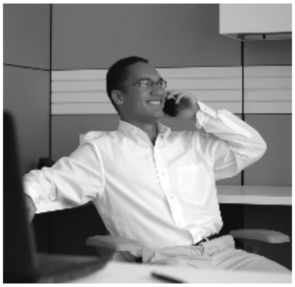
Chapter 1

Computer Network Types, Topologies, and the OSI Model

TOPICS COVERED IN THIS CHAPTER:

- ✓ Computer Network Types
- ✓ Computer Network Topologies
- ✓ The OSI Model
- ✓ Peer Layer Communication
- ✓ Data Encapsulation
- ✓ Device Addressing



It is important to have an understanding of basic personal computer networking concepts before you begin exploring the world of over-the-air (wireless) networking technology, wireless terminology, and mobility. This chapter looks at various topics surrounding foundational computer networking, including computer network types, computer topologies, the OSI model, and network device addressing. It is intended to provide an overview of basic computer networking concepts as an introduction for those who need to gain a basic understanding or for those already familiar with this technology and want a review of these concepts.

You will look at the various types of wireless networks—including wireless personal area networks (WPANs), wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), and wireless wide area networks (WWANs)—in Chapter 4, "Standards and Certifications for Wireless Technologies."

Network Types

Personal computer networking technology has evolved at a tremendous pace over the past couple of decades, and many people across the world now have some type of exposure to the technology. Initially, personal computers were connected, or networked, to share files and printers and to provide central access to the users' data. This type of network was usually confined to a few rooms or within a single building and required some type of cabled physical infrastructure. As the need for this technology continued to grow, so did the types of networks. Computer networking started with the local area network (LAN) and grew on to bigger and better types, including wide area networks (WANs), metropolitan area networks (MANs), and others. The following are some of the common networking types in use today:

- Local area networks (LANs)
- Wide area networks (WANs)
- Metropolitan area networks (MANs)
- Campus area networks (CANs)
- Personal area networks (PANs)

NOTE

You may also come across the term *storage area network (SAN)*. The SAN is basically a separate subnet for offloading of large amounts of data used within an enterprise network. High-speed connections are used, so the data is easily accessible because it appears to be part of the network. The connections are commonly Fibre Channel or iSCSI utilizing the TCP/IP protocol.

Most computer networks now contain some type of wireless connectivity or may consist of mostly wireless connectivity. The need for wireless networking and mobility continues to be in great demand and is growing at a rapid pace.

The Local Area Network

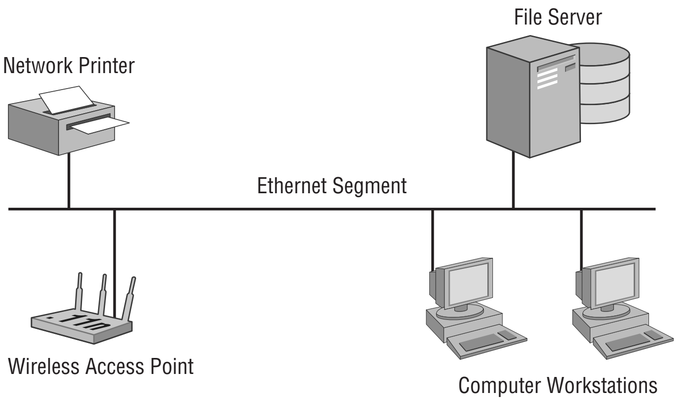
A *local area network (LAN)* can be defined as a group of devices connected in a specific arrangement called a topology. The topology used depends on where the network is installed. Some common legacy topologies such as the bus and ring and more modern topologies such as the star and mesh are discussed later in this chapter. Local area networks are contained in the same physical area and usually are bounded by the perimeter of a room or building. However, in some cases a LAN may span a group of buildings in close proximity that share a common physical connection.

Early LANs were mostly used for file and print services. This allowed users to store data securely and provided a centralized location of data for accessibility even when the user was physically away from the LAN. This central storage of data also gave a network administrator the ability to back up and archive all the saved data for disaster recovery purposes. As for print services, it was not cost effective to have a physical printer at every desk or for every user, so LANs allowed the use of shared printers for any user connected to the local area network. Figure 1.1 illustrates a local area network that includes both wired and wireless networking devices.

The Wide Area Network

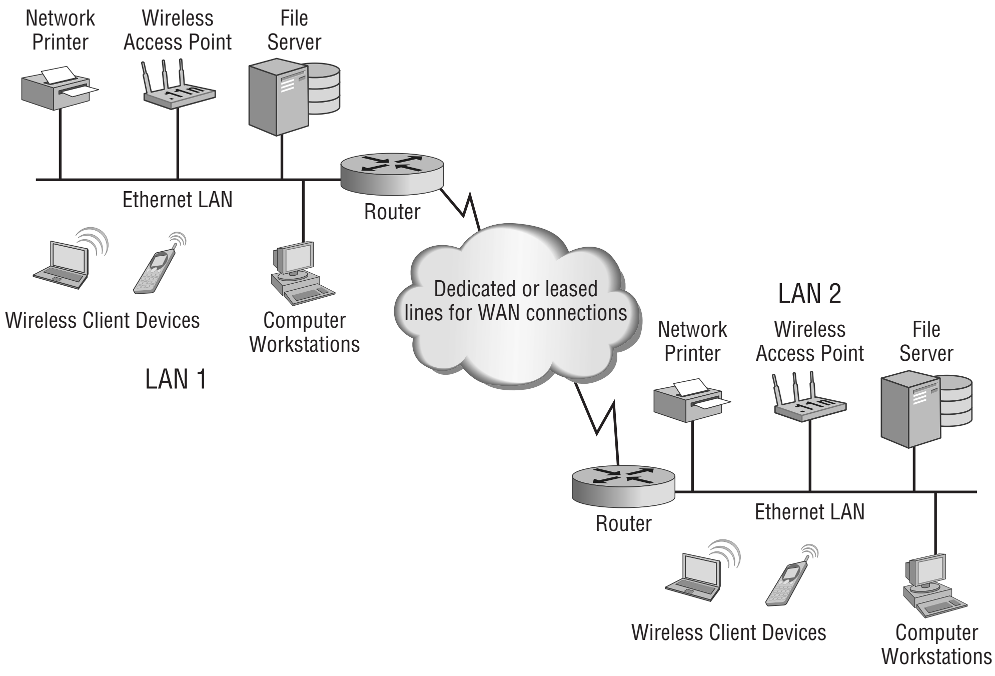
As computer networking continued to evolve, many businesses and organizations that used this type of technology needed to expand the LAN beyond the physical limits of a single room or building. These networks covered a larger geographical area and became known as *wide area networks (WANs)*. As illustrated in Figure 1.2, WAN connectivity mostly consists of point-to-point or point-to-multipoint connections between two or more LANs. The LANs may span a relatively large geographical area. (Point-to-point and point-to-multipoint connections are discussed later in this chapter.) The WAN has allowed users and organizations to share data files and other resources with a much larger audience than a single LAN would.

