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Russ White

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CHAPTER 10

Basic Network Hardware

This chapter covers the following exam topics:

4. Infrastructure

4.1. Identify the status lights on a Cisco device when given instruction by an engineer.

Link light color and status (blinking or solid)

4.2. Use a network diagram provided by an engineer to attach the appropriate cables.

Patch cables, switches and routers, small topologies

4.3. Identify the various ports on network devices.

Console port, serial port, fiber port, Ethernet ports, SFPs, USB port, PoE

Routers, switches, and network appliances—*middleboxes*—are the bread and butter of the network world. Creating a network by connecting these things is more than plugging in a few cables and using the network. Laying out the physical and logical design of a network requires a great deal of thought and work.

This chapter begins with the physical form factor of different kinds of middleboxes and then goes into the ports you will encounter in networks. The first section also considers the status lights on many network devices, a common—and quick—network diagnostic tool.

The second section covers the two basic kinds of network diagrams, the kinds of information they contain, and what they are used for. The third section considers the kinds and uses of network wiring and correlating physical layer network diagrams with physical wiring. The final section considers heat and power problems in a network facility.

> **NOTE** Chapter 23, "Configuring a Network," covers configuring Cisco Systems routers and switches in more detail.

"Do I Know This Already?" Quiz

Take the quiz (either here or use the PTP software) if you want to use the score to help you decide how much time to spend on this chapter. Appendix A, "Answers to the 'Do I Know This Already?' Quizzes," found at the end of the book, includes both the answers and explanations. You can also find answers in the PTP testing software.

Table 10-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Section	Questions
Hardware, Ports, and Lights	1, 2, 3, 4, 5
Network Diagrams	6
Network Wiring	7
Handling the Heat	8

CAUTION   The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark that question as wrong for purposes of the self-assessment. Giving yourself credit for an answer you incorrectly guess skews your self-assessment results and might provide you with a false sense of security.

1. What is the primary purpose of the management network port?
   a. Provide access to the device's command-line interface
   b. Carry customer traffic within the local network
   c. Connect to a low-speed out-of-band management network
   d. Carry customer traffic to destinations outside the local network

2. What is the primary purpose of the console port?
   a. Provide access to the device's command-line interface
   b. Carry customer traffic within the local network
   c. Connect to a low-speed out-of-band management network
   d. Carry customer traffic to destinations outside the local network

3. How are ports numbered on a router?
   a. Module or slot, kind of port, submodule, and port number on the module
   b. Kind of port, module or slot, submodule, and port number on the module
   c. Port number, kind of port, module or slot, submodule
   d. By the physical location of the port on the device

4. What are the four common light indicators on network devices?
   a. Green, malfunctioned; green flashing, passing traffic; yellow, connecting or malfunctioned; red, operating correctly
   b. Green, passing traffic; green flashing, operating correctly; yellow, connecting or malfunctioned; red, malfunctioned
   c. Green, operating correctly; green flashing, passing traffic; yellow, connecting or malfunctioned; red, malfunctioned
   d. Green, operating correctly; green flashing, malfunctioning; yellow, passing traffic; red, disconnected

5. Do the color and status of lights on all routers and switches indicate the same things?

    a. Every network device uses the same colors and patterns of lights to mean the same thing.

    b. The colors of the lights always mean the same things, but the flashing patterns may vary between vendors.

    c. The colors of the lights may vary between vendors, but the flashing patterns always mean the same thing.

    d. The colors and flashing patterns may vary between individual devices.

6. What diagrams are commonly used in network engineering? (Choose two.)

    a. Topological

    b. Physical

    c. Logical

    d. Overlay

    e. Routing

7. Why is it important to manage cables through management hardware?

    a. Because OSHA regulations require well-organized cables

    b. To prevent cables from hanging off their connectors

    c. Because engineers generally like neatness

    d. To aid in the end-to-end tracing of cables

8. What is the importance of separating hot and cold air in a networking equipment room?

    a. To provide a comfortable environment for technicians

    b. To prevent the mixing of hot and cold air, increasing equipment cooling efficiency

    c. To prevent the mixing of hot and cold air, increasing equipment heating efficiency

    d. To use the heat from the equipment more efficiently in the building

Foundation Topics

Hardware, Ports, and Lights

Racks of equipment, wire running all over the place, lights blinking on and off—when you walk into a large room holding lots of networking gear, you might wonder, "What is all this stuff?" You might feel like the person in Figure 10-1.

