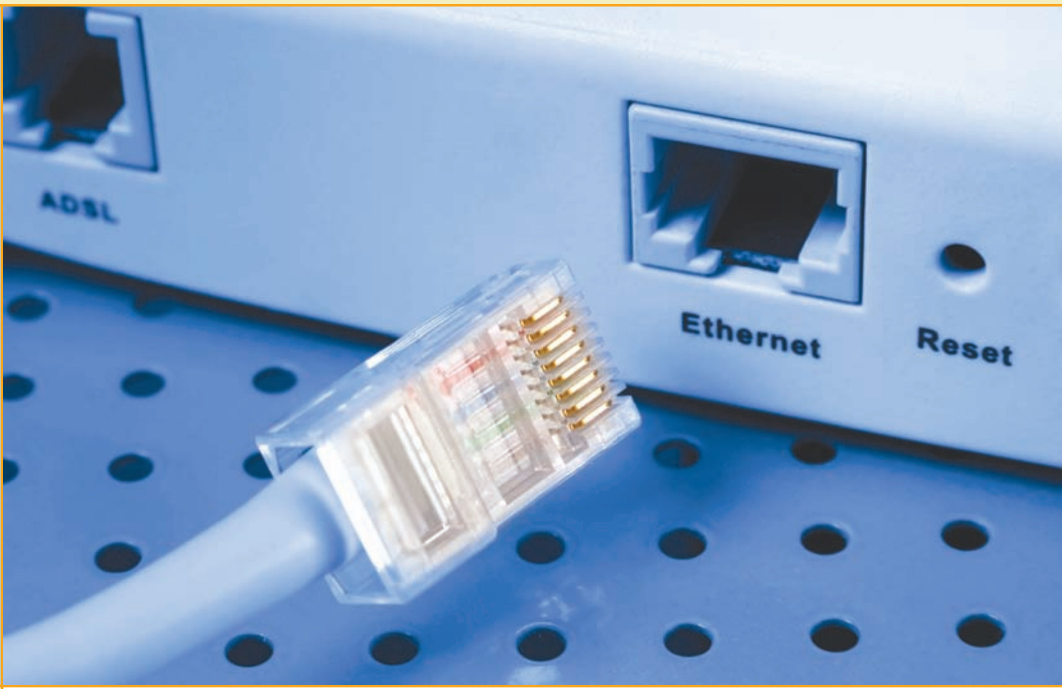
chapter 6 Installing a Physical Network

"I am rarely happier than when spending an entire day programming my computer to perform automatically a task that it would otherwise take me a good ten seconds to do by hand."

—Douglas Adams

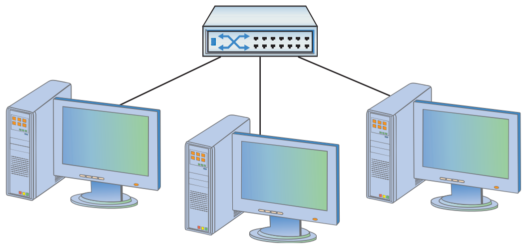


In this chapter, you will learn how to

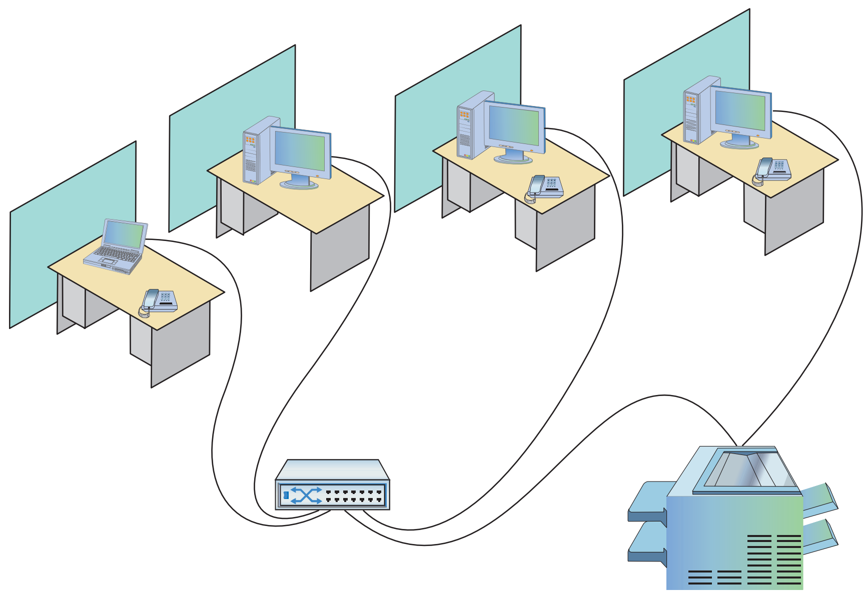
- **Recognize and describe the functions of basic components in a structured cabling system**
- **Explain the process of installing structured cable**
- **Install a network interface card**
- **Perform basic troubleshooting on a structured cable network**

Armed with the knowledge of previous chapters, it's time to start going about the business of actually plugging a physical network together. This might seem easy, because the most basic network is nothing more than a switch with a number of cables snaking out to all of the PCs on the network (Figure 6.1).

On the surface, such a network setup is absolutely correct, but if you tried to run a network using only a switch and cables running to each system, you'd have some serious practical issues. In the real world, you need to deal with physical obstacles like walls and ceilings. You also need to deal with those annoying things called *people*. People are incredibly adept at destroying physical networks. They unplug switches, trip over cables, and rip connectors out of NICs with incredible consistency unless you protect the network from their destructive ways. Although the simplified switch-and-a-bunch-of-cables type of network can function in the real world, the network clearly has some problems that need addressing before it can work safely and efficiently (Figure 6.2).



• **Figure 6.1** What an orderly looking network!



• **Figure 6.2** A real-world network

This chapter takes the abstract discussion of network technologies from previous chapters into the concrete reality of real networks. To achieve this goal, it marches you through the process of installing an entire network system from the beginning. The chapter starts by introducing you to the magical world of structured cabling: the critical set of standards used all over the world to install physical cabling in a safe and orderly fashion. It then delves into the world of larger networks—those with more than a single switch—and shows you some typical methods used to organize them for peak efficiency and reliability. Next, you'll take a quick tour of the most common NICs used in PCs, and see what it takes to install them. Finally, you'll look at how to troubleshoot cabling and other network devices, including an introduction to some fun diagnostic tools.

Historical/Conceptual

Understanding Structured Cabling

If you want a functioning, dependable, real-world network, you need a solid understanding of a set of standards, collectively called **structured cabling**. These standards, defined by the Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA)—yup, the same folks who tell you how to crimp an RJ-45 onto the end of a UTP cable—give professional cable installers detailed standards on every aspect of a cabled network, from the type of cabling to use to the position of wall outlets.

The CompTIA Network+ exam requires you to understand the basic concepts involved in designing a network and installing network cabling, and to recognize the components used in a real network. The CompTIA Network+ exam does not, however, expect you to be as knowledgeable as a professional network designer or cable installer. Your goal is to understand enough about real-world cabling systems to communicate knowledgeably with cable installers and to perform basic troubleshooting. Granted, by the end of this chapter, you'll have enough of an understanding to try running your own cable (I certainly run my own cable), but consider that knowledge a handy bit of extra credit.

A structured cabling system is useful for more than just computer networks.

The idea of structured cabling is to create a safe, reliable cabling infrastructure for all of the devices that may need interconnection. Certainly this applies to computer networks, but also to telephone, video—anything that might need low-power, distributed cabling.

You should understand three issues with structured cabling. Cable basics start the picture, with switches, cabling, and PCs. You'll then look at the components of a network, such as how the cable runs through the walls and where it ends up. This section wraps up with an assessment of connections leading outside your network.

Tech Tip

The Big Wireless Lie

Anyone who makes a trip to a local computer store sees plenty of devices that adhere to the 802.11 (wireless networking) standard. There's little doubt about the popularity of wireless. This popularity, however, gives people the impression that 802.11 is pushing wired networks into oblivion. While this may take place one day in the future, a wireless network's unreliability and relatively slow speed (as compared to Gigabit Ethernet) make it challenging to use in a network that requires high reliability and speed. Wireless makes great sense in homes, your local coffeehouse, and offices that don't need high speed or reliability, but any network that can't afford downtime or slow speeds still uses wires.

Cable Basics—A Star Is Born

This exploration of the world of connectivity hardware starts with the most basic of all networks: a switch, some UTP cable, and a few PCs—in other words, a typical physical star network (Figure 6.3).

No law of physics prevents you from installing a switch in the middle of your office and running cables on the floor to all the computers in your network. This setup will work, but it falls apart spectacularly when applied to the real-world environment. Three problems present themselves to the real-world network tech. First, the exposed cables running along the floor are just waiting for someone to trip over them, causing damage to the network and giving that person a wonderful lawsuit opportunity. Possible accidents aside, simply moving and stepping on the cabling will, over time, cause a cable to fail due to wires breaking or RJ-45 connectors ripping off cable ends. Second, the presence of other electrical devices close to the cable can create interference that confuses the signals going through the wire. Third, this type of setup limits your ability to make any changes to the network. Before you can change anything, you have to figure out which cables in the huge rat's nest of cables connected to the hub go to which machines. Imagine *that* troubleshooting nightmare!

• **Figure 6.3** A switch connected by UTP cable to two PCs

Cross Check

TIA/EIA Standards

You should remember the TIA/EIA 568 standards from Chapter 4, "Ethernet Basics," but do you remember how to tell the difference between 568A and 568B? Why were the standards considered necessary?

Tech Tip

Professional Cabling Certifications with BICSI

Installing structured cabling properly takes a startlingly high degree of skill. Thousands of pitfalls await inexperienced network people who think they can install their own network cabling. Pulling cable requires expensive equipment, a lot of hands, and the ability to react to problems quickly. Network techs can lose millions of dollars—not to mention their good jobs—by imagining they can do it themselves without the proper knowledge. If you are interested in learning more details about structured cabling, an organization called BICSI (www.bicsi.org) provides a series of widely recognized certifications for the cabling industry.

"Gosh," you're thinking (okay, I'm thinking it, but you should be), "there must be a better way to install a physical network." A better installation would provide safety, protecting the star from vacuum cleaners, clumsy co-workers, and electrical interference. It would have extra hardware to organize and protect the cabling. Finally, the new and improved star network installation would feature a cabling standard with the flexibility to enable the network to grow according to its needs, and then to upgrade when the next great network technology comes along.

As you have no doubt guessed, I'm not just theorizing here. In the real world, the people who most wanted improved installation standards were the ones who installed cable for a living. In response to this demand for standards, the TIA/EIA developed standards for cable installation. The TIA/EIA 568 standards you saw in earlier chapters are only part of a larger set of TIA/EIA standards, all lumped together under the umbrella of structured cabling.

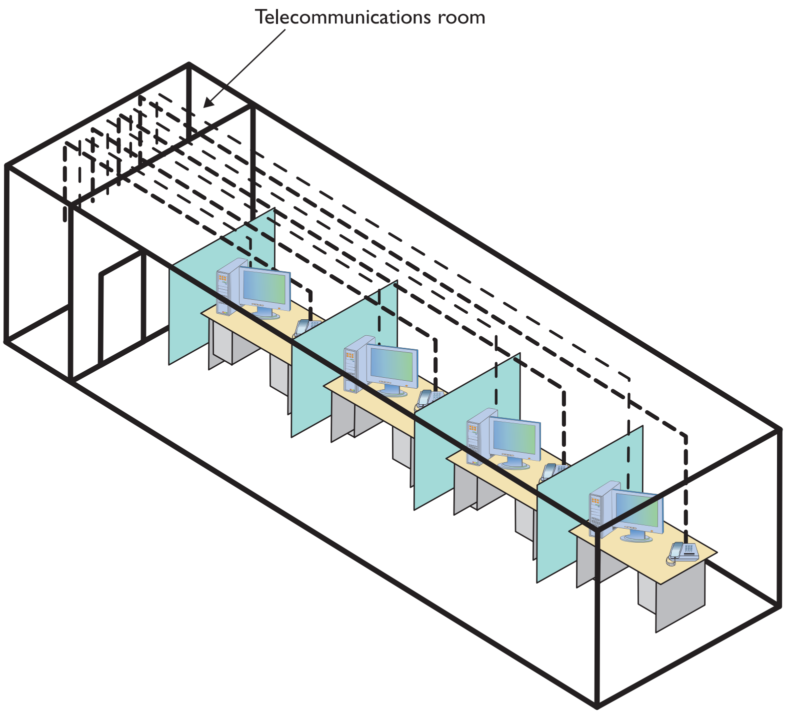
Test Specific

Structured Cable Network Components

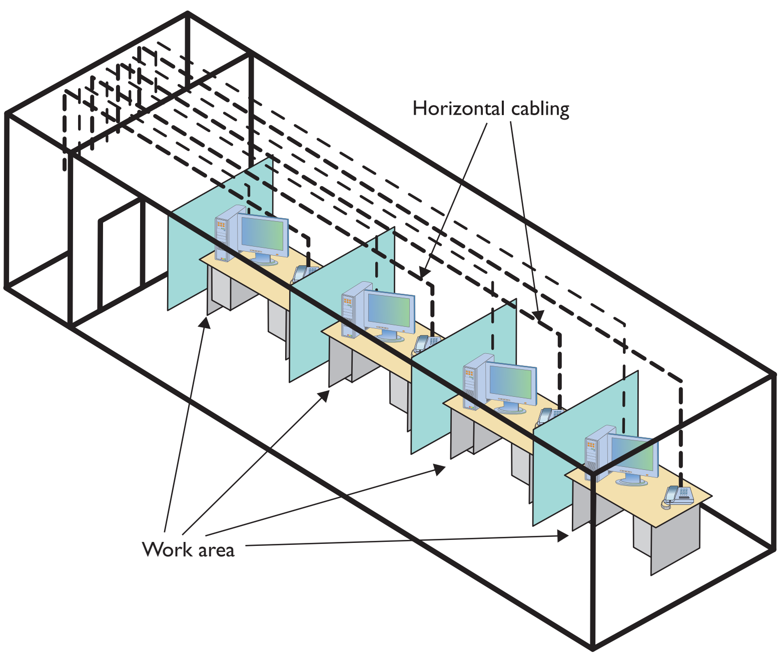
Successful implementation of a basic structured cabling network requires three essential ingredients: a telecommunications room, horizontal cabling, and a work area. Let's zero in on one floor of Figure 5.12 from the previous chapter. All the cabling runs from individual PCs to a central location, the **telecommunications room** (Figure 6.4). What equipment goes in there—a switch or a telephone system—is not the important thing. What matters is that all the cables concentrate in this one area.

