameter core provides the fastest connectivity, because the internal refraction that occurs in a cable moves a signal faster along a narrow core than in a larger one. The reflecting light crosses shorter distances in a narrower core.

Figures 7-4 and 7-5 illustrate how light travels along fiber optic cables with different core diameters.

Figure 7-4. Internal Refraction Within Multimode Fiber

Figure 7-5. Internal Refraction Within Singlemode Fiber
Singlemode Fiber

Singlemode fiber is used for the longest distances, such as among buildings on a large campus or between sites. It has a smaller core than multimode fiber, and a laser is its standard light source. It also has the highest bandwidth. The de facto standard core size for singlemode fiber is 8.3/125 mm, although alternative diameters are occasionally used in a few regions of the world. Specify this size in your design documents to avoid confusion.

As newer servers and other devices require faster connection speeds, there is growing interest in installing singlemode fiber deeper into server environments, not just to connect a distant networking room to the Data Center's network row but also to extend that connection to individual server rows. This is still an uncommon practice, however, because network interface cards for singlemode fiber are more expensive than other types. At shorter distances, there can also be a problem of a singlemode fiber's laser light source traveling too rapidly for a receiver to read, requiring installers to intentionally attenuate the signal.

Table 7-2 shows the minimum cable performance capabilities of different types of fiber cable. (Wavelengths are expressed in nanometers.)

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Cable Type Wavelength</th>
<th>Maximum Attenuation</th>
<th>Minimum Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.5 mm MM</td>
<td>850 nm</td>
<td>3.5 dB/km</td>
<td>500 MHz-km</td>
</tr>
<tr>
<td></td>
<td>1300 nm</td>
<td>1.5 dB/km</td>
<td>500 MHz-km</td>
</tr>
<tr>
<td>50 mm MM</td>
<td>850 nm</td>
<td>3.5 dB/km</td>
<td>160 MHz-km</td>
</tr>
<tr>
<td></td>
<td>1300 nm</td>
<td>1.5 dB/km</td>
<td>500 MHz-km</td>
</tr>
<tr>
<td>8.3 mm SM</td>
<td>1300 nm</td>
<td>1.0 dB/km</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>1550 nm</td>
<td>0.5 dB/km</td>
<td>n/a</td>
</tr>
</tbody>
</table>

NOTE

Don't mix different types of fiber. Unlike mixing different types of copper, which results in an averaged performance, mixing fiber creates substantial signal loss.

Cabling Costs

Because fiber optic cable provides greater performance than copper, you are probably assuming that it is significantly more expensive, too. In truth, the price tags of the two media depend greatly upon the distances involved and levels of performance that are needed.

Copper is generally the less-expensive solution over shorter distances, say the length of your Data Center's server rows, while fiber is less expensive for longer distances such as connections among buildings on a campus. That's because the copper cabling material itself is more expensive than fiber, but the electronic components used in the physical network—namely the network interface cards in each server—are more expensive for fiber than copper. Installations with long cable runs can offset the higher electronics costs, not to mention take full advantage of fiber's greater performance capabilities.

If more than one combination of infrastructure components can provide your Data Center with the features you are looking for, comparison shop to see if you can reduce costs. You don't want to sacrifice functionality or standardization, but you also don't want to buy a $10 item when an equivalent one is available for $5. Don't rely upon vendors to tell you the most cost-effective way of purchasing or configuring your infrastructure components. Many of them won't.
NOTE

My typical Data Center design calls for installing hundreds of copper jacks into the network row and the network substations at the end of each server row. Either of two patch panels from a particular manufacturer can be used to house the jacks—one is a 2U panel with 48 jacks, and the other is a 1U panel with 24 jacks. They are identical in every way except that one is exactly twice the height and capacity of the other; there is no functional or even cosmetic difference between installing four 2U panels or eight 1U panels.

For several consecutive projects, I exclusively used the 1U panels. They enabled me to install an odd number of patch panels where appropriate, and I figured that skipping the 2U panel avoided a superfluous part number and might even have led to a bulk discount on the 1U panels. A later audit of project costs revealed that, although the 1U panels were half the size and capacity of the 2U panels, they were significantly more than half the price. Replacing the 1U panels with 2U panels would have saved thousands of dollars per project!

When this was pointed out to the vendor, he smiled knowingly and said “We just gave you what you ordered.”