The good news is there are only a few classes of equipment in any data processing or networking facility:

Key Topic

- Routers

- Switches

- Patch panels

- Compute servers

- Storage devices

- Optical gear

- Other middleboxes

Figure 10-1 *Racks of Equipment*

The bad news is all these kinds of devices tend to look alike. Figure 10-2 shows a few pieces of computer networking equipment of different kinds (without wiring).
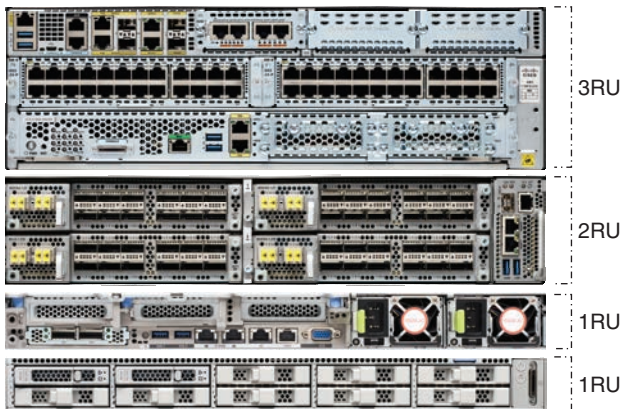
Figure 10-2 *Stacked Networking Equipment*

From top to bottom, Figure 10-2 shows:

■ A Cisco 4000 series integrated services router (ISR). You would generally see this kind of router in a small office, where it provides connectivity to the corporate network and Internet as well as voice, security, and other services.

■ A Cisco 1004 series optical networking convergence system. You would generally see this type of device in a service provider facility or perhaps used for corporate campus connectivity.

- A Cisco UCS C220 rack server. This is a set of hosts attached to the network rather than providing network connectivity.

- A Cisco email security appliance. This specialized appliance is wired into the network so email traffic can pass through rather than providing network connectivity.

In Figure 10-2, each device's height is labeled in **rack units (RUs)**. An RU is 1.75 inches or 44.45 mm high. Designers are always trying to make more functionality fit into a single RU. Equipment with more ports or requiring more cooling surface will require more RUs.

Beyond broad generalizations, the only way to know which equipment does what is to read the labels and recognize broad classes of equipment based on their model numbers. Recognizing hardware based on model numbers is not as hard as it might seem because most companies use only a limited range of equipment. For example, they will use only a few models of routers, switches, and other appliances in any individual facility.

Because the ISR router serves many different purposes, it has many kinds of ports. Look at each section of the ISR's back panel, beginning with the upper-left corner in Figure 10-3.
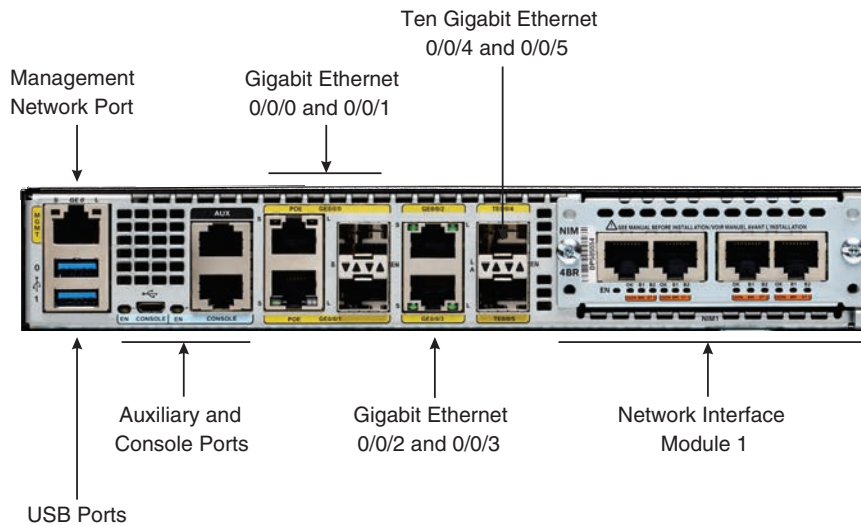
Figure 10-3   *ISR Upper-Left Corner Ports*

The first ports on the left, up to the two 10 Gb/s ports, are *fixed*. You cannot replace fixed ports. Note the lack of screws or a separate plate, unlike the four ports on the left.

Key Topic

The **management network port** connects to a low-speed (normally 1 Gb/s) network to access and manage network equipment. User data is never carried over this network, usually called the *out-of-band management network*. Not all operators build out-of-band management networks. Instead, they manage all their equipment *in-band*, using the same network to carry management and user traffic.

Key Topic

The **auxiliary port** and **console port** provide access to the router's *command-line interface (CLI)* via a terminal application. Console connections come in many forms, including lower-speed Ethernet ports, various kinds of *universal serial bus (USB)*, and multi-pin serial connectors. Most network engineers who spend a lot of time working with physical

hardware build a collection of connectors to connect a laptop or tablet computer to network equipment.