All cables run horizontally (for the most part) from the telecommunications room to the PCs. This cabling is called, appropriately, **horizontal cabling**. A single piece of installed horizontal cabling is called a **run**. At the opposite end of the horizontal cabling from the telecommunications room is the work area. The **work area** is often simply an office or cubicle that potentially contains a PC and a telephone. Figure 6.5 shows both the horizontal cabling and work areas.

Each of the three parts of a basic star network—the telecommunications room, the horizontal cabling, and the work area(s)—must follow a series of strict standards designed to ensure that the cabling system is reliable and easy to manage. The cabling standards set by TIA/EIA enable techs to make sensible decisions on equipment installed in the telecommunications room, so let's tackle horizontal cabling first, and then return to the telecommunications room. We'll finish up with the work area.



• **Figure 6.4** Telecommunications room



• **Figure 6.5** Horizontal cabling and work area

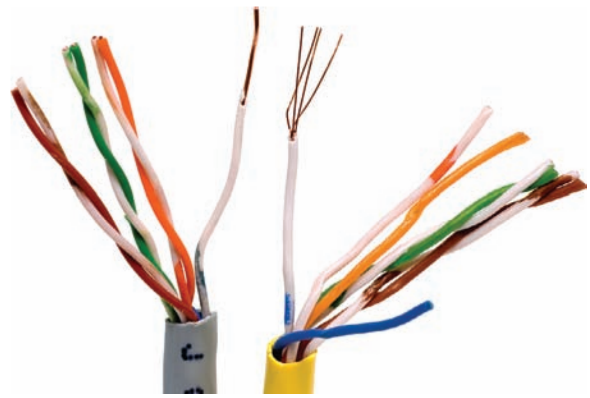
Horizontal Cabling

A horizontal cabling run is the cabling that goes more or less horizontally from a work area to the telecommunications room. In most networks, this is a CAT 5e or better UTP cable, but when we move into the world of structured cabling, the TIA/EIA standards define a number of other aspects to the cable, such as the type of wires, number of pairs of wires, and fire ratings.

Solid Core vs. Stranded Core All UTP cables come in one of two types: solid core or stranded core. Each wire in **solid core** UTP uses a single solid wire. With **stranded core**, each wire is actually a bundle of tiny wire strands. Each of these cable types has its benefits and downsides. Solid core is a better conductor, but it is stiff and will break if handled too often or too roughly. Stranded core is not quite as good a conductor, but it will stand up to substantial handling without breaking. Figure 6.6 shows a close-up of solid and stranded core UTP.

A single piece of cable that runs from a work area to a telecommunications room is called a run.

TIA/EIA specifies that horizontal cabling should always be solid core. Remember, this cabling is going into your walls and ceilings, safe from the harmful effects of shoes and vacuum cleaners. The ceilings and walls enable us to take advantage of the better conductivity of solid core without risk of cable damage. Stranded cable also has an important function in a structured cabling network, but we need to discuss a few more parts of the network before we see where to use stranded UTP cable.



• Figure 6.6 Solid and stranded core UTP

Number of Pairs Pulling horizontal cables into your walls and ceilings is a time-consuming and messy business, and not a process you want to repeat, if at all possible. For this reason, most cable installers recommend using the highest CAT rating you can afford. A few years ago, I would also mention that you should use four-pair UTP, but today, four-pair is assumed. Four-pair UTP is so common that it's difficult, if not impossible, to find two-pair UTP.

Unlike previous CAT standards, TIA/EIA defines CAT 5e and later as four-pair-only cables.

You'll find larger bundled UTP cables in higher-end telephone setups. These cables hold 25 or even 100 pairs of wires (Figure 6.7).

Choosing Your Horizontal Cabling In the real world, network people only install CAT 5e or CAT 6 UTP, although CAT 6a is also starting to show up as 10GBaseT begins to see acceptance. Installing higher-rated cabling is done primarily as a hedge against new network technologies that may require a more advanced cable. Networking *caveat emptor* warning: many network installers take advantage of the fact that a lower CAT level will work on most networks, and bid a network installation using the lowest-grade cable possible.

• Figure 6.7 25-pair UTP

The Telecommunications Room

The telecommunications room is the heart of the basic star. This room—technically called the **intermediate distribution frame (IDF)**—is where all the horizontal runs from all the work areas come together. The concentration of all this gear in one place makes the telecommunications room potentially one of the messiest parts of the basic star. Even if you do a nice, neat job of organizing the cables when they are first installed, networks change over time. People move computers, new work areas are added, network topologies are added or improved, and so on. Unless you impose some type of organization, this conglomeration of equipment and cables is bound to decay into a nightmarish mess.

The telecommunications room is also known as an intermediate distribution frame (IDF), as opposed to the main distribution frame (MDF), which we will discuss later in the chapter.

Fortunately, the TIA/EIA structured cabling standards define the use of specialized components in the telecommunications room that make organizing

Cross Check

Fire Ratings

You saw another aspect of cabling way back in Chapter 3, "Cabling and Topology," so check your memory here. What are fire ratings? When should you use plenum-grade cabling and when should you use riser-grade cabling? What about PVC? What are the differences?

• **Figure 6.8** A short equipment rack

• **Figure 6.9** A floor-to-ceiling rack

a snap. In fact, it might be fair to say that there are too many options! To keep it simple, we're going to stay with the most common telecommunications room setup, and then take a short peek at some other fairly common options.

Equipment Racks The central component of every telecommunications room is one or more equipment racks. An **equipment rack** provides a safe, stable platform for all the different hardware components. All equipment racks are 19 inches wide, but they vary in height from two- to three-foot-high models that bolt onto a wall (Figure 6.8), to the more popular floor-to-ceiling models (Figure 6.9).

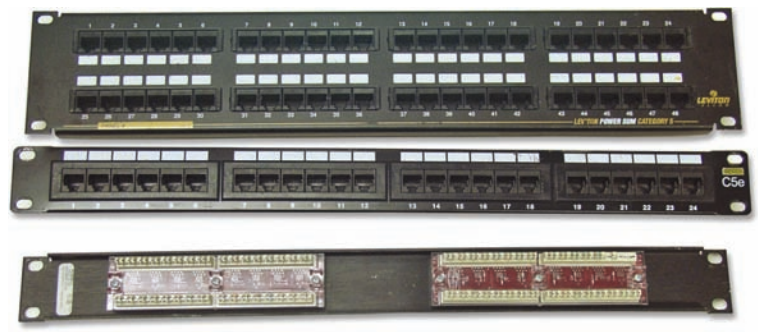
You can mount almost any network hardware component into a rack. All manufacturers make rack-mounted switches that mount into a rack with a few screws. These switches are available with a wide assortment of ports and capabilities. There are even rack-mounted servers, complete with slide-out keyboards, and rack-mounted uninterruptible power supplies (UPSs) to power the equipment (Figure 6.10).

All rack-mounted equipment uses a height measurement known simply as a **U**. A U is 1.75 inches. A device that fits in a 1.75-inch space is called a 1U; a device designed for a 3.5-inch space is a 2U. Most rack-mounted devices are 1U, 2U, or 4U. The rack in Figure 6.10 is called a 96U rack to reflect the total number of Us it can hold.

Actual rack measurements may vary slightly from manufacturer to manufacturer.

• **Figure 6.10** A rack-mounted UPS

Patch Panels and Cables Ideally, once you install horizontal cabling, it should never be moved. As you know, UTP horizontal cabling has a solid core, making it pretty stiff. Solid core cables can handle some rearranging, but if you insert a wad of solid core cables directly into your switches, every time you move a cable to a different port on the switch, or move the switch itself, you will jostle the cable. You don't have to move a solid core cable many times before one of the solid copper wires breaks, and there goes a network connection! Luckily for you, you can easily avoid this problem by using a patch panel. A **patch panel** is simply a box with a row of female connectors (ports) in the front and permanent connections in the back, to which you connect the horizontal cables (Figure 6.11).



• **Figure 6.11** Typical patch panels

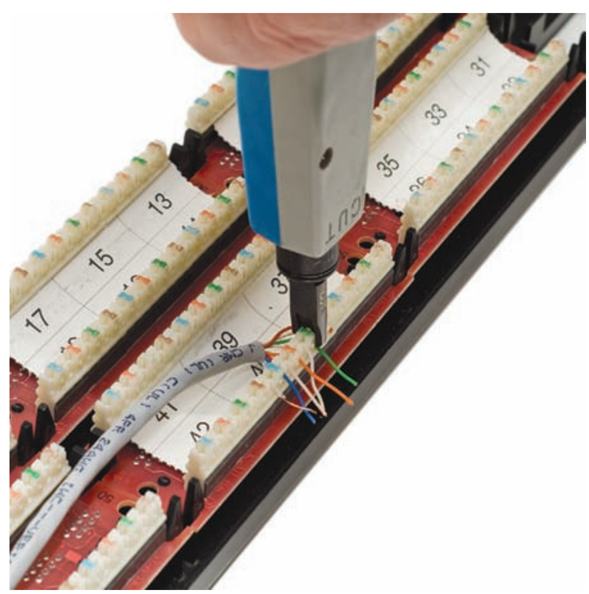
The most common type of patch panel today uses a special type of connecter called a **110-punchdown block**, or simply a *110 block*. UTP cables connect to a 110-punchdown block using—you guessed it—a **punchdown tool**. Figure 6.12 shows a typical punchdown tool while Figure 6.13 shows the punchdown tool punching down individual strands.

The punchdown block has small metal-lined grooves for the individual wires. The punchdown tool has a blunt end that forces the wire into the groove. The metal in the groove slices the cladding enough to make contact.

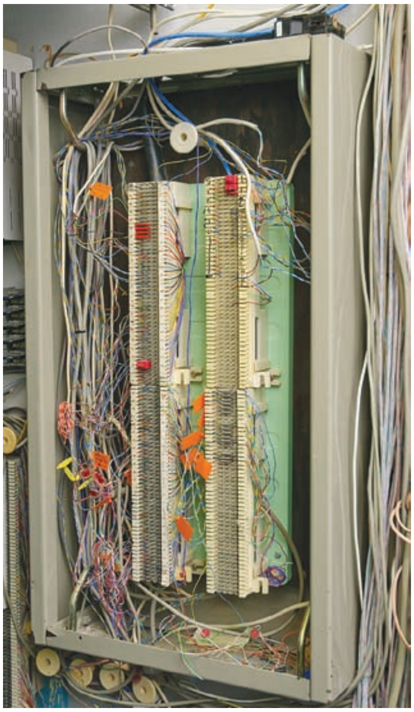
At one time the older 66-punchdown block patch panel, found in just about every commercial telephone installation (Figure 6.14), saw some use in the PC network world. Because of its ease and convenience, however, the 110 block is slowly displacing the 66 block for both telephone service and PC LANs. Given their large installed base, it's still very common to find a group of 66-block patch panels in a telecommunications room separate from the PC network's 110-block patch panels.

The CompTIA Network+ exam uses the terms 110 block and 66 block exclusively to describe the punchdown blocks common in telecommunication. In the field, in contrast, and in manuals and other literature, you'll see the punchdown blocks referred to as 110-punchdown blocks and 66-punchdown blocks as well. Some manufacturers even split punchdown into two words, i.e. punch down. Be prepared to be nimble in the field, but expect 110 block and 66 block on the exam.