FIGURE 1.1 Example of a local area network (LAN)



WANs can use leased lines from telecommunication providers (commonly known as *telcos*), fiber connections, and even wireless connections. The use of wireless for bridging local area networks is growing at a fast pace because it can often be a cost-effective solution for connecting LANs.

FIGURE 1.2 Wide area network (WAN) connecting two LANs



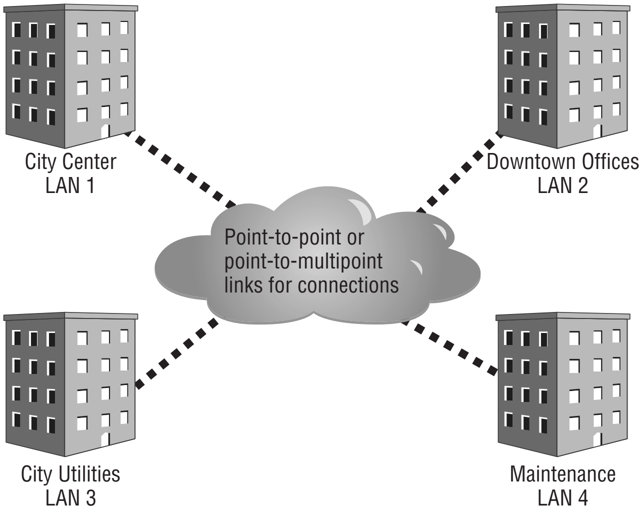
The Metropolitan Area Network

The *metropolitan area network (MAN)* interconnects devices for access to computer resources in a region or area larger than that covered by local area networks (LANs) but yet smaller than the areas covered by wide area networks (WANs). A MAN consists of networks that are geographically separated and can span from several blocks of buildings to entire cities (see Figure 1.3). MANs include fast connectivity between local networks and may include fiber optics or other wired connectivity that is capable of longer distances and higher capacity than those in a LAN.

MANs allow for connections to outside larger networks such as the Internet. They may include cable television, streaming video, and telephone services. Devices and connectivity used with metropolitan area networks may be owned by a town, county, or other locality and may also include the property of individual companies. Wireless MANs are also becoming a common way to connect the same type of areas but without the physical cabling limitations.

The MAN is growing in popularity as the need for access in this type of environment also increases.

FIGURE 1.3 Example of a metropolitan area network connecting a small town



The Campus Area Network

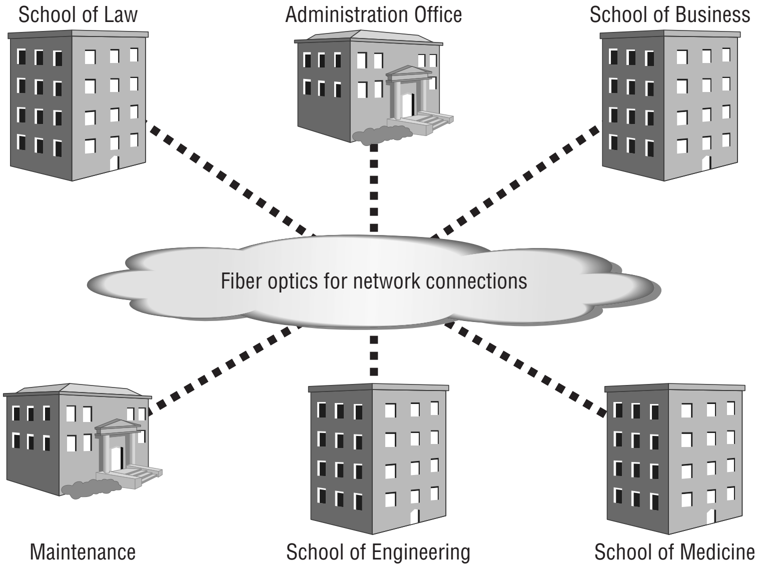
A *campus area network (CAN)* includes a set of interconnected LANs that basically form a smaller version of a wide area network (WAN) within a limited geographical area, usually an office or school campus. Each building within the campus generally has a separate LAN. The LANs are often connected using fiber-optic cable, which provides a greater distance than copper wiring using IEEE 802.3 Ethernet technology. However, using wireless connections between the buildings in a CAN is an increasingly common way to connect the individual LANs. These wireless connections or wireless bridges provide a quick, cost-effective way to connect buildings in a university campus, as shown in Figure 1.4.

In a university campus environment, a CAN may link many buildings, including all of the various schools—School of Business, School of Law, School of Engineering, and so on—as well as the university library, administration buildings, and even residence halls. Wireless LAN deployments are becoming commonplace in university residence halls. With the rapidly increasing number of wireless mobile devices on university campuses, the number of wireless access points and the capacity of each need to be considered.

As in the university campus environment, a corporate office CAN may connect all the various building LANs that are part of the organization. This type of network will have the characteristics of a WAN but be confined to the internal resources of the corporation or organization. Many organizations are deploying wireless networks within the corporate CAN as a way to connect various parts of the business together. As with the university CAN, in the corporate world wireless can be a quick, cost-effective way to provide connectivity between buildings and departments.