Storage Area Networks (SANs)

A growing number of server environments now incorporate a storage area network (SAN) into their design. A SAN enables data from different servers to be transmitted over a dedicated network and stored, as needed, on various storage devices. Without a SAN, a server must be cabled directly to its own storage unit. With a SAN, any server in the network can potentially connect to any storage device in the network. This enables greater management of storage resources and, because data isn't residing on the servers themselves, frees up their processing abilities for other tasks.

From the perspective of Data Center infrastructure design, a SAN is largely the same as any other network. If you choose to have one within your Data Center, you must allocate cabinet space for SAN-related devices and provide structured cabling for connectivity. Fifty micron multimode fiber is the current standard medium. One SAN element that is different from the infrastructure perspective, however, is that (at least today) SAN equipment doesn't enable consolidated connections between devices in the way that conventional networking equipment does. This means that a SAN often requires larger amounts of cabling—both structured cabling and patch cords—than other networks.

Because a SAN is the same as any other network from a Data Center infrastructure perspective, consider housing your SAN's disk equipment and patching fields alongside your standard network's devices and cabling. Terminating the structured cabling for both your regular and storage networks provides consistency for Data Center users, making both systems easier to understand. Make sure that the components of both network systems are clearly labeled, so users can readily tell the difference between them.
Determining Connectivity Requirements

Servers and networking devices have a wide range of connectivity needs. A single server cabinet filled with equipment can therefore require dozens of connections or just a few. How, then, do you decide how much structured cabling to provide in your Data Center?

If you organize equipment in your Data Center by type of server, then research what connectivity each server requires and equip accordingly the corresponding rows where you plan to install them. This approach is simple when a server environment first comes online, but can cause headaches in the future. It creates different levels of infrastructure in the Data Center and locks in where equipment must be placed in the room. If you fail to accurately predict how many of a given server your Data Center is going to host or if technology changes, you must periodically retrofit portions of the Data Center to keep up.

If you organize equipment in your Data Center by function or work group, then choose a level of connectivity that can accommodate most servers and combinations of devices that might be grouped together in a server cabinet. Equip all Data Center cabinet locations with this amount of cabling. This might seem a less precise approach because you are designing to a theoretical average rather than specific equipment. It is a superior design, though, because it leads to a uniform amount of infrastructure rather than to peaks and valleys. Because all server rows are identically equipped and the room is organized by function rather than form, servers with high and low connectivity needs can be mixed together so as not to exceed the amount of cabling provided at any single server cabinet location.

NOTE

When specifying fiber quantities in your design documents, choose your terminology—ports, strands, or pairs—and be consistent. Merely calling for "24 fiber" at a location, for example, can be interpreted in two ways.

Depending upon the type of a connector used, a patch cord may occupy one port in a patching field while containing two strands. That same cable can also be referred to as one fiber pair. It is equally correct to describe that connection as one port, two strands, or one pair of fiber, so that request for "24 fiber" could mean 24 strands (12 ports), or 24 ports (48 strands).

I recommend using strands. The term is used consistently in the fiber industry, and any misunderstandings that do occur are going to result in an overabundance of connections, which is easier to deal with than not having enough.

As you determine how much connectivity to provide to each server cabinet location, be aware of how much space those cable runs occupy in your Data Center's network substations (or network row, if you choose to make direct connections). Higher cabling density requires more space to house patch panels and fiber housings, which means you might need to set aside additional cabinet locations to house them.

NOTE

My current standard for Data Center connectivity is to provide 24 strands (12 ports) of 50 mm multimode fiber and 24 ports of Category 5E copper to each server cabinet location. That is 432 connections for a row of 12 server cabinets. Placing a network device within each network substation then enables me to reduce the connections to the network row from 432 down to just 36—24 strands (12 ports) of fiber and 24 ports of copper.

These quantities address the connectivity needs of most combinations of servers, although it cannot accommodate a server cabinet filled entirely with 1U servers. I try to avoid such a massive installation anyway, though, because of the intense heat and weight it generates.

Network Redundancy

Where electrical redundancy is provided to your servers by electrical conduits running from more than one power distribution unit, network redundancy is provided by structured cabling running from more than one networking device. Whereas electrical conduits must be hardwired into the PDUs, however, structured cabling is standalone infrastructure that any networking devices can be plugged into. Each cable is essentially providing its own path, and you just need additional networking devices to make them redundant.