• **Figure 6.12** Punchdown tool



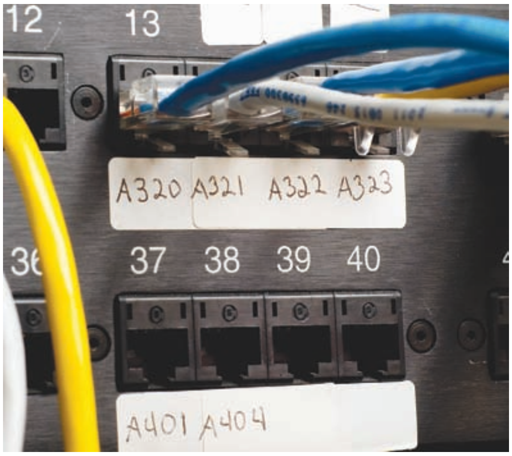
• **Figure 6.13** Punching down a 110 block



• **Figure 6.14** 66-block patch panels

Not only do patch panels prevent the horizontal cabling from being moved, they are also your first line of defense in organizing the cables. All patch panels have space in the front for labels, and these labels are the network tech's best friend! Simply place a tiny label on the patch panel to identify each cable, and you will never have to experience that sinking feeling of standing in the telecommunications room of your nonfunctioning network, wondering which cable is which. If you want to be a purist, there is an official, and rather confusing, TIA/EIA labeling methodology called **TIA/EIA 606**, but a number of real-world network techs simply use their own internal codes (Figure 6.15).

> **Tech Tip**
>
> **Serious Labeling**
>
> *The TIA/EIA 606 standard covers proper labeling and documentation of cabling, patch panels, and wall outlets. If you want to know how the pros label and document a structured cabling system (and you've got $360 to blow), check out the TIA/EIA 606 standard hardcopy from TIA.*



• **Figure 6.15** Typical patch panels

Patch panels are available in a wide variety of configurations that include different types of ports and numbers of ports. You can get UTP, STP, or fiber ports, and some manufacturers combine several different types on the same patch panel. Panels are available with 8, 12, 24, 48, or even more ports. UTP patch panels, like UTP cables, come with CAT ratings, which you should be sure to check. Don't blow a good CAT 6 cable installation by buying a cheap patch panel—get a CAT 6 patch panel! Most manufacturers proudly display the CAT level right on the patch panel (Figure 6.16).

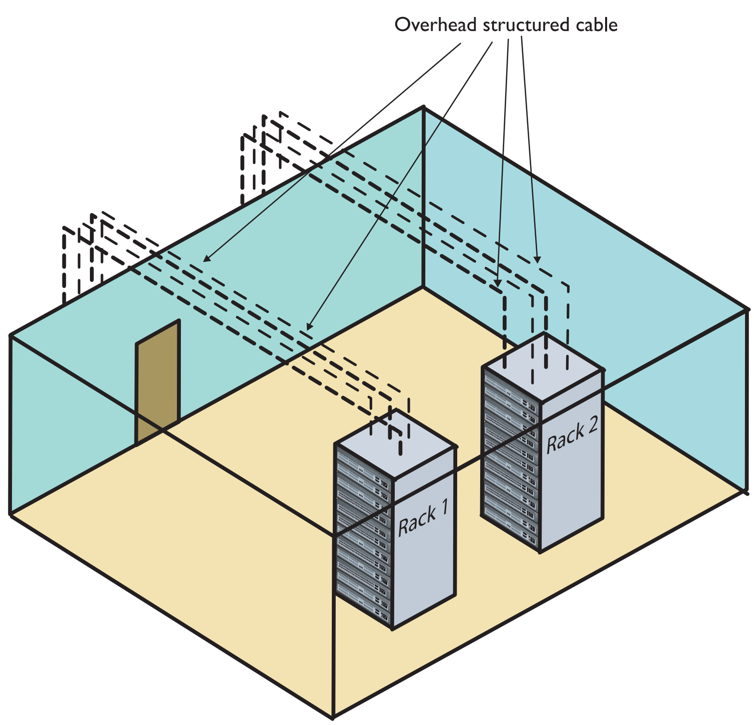
• **Figure 6.16** CAT level on patch panel

Once you have installed the patch panel, you need to connect the ports to the switch through **patch cables**. Patch cables are short (typically two- to five-foot) UTP cables. Patch cables use stranded rather than solid cable, so they can tolerate much more handling. Even though you can make your own patch cables, most people buy premade ones. Buying patch cables enables you to use different-colored cables to facilitate organization (yellow for accounting, blue for sales, or whatever scheme works for you). Most prefabricated patch cables also come with a reinforced (booted) connector specially designed to handle multiple insertions and removals (Figure 6.17).

A telecommunications room doesn't have to be a special room dedicated to computer equipment. You can use specially made cabinets with their own little built-in equipment racks that sit on the floor or attach to a wall, or use a storage room, as long as the equipment can be protected from the other items stored there. Fortunately, the demand for telecommunications rooms has been around for so long that most office spaces have premade telecommunications rooms, even if they are no more than a closet in smaller offices.

At this point, the network is taking shape (Figure 6.18). We've installed the TIA/EIA horizontal cabling and configured the telecommunications room. Now it's time to address the last part of the structured cabling system: the work area.

• **Figure 6.17** Typical patch cable



• **Figure 6.18** Network taking shape

• **Figure 6.19** Typical work area outlet

• **Figure 6.20** Properly labeled outlet

Structured cabling goes beyond a single building and even describes methods for interconnecting multiple buildings. The CompTIA Network+ certification exam does not cover interbuilding connections.

The Work Area

From a cabling standpoint, a work area is nothing more than a wall outlet that serves as the termination point for horizontal network cables: a convenient insertion point for a PC and a telephone. A wall outlet itself consists of one or two female jacks to accept the cable, a mounting bracket, and a faceplate. You connect the PC to the wall outlet with a patch cable (Figure 6.19).

The female RJ-45 jacks in these wall outlets also have CAT ratings. You must buy CAT-rated jacks for wall outlets to go along with the CAT rating of the cabling in your network. In fact, many network connector manufacturers use the same connectors in the wall outlets that they use on the patch panels. These modular outlets significantly increase ease of installation. Make sure you label the outlet to show the job of each connector (Figure 6.20). A good outlet will also have some form of label that identifies its position on the patch panel. Proper documentation of your outlets will save you an incredible amount of work later.

The last step is connecting the PC to the wall outlet. Here again, most folks use a patch cable. Its stranded cabling stands up to the abuse caused by moving PCs, not to mention the occasional kick.

You'll recall from Chapter 5, "Modern Ethernet," that 10/100/1000BaseT networks specify a limit of 100 meters between a hub or switch and a node. Interestingly, though, the TIA/EIA 568 specification allows only UTP cable lengths of 90 meters. What's with the missing 10 meters? Have you figured it out? Hint: the answer lies in the discussion we've just been having. Ding! Time's up! The answer is…the patch cables! Patch cables add extra distance between the hub and the PC, so TIA/EIA compensates by reducing the horizontal cabling length.

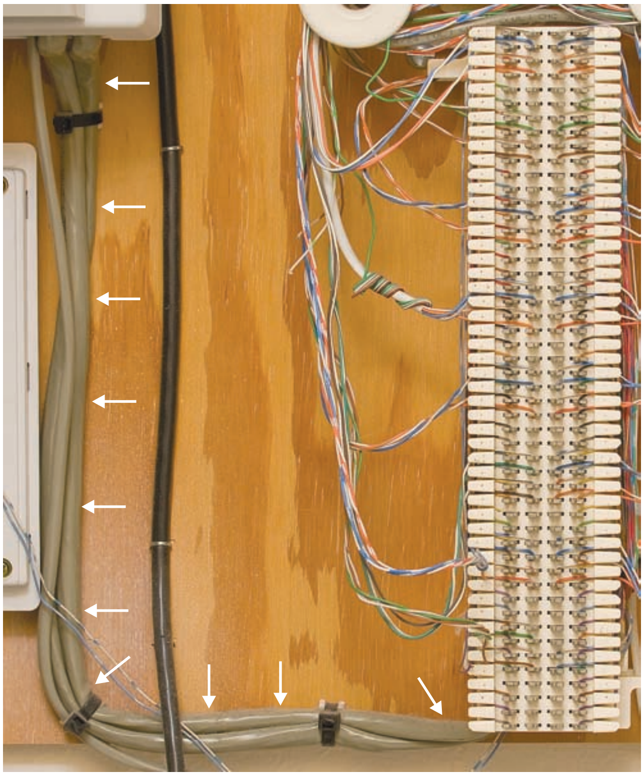
The work area may be the simplest part of the structured cabling system, but it is also the source of most network failures. When a user can't access the network and you suspect a broken cable, the first place to look is the work area.

Structured Cable—Beyond the Star

Thus far you've seen structured cabling as a single star topology on a single floor of a building. Let's now expand that concept to an entire building and learn the terms used by the structured cabling folks, such as the demarc and NIU, to describe this much more complex setup.

It's hard to find a building today that isn't connected to both the Internet and the telephone company. In many cases this is a single connection, but for now let's treat them as separate connections.

As you saw in the previous chapter, a typical building-wide network consists of a high-speed backbone that runs vertically through the building, and connects to multispeed switches on each floor that in turn service the individual PCs on that floor. A dedicated telephone cabling backbone that enables the distribution of phone calls to individual telephones runs alongside the network cabling. While every telephone installation varies, most commonly you'll see one or more strands of 25-pair UTP cables running to the 66 block in the telecommunications room on each floor (Figure 6.21).



• **Figure 6.21** 25-pair running to local 66-block

Demarc

Connections from the outside world—whether network or telephone—come into a building at a location called a **demarc**, short for *demarcation point*. The term "demarc" refers to the physical location of the connection and marks the dividing line of responsibility for the functioning of the network. You take care of the internal functioning; the person or company that supplies the upstream service to you must support connectivity and function on the far side of the demarc.

In a private home, the DSL or cable modem supplied by your ISP is a **network interface unit (NIU)** that serves as a demarc between your home network and your ISP, and most homes have a network interface box, like the one shown in Figure 6.22, that provides the connection for your telephone.

In an office environment the demarc is usually more complex, given that a typical building simply has to serve a much larger number of telephones and computers. Figure 6.23 shows the demarc for a midsized building, showing both Internet and telephone connections coming in from the outside.

One challenge to companies that supply ISP/telephone services is the need to diagnose faults in the system. Most of today's NIUs come with extra "smarts" that enable the ISP or telephone company to determine if the customer has

Tech Tip

NUI=NIB=NID: huh?

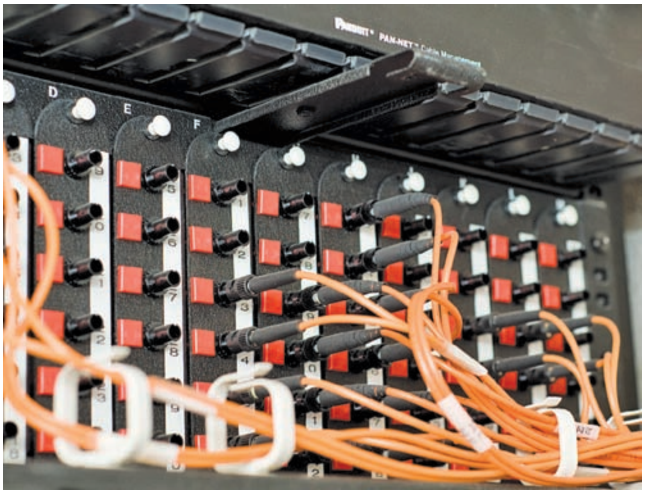
The terms used to describe the devices that often mark the demarcation point in a home or office get tossed about with wild abandon. Various manufacturers and technicians call them network interface units, network interface boxes, *or* network interface devices. *(Some techs call them demarcs, just to muddy the waters further, but we won't go there.) By name or by initial—NIU, NIB, or NID—it's all the same thing, the box that marks the point where your responsibility is on the inside.*

• **Figure 6.22** Typical home network interface box

The best way to think of a demarc is in terms of responsibility. If something breaks on one side of the demarc, it's your problem; on the other side, it's the ISP/phone company's problem.

• **Figure 6.23** Typical office demarc

disconnected from the NIU. These special (and very common) NIUs are known as **smart jacks**. Smart jacks also have the very handy capability to set up a remote loopback—critical for loopback testing when you're at one end of the connection and the other connection is blocks or even miles away.



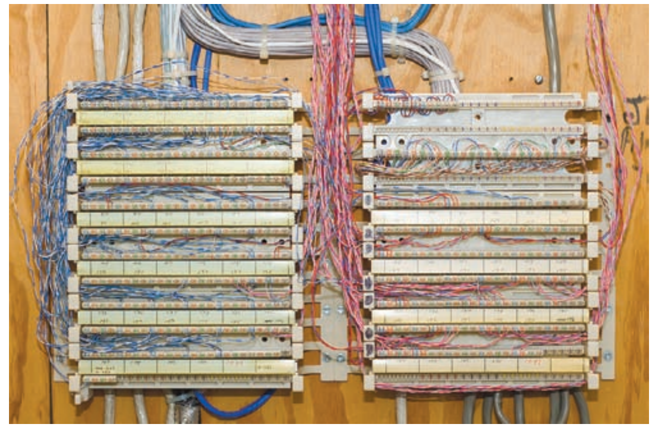
• **Figure 6.24** LAN vertical cross-connect

Connections Inside the Demarc

After the demarc, network and telephone cables connect to some type of box, owned by the customer, that acts as the primary distribution tool for the building. Any cabling that runs from the NIU to whatever box is used by the customer is the **demarc extension**. For telephones, the cabling might connect to a special box called a **multiplexer**, and on the LAN side almost certainly to a powerful switch. This switch usually connects to a patch panel. This patch panel in turn leads to every telecommunications room in the building. This main patch panel is called a **vertical cross-connect**. Figure 6.24 shows an example of a fiber patch panel acting as a vertical cross-connect for a building.