Operators typically use console ports to configure a device to connect to the network. Once the device is connected, operators use telnet, *Secure Shell (SSH)*, and other methods to connect to and configure the device. You can think of the console port in most modern networks as a sort of "backup plan"; this is how you connect if all the other ways fail.

> **NOTE**   Chapter 21, "Managing Networks," and Chapter 23, "Configuring a Network," cover accessing routers through Telnet and SSH.

Gigabit Ethernet 0/0/0 and *0/0/1* are the first two network ports in this fixed configuration portion of the router. Each of these ports can be used in one of two ways: as a *Power over Ethernet (POE)* port using an RJ-45 connector or by inserting a pluggable optical connector into the slot next to the RJ-45 port. The single marked-out area over these four ports indicates only one port can be used at a time for each of these interfaces. Inserting a pluggable interface disables the RJ-45 port.

> **NOTE**   Chapter 7, "Wired Networks," covers pluggable and optical connectors.

Gigabit Ethernet 0/0/2 and *0/0/3* are RJ-45-only 1 Gb/s Ethernet ports. These ports do not support POE or pluggable interfaces.

Ten Gigabit 0/0/4 and *0/0/5* are pluggable high-speed interfaces. These are the last two interfaces in the fixed portion of the router configuration.

The first network interface module (**NIM**) is to the right of the two 10 Gb/s ports. Each kind of NIM supports different interface combinations. NIM1 in Figure 10-3 is a *4BR*, which supports voice and *Integrated Services Digital Network (ISDN)* connections. The screws on the left and right sides of the NIM indicate this part of the router is replaceable.

Two more unfilled NIM slots are available to the right of NIM1; Figure 10-3 does not show these slots.

Figure 10-4 shows the center-right module of the ISR.
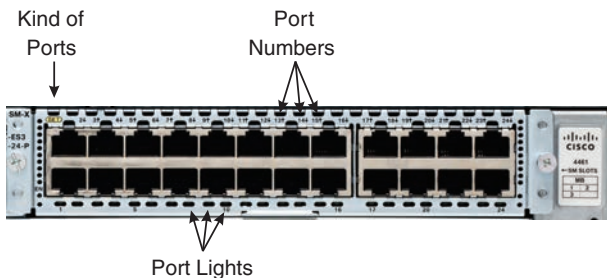
Figure 10-4 *ISR Center-Right Ports*

This set of ports and the one to the left of them are replaceable, as you might expect, because of the screws on either end of the module. Each router with replaceable modules

uses different terminology, such as NIM, *5M slot* (as shown here), *VIP*, and many others. These different names describe some significant physical characteristic or capability of the module.

Chassis devices also have **line cards**. There are two differences between a line card and some kind of module:

■ A line card normally has a separate forwarding engine, while a module uses the router's forwarding engine.

■ A line card usually is larger than a module.

Many line cards or modules indicate the *kind of port* they contain, such as the one shown in the upper left of Figure 10-4. This module contains twenty-four 1 Gb/s ports using RJ-45 connectors. The module's model number, SM-X, is just to the left of the port indicator. You can search for this model number on the Cisco website to discover the capabilities of each port in this module, such as whether they support POE.

In this case, the port numbers are all along the top of the module. A small arrow beside each port number indicates whether the number relates to the upper or lower port. Odd ports are almost always on the top of a row of ports, while even ports are almost always on the bottom.

You might have noticed the ports in Figure 10-3 contained three numbers—TE0/0/4 and TE0/0/5, for instance. Port numbers follow a fairly standard convention across all network equipment manufacturers:

Key Topic

■ Two or three letters indicate the speed of the port. *GE* is for *Gigabit Ethernet*, *TE* is for *Ten Gigabit Ethernet*, etc.

■ If there is one number, the router has only fixed ports. These ports are numbered starting at 1 and ending at the maximum port count.

■ If there are two numbers, the router has slots for modules or line cards. The first number indicates the line card or module slot, and the second indicates the port number on the module or line card.

■ If there are three numbers, the router has slots for modules or line cards, and the modules or line cards have slots for submodules. The first number indicates the line card or module slot, the second indicates the submodule slot, and the third indicates the port number on the module or line card.

A small sticker with a table is shown on the right side of Figure 10-4. The table's upper-left cell is marked with a *1*, indicating the upper-left slot contains module 1. The upper-right cell in the table is marked with a *2*, indicating the upper-right slot contains module 2.