This means that, as long as you provide abundant structured cabling throughout the Data Center, you increase redundancy as much as you want by simply installing more networking devices at the network row and network substations. If you want to provide a minimum level of redundancy over the entire Data Center, install a second set of networking devices in the network row and patch to key components at the network substations. If you want to provide an even greater level of redundancy, double the networking devices at each network substation.

Providing this redundancy may or may not require additional cabling infrastructure. It depends upon how many network connections a given server requires, and how many servers are patched into a Data Center's network devices. Most servers require a minimum of two connections, one for a primary Ethernet connection and another for either a console connection or a secondary Ethernet connection.
Networking Room

While power for your Data Center originates from an electrical room elsewhere in the building, data cabling similarly connects back to a networking room. It is here that structured cabling from the entire building, and in some cases an entire site, terminates.

Typically the networking room contains one or more rows of cabinets to house network devices and patch fields. These rows are often configured similarly to the Data Center's network row. Connections here, however, are to other rooms—the Data Center, labs with networks, distribution rooms with cabling for office computers—rather than to server rows.

Run structured cabling from your Data Center network row into the networking room. Copper, multimode fiber, and singlemode fiber provided between these locations is usually a good idea. The presence of the singlemode fiber enables easy patching into the building-to-building structured cabling system that also terminates in the networking room. This is especially important if your site contains more than one server environment and you want to incorporate them into the same network.

NOTE

As stated previously, my current cabling standard is 24 ports of Category 5E cable and 24 strands (12 ports) of 50 mm multimode fiber to each server cabinet location, and then that same amount—for each entire server row—between each network substation and the network row.

To complete the connection to the networking room, I run 24 ports of Category 5E cable, 24 strands (12 ports) of 50 mm multimode fiber, and 24 strands (12 ports) of 8.3 mm singlemode fiber from the network row.

Common Termination Options

Structured cabling typically terminates into female connectors, known as jacks or ports, within a container such as a fiber housing, patch panel, multimedia box, or data faceplate. (The terms jack and port can be used universally to describe fiber, copper, or even voice connectors.) While plugs and connectors are rated in the same way that copper and fiber is, the housings themselves are not. From a performance standpoint, it makes little difference what container you terminate a cable into.

Space constraints are usually the biggest challenge when it comes to providing a high amount of connectivity into a Data Center, or when it comes time to expand that system. Look for the housings that:

- Hold the most connections in a given space
- Provide some physical protection for the cabling
- Are easy for Data Center users to access
- Can be readily expanded in the future

Fiber housings and copper patch panels are used for terminating structured cabling directly into cabinets. These are optimal for locations where you want a Data Center user to have immediate access to data connections without needing to lift floor tiles or reach above a cabinet to plug in to a raceway. Avoid using fiber housings and copper patch panels at cabinets that you may reposition later, since these housings are screwed into cabinets and generally expected to be permanent installations. Multimedia data boxes are typically used when terminating structured cabling below a raised floor, while faceplates are used in overhead raceways.

Technically, you can mix what housings are used where—say installing data faceplates under a raised floor or multimedia boxes in a server cabinet, but there is no point in doing so.

NOTE

I have seen structured cabling purposefully terminated into patch panels below a raised floor at empty server cabinet locations. When cabinets arrive with servers, patch panels are then raised above the floor and screwed in to the cabinets. The strategy behind this approach is that, once servers are installed, Data Center users plug in to the patch panels and never have to raise floor tiles and risk damaging patch cords. I believe that such risk is minimal, and that this practice adds an unnecessary step to the installation process. It also reduces the future mobility of a Data Center's server cabinets.
Copper Cabling Terminators

Data Center copper cabling typically terminates into connectors and jacks known as RJ-45s. The plug looks like a wider version of the one that connects to your telephone, complete with a tab at the end that clicks when inserted into its corresponding jack. That telephone plug is actually an RJ-11. Both types are part of the registered jack (RJ) series of telephone and data connectors first established by the Bell telephone companies.

Crosstalk and other performance losses for a copper cable, outlined in the portion of this chapter addressing cable categories, occur predominantly where a cable is terminated. To diminish these losses, use quality RJ-45 connectors and jacks. Using connectors that are of a higher rating than your structured cabling not only reduces signal loss or interference, but it is also a cost-effective method of improving the performance of your entire network. The increased cost per connector is marginal when using Cat 6 jacks rather than Cat 5E, which is much less expensive than running miles (kilometers) of more expensive cabling in a server environment.