Telephone systems also use vertical cross-connects. Figure 6.25 shows a vertical cross-connect for a telephone system. Note the large number of 25-pair UTP cables feeding out of this box. Each 25-pair cable leads to a telecommunications room on a floor of the building.

The combination of demarc, telephone cross-connects, and LAN cross-connects needs a place to live in a building. The room that stores all of this equipment is known as a **main distribution frame (MDF)** to distinguish it from the multiple IDF rooms (a.k.a., telecommuni-cations rooms) that serve individual floors.



• **Figure 6.25** Telephone vertical cross-connect

The ideal that every building should have a single demarc, a single MDF, and multiple IDFs is only that—an ideal. Every structured cabling installation is unique and must adapt to the physical constraints of the building provided. One building may serve multiple customers, creating the need for multiple NIUs each serving a different customer. A smaller building may combine a demarc, MDF, and IDF into a single room. With structured cabling, the idea is to appreciate the terms while at the same time appreciate that it's the actual building and the needs of the customers that determine the actual design of structured cabling system.

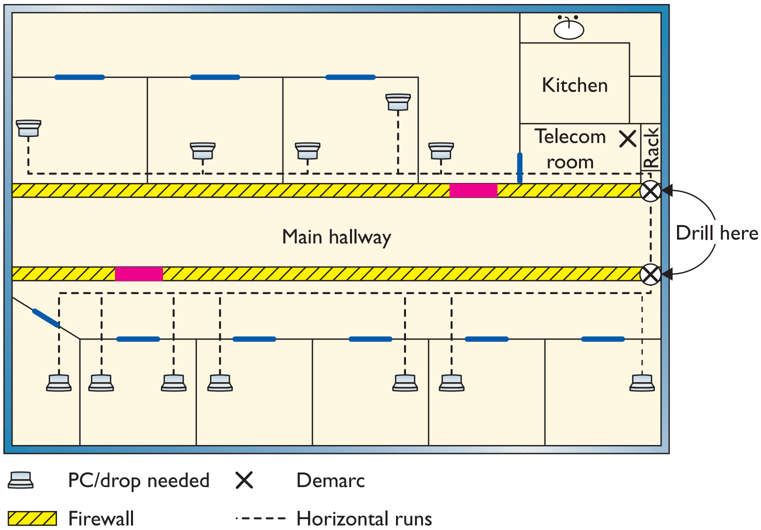
Installing Structured Cabling

A professional installer always begins a structured cabling installation by first assessing your site and planning the installation in detail before pulling a single piece of cable. As the customer, your job is to work closely with the installer. That means locating floor plans, providing access, and even putting on old clothes and crawling along with the installer as he or she combs through your ceilings, walls, and closets. Even though you're not the actual installer, you must understand the installation process, so you can help the installer make the right decisions for your network.

Structured cabling requires a lot of planning. You need to know if the cables from the work areas can reach the telecommunications room—is the distance less than the 90-meter limit dictated by the TIA/EIA standard? How will you route the cable? What path should each run take to get to the wall outlets? Don't forget that just because a cable looks like it will reach, there's no guarantee that it will. Ceilings and walls often include hidden surprises like firewalls—big, thick, concrete walls designed into buildings that require a masonry drill or a jackhammer to punch through. Let's look at the steps that go into proper planning.

Getting a Floor Plan

First, you need a blueprint of the area. If you ever contract an installer and they don't start by asking for a floor plan, fire them immediately and get one who does. The floor plan is the key to proper planning; a good floor plan shows you the location of closets that could serve as telecommunications



• **Figure 6.26** Hand-drawn network floor plan

rooms, alerts you to any firewalls in your way, and gives you a good overall feel for the scope of the job ahead.

If you don't have a floor plan—and this is often the case with homes or older buildings—you'll need to create your own. Go get a ladder and a flashlight—you'll need them to poke around in ceilings, closets, and crawl spaces as you map out the location of rooms, walls, and anything else of interest to the installation. Figure 6.26 shows a typical do-it-yourself floor plan, drawn out by hand.

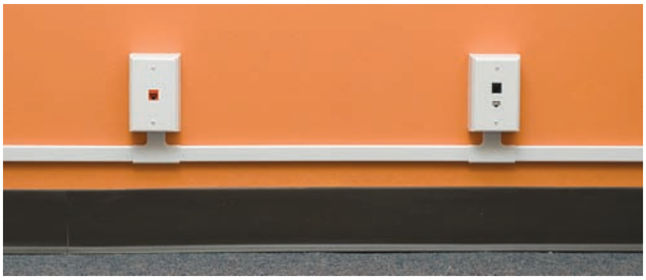
Mapping the Runs

Now that you have your floor plan, it's time to map the cable runs. Here's where you run around the work areas, noting the locations of existing or planned systems to determine where to place each cable drop. A **cable drop** is the location where the cable comes out of the wall in the workstation. You should also talk to users, management, and other interested parties to try and understand their plans for the future. It's much easier to install a few extra drops now than to do it a year from now when those two unused offices suddenly find themselves with users who immediately need networked computers!

> Watch out for the word *drop*, as it has more than one meaning. A single run of cable from the telecommunications room to a wall outlet is often referred to as a drop. The word drop is also used to define a new run coming through a wall outlet that does not yet have a jack installed.

This is also the point where cost first raises its ugly head. Face it: cables, drops, and the people who install them cost money! The typical price for a network installation is around US $150 per drop. Find out how much you want to spend and make some calls. Most network installers price their network jobs by quoting a per-drop cost.

While you're mapping your runs, you have to make another big decision: Do you want to run the cables in the walls or outside them? Many companies sell wonderful external **raceway** products that adhere to your walls, making for a much simpler, though less neat, installation than running cables in the walls (Figure 6.27). Raceways make good sense in older buildings or when you don't have the guts—or the rights—to go into the walls.



• **Figure 6.27** A typical raceway

Determining the Location of the Telecommunications Room

While mapping the runs, you should decide on the location of your telecommunications room. When deciding on this location, keep five issues in mind:

- **Distance** The telecommunications room must be located in a spot that won't require cable runs longer than 90 meters. In most locations, keeping runs under 90 meters requires little effort, as long as the telecommunications room is placed in a central location.
- **Power** Many of the components in your telecommunications room need power. Make sure you provide enough! If possible, put the telecommunications room on its own dedicated circuit; that way, when someone blows a circuit in the kitchen, it doesn't take out the entire network.
- **Humidity** Electrical components and water don't mix well. (Remind me to tell you about the time I installed a rack in an abandoned bathroom, and the toilet that later exploded.) Remember that dryness also means low humidity. Avoid areas with the potential for high humidity, such as a closet near a pool or the room where the cleaning people leave mop buckets full of water. Of course, any well air-conditioned room should be fine—which leads to the next big issue…
- **Cooling** Telecommunications rooms tend to get warm, especially if you add a couple of server systems and a UPS. Make sure your telecommunications room has an air-conditioning outlet or some other method of keeping the room cool. Figure 6.28 shows how I installed an air-conditioning duct in my small equipment closet. Of course, I did this only after I discovered that the server was repeatedly rebooting due to overheating!
- **Access** Access involves two different issues. First, it means preventing unauthorized access. Think about the people you do and don't want messing around with your network, and act accordingly. In my small office, the equipment closet literally sits eight feet from me, so I don't concern myself too much with unauthorized access. You, on the other hand, may want to consider placing a lock on the door of your telecommunications room if you're concerned that unscrupulous or unqualified people might try to access it.

• **Figure 6.28** An A/C duct cooling a telecommunications room

One other issue to keep in mind when choosing your telecommunications room is expandability. Will this telecommunications room be able to grow with your network? Is it close enough to be able to service any additional office space your company may acquire nearby? If your company decides to take over the floor above you, can you easily run vertical cabling to another telecommunications room on that floor from this room? While the specific issues will be unique to each installation, keep thinking "expansion" as you design—your network will grow, whether or not you think so now!

So, you've mapped your cable runs and established your telecommunications room—now you're ready to start pulling cable!

• **Figure 6.29** Cable trays over a drop ceiling

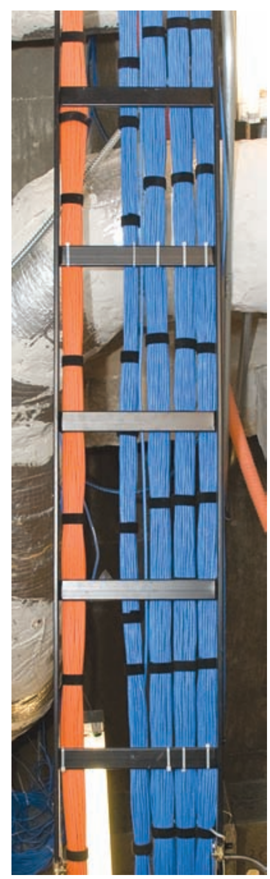
Pulling Cable

Pulling cable is easily one of the most thankless and unpleasant jobs in the entire networking world. It may not look that hard from a distance, but the devil is in the details. First of all, pulling cable requires two people if you want to get the job done quickly; having three people is even better. Most pullers like to start from the telecommunications room and pull toward the drops. In an office area with a drop ceiling, pullers will often feed the cabling along the run by opening ceiling tiles and stringing the cable via hooks or **cable trays** that travel above the ceiling (Figure 6.29). Professional cable pullers have an arsenal of interesting tools to help them move the cable horizontally, including telescoping poles, special nylon pull ropes, and even nifty little crossbows and pistols that can fire a pull rope long distances!

Cable trays are standard today, but a previous lack of codes or standards for handling cables led to a nightmare of disorganized cables in drop ceilings all over the world. Any cable puller will tell you that the hardest part of installing cables is the need to work around all the old cable installations in the ceiling (Figure 6.30).

Local codes, TIA/EIA, and the National Electrical Code (NEC) all have strict rules about how you pull cable in a ceiling. A good installer uses either hooks or trays, which provide better cable management, safety, and protection from electrical interference (Figure 6.31). The faster the network, the more critical good cable management becomes. You probably won't have a problem laying UTP directly on top of a drop ceiling if you just want a 10BaseT network, and

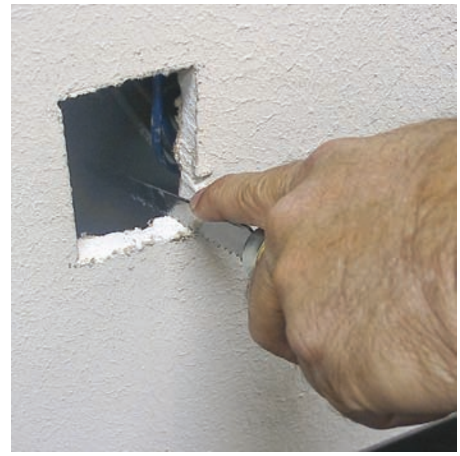
• **Figure 6.30** Messy cabling nightmare



• **Figure 6.31** Nicely run cables

you might even get away with this for 100BaseT—but forget about doing this with Gigabit or beyond. Cable installation companies are making a mint from all the CAT 5 and earlier network cabling installations that need to be redone to support Gigabit Ethernet.

Running cable horizontally requires relatively little effort, compared to running the cable down from the ceiling to a pretty faceplate at the work area, which often takes a lot of skill. In a typical office area with sheetrock walls, the installer first decides on the position for the outlet, usually using a stud finder to avoid cutting on top of a stud. Once the worker cuts the hole (Figure 6.32), most installers drop a line to the hole using a weight tied to the end of a nylon pull rope (Figure 6.33). They can then attach the network cable to the pull rope and pull it down to the hole. Once the cable is pulled through the new hole, the installer puts in an outlet box or a low-voltage **mounting bracket** (Figure 6.34). This bracket acts as a holder for the faceplate.



• **Figure 6.32** Cutting a hole

Back in the telecommunications room, the many cables leading to each work area are consolidated and organized in preparation for the next stage: making connections. A truly professional installer takes great care in organizing the equipment closet. Figure 6.35 shows a typical installation using special cable guides to bring the cables down to the equipment rack.

• **Figure 6.33** Locating a dropped pull rope

Making Connections

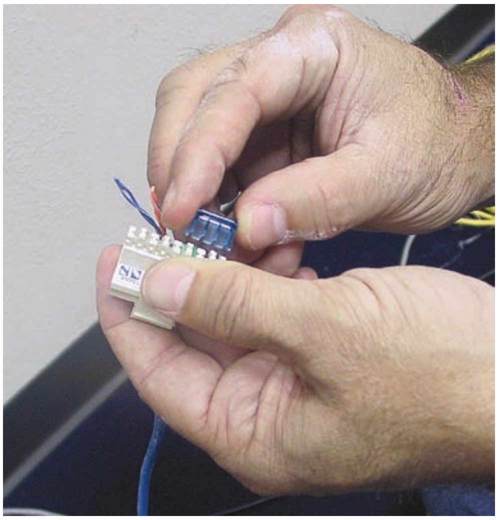
Making connections consists of connecting both ends of each cable to the proper jacks. This step also includes the most important step in the entire process: testing each cable run to ensure that every connection meets the requirements of the network that will use it. Installers also use this step to document and label each cable run—a critical step too often forgotten by inexperienced installers, and one you need to verify takes place!

Connecting the Work Areas

Let's begin by watching an installer connect a cable run. In the work area, that means the cable installer will now crimp a

• **Figure 6.34** Installing a mounting bracket

• **Figure 6.35** End of cables guided to rack



• **Figure 6.36** Crimping a jack

jack onto the end of the wire and mount the faceplate to complete the installation (Figure 6.36).