Figure 10-4 shows the module in the upper-right slot according to the table, so the interfaces in this module would be GE2/0/1 through GE2/0/24. In this case, the center number is 0 because these ports are connected to the main module itself, not a submodule.

Finally, there is a light for each port along the bottom of the module, shown in Figure 10-4.

Key Topic

Almost every port you encounter in computer networks will have an associated light. These lights, or *light-emitting diodes (LEDs)*, are an important diagnostic tool—if you know what

the color and condition of the light mean. Some lights are generally assumed to be common among all networking hardware, such as

- A **solid green status light** means the port is operating correctly.

- A **flashing green status light** means the port is connected and data is being transmitted.

- A **yellow status light** means the port is connecting or has malfunctioned.

- A **red status light** means the port has malfunctioned.

Unfortunately, however, these lights do not always mean the same thing on every piece of networking hardware. For instance, on the Cisco 1120 Connected Grid Router, the pluggable Ethernet 1/1 and 1/2 ports have two lights—one for port speed and another for port status.

- If the port speed light blinks green twice and then pauses, the port is connected at 100 Mb/s.

- If the port speed light blinks green three times and then pauses, the port is connected at 1 Gb/s.

- If the port status light is solid green, the port is connected and active.

- If the port status light is yellow, the port is connected, but there is an error condition.

- If the port status light is flashing green, the pluggable interface can be safely removed.

If you believe a flashing green light means data is being transmitted on a Cisco 1120 Connected Grid, you could be misled.

To add confusion, you can program the lights on many systems to use any color combination you like. Many large-scale operators prefer to use blue rather than green and only solid lights. When you walk into a large data center, the sheer volume of flashing lights can be a bit overwhelming, making it harder to find failed connections rather than easier.

You should always check the equipment manual if you are unsure about the different states of the port lights.

Figure 10-5 shows the lowest of the three sections of the ISR.
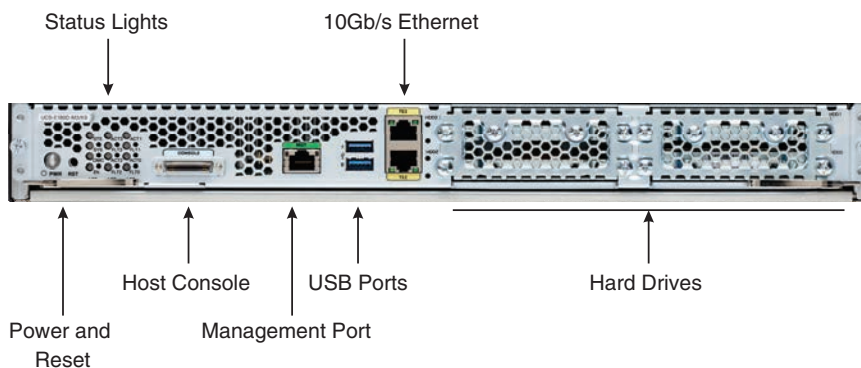
Figure 10-5 *Host (Server) Module in ISR*

The lower section of this ISR contains a host. For some small offices, having a local server installed in a device like this might be useful to support email, web hosting, or other applications. This host module has its own power indicator, reset button, status lights, and console port. There is also a management port for the out-of-band management network described earlier.

This host (server) module has two 10 Gb/s Ethernet ports. These ports would be configured through the host console rather than the router CLI. Four hard drives are also included on this module's right side; each pair has its own cover plate.

Figure 10-6 illustrates the back of another kind of Cisco router—a Cisco 8200 series.

Figure 10-6   *A Cisco Systems 8200 Series Router*

Some routers or other network devices have console, management network, or other ports along the back. The Cisco 8200, however, has only three components. There are two power supplies, one on either side of the router. Each of these power supplies can be removed and replaced. You need to see if you can replace these while the router is powered up and running.

Four fans, often called fan trays, are along the back of the router. These draw air through the router, across the optical ports, electrical ports, and processors. It is critical to cool these components correctly. The fans are replaceable.

Network Diagrams

Networking diagrams are crucial to the documentation required to operate, troubleshoot, and modify a network. Building a good network diagram requires a solid grasp of how the network is built, how it works, and what the diagram itself is supposed to accomplish. There are two broad categories of network diagrams: *physical* and *logical*.

Figure 10-7 illustrates a **physical network diagram**.