All of the physical connection mediums and devices are the property of the office or school campus, and responsibility for the maintenance of the equipment lies with the office or campus as well.

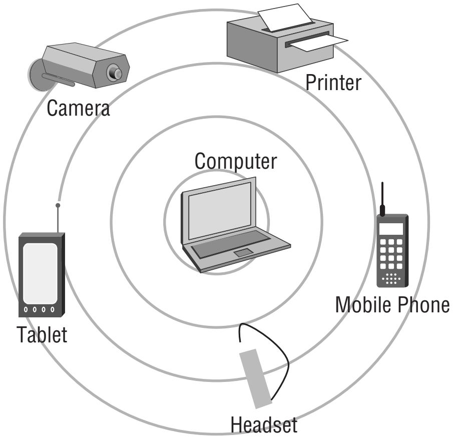
FIGURE 1.4 Campus area network connecting a school campus



The Personal Area Network

Personal area networks (PANs) are networks that connect devices within the immediate area of individual people. PANs may consist of wired connections, wireless connections, or both. On the wired side, this includes universal serial bus (USB) devices such as printers, keyboards, and computer mice that may be connected with a USB hub. With wireless technology, PANs are short-range computer networks and in many cases use Bluetooth wireless technology. Wireless Bluetooth technology is specified by the IEEE 802.15 standard and is not IEEE 802.11 wireless local area technology. Bluetooth will be discussed in more detail in Chapter 4. Like wired PANs, wireless PANs are commonly used in connecting an individual's wireless personal communication accessories such as phones, headsets, computer mice, keyboards, tablets, and printers and are centered on the individual personal workspace without the need for physical cabling. Figure 1.5 illustrates a typical wireless PAN configuration.

FIGURE 1.5 Wireless Bluetooth network connecting several personal wireless devices



Network Topologies

A computer physical network topology is the actual layout or physical design and interconnection of a computer network. A topology includes the cabling and devices that are part of the network. In the following sections you will learn about several different types of network topologies:

- Bus
- Ring
- Star
- Mesh
- Ad-hoc
- Point-to-point
- Point-to-multipoint

The bus, ring, star, mesh, and ad-hoc topologies are typically what make up the local area network (LAN) you learned about previously. Point-to-point and point-to-multipoint topologies can be commonly used for connecting LANs and are mostly used for wide area network (WAN) connections. The size of your network will determine which topologies will apply. If your network is a single building and not part of a larger corporate network, the LAN topologies may be the extent of the technologies used. However, once that LAN connects to a different LAN, you are moving up and scaling to a wide area network.

The Bus Topology

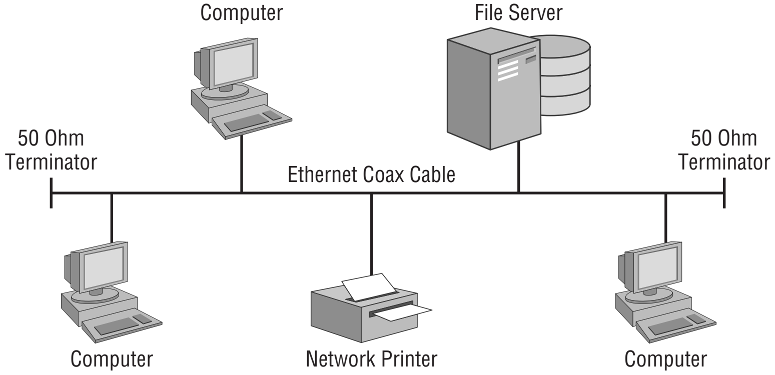
A *bus* topology consists of multiple devices connected along a single shared medium with two defined endpoints. It is sometimes referred to as a high-speed linear bus and is a single collision domain in which all devices on the bus network receive all messages. Both endpoints of a bus topology have a 50 ohm termination device, usually a Bayonet Neill-Concelman (BNC) connector with a 50 ohm termination resistor. The bus topology was commonly used with early LANs but is now considered a legacy design.

One disadvantage to the bus topology is that if any point along the cable is damaged or broken, the entire LAN will cease to function. This is because the two endpoints communicate only across the single shared medium. There is no alternative route for them to use in the event of a problem.

Troubleshooting a bus network is performed by something known as the half-split method. A network engineer "breaks" or separates the link at about the halfway point and measures the resistance on both ends. If the segment measures 50 ohms of resistance, there is a good chance that side of the LAN segment is functioning correctly. If the resistance measurement is not 50 ohms, it signals a problem with that part of the LAN segment. The engineer continues with this method until the exact location of the problem is identified.

Figure 1.6 illustrates an example of the bus topology.

FIGURE 1.6 Example of the bus topology



Real World Scenario

Troubleshooting the Bus Topology

Many years ago I was called to troubleshoot a problem on a small local area network using a bus topology. The network consisted of a network file server, about 20 client stations, and a few network printers. The users complained of intermittent connection problems with the network. After spending some time looking over the network, I decided to test the bus using the half-split method and checked to verify that the cable was reporting the correct resistance using a volt-ohm-milliamp (VoM) meter. Sure enough, one side of the network cable reported the correct resistance reading, but the other side was giving intermittent results.

After spending some time repeating the troubleshooting method, I was able to determine the problem. It turns out that someone had run the coax (bus) cable underneath a heavy plastic office chair mat and one of the little pegs used to protect the flooring was causing the intermittent connection as it struck the cable when the user moved their chair around the mat. I quickly replaced and rerouted the section of cable in question. It is a good thing I was there during the normal business operating hours when the person was moving around in the chair or I might have never found the problem. Ah, the joys of troubleshooting a bus topology.