Note the back of the jack shown in Figure 6.36. This jack uses the popular 110-punchdown connection just like the one shown earlier in the chapter for patch panels. All 110 connections have a color code that tells you which wire to punch into which connection on the back of the jack.

Rolling Your Own Patch Cables

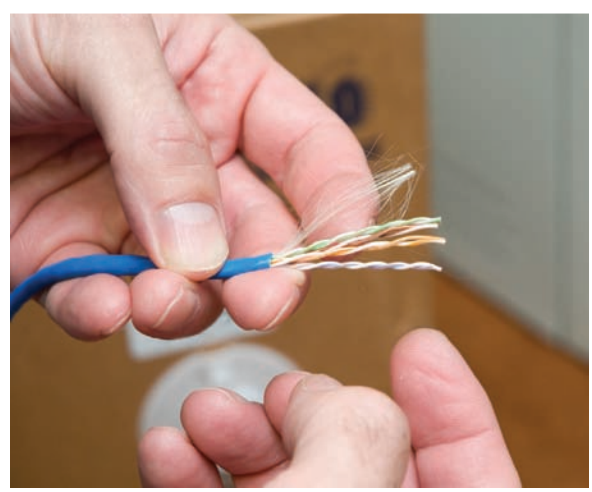
While most people prefer to simply purchase premade patch cables, it's actually fairly easy to make your own. To make your own, be sure to use stranded UTP cable that matches the CAT level of your horizontal cabling. There are also specific crimps for stranded cable, so don't use crimps designed for solid cable. Crimping is simple enough, although getting it right takes some practice.

Figure 6.37 shows the two main tools of the crimping trade: an RJ-45 crimper with built-in stripper, and a pair of wire snips. Professional cable installers naturally have a wide variety of other tools as well.

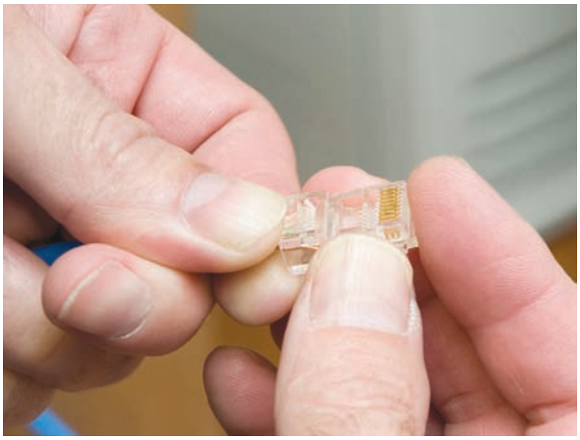
Here are the steps for properly crimping an RJ-45 onto a UTP cable. If you have some crimps, cable, and a crimping tool handy, follow along!

1. Cut the cable square using RJ-45 crimpers or scissors.
2. Strip off ½ inch of plastic jacket from the end of the cable (Figure 6.38).
3. Slowly and carefully insert each individual wire into the correct location according to either TIA/EIA 568A or B (Figure 6.39). Unravel as little as possible.
4. Insert the crimp into the crimper and press (Figure 6.40). Don't worry about pressing too hard; the crimper has a stop to prevent you from using too much pressure.

• **Figure 6.37** Crimper and snips



• **Figure 6.38** Properly stripped cable



• **Figure 6.39** Inserting the individual strands

• **Figure 6.40** Crimping the cable

Figure 6.41 shows a nicely crimped cable. Note how the plastic jacket goes into the crimp.

A good patch cable should include a boot. Figure 6.42 shows a boot being slid onto a newly crimped cable. Don't forget to slide each boot onto the patch cable *before* you crimp both ends!

After making a cable you need to test it to make sure it's properly crimped. Read the section on testing cable runs later in this chapter to see how to test them.

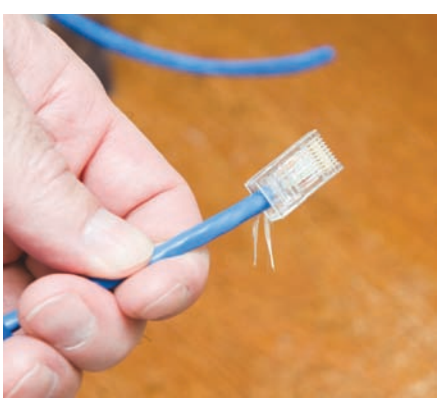
Try This!

Crimping Your Own Cable

If you've got some spare CAT 5 lying around (and what tech enthusiast doesn't?) as well as a cable crimper and some crimps, go ahead and use the previous section as a guide and crimp your own cable. This is an essential skill for any network technician. Remember, practice makes perfect!

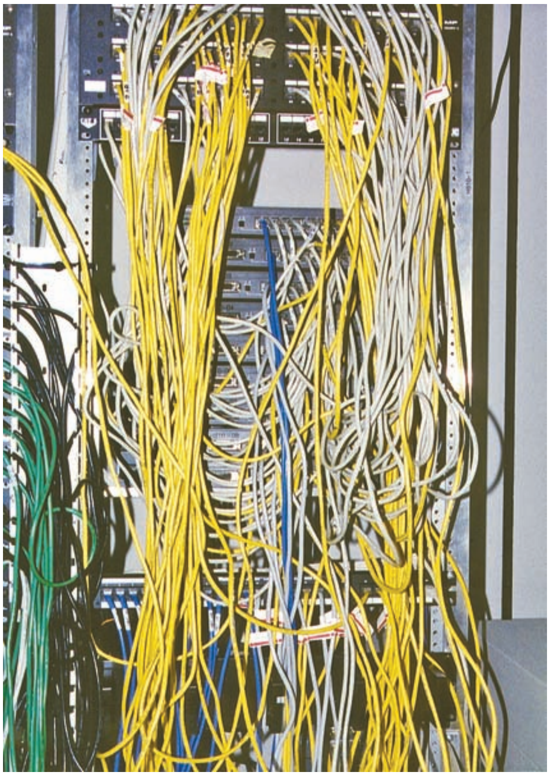
Connecting the Patch Panels

Connecting the cables to patch panels requires you to deal with two issues. The first is patch cable management. Figure 6.43 shows the front of a small network's equipment rack—note the complete lack of cable management!



• **Figure 6.41** Properly crimped cable

• **Figure 6.42** Adding a boot

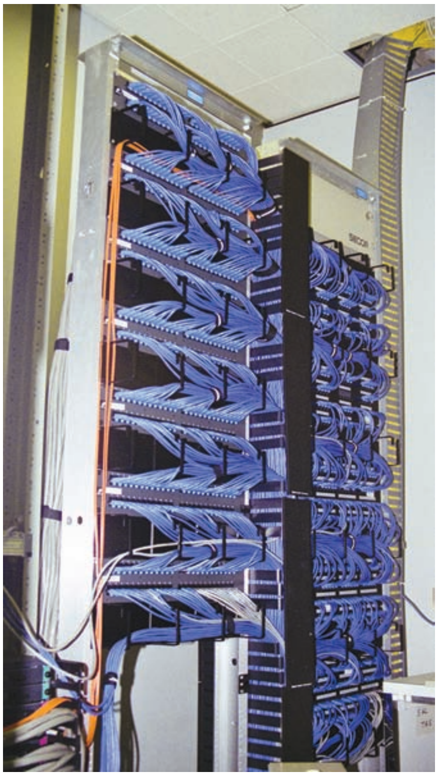


• **Figure 6.43** Bad cable management

Managing patch cables means using the proper cable management hardware. Plastic D-rings guide the patch cables neatly along the sides and front of the patch panel. Finger boxes are rectangular cylinders with slots in the front; the patch cables run into the open ends of the box, and individual cables are threaded through the fingers on their way to the patch panel, keeping them neatly organized.

Creativity and variety abound in the world of cable-management hardware—there are as many different solutions to cable management as there are ways to screw up organizing them. Figure 6.44 shows a rack using good cable management—these patch cables are well secured using cable-management hardware, making them much less susceptible to damage from mishandling. Plus, it looks much nicer!

The second issue to consider when connecting cables is the overall organization of the patch panel as it relates to the organization of your network. Organize your patch panel so that it mirrors the layout of your network. You can organize according to the physical layout, so the different parts of the patch panel correspond to different parts of your office space—for example, the north and south sides of the hallway. Another popular way to organize patch panels is to make sure they match the logical layout of the network, so the different user groups or company organizations have their own sections of the patch panel.



• **Figure 6.44** Good cable management

Testing the Cable Runs

Well, in theory, your horizontal cabling system is now installed and ready for a switch and some systems. Before you do this, though, you must test each cable run. Someone new to testing cable might think that all you need to do is verify that each jack has been properly connected. While this is an important and necessary step, the interesting problem comes after that: verifying that your cable run can handle the speed of your network.

Before we go further, let me be clear: a typical network admin/tech cannot properly test a new cable run. TIA/EIA provides a series of incredibly complex and important standards for testing cable, requiring a professional cable installer. The testing equipment alone totally surpasses the cost of most smaller network installations. Advanced network testing tools easily cost over $5,000, and some are well over $10,000! Never fear, though—a number of lower-end tools work just fine for basic network testing.

The test tools described here also enable you to diagnose network problems.

Most network admin types staring at a potentially bad cable want to know the following:

- How long is this cable? If it's too long the signal will degrade to the point it's no longer detectable on the other end.
- Are any of the wires broken or not connected in the crimp? If a wire is broken, it no longer has **continuity**.
- If there is a break, where is it? It's much easier to fix if the location is detectable.
- Are all of the wires terminated in the right place in the plug or jack?
- Is there electrical or radio interference from outside sources? UTP is susceptible to electromagnetic interference.
- Is the signal from any of the pairs in the same cable interfering with another pair?

To answer these questions you must verify that both the cable and the terminated ends are correct. Making these verifications requires a **cable tester**. Various models of cable testers can answer some or all of these questions, depending on the amount of money you are willing to pay. At the low end of the cable tester market are devices that only test for continuity. These cheap (under $100) testers are often called **continuity testers** (Figure 6.45). Many of these cheap testers require you to insert both ends of the cable into the tester. Of course, this can be a bit of a problem if the cable is already installed in the wall!

• **Figure 6.45** Continuity tester

Better testers can run a wire map test that goes beyond mere continuity, testing that all the wires on both ends of the cable connect to the right spot. A wire map test will pick up shorts, crossed wires, and more.

Many techs and network testing equipment use the term **wiremap** to refer to the proper connectivity for wires, as in, "Hey Joe, check the wiremap!"

A multimeter works perfectly well to test for continuity, assuming you can place its probes on each end of the cable. Set the multimeter to its continuity setting if it has one (Figure 6.46) or to Ohms. With the latter setting,

Tech Tip

Fat Probes

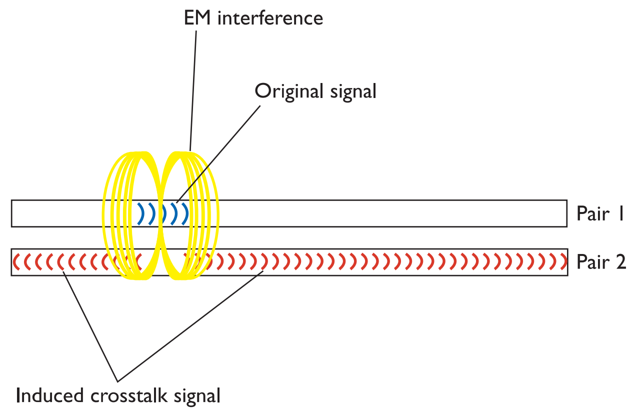
If you have a multimeter with probes too large to connect to individual contacts on an RJ-45, you can use an old tech trick to finesse the problem. Take a patch cable and cut off about two feet, so you have a short cable with one end bare. Strip an inch of the cladding away from the bare end to expose the wires. Strip a little of the sheath off each wire and plug the cable into the jack. Now you can test continuity by putting the probes directly onto the wire!

• **Figure 6.46** Multimeter

if you have a connection, you get zero Ohms, and if you don't have a connection, you get infinite Ohms.

Medium-priced testers (~$400) certainly test continuity and wiremap and include the additional capability to determine the length of a cable, and can even tell you where a break is located on any of the individual wire strands. This type of cable tester (Figure 6.47) is generically called a **time domain reflectometer (TDR)**. Most medium-priced testers come with a small loopback device to insert into the far end of the cable, enabling the tester to

• **Figure 6.47** A typical medium-priced TDR called a Microscanner



• **Figure 6.48** Crosstalk

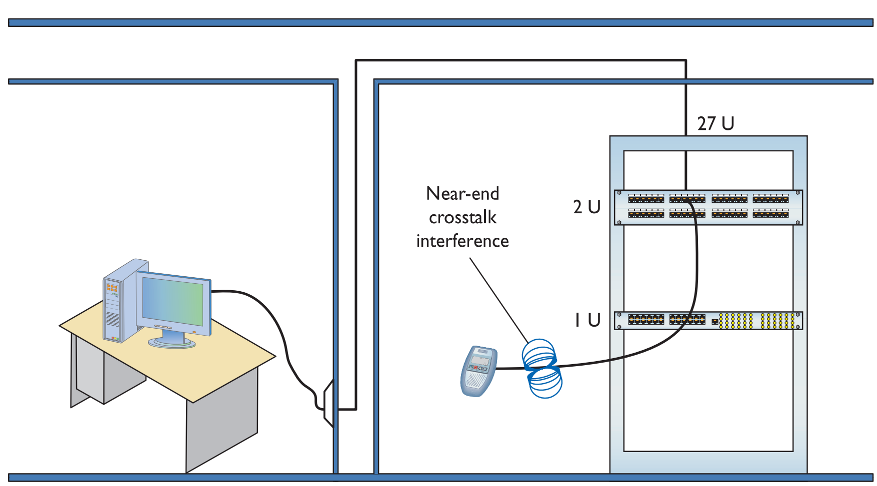
work with installed cables. This is the type of tester you want to have around!