In Figure 10-7:

- **CO:** Core router
- **ED:** Edge router
- **FW:** Firewall
- **SV:** Server
- **PP:** Patch panel
- **NET:** Internet connection router
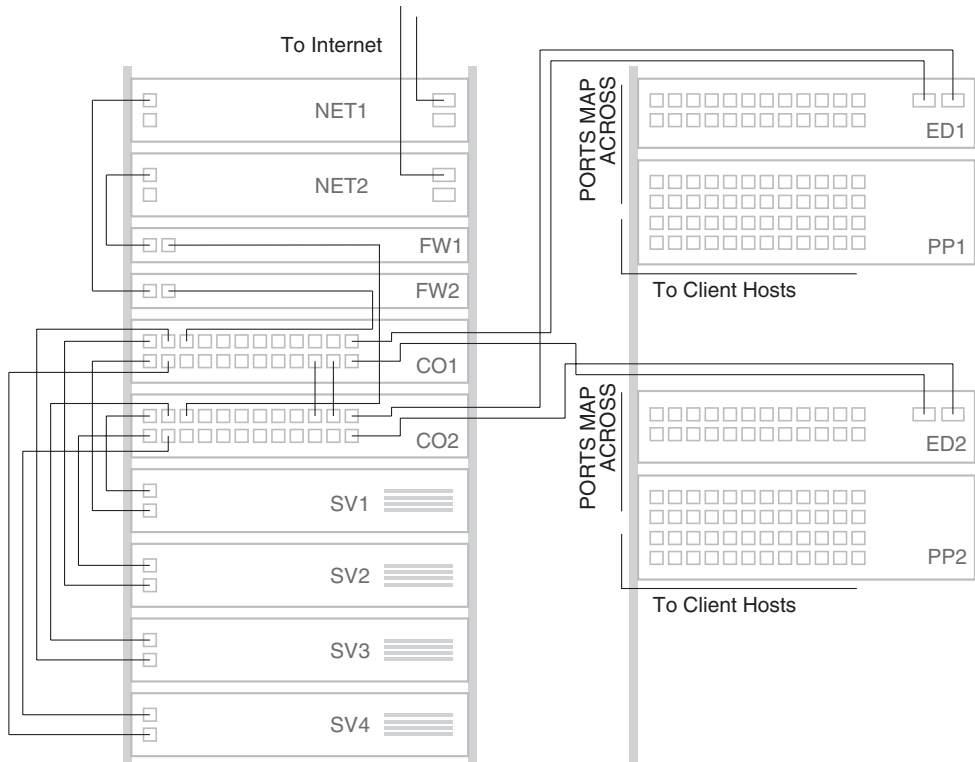
Figure 10-7 *A Physical Network Diagram*

Physical diagrams show where each wire originates and terminates in a network or section. It is common for large-scale networks to require hundreds of physical diagrams to accurately describe how each cable runs, what it connects to, etc.

Physical diagrams are good for understanding a network's physical component, location, and how cables are physically run. For instance, the physical diagram is a good place to start if

■ You want to ensure two redundant cables do not run through a single cable tray or conduit—called *circuit grooming*.

■ You want to plan out how many cables are needed of a specific length.

■ You want to know about the physical size of a piece of equipment—perhaps so you can plan for a replacement.

Physical diagrams do not always contain the following:

■ Port numbers, because these can be inferred from where a cable is shown connecting to a piece of equipment. For instance, you can infer the connection from *CO1* port 2 is connected to *CO2* port 3 from this simple diagram.

■ Any kind of addresses. You normally will not find IP addresses, physical interface addresses, or any other addresses on a physical network diagram.

10

Key Topic

Figure 10-8 shows a logical diagram of the same network.
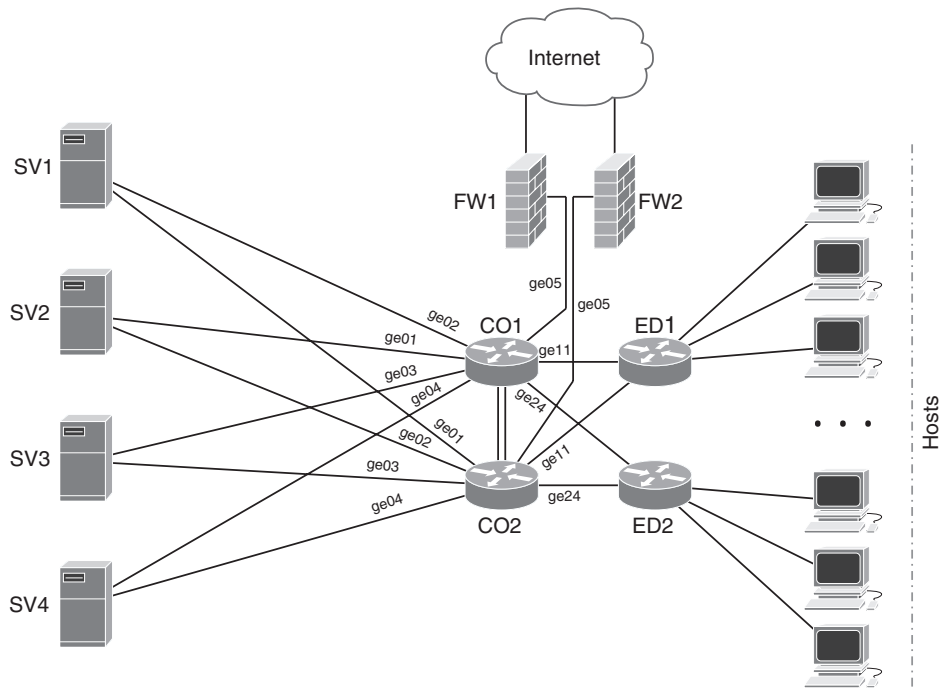
Figure 10-8   *Logical Network Diagram*