NOTE

Although this technique is not endorsed by TIA/EIA standards, it works. Most of the Data Centers I help manage were installed with high-performing Category 5E copper cabling and Category 6 jacks. That particular Cat5E cabling is rated to provide 350 MHz bandwidth and when paired with Category 6 jacks provides Cat6 performance for less than if Cat6 cabling had been installed.

Fiber Cabling Terminators

Three types of jacks and connectors are typically used for the termination of Data Center fiber cabling:

- Subscription Channel (SC) jack
- Mechanical Transfer Registered Jack (MT-RJ)
- Lucent Connector (LC) jack

SCs, the oldest type of connector, were originally developed by Nippon Telegraph and Telephone Corporations. SC plugs contain two small squares that are held side by side in a bracket.

Although still a perfectly capable jack, SCs have been largely replaced by smaller MT-RJ and LC connectors. These two connectors, modeled after the RJ-45 plug used for copper connections, each contain the same number of strands as an SC but at half the size.
Color-Coding Cabling Materials

Consider using different colors of cabling and components to help illustrate how your Data Center is organized. Multimedia boxes, data faceplates, copper jacks, and tie wraps can all be obtained in multiple colors. Perhaps you want to highlight all cable runs that connect the Data Center and networking room. Maybe you want to color-code connections that are part of a highly secure network, enabling them to be obvious for those who know what to look for without having to use labeling that reveals too much. Whatever your goal, color-coding cabling materials is an effective way to emphasize specific connections in your Data Center. Because these components are permanent installations, be sure that whatever you want to mark in this manner is meant to be a longstanding characteristic of your Data Center, too.

NOTE

I find it helpful to color-code copper jacks in the Data Center based upon where they connect—black for those that lead to network cabinet locations, white for those that lead to server cabinet locations, and lavender for those that exit the Data Center. (I would continue this color scheme with fiber ports, too, but they aren't available in multiple colors.) This results in a block of black jacks in the network row, a cluster of white jacks above or below each server cabinet location, and a clear juxtaposition within the network substation of which connections go where.

Figure 7-6 shows a patching field in a network substation. The top jacks (black) connect to the Data Center's network row, and the bottom jacks (white) connect to the server cabinet locations that are supported by the substation.

Figure 7-6. A Color-Coded Patch Field

Building-to-Building Connectivity

While this book focuses predominantly upon infrastructure within a Data Center, some mention needs to be made of the external cabling system that must be in place for your servers and networking devices to communicate with the outside world. This is known as site-to-site or building-to-building connectivity.

Typically, a company owns the external structured cabling on its site and then, once that cabling extends beyond its property lines, leases the conduits with which it connects. (That is assuming that the business owns the property and buildings, of course. If the site itself is leased, then the landlord is the true owner of the onsite cabling.) Conduits off of the property are owned by local service providers, such as a telephone or cable company, or sometimes by the area municipality. If you are uncertain what agencies have conduits in the ground in the region where your site is, ask the cabling contractors who are installing your Data Center's structured cabling.

Due to the distances involved and the desire for fast connection speeds, most connectivity between buildings is accomplished through singlemode fiber. In areas where conventional fiber can't be installed, lasers can be employed to provide point-to-point connectivity over short distances. This was previously accomplished with microwaves, but lasers provide greater bandwidth.

A star-and-ring topology, which provides redundant cabling to each building, is the industry standard configuration for building-to-building connectivity. You always want two different cabling paths into a building, for redundancy. The paths should be at least 50 feet (15.2 meters) apart, and ideally should be on opposite sides of a building. The farther apart they are, the less susceptible both are to damage from a single event.

The number of strands needed for your building-to-building connectivity depends upon how much traffic you expect—24 strands is typical for small company sites; 72 is more appropriate for larger ones.
Figure 7-7 illustrates a standard configuration for structured cabling among the buildings on a site. Each black dot represents a building.

Figure 7-7. A Star-and-Ring Topology

When working with a service provider, be clear about what redundancy you want in your system. Establish service level agreements with the provider that define its response times and repair responsibilities. Also, clarify how representatives from the service provider are to access your site during emergencies. Finally, to reduce repair times, it can be beneficial to maintain spare components on your site, for example, extra power supplies or controller cards.