If you want a device that fully tests a cable run to the very complex TIA/EIA standards, the price shoots up fast. These higher-end testers can detect things the lesser testers cannot, such as crosstalk and attenuation.

Crosstalk poses a threat to properly functioning cable runs. Today's UTP cables consist of four pairs of wires, all squished together inside a plastic tube. When you send a signal down one of these pairs, the other pairs pick up some of the signal, as shown in Figure 6.48. This is called **crosstalk**.

Every piece of UTP in existence generates crosstalk. Worse, when you crimp the end of a UTP cable to a jack or plugs, crosstalk increases. A poor-quality crimp creates so much crosstalk that a cable run won't operate at its designed speed. To detect crosstalk, a normal-strength signal is sent down one pair of wires in a cable. An electronic detector, connected on the same end of the cable as the end emanating the signal, listens on the other three pairs and measures the amount of interference, as shown in Figure 6.49. This is called **near-end crosstalk (NEXT)**.

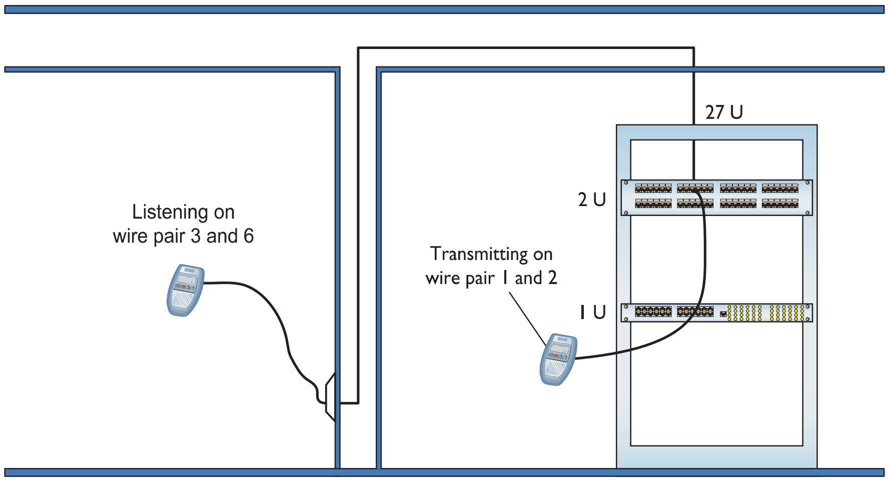
If you repeat this test, sending the signal down one pair of wires, but this time listening on the other pairs on the far end of the connection, you test for **far-end crosstalk (FEXT)**, as shown in Figure 6.50.



• **Figure 6.49** Near-end crosstalk

As if that's not bad enough, as a signal progresses down a piece of wire the signal becomes steadily weaker: what's called **attenuation**. As a cable run gets longer, the attenuation increases, and the signal becomes more susceptible to crosstalk. So a tester must send a signal down one end of a wire, test for NEXT and FEXT on the ends of every other pair, and then repeat this process for every pair in the UTP cable.

Both NEXT and FEXT are measured in decibels (db).



• **Figure 6.50** Far-end crosstalk

• **Figure 6.51** A typical cable certifier—a Microtest OMNIScanner (photo courtesy of Fluke Networks)

This process of verifying that every cable run meets the exacting TIA/EIA standards requires very powerful testing tools, generally known as **cable certifiers** or just certifiers. Cable certifiers can both do the high-end testing and generate a report that a cable installer can print out and hand to a customer to prove that the installed cable runs pass TIA/EIA standards. Figure 6.51 shows an example of this type of scanner made by Fluke (www.fluke.com) in its Microtest line. Most network techs don't need these advanced testers, so unless you have some deep pockets or find yourself doing serious cable testing, stick to the medium-priced testers.

Testing Fiber

Fiber-optic cabling is an entirely different beast in terms of termination and testing. The classic termination method requires very precise stripping, polishing the end of the tiny fiber cable, adding epoxy glue, and inserting the connector. A fiber technician uses a large number of tools (Figure 6.52) and an almost artistic amount of skill. Over the years easier terminations have been developed, but putting an ST, SC, LC, or other connector on the end of a piece of fiber is still very challenging.

A fiber-optic run has problems that are both similar to and different from those of a UTP run. Since most fiber-optic network runs only use two cables, they don't experience crosstalk. Fiber-optic cables do break, so a good tech always keeps an **optical time domain reflectometer (OTDR)** handy (Figure 6.53). OTDRs determine continuity and, if there's a break, tell you exactly how far down the cable to look for the break.

TIA/EIA has very complex requirements for testing fiber runs, and the cabling industry sells fiber certifiers to make sure a fiber will carry its designed signal speed.

The three big issues with fiber are attenuation, light leakage, and modal distortion. The amount of light propagating down the fiber cable diffuses

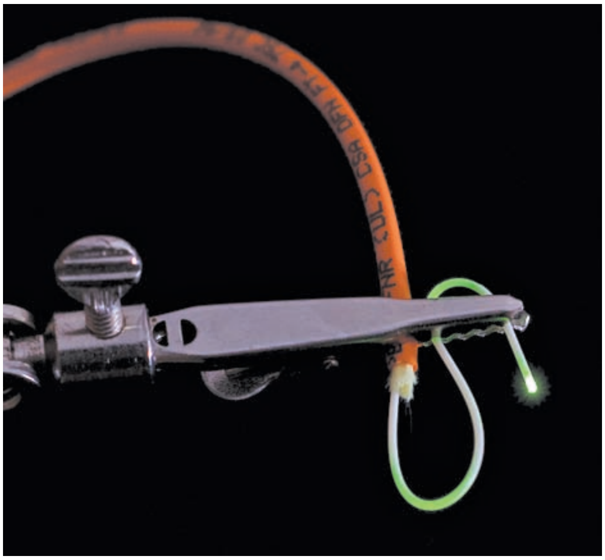
• **Figure 6.52** Older fiber termination kit

Attenuation is the weakening of a signal as it travels long distances. *Dispersion* is when a signal spreads out over long distances. Both attenuation and dispersion are caused when wave signals travel too far without help over fiber-optic media. The confusing part is that dispersion can cause attenuation and *vice versa*.

over distance, which causes attenuation or **dispersion** (when the light signal spreads). If you bend a fiber-optic cable too much you get **light leakage**, as shown in Figure 6.54. Every type of fiber cabling has a very specific maximum bend radius. Modal distortion is unique to multimode fiber-optic cable. As the light source illuminates, it sends out light in different modes. Think of a mode as a slightly different direction. Some light shoots straight down the fiber; other modes bounce back and forth at a sharp angle.

The process of installing a structured cabling system is rather involved, requires a great degree of skill, and should be left to professionals. By understanding the process, however, you can tackle most of the problems that come up in an installed structured cabling system. Most importantly, you'll understand the lingo used by the structured cabling installers so you can work with them more efficiently.

• **Figure 6.53** An optical time domain reflectometer (photo courtesy of Fluke Networks)



• **Figure 6.54** Light leakage—note the colored glow at the bends but the dark cable at the straight

NICs

Tech Tip

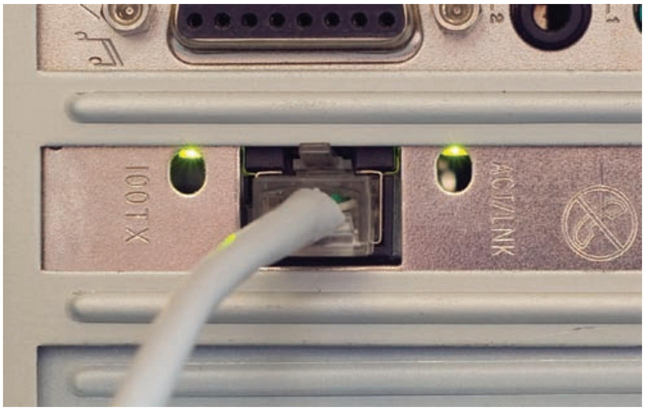
Onboard NICs

It's a rare motherboard these days that doesn't include an onboard NIC. This of course completely destroys the use of the acronym "NIC" for network interface card because there's no card involved. But heck, we're nerds and, just as we'll probably never stop using the term "RJ-45" when the correct term is "8P8C," we'll just keep using the term "NIC." I know! Let's just pretend it stands for network interface connection*!*

Now that the network is completely in place, it's time to turn to the final part of any physical network: the NICs. A good network tech must recognize different types of NICs by sight and know how to install and troubleshoot them. Let's begin by reviewing the differences between UTP and fiber-optic NICs.

All UTP Ethernet NICs use the RJ-45 connector. The cable runs from the NIC to a hub or a switch (Figure 6.55). It is impossible to tell one from the other simply by looking at the connection.

Fiber-optic NICs come in a wide variety; worse, manufacturers will use the same connector types for multiple standards. You'll find a 100BaseFX



• **Figure 6.55** Typical UTP NIC

card designed for multimode cable with an SC connector, for example, and an identical card designed for single-mode cable, also with an SC connector. You simply must see the documentation that comes with the two cards to tell them apart. Figure 6.56 shows a typical fiber-optic network card.

• **Figure 6.56** Typical fiber NIC (photo courtesy of 3Com Corp.)

Buying NICs

Some folks may disagree with this, but I always purchase name-brand NICs. For NICs, stick with big names, such as 3Com or Intel. The NICs are better made, have extra features, and are easy to return if they turn out to be defective. Plus, it's easy to replace a missing driver on a name-brand NIC, and to be sure that the drivers work well. The type of NIC you purchase depends on your network. Try to think about the future and go for multispeed cards if your wallet can handle the extra cost. Also, where possible, try to stick with the same model of NIC. Every different model you buy means another set of driver disks you need to haul around in your tech bag. Using the same model of NIC makes driver updates easier, too.

> Many people order desktop PCs with NICs simply because they don't take the time to ask if the system has a built-in NIC. Take a moment and ask about this!

Physical Connections

I'll state the obvious here: If you don't plug the NIC into the computer, it just isn't going to work! Many users happily assume some sort of quantum magic when it comes to computer communications, but as a tech, you know better. Fortunately, most PCs come with built-in NICs, making physical installation a nonissue. If you're buying a NIC, physically inserting the NIC into one of the PC's expansion slots is the easiest part of the job. Most PCs today have two types of expansion slots. The older, but still common expansion slot is the Peripheral Component Interconnect (PCI) type (Figure 6.57).

• **Figure 6.57** PCI NIC

The newer PCI Express (PCIe) expansion slots now have some good adoption from NIC suppliers. PCIe NICs usually come in either one-lane (×1) or two-lane (×2) varieties (Figure 6.58).

If you're not willing to open a PC case, you can get NICs with USB or PC Card connections. USB is convenient, but at a maximum speed of 480 Mbps is slower than Gigabit Ethernet; and PC Card is only a laptop solution (Figure 6.59). USB NICs are handy to keep in your toolkit. If you walk up to a machine that might have a bad NIC, test your suspicions by inserting a USB NIC and moving the network cable from the potentially bad NIC to the USB one. (Don't forget to bring your driver disc along!)

• Figure 6.58 PCIe NIC

• Figure 6.59 USB NIC

Drivers

Installing a NIC's driver into a Windows, Macintosh, or Linux system is easy: just insert the driver CD when prompted by the system. Unless you have a very offbeat NIC, the operating system will probably already have the driver preinstalled, but there are benefits to using the driver on the manufacturer's CD. The CDs that comes with many NICs, especially the higher-end, brand-name ones, include extra goodies such as enhanced drivers and handy utilities, but you'll only be able to access them if you install the driver that comes with the NIC.

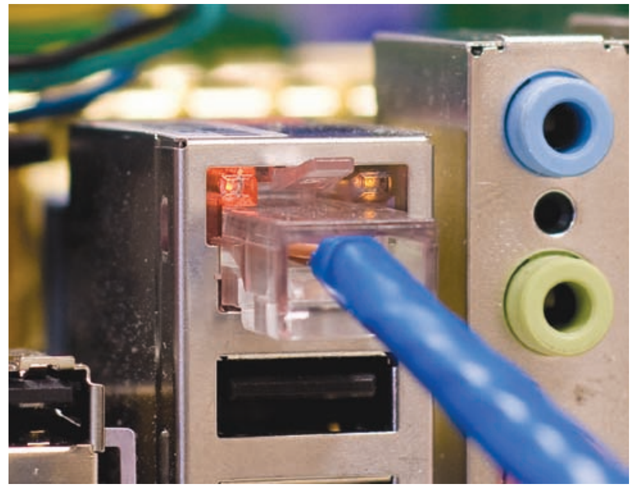
Every operating system has some method to verify that the computer recognizes the NIC and is ready to use it. Windows systems have the Device Manager, Ubuntu Linux users can use the Network applet under the Administration menu, and your Macintosh has the Network utility in System Preferences. Actually, most operating systems have multiple methods to show that the NIC is in good working order. Learn the ways to do this for your OS as this is the ultimate test of a good NIC installation.