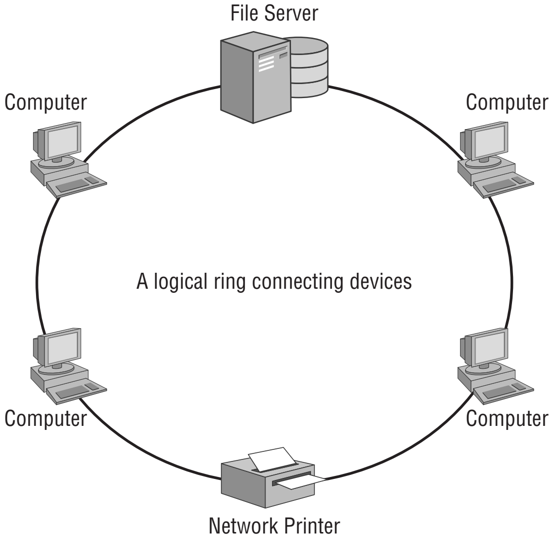
The Ring Topology

The *ring* topology is rarely used with LANs today, but it is still widely used by Internet service providers (ISPs) for high-speed, resilient backhaul connections over fiber-optic links. In the ring topology, each device connects to two other devices, forming a logical ring pattern.

Ring topologies in LANs may use a token-passing access method, in which data travels around the ring in one direction. Only one device at a time will have the opportunity to transmit data. Because this access method travels in one direction, it does not need to use collision detection and often outperforms the bus topology, achieving higher data transfer rates than are possible using a collision detection access method. Each computer on the ring topology can act as a repeater, a capacity that allows for a much stronger signal.

The IEEE standard for LANs is IEEE 802.5, specifying Token Ring technology. IEEE 802.5 Token Ring technology used in LANs was a very efficient method used to connect devices, but it was usually more expensive than the bus or star topologies. Because of the token-passing method used, early 4 Mbps Token Ring networks could sometimes outperform a 10 Mbps IEEE 802.3 collision-based Ethernet network. Token Ring technology speeds increased to 16 Mbps but decreased in popularity as Ethernet speeds increased. Even though this is a ring topology, devices are connected through a central device and appear to be similar to devices on an Ethernet hub or switch. Figure 1.7 shows an example of the ring topology.

FIGURE 1.7 An example of the ring topology



The Star Topology

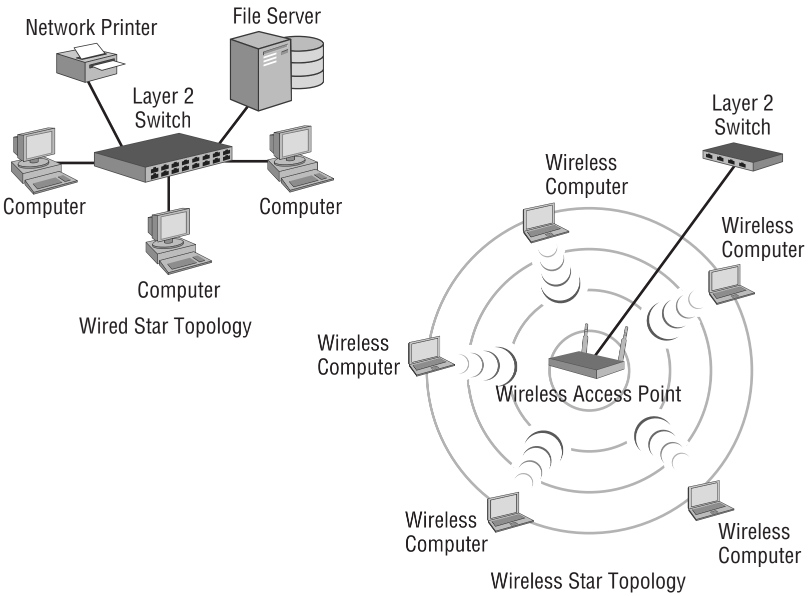
The *star* topology, as shown in Figure 1.8, is the most commonly used method of connecting devices on a LAN today. It consists of multiple devices connected by a central connection device. Hubs, switches, and wireless access points are all common central connection devices, although hubs are rarely used today. The hub provides a single collision domain similar to a bus topology. However, the Ethernet switch and wireless access point both have more intelligence—the ability to decide which port specific network traffic can be sent to. Note that in Figure 1.8, the wireless star topology includes an Ethernet switch, which could also have extended devices connected to it with wires. In that sense, it is possible to have a wired/wireless hybrid topology.

A big advantage to the star over the bus and some ring topologies is that if a connection is broken or damaged, the entire network does not cease to function; only a single device in the star topology is affected. However, the central connection device such as a switch or wireless access point can be considered a potential central point of failure.

The Mesh Topology

A device in a mesh network will process its own data as well as serving as a communication point for other mesh devices. Each device in a *mesh* topology (see Figure 1.9) has one or more connections to other devices that are part of the mesh. This approach provides both network resilience in case of link or device failure and a cost savings compared to full redundancy. Mesh technology can operate with both wired and wireless infrastructure network devices. Wireless mesh networks are growing in popularity because of the potential uses in outdoor deployments and the cost savings they provide.

FIGURE 1.8 A common star topology using either wired or wireless devices



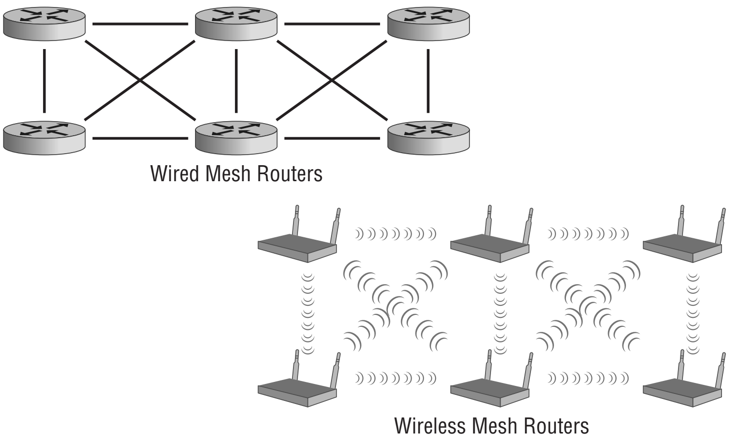
From an IEEE 802.11 wireless perspective, wireless mesh technology has now been standardized, although most manufacturers continue to use their proprietary methods. The amendment to the IEEE 802.11 standard for mesh networking is 802.11s. This amendment was ratified in 2011 and is now part of the latest wireless LAN standard, IEEE 802.11-2012. In addition to IEEE 802.11 networks, mesh is also standardized in IEEE 802.15 personal area networks for use with Zigbee and IEEE 802.16 Wireless MAN networks. Wireless standards will be discussed in more detail in Chapter 4.