You want your Data Center labeling to be able to pass the novice test. Someone completely unfamiliar with a server environment—not just unfamiliar with yours but having never been in any Data Center before—should be able to easily make or trace a connection from one cabinet location in the room to another. When Data Center connections are simple to follow, equipment installations and troubleshooting become easier, and changes for human error are reduced.

**NOTE**

I have toured dozens of server environments where every patch cord in the room has some form of labeling tag at both ends. While this is admirably thorough, it takes a lot of staff time to maintain. Even a moderately sized Data Center can use thousands of patch cords, and spending just a few minutes to label each cord can add up to hundreds of hours per year. This extra work is completely unnecessary if your Data Center is well organized and if all of its termination points are clearly labeled.

While most Data Center users are going to examine the labeling only where structured cabling terminates, it is also helpful to provide certain markings on the cable runs themselves. This can avoid later confusion about exactly what kind of cabling was installed in your Data Center and make it easier to troubleshoot any infrastructure problems.

For copper cabling, label all cable jackets with the following:

- Name of the manufacturer
- Gauge of copper wire
- Pair count
- Category rating
- Sequential length markings
- Minimum performance specifications (i.e., EIA/TIA 568B)

For fiber cabling, label all cable jackets with the following:

- Name of the manufacturer
- Fiber size and type (i.e., 50/125 mm MM)
- Sequential length markings

**Cabinet Installations**

While cable runs to your Data Center's server cabinet locations terminate in multimedia boxes under-floor or data faceplates overhead, cable runs to your Data Center's network row and network substations terminate directly into cabinets by way of fiber housings and copper patch panels. These cabinets are the only ones to house both structured cabling and equipment, specifically networking devices. Both the cabinets and incoming cabling must be installed in a particular manner to function correctly.
NOTE

Copper jacks aren't the only Data Center components that you can color-code. You can color-code the cabinets as well. I use black cabinets for the network row and substations and white cabinets for server rows. This continues the pattern started with the room's copper jacks, and provides an immediate clue to the room's organization to new users and visitors.

Figure 7-12 shows a server row with color-coded cabinets. The two black cabinets at the left end of the row house networking devices; the white cabinets house servers.

Figure 7-12. Color-Coded Cabinets

First, secure the network cabinets to your Data Center floor, by running a threaded rod down to the cement and bolting each cabinet at all four corners. With structured cabling terminated in the network cabinets, you aren't going to reposition them in the Data Center as you might the server cabinets whose data connections terminate adjacent to but outside of them. You might as well gain the stability that comes from securing the network cabinets. In some regions, there might even be tax benefits associated with securing the cabinets. Equipment that is secured to a building is considered a capital improvement and therefore deductible whereas unattached infrastructure items are merely expenses.

Second, route structured cabling down the sides of the cabinet. You want to stay within the frame of the cabinet while still leaving as much internal space open for the installation of networking devices as possible.

Here is where limiting the diameter of the Data Center's cable bundles is helpful. Cabling contractors might experience difficulty in routing structured cabling inside your network cabinets. A cable bundle is fairly rigid, but it is not like a wire coat hanger that can be bent and then retain its new shape. Even if it could, a contractor still has to be careful of the path of the cable due to minimum bend radii.

One way to help with this challenge is to install vertical front-and-rear wire management on the sides of each network cabinet. This style of wire manager has two channels—one that extends past the front of the cabinet face and another that sits behind it. Structured cabling can be routed through the "rear" channel, keeping it away from networking devices. The drawback of this solution is that the wire management requires room between each network cabinet, adding to how much Data Center floor space they occupy. Over the course of an entire network row, that can add up.

A second approach is installation of several horizontal guide rods into each network cabinet with cable bundles secured to them. Typically, #8-32 threaded zinc plate rods, cut to match the depth of the cabinet, along with the same size of hex nuts and washers, work well.

Figure 7-13 shows cable bundles routed along the sides of a network cabinet. The bundles are secured to several horizontal guide rods so as to stay clear of networking devices but remain within the silhouette of the cabinet.
NOTE

Throughout this book, I refer to the use of four-post cabinets to house Data Center equipment. Two-post metal frames, known as relay racks or open bay racks, can also be used in many situations. These racks are lighter and generally less expensive, and have a smaller profile than four-post cabinets.