Logical network diagrams are abstracted in some ways:

- Notice the patch panels are not shown in the logical diagram.

- You can no longer tell which cable runs might be longer or shorter.

- You can no longer tell what device each rack is in.

Use a logical diagram to follow the traffic flow or understand the control plane configuration and operation. Logical diagrams can also contain the following:

- Which routing protocol is running between pairs of routers

- Any policy implemented at a given point in a network, such as packet filtering, route aggregation, etc.

- Where links are connected (such as the labels given in Figure 10-8)

- IP addresses

- Where services are running or located in the network

Many network operators assign device names based on the device's location, bringing more information from the physical world into their logical diagrams.

Two simple rules of thumb are extremely helpful when working with network diagrams:

- Physical diagrams follow the flow of the wires; logical diagrams follow the flow of the packets.

- You should include whatever is helpful without crowding the diagram. You can always have more than one diagram with different pieces of information.

Network Wiring

Every network engineer—at some point in their career, at least—runs network wiring, so it is essential to understand how to perform this fundamental task. Figure 10-9 illustrates cable management.
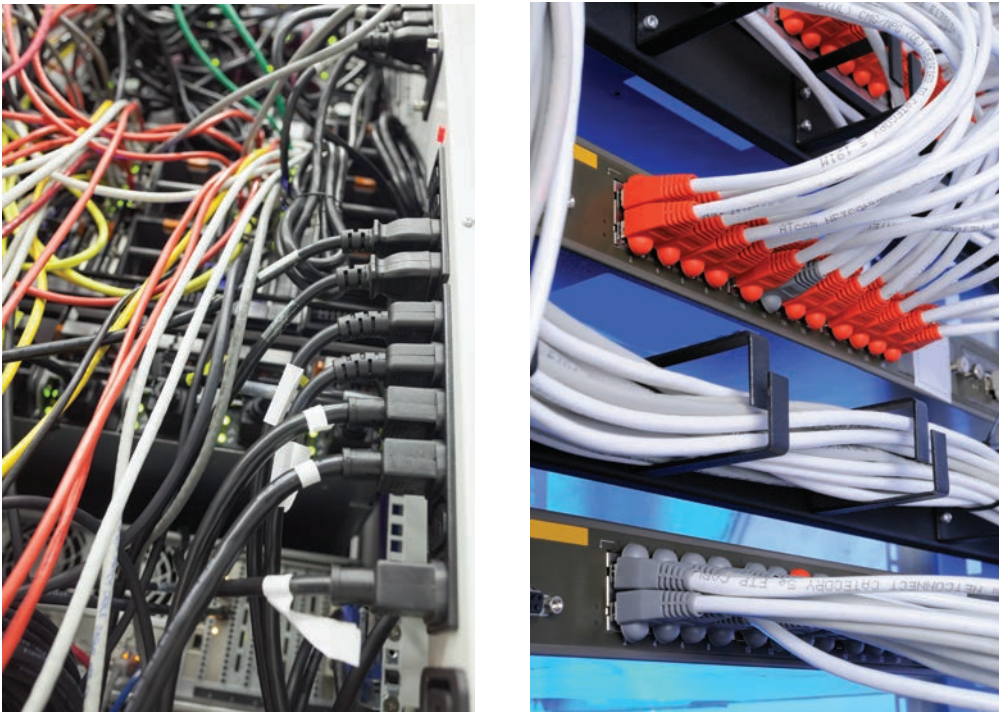
Figure 10-9 *With and Without Cable Management*

The left side of Figure 10-9 shows a rack cabled without management aids, bundling, or even separation. The result is a tangled mess; seeing and replacing equipment is challenging. In contrast, on the right side of Figure 10-9, the operator cabled the rack neatly and spaced the equipment apart, using horizontal D-ring organizers to hold cables in neat horizontal rows.