As mentioned earlier, IEEE 802.11 wireless device manufacturers currently continue to use proprietary Layer 2 routing protocols, forming a self-healing wireless infrastructure (mesh) in which edge devices can communicate. Manufacturers of enterprise wireless networking infrastructure devices provide support for mesh access points (APs) such that the mesh APs connect back to APs that are directly wired into the network backbone infrastructure. The APs, wireless LAN controllers or software-based cloud solutions in this case, are used to configure both the wired and mesh APs.

Ad Hoc Connections

In the terms of computer networking, the *ad hoc* network is a collection of devices connected without a design or a plan for the purpose of sharing information or resources. Another term for an ad hoc network is *peer-to-peer network*.

FIGURE 1.9 Mesh networks can include either wired or wireless devices.

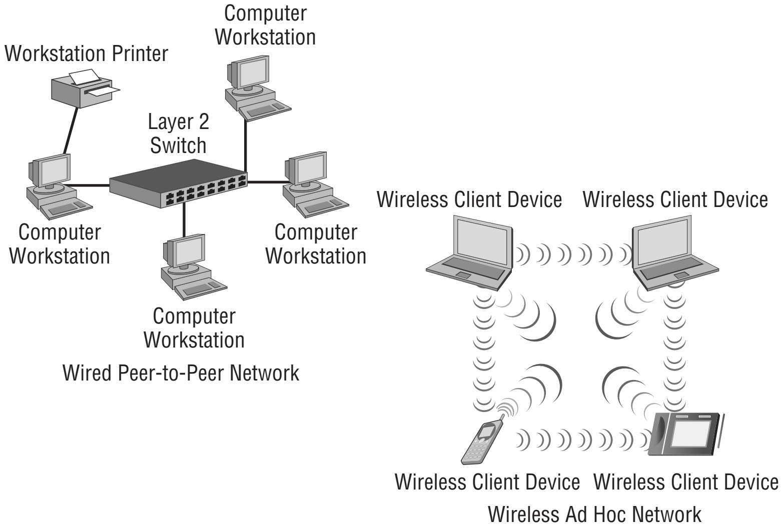


In a wired peer-to-peer network, all computing devices are of equal status. In other words, there is no server that manages the access to network resources. All peers can either share their own resources or access the resources of their devices on the network.

An ad hoc wireless network is one that does not contain a distribution system, which means no wireless access point is contained in the system to provide centralized communications.

Figure 1.10 shows an example of a wired peer-to-peer network and a wireless ad hoc network.

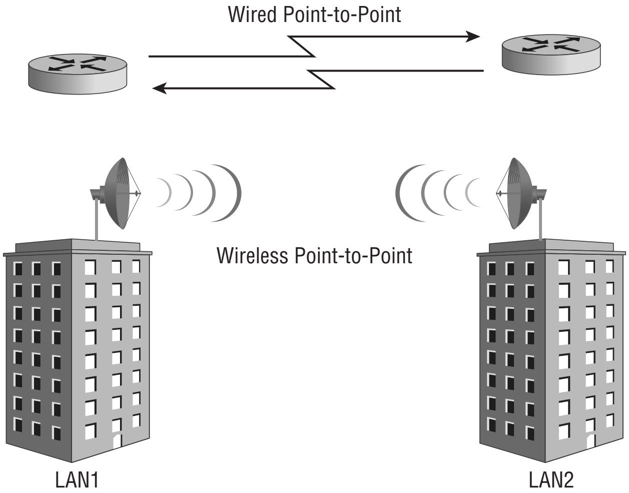
FIGURE 1.10 Wired peer-to-peer and wireless ad hoc networks



Point-to-Point Connections

When at least two LANs are connected, it is known as a *point-to-point connection* or link (see Figure 1.11). The connection can be made using either wired or wireless network infrastructure devices and can include bridges, wireless access points, and routers. Wireless point-to-point links can sometimes extend very long distances depending on terrain and other local conditions. Point-to-point links provide a connection between LANs, allowing users from one LAN to access resources on the other connected local area network.

FIGURE 1.11 Point-to-point connections using either wired or wireless

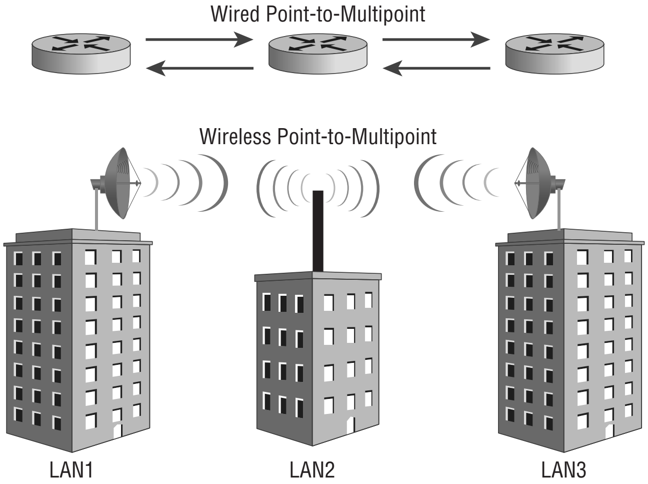


Wired point-to-point links consist of fiber-optic connections or leased lines from local telecommunication providers. Wireless point-to-point links typically call for semi-directional or highly directional antennas. Wireless point-to-point links include directional antennas and encryption to protect the wireless data as it propagates through the air from one network to the other. With some regulatory domains such as the Federal Communications Commission (FCC), when an omnidirectional antenna is used in this configuration it is considered a special case, called a point-to-multipoint link.