Such racks often have lesser weight-bearing ability than four-post cabinets, however. I have seen cheaper racks actually warp under the weight of networking devices. Two-post racks also can’t stand upright on their own—they must be mounted to the floor. Because of this, two-post racks are suitable for network rows and network substations but not for housing servers.

Testing and Verifying Structured Cabling

Once your structured cabling is in place, have the cabling contractor test all components to make sure that the entire system, both copper and fiber, is providing the level of performance expected of them. Tables 7-1 and 7-2 from earlier in the chapter summarize these values, taken from TIA/EIA 568B.

Although testing requirements differ between copper and fiber cabling, there are certain procedures that you want contractors to follow for both media, including the following:

- **Provide documentation on what testing procedures and equipment are being used**— List specific manufacturers and model numbers, and when the equipment was last calibrated. An approved service provider should have calibrated all test equipment within the past two years.

- **Perform tests on the entire system cabling, not just individual components**— If anything disturbs a termination after it is tested, consider the test invalid and do it again.

- **Provide test results in both hardcopy and computer-readable format**— Cable test results can come in an array of presentation formats, many of which include very small type sizes. Hardcopy is helpful for initially reading the mountain of test results; softcopy is useful for storing the data long term.

Be clear in your design documents that a cabling installation isn’t considered acceptable until all terminations meet the appropriate standards, and that any components that do not meet the standards must be removed and replaced at no cost.

Have copper-structured cabling tested to confirm that there are no opens, shorts, or incorrectly crossed pairs, a test known as wire mapping. It should also be tested, per TIA/EIA 568B, to make sure that all components meet the expected parameters for NEXT, PS-NEXT, ELFEXT, PS-ELFEXT, return loss, propagation delay, and delay skew, as outlined previously in Table 7-1.

Current copper testing standards call for what is known as permanent link testing, which eliminates the testing materials—the patch cord and connector used to plug the tester in to the structured cabling that is being measured—from the results. (The prior standard called for a basic link test, which did not eliminate these materials.)

Have fiber optic structured cabling likewise tested to make sure that all components meet the expected parameters for maximum attenuation and minimum bandwidth, as outlined previously in Table 7-2.
Structured Cabling Warranties

While Data Center cabling infrastructure should be tested and verified as part of their installation process, what if you discover bad ports at a much later date? This is not unheard of in very large Data Centers, since data ports at the far end of a room may go unused for months or even years after the room's initial construction.

Malfunctioning ports are typically addressed according to the warranties that accompany the installations. Most structured cabling manufacturers provide a warranty on their materials for at least 20 years and, if an authorized installer performed the work, cover their labor for the same amount of time.

Labor performed by a non-approved installer will be covered according only to that installer's warranty. This is good incentive to use established companies, rather than an unproven vendor who might not still be in business when later problems arise.

In my personal experience, reputable cable installers are quick to stand by their work and remediate a non-working installations for free, even if the original work was done years earlier. Such responsiveness fosters goodwill and makes it more likely for the customer to return with future business.

If you use multiple cable installers at your site, carefully document who does what work. It is unrealistic to expect even the most agreeable vendor to reinstall cabling without charge if there is uncertainty over when they installed it in the first place.

Wire Management

Wire management is an important tool for keeping your Data Center neat and organized and for encouraging Data Center users to correctly patch into the room's structured cabling infrastructure. These components come in many shapes, sizes, and materials, enabling you to customize a solution for your particular server environment. Some patch panels and fiber housings can also be ordered to include their own wire management. Vertical wire management is typically mounted onto the external frame of Data Center cabinets, while horizontal pieces can be mounted either that way or installed within the cabinet.

Size your Data Center's wire management based upon how many patch cords you expect to route through it—obviously, the more cables a wire manager must accommodate, the thicker it needs to be. A good rule of thumb is wire management that is at least as big as any copper patch panels and half as big as any fiber housings that it is intended to guide cabling to. If you have a copper patch panel that occupies 2U of cabinet space, make sure that there is a total of 2U of wire management adjacent to it. If the jacks that those copper cables plug in to need that much space, it is a safe bet that the cables themselves need at least that much room. Fiber cables are thinner than the ports they plug in to, which is why the ratio is cut in half for them.

Install ample wire management in areas where you want cables routed through and none in those where you don't. A carefully chosen combination of patch fields and wire management can guide how Data Center users' patch cables into the system.