Bonding

Most switches enable you to use multiple NICs for a single machine, a process called **bonding** or *link aggregation*. Bonding effectively doubles (or more) the speed between a machine and a switch. In preparing for this book, for example, I found that the connection between my graphics development computer and my file server was getting pounded by my constant sending/receiving massive image files, slowing down everyone else's file access. Rather than upgrading the switches and NICs from Gigabit to 10-Gigabit Ethernet—still fairly expensive at this writing—I found that simply doubling the connections among those three machines—graphics computer, switch, and file server—increased performance all around. If you want to add link aggregation to your network to increase performance, try to use identical NICs and switches from the same companies to avoid the hint of incompatibility.

Link Lights

All UTP NICs made today have some type of light-emitting diodes (LEDs) that give information about the state of the NIC's link to whatever's on the other end of the connection. Even though you know the lights are actually LEDs, get used to calling them **link lights**, as that's the term all network techs use. NICs can have between one and four different link lights, and the LEDs can be any color. These lights give you clues about what's happening with the link and are one of the first items to check whenever you think a system is disconnected from the network (Figure 6.60).



• **Figure 6.60** Mmmm, pretty lights!

A link light tells you that the NIC is connected to a hub or switch. Hubs and switches also have link lights, enabling you to check the connectivity at both ends of the cable. If a PC can't access a network and is acting disconnected, always first check the link lights. Multispeed devices usually have a link light that tells you the speed of the connection. In Figure 6.61, the light for port 2 on the top photo is orange, signifying that the other end of the cable is plugged into either a 10BaseT or 100BaseT NIC. The same port connected to a Gigabit NIC—that's the lower picture—displays a green LED.

• **Figure 6.61** Multispeed lights

A properly functioning link light is steady on when the NIC is connected to another device. No flickering, no on and off, just on. A link light that is off or flickering shows a connection problem.

Another light is the **activity light**. This little guy turns on when the card detects network traffic, so it makes an intermittent flickering when operating properly. The activity light is a lifesaver for detecting problems, because in the real world, the connection light will sometimes lie to you. If the connection light says the connection is good, the next step is to try to copy a file or do something else to create network traffic. If the activity light does not flicker, there's a problem.

You might run into yet another light on some much older NICs, called a collision light. As you might suspect from the name, the **collision light** flickers when it detects collisions on the network. Modern NICs don't have these, but you might run into this phrase on the CompTIA Network+ certification exam.

Keep in mind that the device on the other end of the NIC's connection has link lights too! Figure 6.62 shows the link lights on a modern switch. Most switches have a single LED per port to display connectivity and activity.

• **Figure 6.62** Link lights on a switch

No standard governs how NIC manufacturers use their lights and, as a result, they come in an amazing array of colors and layouts. When you encounter a NIC with a number of LEDs, take a moment and try to figure out what each one means. Although different NICs have different ways of arranging and using their LEDs, the functions are always the same: link, activity, and speed.

• Figure 6.63 Optical connection tester

Many fiber-optic NICs don't have lights, making diagnosis of problems a bit more challenging. Nevertheless, most physical connection issues for fiber can be traced to the connection on the NIC itself. Fiber-optic cabling is incredibly delicate; the connectors that go into NICs are among the few places that anyone can touch fiber optics, so the connectors are the first thing to check when problems arise. Those who work with fiber always keep around a handy optical tester to enable them to inspect the quality of the connections. Only a trained eye can use such a device to judge a good fiber connection from a bad one—but once you learn how to do it, this kind of tester is extremely handy (Figure 6.63).

Diagnostics and Repair of Physical Cabling

"The network's down!" is easily the most terrifying phrase a network tech will ever hear. Networks fail for many reasons, and the first thing to know is that good-quality, professionally installed cabling rarely goes bad. Chapter 15, "Network Troubleshooting," covers principles of network diagnostics and support that apply to all networking situations, but let's take a moment now to discuss what to do when you think you've got a problem with your physical network.

Diagnosing Physical Problems

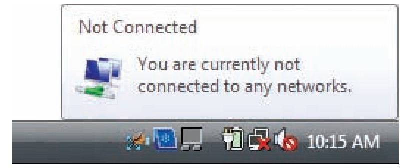
Look for errors that point to physical disconnection. A key clue that you may have a physical problem is that a user gets a "No server is found" error, or tries to use the operating system's network explorer utility (like Network in Windows Vista) and doesn't see any systems besides his or her own. First try to eliminate software errors: if one particular application fails, try another. If the user can't browse the Internet, but can get his e-mail, odds are good that the problem is with software, not hardware—unless someone unplugged the e-mail server!

Multiple systems failing to access the network often points to hardware problems. This is where knowledge of your network cabling helps. If all the systems connected to one switch suddenly no longer see the network, but all the other systems in your network still function, you not only have a probable hardware problem, you also have a suspect—the switch.

Check Your Lights

If you suspect a hardware problem, first check the link lights on the NIC and switch. If they're not lit, you know the cable isn't connected somewhere. If you're not physically at the system in question (if you're on a tech call, for example), you can have the user check his or her connection status through the link lights or through software. Every operating system has some way to tell you on the screen if it detects the NIC is disconnected. The network status icon in the Notification Area in Windows Vista, for example, will display a little red × when a NIC is disconnected (Figure 6.64). A user who's unfamiliar with link lights (or who may not want to crawl under his or her desk) will have no problem telling you if the icon says "Not connected."

If your problem system is clearly not connecting, eliminate the possibility of a failed switch or other larger problem by checking to make sure other people can access the network, and that other systems can access the shared resource (server) that the problem system can't see. Make a quick visual inspection of the cable running from the back of the PC to the outlet. Finally, if you can, plug the system into a known good outlet and see if it works. A good network tech always keeps a long patch cable for just this purpose. If you get connectivity with the second outlet, you should begin to suspect the structured cable running from the first outlet to the switch. Assuming the cable was installed properly and had been working correctly before this event, a simple continuity test will confirm your suspicion in most cases.



• **Figure 6.64** Disconnected NIC in Vista

Check the NIC

Be warned that a bad NIC can also generate this "can't see the network" problem. Use whatever utility provided with your OS to verify that the NIC works. If you've got a NIC with diagnostic software, run it—this software will check the NIC's circuitry. The NIC's female connector is a common failure point, so NICs that come with diagnostic software often include a special test called a **loopback test**. A loopback test sends data out of the NIC and checks to see if it comes back. Some NICs perform only an internal loopback, which tests the circuitry that sends and receives, but not the actual connecting pins. A true external loopback requires a **loopback plug** inserted into the NIC's port (Figure 6.65). If a NIC is bad, replace it—preferably with an identical NIC so you don't have to reinstall drivers!

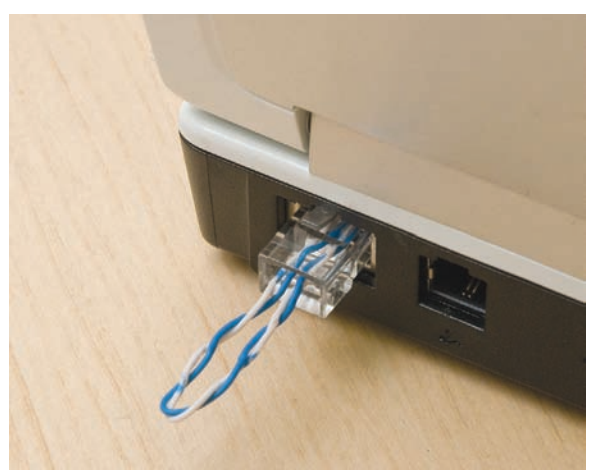
Onboard NICs on laptops are especially notorious for breaking due to constant plugging/unplugging. On some laptops the NICs are easy to replace; on others it requires a motherboard replacement.

Cable Testing

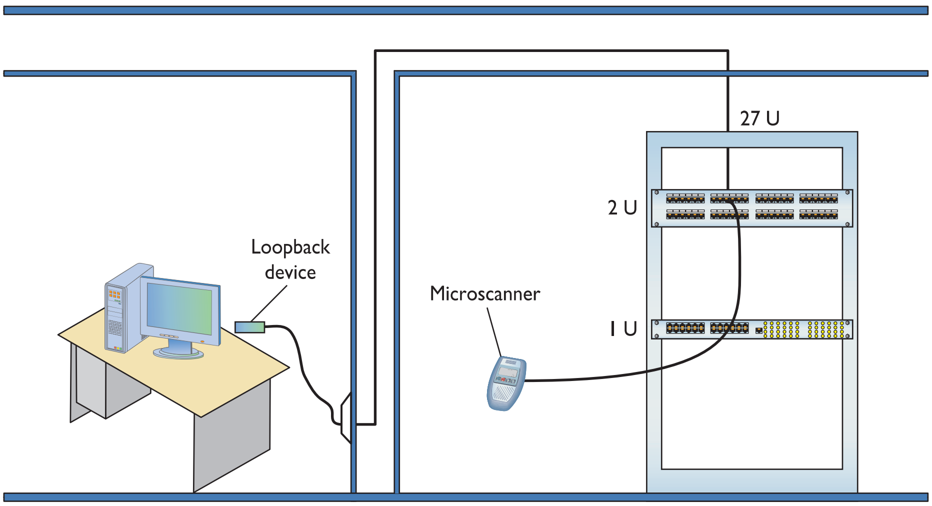
The vast majority of the network disconnect problems occur at the work area. If you've tested those connections, though, and the work area seems fine, it's time to consider deeper issues.

With the right equipment, diagnosing a bad horizontal cabling run is easy. Anyone with a network should own a midrange tester with TDR such as the Fluke Microscanner. With a little practice, you can easily determine not only whether a cable is disconnected, but also where the disconnection takes place. Sometimes patience is required, especially if you've failed to label your cable runs, but you will find the problem.

When you're testing a cable run, always include the patch cables as you test. This means unplugging the patch cable from the PC, attaching a tester, then going to the telecommunications room. Here you'll want to unplug the patch cable



• **Figure 6.65** Loopback plug



• **Figure 6.66** Loopback plug in action

from the switch and plug the tester into that patch cable, making a complete test as shown in Figure 6.66.

Testing in this manner gives you a complete test from the switch to the system. In general, a broken cable must be replaced. A bad patch cable is easy, but what happens if the horizontal cable is to blame? In these cases, I get on the phone and call my local installer. If a cable's bad in one spot, the risk of it being bad in another is simply too great to try anything other than total replacement.

Problems in the Telecommunications Room

Even a well-organized telecommunications room is a complex maze of equipment racks, switches, and patch panels. The most important issue to remember as you work is to keep your diagnostic process organized and documented. For example, if you're testing a series of cable runs along a patch panel, start at one end and don't skip connections. Place a sticker as you work to keep track of where you are on the panel.

• **Figure 6.67** An excellent voltage event recorder (photo courtesy of Fluke Networks)

Your biggest concerns in the telecommunications room are power and temperature. All those boxes in the rack need good-quality power. Even the smallest rack should run off of a good UPS, but what if the UPS reports lots of times when it's kicking on? Don't assume the power coming from your physical plant (or power company) is okay. If your UPS comes on too often, it might be time to install a voltage event recorder (Figure 6.67). As its name implies, a **voltage event recorder** plugs into your power outlet and tracks the voltage over time. These devices often reveal interesting issues. A small network was having trouble sending an overnight report to a main branch—the uploading servers reported that they were not able to connect to the Internet. Yet in the morning the report could be run manually with no problems. After placing a voltage event recorder in the telecommunications room, it was discovered that the building management was turning off the power as a power saving measure. This would have been hard to determine without the proper tool.

The temperature in the telecommunications room should be maintained and monitored properly. If you lose the air conditioning, for example, and leave systems running, the equipment will overheat and shut down—sometimes with serious damage. To prevent this, all serious telecommunications rooms should have temperature monitors.

Toners

It would be nice to say that all cable installations are perfect, and that over the years they won't grow into horrific piles of spaghetti-like, unlabeled cables. In the real world, though, you might eventually find yourself having to locate or *trace* cables. Even in the best-planned networks, labels fall off ports and outlets, mystery cables appear behind walls, new cable runs are added, and mistakes are made counting rows and columns on patch panels. Sooner or later, most network techs will have to be able to pick out one particular cable or port from a stack.

When the time comes to trace cables, network techs turn to a device called a toner for help. **Toner** is the generic term for two separate devices that are used together: a tone generator and a tone probe. The **tone generator** connects to the cable using alligator clips, tiny hooks, or a network jack, and it sends an electrical signal along the wire at a certain frequency. The **tone probe** emits a sound when it is placed near a cable connected to the tone generator (Figure 6.68). These two devices are often referred to by the brand name Fox and Hound, a popular model of toner made by the Triplett Corporation.

• Figure 6.68 Fox and Hound

To trace a cable, connect the tone generator to the known end of the cable in question, and then position the tone probe next to the other end of each of the cables that might be the right one. The tone probe will make a sound when it's placed next to the right cable. Some toners have one tone probe that works with multiple tone generators. Each generator emits a separate frequency, and the probe sounds a different tone for each one. Even good toners are relatively inexpensive ($75); although cheap toners can cost less than $25, they don't tend to work well, so it's worth spending a little more. Just keep in mind that if you have to support a network, you'd do best to own a decent toner.