Point-to-Multipoint Connections

A network infrastructure connecting more than two LANs is known as a *point-to-multipoint connection* or link (see Figure 1.12). When used with wireless, this configuration usually consists of one omnidirectional antenna and multiple semidirectional or highly directional antennas. Point-to-multipoint links are often used in campus-style deployments, where connections to multiple buildings or locations may be required. Like point-to-point connections; wired point-to-multipoint connections can use either direct wired connections such as fiber-optic cables or leased line connectivity available from telecommunication providers.

FIGURE 1.12 Point-to-multipoint connections using either wired or wireless connections



The OSI Model

Before we continue with other mobility topics, you should have some background on computer networking theory. The basics of a computer networking discussion start with the *Open Systems Interconnection (OSI)* model, a conceptual seven-layer model. The OSI model has been around for decades. It came about in 1984 and was developed by the International Organization for Standardization (ISO). The ISO is a worldwide organization that creates standards on an international scale. The OSI model describes the basic concept of communications in the computer network environment. Be careful not to confuse the two.

There are seven layers to the OSI model. Each layer is made up of many protocols and serves a specific function. You will take a quick look at all seven layers of the OSI model. Some wireless-specific functionality of the OSI model will be discussed later in Chapter 5, “IEEE 802.11 Terminology and Technology.” Figure 1.13 illustrates the seven layers of the conceptual OSI model.

The following sections describe how each layer is used.

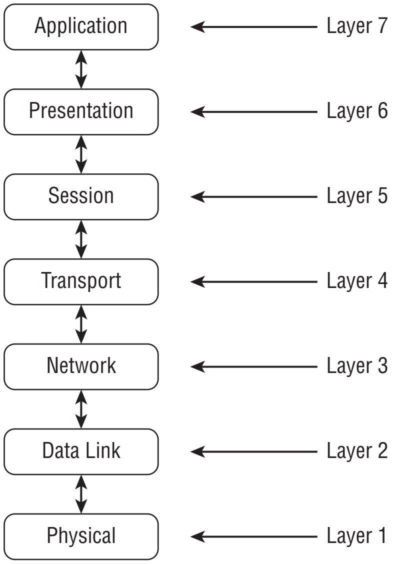
Layer 1 – The Physical Layer

The *Physical layer* (sometimes referred as the PHY) is the lowest layer in the OSI model. The PHY consists of bit-level data streams and computer network hardware connecting the devices together. This hardware that connects devices includes network interface cards, cables, Ethernet switches, wireless access points, and bridges. Keep in mind some of these hardware devices, such as Ethernet switches and bridges, actually have Data Link layer (Layer 2) functionally and operate at that layer but also make up the actual physical connections. In the case of wireless networking, radio frequency (RF) uses air as the medium for wireless communications. With respect to wireless networking, the Physical layer consists of two sublayers:

- Physical Layer Convergence Protocol (PLCP)
- Physical Medium Dependent (PMD)

The PLCP, the higher of the two layers, is the interface between the PMD and Media Access Control (MAC) sublayer of the Data Link layer. This is where the Physical layer header is added to the data. The PMD is the lower sublayer at the bottom of the protocol stack and is responsible for transmitting the data onto the wireless medium. Figure 1.14 shows the two sublayers that make up the Physical layer.

FIGURE 1.13 Representation of the OSI Model

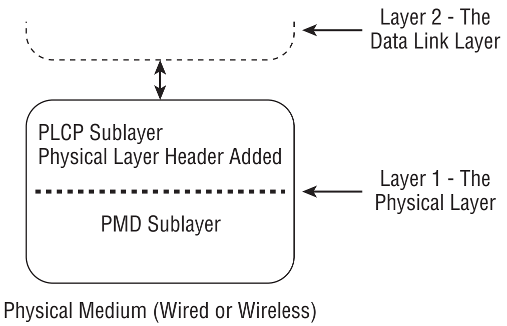


Layer 2 – The Data Link Layer

The *Data Link layer* is responsible for organizing the bit-level data for communication between devices on a network and detecting and correcting Physical layer errors. This layer consists of two sublayers:

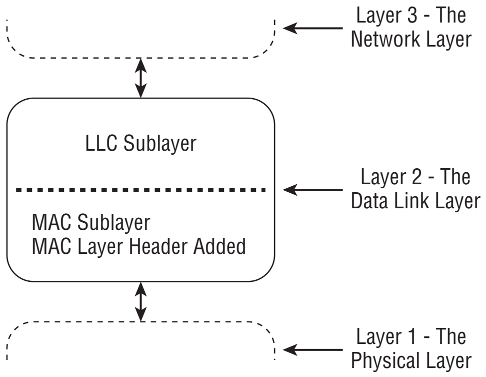
- Logical Link Control (LLC)
- Media Access Control (MAC)

FIGURE 1.14 Physical layer sublayers, PMD and PLCP


Layer 2 - The Data Link Layer
PLCP Sublayer
Physical Layer Header Added
PMD Sublayer
Layer 1 - The Physical Layer
Physical Medium (Wired or Wireless)

The bit-level communication is accomplished through Media Access Control (MAC) addressing. A *MAC address* is a unique identifier of each device on the computer network and is known as the physical or sometimes referred to as the hardware address. (MAC addresses are discussed later in this chapter.) Figure 1.15 illustrates the two sublayers of the Data Link layer, Layer 2.

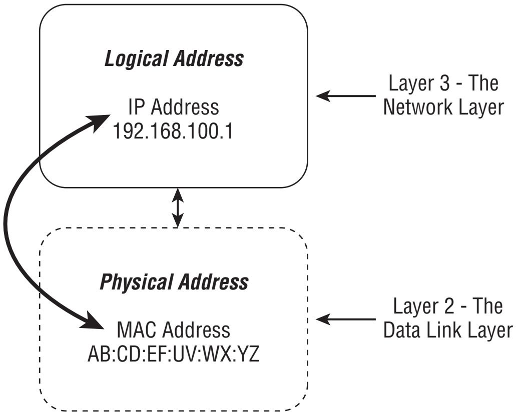
FIGURE 1.15 Data Link layer sublayers, LLC and MAC


Layer 3 - The Network Layer
LLC Sublayer
MAC Sublayer
MAC Layer Header Added
Layer 2 - The Data Link Layer
Layer 1 - The Physical Layer

Layer 3 – The Network Layer

The *Network layer* is where the Internet Protocol (IP) resides. The Network layer is responsible for addressing and routing data by determining the best route to take based on what it has learned or been assigned. An IP address is defined as a numerical identifier or logical address assigned to a network device. The IP address can be static, manually assigned by a user, or it can be dynamically assigned from a server using Dynamic Host Configuration Protocol (DHCP). (IP addresses are discussed later in this chapter.) Figure 1.16 illustrates the Layer 2 MAC address translation to a Layer 3 IP address.