For example, if you don't want patch cords to be routed along the top of your network row, don't install horizontal wire management there. Place those components lower on each cabinet instead. Given a choice between using existing wire management or stringing cables somewhere else, the vast majority of people follow what is already in place.

Install a comprehensive wire management system on the front of your network row, where connections from the Data Center's network substations terminate, to enable users to easily patch to and from anywhere in the room. Use thick, vertical wire managers on either side of each cabinet to accommodate large numbers of patch cords. You also want thinner horizontal components among every couple of patch panels to guide patch cords into the vertical pieces.

**Figure 7-14** shows a comprehensive wire management system, which includes both vertical and horizontal components, on a network row.
Figure 7-14. Horizontal and Vertical Wire Management

Figure 7-15 shows two examples of how wire management and patch panels can guide Data Center users on how to route patch cords:

- The configuration on the left features wire management that encourages users to patch above and below the patch fields and then into the vertical wire management.
- The configuration on the right relies upon convex, v-shaped patch panels to encourage users to route cabling directly into vertical wire management.

Figure 7-15. Alternate Wire Management Configurations

Be judicious about the installation of wire management into server cabinets, especially pieces that connect cabinets together or unintentionally encourage Data Center users to string patch cords between cabinets. Both conditions inhibit the flexibility of your Data Center and should be allowed only in rare circumstances.
Some cabinets come equipped with their own internal wire management. I usually stay away from this style of cabinet because the built-in devices make the cabinet wider or occupy vertical internal space that could otherwise hold additional server equipment, or both.

If wire management is needed at server cabinet locations, I prefer to install it externally on key cabinets. This conserves equipment space in the Data Center and is more flexible, enabling wire management to be reconfigured or removed as needed. It is also easier to customize than built-in systems, enabling you to install components only where cable density warrants it.

Common Problems

As stated at the start of this chapter, a Data Center's structured cabling is one of its most complex infrastructure systems. As such, it is also the most likely to feature mistakes during initial construction. Here are several installation errors to watch out for in your server environment's cabling:

• **Structured cabling is routed sloppily in the network cabinets**— The neatness of cable runs installed in your Data Center can vary depending upon the contractor. Carelessly routed cable bundles can either block internal cabinet space needed to install equipment or stray outside the cabinet frame and expose them to damage from other cabinets being placed adjacent to each other. Even the most well-intended cabling contractor might not understand when a cable run is in the way of future installations if he or she is unfamiliar with your Data Center design. The best way to avoid this problem is an included drawing or picture of properly routed cables in your design documents.

• **Incorrect structured cabling is ordered and installed**— Chapter 5, "Overhead or Under-Floor Installation?" mentions the possibility of mixing up plenum and non-plenum cabling. That is not the only mixup in materials that can occur.

  **Note**

  Although the Data Center design documents I use clearly call for indoor plenum-rated cabling, down to the part number and manufacturer, in separate projects I have had cabling contractors order and begin to install non-plenum cable, heavily jacketed cable designed for outdoor use, and even armored cable. In each case, the contractor took responsibility for the mistake and agreed to fix it, but there was inevitably little time to do so and still have the Data Center come online on schedule. In some instances, the cabling was hurriedly replaced, while in others (in which there was no fire code violation) I simply had to accept the mistake.

  Catching incorrect materials can be especially difficult if the project site is at a remote location that you are unable to visit frequently. Most of the time, the first hint I receive that incorrect cabling has been ordered comes when a contractor complains that they can't route it in to network cabinets in the manner specified. Both the armored and outdoor cabling are thicker than what is normally called for, which prevents it from fitting in the tight spaces.

• **Strand counts are mistaken as port counts or vice-versa**— With no standard for referring to fiber counts by strands or ports (2 strands = 1 port), it is easy for an incorrect amount of fiber to be installed. The best precaution against this mistake is one term chosen and used consistently in your documentation. A drawing in your design package that shows typical fiber terminations at the network and server cabinet locations can also reduce confusion.

• **Labeling of connections is incomplete or unclear**— Make sure that cabling contractors have a good understanding of how your Data Center's patching fields and other components are to be labeled. Labeling can be a tedious and confusing job and so is often skimped on. It doesn't help that some fiber housings come with a pre-printed numbering scheme. It inevitably won't match the one for your Data Center, so it usually just creates confusion. To avoid this problem, provide illustrations of proper labeling within your Data Center design documents.