As shown on the left side of Figure 10-9, cables hanging off their connectors will strain their connectors. This strain can sometimes cause failures. While most commercially built cables will have *strain gages* (also spelled *strain gauges*) to reduce damage to internal connections, cable management techniques like those shown on the right side of Figure 10-9 can prevent failures of this kind.

Other kinds of **rack-mounted cable organizers** include

- Vertical fingerboards

- Vertical lacing bars

- Vertical cable ladders

- Horizontal fingerboards

- Horizontal cable shelves

- Horizontal lacing bars

Cable management systems can take up rack space, so carefully plan the rack layout to include these elements. Raised floors have generally been abandoned in most designs for overhead cable racks, such as the one shown in Figure 10-10.

Figure 10-10   *Overhead Cable Tray*

Engineers must design overhead cable trays to carry the weight of the supported cables. Sometimes, this weight must be calculated into ceiling or rack weight loads.

Copper cables produce heat when power is running through them. Low-power Ethernet cables might not individually produce enough heat to cause damage, but large groups of cables bundled into a tray can. Because of this, heat is also a factor when designing an overhead cable tray system.

Some operators like to include loops in their optical cables, but loops should never be included in copper cables. Copper cables should be cut or commercially built as close to the length needed as possible. Loops add weight to the cable system, act like antennas, or interfere with signal transmission.

You should use patch panels when wiring might frequently change, such as connecting network equipment to network wall jacks in a room or building. Patch panels can also be useful when cable lengths change while replacing equipment.

In summary, wiring to a physical network diagram is easy on the surface but more difficult if the job is to be done correctly.

Handling the Heat

All equipment used in information technology—hosts, routers, switches, and even copper cables—generates heat during operation. However, operating equipment at higher temperatures can reduce its life span or—if the temperature is high enough—cause immediate failures.

Heat is managed in information technology operations by

- Vendors working to reduce the heat their devices produce.

- Vendors designing devices for efficient airflow.

- Liquid cooling.

- Hot air containment.

The first three of these are outside the scope of this book. Hot air containment is common and easily impacted by everyday maintenance tasks. Figure 10-11 illustrates a simple cooling system without hot air containment.
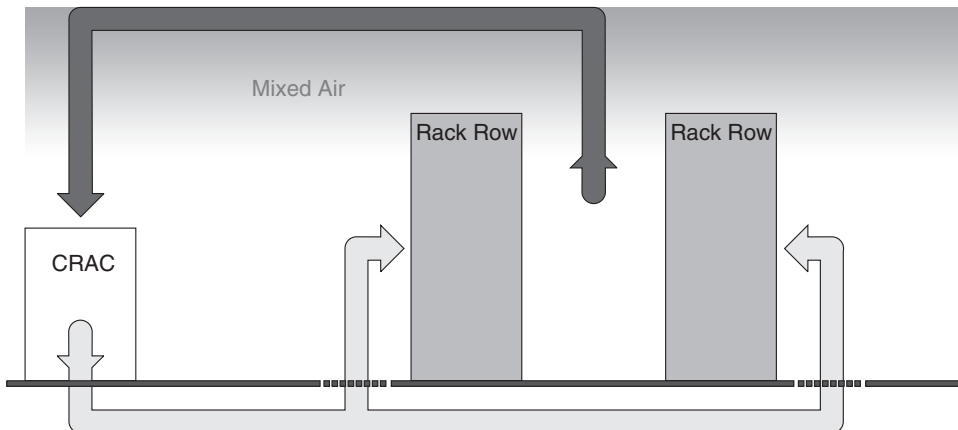
Figure 10-11 *Simple Cooling System*

Figure 10-11 shows a pair of rows of racks from the end. In the figure, a *computer room air conditioner (*CRAC*)* cools the air and pushes it into the space between the building and a raised floor. Equipment racks sit on this raised floor. This cool air is vented in front of each rack through a floor vent and pulled through the rack, front to back, to cool the equipment.

Hot air expelled from the back of each rack rises toward the ceiling. Fans draw hot air back into the CRAC, cooling it, and the cycle starts again.

10

Key Topic

When pairs of racks are placed back-to-back, a **hot aisle** is created. The more fully sealed off this hot aisle is, the more efficient the cooling process is. In a fully sealed system, there is no mixed air; hot air is directed through ductwork back into the CRAC.