FIGURE 1.16 Data Link layer (Layer 2) to Network layer (Layer 3) address translation



Layer 4 – The Transport Layer

The *Transport layer* consists of both connection-oriented and connectionless protocols providing communications between devices on a computer network. Although there are several protocols that operate at this layer, you should be familiar with two commonly used Layer 4 protocols:

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)

TCP is a connection-oriented protocol and is used for communications that require reliability, analogous to a circuit-switched telephone call.

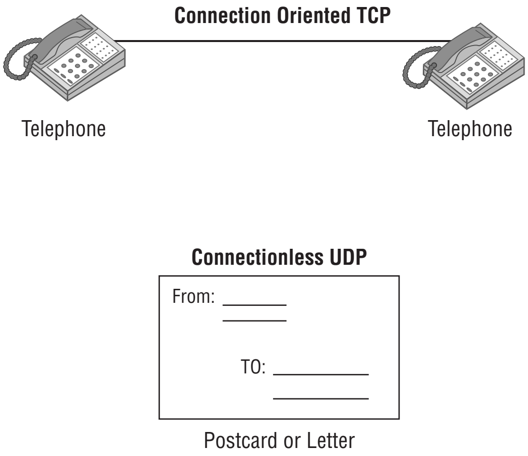
UDP is a connectionless protocol and is used for simple communications requiring efficiency, analogous to sending a postcard through a mail service. You would not know if the postcard was received or not. UDP and TCP port numbers are assigned to applications for flow control and error recovery. Figure 1.17 represents the relationship between the Transport layer protocols TCP and UDP.

Layer 5 – The Session Layer

The *Session layer* opens, closes, and manages communications sessions between end-user application processes located on different network devices. The following protocols are examples of Session layer protocols:

- Network File System (NFS)
- Apple Filing Protocol (AFP)
- Remote Procedure Call Protocol (RPC)

FIGURE 1.17 Comparison between TCP and UDP protocols



Layer 6 – The Presentation Layer

The *Presentation layer* provides delivery and formatting of information for processing and display. This allows for information that is sent from one device on a network (the source) to be understood by another device (the destination) on the network.

Layer 7 – The Application Layer

The *Application layer* can be considered the interface to the user. Application is another term for a program that runs on a computer or other networking device and that is not what we are looking at here. Protocols at this layer are for network operations such as, for example, transferring files, browsing web pages, and sending email. The following list includes some of the more common examples of Application layer protocols we use daily:

- File Transfer Protocol (FTP) for transfering data
- Hypertext Transfer Protocol (HTTP) for web browsing
- Post Office Protocol v3 (POP3) for email

Common Application layer protocols will be discussed further in Chapter 2, “Common Network Protocols and Ports.”

How the Layers Work Together

In order for computers and other network devices to communicate with one another using the OSI model, a communication infrastructure of some type is necessary. In a wired network, such an infrastructure consists of cables, repeaters, bridges, and Layer 2 switches. In a wireless network, the infrastructure consists of access points, bridges, repeaters, radio frequency, and the open air. Some of these devices will be discussed in more detail in Chapter 6, "Computer Network Infrastructure Devices."

Wireless networking functions at the two lowest layers of the OSI model, Layer 1 (Physical) and Layer 2 (Data Link). However, to some degree Layer 3 (Network) plays a role as well, generally for the TCP/IP protocol capabilities.

OSI Model Memorization Tip

One common method you can use to remember the seven layers of the OSI model from top to bottom is to memorize the following sentence: All people seem to need data processing. Take the first letter from each word and that will give you an easy way to remember the first letter that pertains to each layer of the OSI model.

- **A**ll (**A**pplication)
- **P**eople (**P**resentation)
- **S**eem (**S**ession)
- **T**o (**T**ransport)
- **N**eed (**N**etwork)
- **D**ata (**D**ata Link)
- **P**rocessing (**P**hysical)

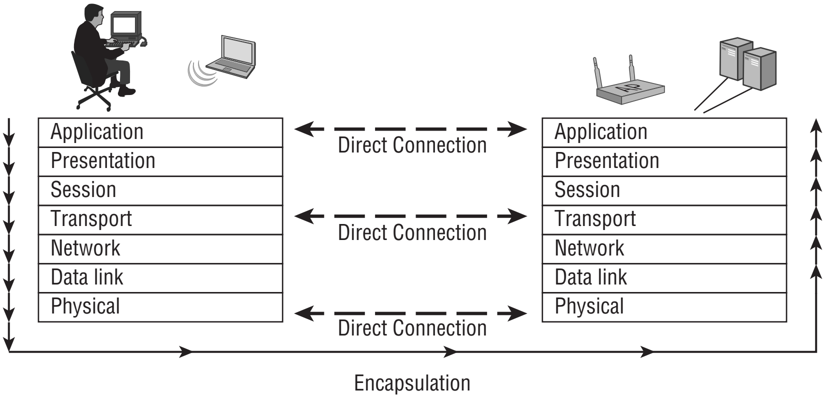
Here's another one, this time from the bottom to the top:

- **P**lease (**P**hysical)
- **D**o (**D**ata Link)
- **N**ot (**N**etwork)
- **T**hrow (**T**ransport)
- **S**ausage (**S**ession)
- **P**izza (**P**resentation)
- **A**way (**A**pplication)

Peer Layer Communication

Peer layers communicate with other layers in the OSI model and the layers underneath are their support systems. Peer layer communication is the "horizontal" link between devices on the network. Figure 1.18 shows three examples of *peer layer communication*. Keep in mind, however, that this principle applies to all seven layers of the OSI model. This allows for the layers to communicate with the layer to which a device is sending or receiving information.