  **Note**

  In early 2000, I had a contractor who thoroughly labeled components in the structured cabling system of a new Data Center in Raleigh, North Carolina. Unfortunately, the planning and facilities consultant involved in the project took the odd step of deciding that the network substation at the end of each server row shouldn't be counted in the numbering scheme.

  That Data Center is 7914 square feet (735.2 square meters) and contains about 730 cabinet locations. Hundreds of multimedia boxes and thousands of patch panels and fiber housings had to be relabeled. Doing so ultimately required three coworkers and me to spend about 300 hours to correct the error.

• **Multimedia boxes aren't fully assembled**— When structured cabling terminates into a multimedia box under a raised floor, make sure that the boxes are assembled completely. Some simply snap together, while others need to have their pieces further secured by screws. Contractors occasionally take a shortcut by snapping the boxes together and skipping the screws. This makes the boxes prone to coming apart and exposing cable strands over time. Spell out the proper assembly of these components in your Data Center design documents.
A Data Center's physical network is crucial for a company's servers to communicate with one another and the outside world. This network must feature high-performing cabling media and abundant connections and be well organized for ease of use and future expandability.

Provide a full complement of structured cabling to all server cabinet locations when the Data Center is constructed. Incorporate short cable runs into the design for better performance and lower costs. Also, be sure to pick the correct cabling media for your server environment's connectivity, based upon the performance needed and distances involved.

There are two approaches to laying out a Data Center's structured cabling. One is cables directly connected from a network row to server cabinet locations. This can work in small server environments but is difficult to manage and maintain in larger ones. The other is cables run from a network row to a substation at the end of each server row. This is more manageable, shortens the length of cable runs, and adds redundancy to the network.

Copper and fiber-optic cabling are used to provide Data Center connectivity. Copper is used for shorter connections, up to 109.4 yards (100 meters). Copper cabling and components are rated by categories, and Data Center cabling traditionally falls into Category 5, 5E, or 6. These categories define standards for frequency, signal loss, impedance, several forms of crosstalk, return loss, and delay skew. Fiber is used for longer connections, up to several miles. Data Center fiber comes in three types that differ primarily by the diameter of their core: 62.5 mm multimode, 50 mm multimode, and 8.3 m singlemode. Their specifications included standards for signal loss and bandwidth.

Copper cable costs more than fiber cable, but the associated network cards that must be installed in servers are inexpensive, making this a good medium to use over a shorter distance. Fiber is the opposite—cable material is less, and network interface cards are more. Together with the distance advantages of fiber, this makes it a better solution for longer connections.

Decide how much cabling to run to server cabinet locations based upon how you organize servers and what connectivity they require. If the Data Center is organized by server type, stagger infrastructure levels to meet their needs. If the Data Center is organized by function or work group, provide enough connectivity to meet most combinations of servers. The second approach is preferable because it is more flexible and easier to manage.

Ample structured cabling in the Data Center enables redundancy to be added at any point where additional networking devices are installed.

Data Center structured cabling ultimately terminates back to a networking room. This room serves the same role for the building or entire site that the network row does for the Data Center—it is the ultimate destination for all network cabling. Install copper, multimode fiber, and singlemode fiber in the networking room to enable easy patching into any site network.

In a server environment, copper cabling terminates into RJ-45 connectors and jacks while fiber cabling terminates into SC, MT-RJ, or LC connectors and jacks. Consider color-coding these and other cabling components to highlight how your Data Center is organized. While a company usually owns all structured cabling up to its property boundaries, further connectivity is provided by conduits leased from a service provider such as a telephone or cable company. Have redundant cabling paths into your site, and establish clear service-level agreements with your service provider.

Include thorough directions in your design package to ensure that cabling and components are installed correctly. These directions should call for trained personnel to perform the installations, careful bundling and combing of structured cabling, generous bend radii, use of reverse fiber positioning, labeling of all cabling with from/to information, and careful termination of cabling into network cabinets.

Have cabling contractors test cabling materials once they are installed to ensure that they meet expected standards. Require contractors to document their test procedures, test the system as a whole, and provide results in both hardcopy and softcopy.

Install wire management strategically to guide how Data Center users patch into the cabling infrastructure—provide ample wire management where you want cable routed and none where you don't.

Common installation mistakes with structured cabling include sloppy routing in network cabinets, use of incorrect cabling, confusion between fiber ports and strands, inadequate labeling, and failure to fully assemble multimedia boxes.