Large-scale data centers may pull air from the outside and cool it through an evaporative process, as shown in Figure 10-12.
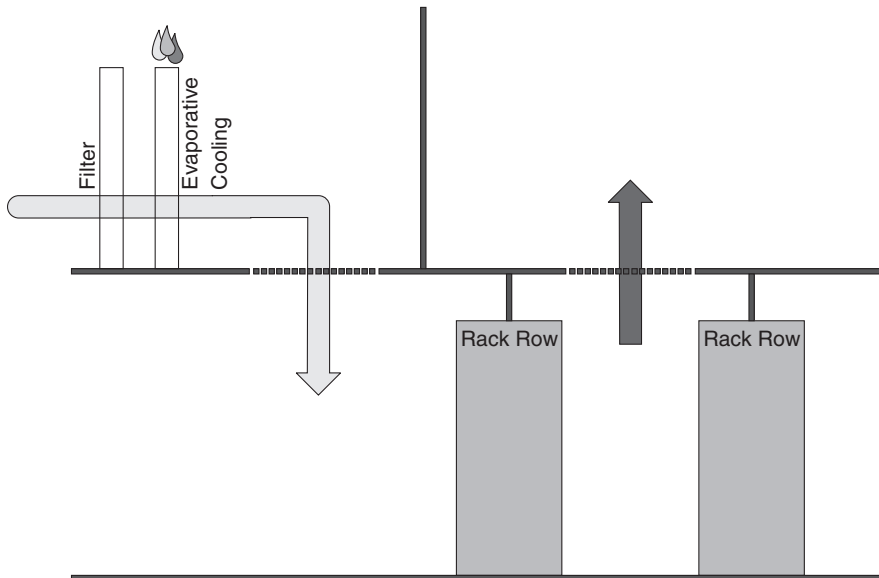
Figure 10-12   *Evaporative Cooling*

Figure 10-12 again shows a pair of data center racks from the end. In this figure, air is drawn directly from the outside by fans, through a filter, and then through a waterfall-like evaporative cooling system. As hotter air flows through the water, the water evaporates, consuming heat from the air and leaving the cooler. This air is then pushed into the data center by fans.

Equipment fans draw this cool air through the rack, cooling the equipment by heating the air. The air is expelled into the hot aisle, wholly isolated from the **cold aisle**, and then pulled by fans back into the outside environment.

Chapter Review

Users tend to think of "the network" as a sort of virtual thing: it exists "out there," but where "there" is, and how bits are translated into signals, signals are carried from place to place, and data is processed are all something of a mystery. Network engineers, however, know that while networks can be described in virtual terms, networks are built out of physical cables, servers, racks, and cooling systems.

Understanding these components and how to use them to build a network is critical to network engineering. This understanding combines wiring diagrams with knowledge of ports, lights, racks, cable management, and cooling to build a physical network.

One key to doing well on the exams is to perform repetitive-spaced review sessions. Review this chapter's material using either the tools in the book or interactive tools for the same material found on the book's companion website. Refer to the online Appendix D, "Study Planner," element for more details. Table 10-2 outlines the key review elements and where you can find them. To better track your study progress, record when you completed these activities in the second column.

Table 10-2   Chapter Review Tracking

Review Element	Review Date (s)	Resource Used
Review key topics		Book, website
Review key terms		Book, website
Repeat DIKTA questions		Book, PTP
Review concepts and actions		Book, website

Review All the Key Topics

Table 10-3 lists the key topics for this chapter.

Table 10-3   Key Topics for Chapter 10

Key Topic Element	Description	Page Number
List	Classes of networking equipment	198
Paragraph	Management network port	200
Paragraph	Auxiliary and console ports	200
List	Port number conventions	202
List, paragraph	LED color meaning	202
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Key Terms You Should Know

Key terms in this chapter include

rack unit (RU), management port, auxiliary port, console port, NIM, chassis device, line card, letters in a port number, numbers in a port number, solid green status light, flashing green status light, yellow status light, red status light, physical network diagram, logical network diagram, rack-mounted cable organizers, CRAC, hot aisle, cold aisle

10

Concepts and Actions

Review the concepts considered in this chapter using Table 10-4. You can cover the right side of this table and describe each concept or action in your own words to verify your understanding.

Table 10-4 Concepts and Actions

Management network port	Connects to a low-speed out-of-band management network
Console port	Provides access to the CLI
Port numbering	Type, module, submodule, port number
Physical network diagram	Good for understanding each physical component of a network, where they are placed, and how they are physically connected
Logical network diagram	Good for understanding traffic flow, control plane configuration, and control plane operation
Physical network diagram follows	The flow of the wires
Logical network diagram follows	The flow of the packets
Strain gage	Helps prevent damage to a connector when the weight of the cable is placed on the connector
Cold aisle	Generally in front of equipment racks, where most equipment is configured to draw air for cooling
Hot aisle	Generally between rows of equipment; may be contained to prevent air mixing