More advanced toners include phone jacks, enabling the person manipulating the tone generator to communicate with the person manipulating the tone probe: "Jim, move the tone generator to the next port!" These either come with their own headset or work with a *butt set*, the classic tool used by telephone repairmen for years (Figure 6.69).

A good, medium-priced cable tester and a good toner are the most important tools used by folks who must support, but not install, networks. A final tip: be sure to bring along a few extra batteries—there's nothing worse than sitting on the top of a ladder holding a cable tester or toner that has just run out of juice!

• Figure 6.69 Technician with a butt set

Chapter 6 Review

Chapter Summary

After reading this chapter and completing the exercises, you should understand the following about installing a physical network.

Recognize and describe the functions of basic components in a structured cabling system

- Structured cabling refers to a set of standards established by the TIA/EIA regarding network cabling. The three basic structured cabling network components are the telecommunications room (a.k.a. server room), the horizontal cabling, and the work area (or the actual workers' office space).
- While wireless networks are popular, they lack the reliability and speed of wired networks.
- All cabling should run from individual PCs to a telecommunications room.
- A telecommunications room should have one or more sturdy equipment racks, used to hold mountable network devices (hubs, switches, and routers); this space also houses server PCs, patch panels, UPSs, monitors, keyboards, mice, tape backup drives, and more.
- Horizontal cabling usually refers to the cabling that runs from the telecommunications room out to the work areas of a single office building floor.
- The work area is where PCs and printers connect to the ends of the horizontal cabling. In other words, the work area is the actual office space where the jacks should be located for connecting to the network.
- UTP cable comes in one of two types: solid core and stranded core. Horizontal cabling should always be solid core.
- Solid core UTP is a better conductor than stranded core, but breaks easily if handled roughly. Stranded core holds up better to substantial handling.
- Equipment racks are 19 inches wide and come in a variety of heights. Rack-mounted equipment is manufactured to fit in the 19-inch width, but they too vary by height.
- Rack-mounted equipment heights are measured in Us, each U being equal to just under 1.75 inches.
- UTP cables can be connected to a 110 block in a patch panel by using a punchdown tool.
- The TIA/EIA 606 labeling standard can help a technician keep track of cables.
- Patch cables are used to connect the ports on a patch panel to a switch. While solid core horizontal runs typically connect to the 110 block, patch cables are usually stranded core.
- Patch cables are also used in the work area to connect a PC to the RJ-45 wall jack.
- TIA/EIA 568 limits horizontal runs to 90 meters, allowing 10 meters for patch cables before the 100-meter limit of UTP cable is reached.
- The demarc location is where the connection is made from the outside world to a private network. An Internet service provider or telephone company provides service through its demarc.
- A network interface unit, such as a cable modem, may sit between the demarc and local network.
- Demarcs and cross-connects typically reside in a room called the main distribution frame.

Explain the process of installing structured cable

- A good installation entails planning the cabling runs with an actual floor plan, as well as poking around in walls and ceilings.
- Raceway products may be used to run cable externally rather than inside walls.
- When planning cable runs, keep five things in mind: distance, power, dryness, temperature, and access.
- Cable trays may be used to aid in pulling cable within a drop ceiling.
- If you make your own patch cables, be sure to use the correct crimp, as they differ for solid core and stranded core UTP.
- A variety of cable testers, including time domain reflectometers and optical time domain reflectometers, can be used to test for continuity, attenuation, and crosstalk.
- Big issues with fiber include attenuation, light leakage, and modal distortion.

Install a network interface card

- All UTP Ethernet NICs use an RJ-45 connector. Fiber-optic NICs use a variety of connectors, depending on the manufacturer.
- Most motherboards now include an onboard NIC.
- Using the same model of NIC for all the PCs on your network makes installing and updating drivers much easier.
- The most common type of expansion card for NICs is PCI, but there are also PCIe × 1 and PCIe × 2 options.
- USB NICs are convenient and you don't have to open the computer case to install one, but their maximum speed of 480 Mbps is slower than Gigabit Ethernet.
- The link lights on a NIC indicate the status of the NIC, such as if it's connected to a network and if there is any network activity. Link lights may include the activity light and collision light.

Perform basic troubleshooting on a structured cable network

- A "no server found" error is likely caused by a physical connection problem. If one program (such as a web browser) works but another (such as e-mail) does not, the problem is likely software related.
- If you suspect a hardware problem, check the link lights on the NIC and the switch. If the lights are not on, the cable is probably disconnected or the port may be faulty.
- A loopback test can check a NIC's circuitry, but not the actual connecting pins.
- When testing cables, be sure to test the entire run, including the patch cable in the work area, the cable leading from the work area wall back to the telecommunications room, and the patch cable from the patch panel to the switch.
- Tools that are helpful for troubleshooting a structured cable network include a voltage event recorder and a toner.

Key Terms

110-punchdown block *(103)*
activity light *(125)*
attenuation *(119)*
bonding *(124)*
cable certifier *(120)*
cable drop *(110)*
cable tester *(117)*
cable trays *(112)*
collision light *(125)*
continuity *(117)*
continuity tester *(117)*
crosstalk *(119)*
demarc *(107)*
demarc extension *(108)*
dispersion *(121)*
equipment rack *(102)*
far-end crosstalk (FEXT) *(119)*
horizontal cabling *(99)*
intermediate distribution frame (IDF) *(101)*
light leakage *(121)*
link light *(125)*
loopback plug *(127)*
loopback test *(127)*
main distribution frame (MDF) *(109)*
mounting bracket *(113)*
multiplexer *(108)*
near-end crosstalk (NEXT) *(119)*
network interface unit (NIU) *(107)*
optical time domain reflectometer (OTDR) *(120)*
patch cable *(105)*
patch panel *(103)*
punchdown tool *(103)*
raceway *(110)*
run *(99)*
smart jack *(108)*
solid core *(100)*
stranded core *(100)*
structured cabling *(97)*
telecommunications room *(99)*
TIA/EIA 606 *(104)*
time domain reflectometer (TDR) *(118)*
tone generator *(129)*
tone probe *(129)*
toner *(129)*

U *(102)*
vertical cross-connect *(108)*
voltage event recorder *(128)*
wiremap *(117)*
work area *(99)*

Key Term Quiz

Use the Key Terms list to complete the sentences that follow. Not all terms will be used.

1. All the cabling from individual work areas runs via __________________ to a central location.
2. The central location that all cabling runs to is called the __________________.
3. A single piece of installed horizontal cabling is called a(n) __________________.
4. The set of standards established by the EIA/TIA regarding network cabling is called ___________.
5. You use a(n) __________________ to connect a strand of UTP to a 110 block or 66 block.
6. A short UTP cable that uses stranded, rather than solid, cable is called a(n) __________________ and can tolerate much more handling near a patch panel.
7. The type of network interface unit (NUI) that enables an ISP or telephone company to determine if a home DSL box or cable router has been disconnected is called a(n) ______________.
8. The spot where a cable comes out of the wall at the workstation is called a(n) _________________.
9. The height measurement known as U is used for devices that fit into a(n) __________________.
10. The term ____________________ describes the process of a signal weakening as it progressed down a piece of wire.

Multiple-Choice Quiz

1. Which item describes the length of cable installed within walls from a telecommunications room out to a jack?
   A. Cable drop
   B. Cable run
   C. Cable tester
   D. Cable tray
2. What is the term used to describe where the network hardware and patch panels are kept?
   A. Drop room
   B. Telecommunications room
   C. Routing room
   D. Telecloset room
3. Aside from outright breakage, what's the primary worry with bending a fiber optic cable too much?
   A. Attenuation
   B. Bonding
   C. Light leakage
   D. Near-end crosstalk
4. When connecting a cable run onto a patch panel, which tool should be used?
   A. 110-punchdown tool
   B. Crimper
   C. TDR
   D. Tone generator
5. Which of the following NIC types offers the most versatility?
   A. 10
   B. 10/100
   C. 10/100/1000
   D. Only a nonmultispeed NIC
6. What is the structured cabling name for the end user's office space where network computers will be set up?
   A. Backbone
   B. Building entrance
   C. Cable drop
   D. Work area

7. What type of twisted-pair cabling would work best within ceilings near lighting?
   - A. Solid core plenum
   - B. Solid core PVC
   - C. Stranded core plenum
   - D. Stranded core PVC
8. Why would network techs use stranded core cabling from a patch panel's ports to a switch?
   - A. Cost
   - B. Fire rating
   - C. Flexibility
   - D. Safety
9. What is the first thing a professional cable installer should do when providing an estimate at a site?
   - A. Power on additional lighting.
   - B. Put on a grounding wrist strap.
   - C. Request a floor plan.
   - D. Set up ladders.
10. What component would best allow more servers to be installed in the limited space of a telecommunications room?
    - A. Cable tray
    - B. Outlet box
    - C. Patch panel
    - D. Equipment rack
11. How tall is a network router that is 8U?
    - A. 8 inches
    - B. 8 centimeters
    - C. 14 inches
    - D. 14 centimeters
12. Your first day on the job, you get a call from the owner complaining that her network connection is down. A quick check of the central switch verifies that it's in good working order, as is the boss's PC. As luck would have it, your supervisor calls at just that time and tells you not to worry; she'll be by in a jiffy with her TDR to help root out the problem. What is she talking about?
    - A. Tune domain resonator, her network tone generator
    - B. Time detuning resonator, her network tester
    - C. Time domain reflectometer, her network tester
    - D. Time detail resource, her network schematic
13. Jenny's office building recently had sections renovated, and now some users are complaining that they can't see the network. She suspects that the workers might have inadvertently broken wires when they did ceiling work. George suggests she use a toner to figure out which wires go to the complaining users. Erin disagrees, saying that Jenny should use a Fox and Hound. Who's right?
    - A. Only George is right.
    - B. Only Erin is right.
    - C. Both George and Erin are right.
    - D. Neither George nor Erin is right.
14. What is generated by every piece of UTP cable in existence?
    - A. Modal distortion
    - B. Crosstalk
    - C. EMI
    - D. ESD
15. Which statement about structured cable is correct?
    - A. The term "demarc" refers to a physical location while the phrase "network interface unit" refers to a piece of equipment provided by an ISP.
    - B. The term "demarc" refers to a piece of equipment provided by an ISP while the phrase "network interface unit" refers to a piece of equipment provided by the customer.
    - C. The terms "demarc" and "network interface unit" refer to pieces of equipment provided by an ISP.
    - D. A demarc is used for fiber cabling while a network interface unit is used for UTP.

Essay Quiz

1. Sketch a rough draft of your classroom, office, or the room you are in right now. Indicate any doors, windows, closets, lights, plumbing fixtures, desks or tables, and even any visible electrical wall outlets. Then indicate with a large letter *X* where you would place a new cable drop. Jot down some notes explaining why you would choose the location you did.
2. Your CompTIA A+ Certified co-worker is listening in on a conversation you are having with your boss, and he thinks he knows what a "demarc" is. Write a quick note to him describing the true meaning of a structured cabling building entrance, so you can leave it on his desk before you leave for the day.
3. The management team at your company wants to network five offices with low-cost PVC stranded core cabling throughout the dropped ceiling in your offices. Compose a memo that justifies the cost of using more expensive cabling. Use any standard memo format that you are already familiar with.
4. The youth group at a local community organization has received funding to help with creating a computer network. They have already purchased the required number of PCI 10/100/1000 NICs. You have been asked by one of the group's leaders to assist with installing the NICs. You want to help, but time doesn't permit you to volunteer any more hours in a week than you already do. It makes better sense to organize a step-by-step fact sheet that describes installing a NIC into an open slot on a computer. When you have finished, e-mail the fact sheet you created to your instructor (or a friend) for comments.

Lab Projects

• Lab Project 6.1

You are a recently hired network technician at a local business. During the interview phase with the company, some questions were raised about installing cable. You made it clear that professional cable installation was the way to go. You justified your statements and impressed the interviewers with your knowledge and honesty, so they hired you.

Now you need to research the company names and "per drop" prices of professional cable installers in your area. Use the Internet to gather research from at least two companies. Prepare a PowerPoint presentation to present your findings to management. Be sure to use color, graphics, and slide transitions (as time permits) to further impress your new bosses!

• Lab Project 6.2

You have become the de facto network administrator for your employer at a nearby tax preparation company. The owner of this small business stays close to all expenses. She realizes that you could use additional tools to help with installing cable for her soon-to-be-expanded office network. You see this as the opportunity to purchase a cable tester and a tone generator. Your boss casually says to check out some prices. You know that well-laid-out numbers could get approval on the toys you'd like!

Prepare a spreadsheet that shows three levels, including prices, for each of these items. Arrange your spreadsheet in a "good/better/best" layout, with "best" listed on top for the most attention. Use the following chart as a guide:

"BEST"	**Brand/Model**	**Price**
Cable Tester A		$.
Tone Generator A		$.
Total for A Items		$.
"BETTER"	**Brand/Model**	**Price**
Cable Tester B		$.
Tone Generator B		$.
Total for B Items		$.
"GOOD"	**Brand/Model**	**Price**
Cable Tester C		$.
Tone Generator C		$.
Total for C Items		$.