FIGURE 1.18 Peer communication between three of the seven layers



Data Encapsulation

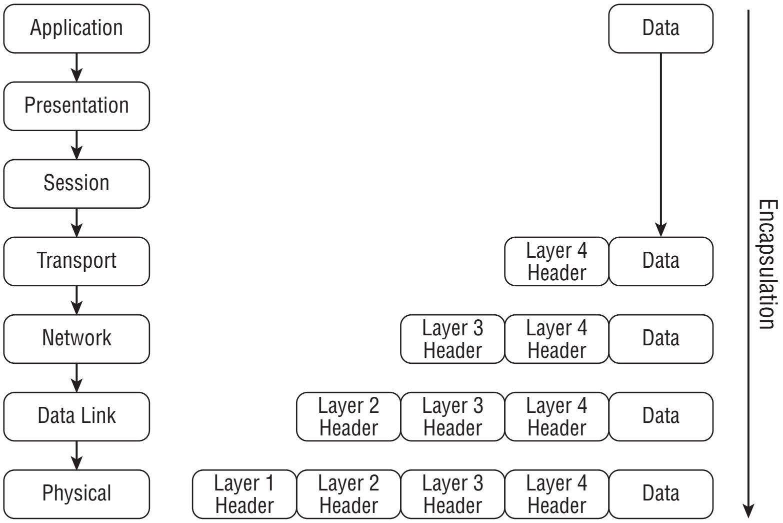
The purpose of *encapsulation* is to allow Application layer data communication between two stations on a network using the lower layers as a support system. As data moves down the OSI model from the source to the destination, it is encapsulated. As data moves back up the OSI model from the source to the destination, it is de-encapsulated. Some layers will add a header and/or trailer when information is being transmitted and remove it when information is being received. Encapsulation is the method in which lower layers support upper layers. Figure 1.19 illustrates this process.

Device Addressing

Every device on a network requires unique identification. This can be accomplished in a couple of ways:

- Physical addresses
- Logical addresses

FIGURE 1.19 Information is added at each layer of the OSI model as data moves between devices



The *physical address* of a network adapter is also known as the Media Access Control (MAC) address. As shown in Figure 1.20, every device on a network (like every street address in a city) must have a unique address. The physical address is required in order for a device to send or receive information (data). An analogy to this is sending a package to be delivered via a courier service. Before you hand over the package to the courier, you would write the name and physical street address of the recipient on the package. This would ensure that the package is delivered correctly to the recipient.

The *logical address* is also known as the Internet Protocol (IP) address. Each device on a Layer 3 network or subnet must have a unique IP address (like every city's zip code). The IP address can be mapped to the physical address by using the Address Resolution Protocol (ARP).

The streets shown in Figure 1.20—1st, Main, and 2nd—represent local area network subnets. The street addresses—10, 20, and so on—represent the unique address of each structure on a street as a MAC address would a device on a LAN.

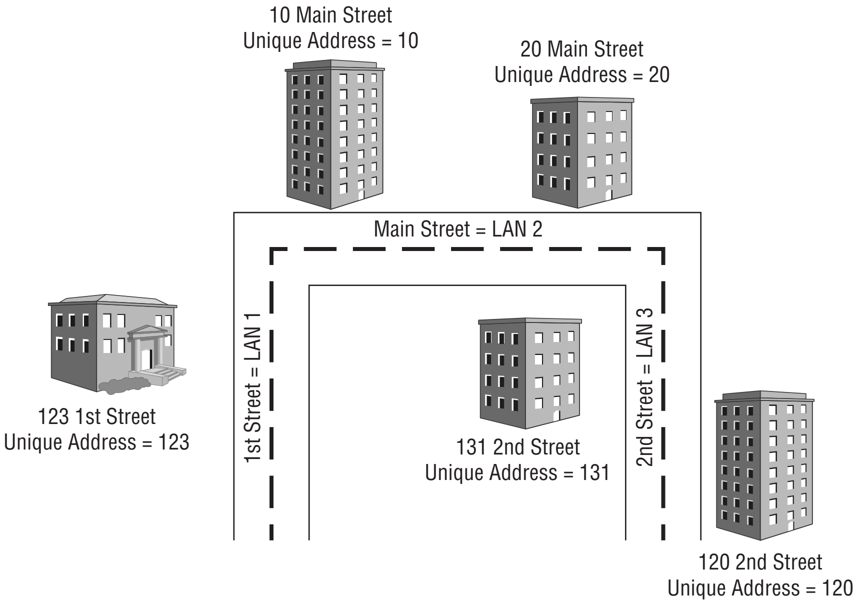
Physical Addressing

The physical address of a network device is called a MAC address because the *MAC sublayer* of the Data Link layer handles media access control. The MAC address is a 6-byte (12-character) hexadecimal address in the format AB:CD:EF:12:34:56. The first 3 bytes (or octets) of a MAC address are called the organizationally unique identifier (OUI). Some manufacturers produce many network devices and therefore require several OUIs. A table of all OUIs is freely available from the IEEE Standards Association website at

`http://standards.ieee.org/develop/regauth/oui/oui.txt`

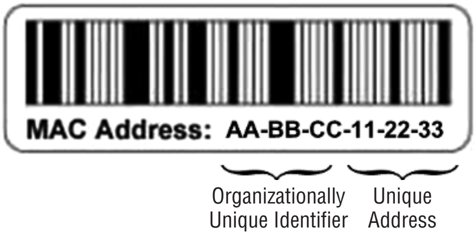
MAC addresses are globally unique; an example is shown in Figure 1.21. The first 3 bytes or octets (6 characters) are issued to manufacturers by the IEEE. The last 3 bytes or octets (6 characters) are incrementally assigned to devices by the manufacturer.

FIGURE 1.20 The MAC address is analogous to the address of buildings on a street.



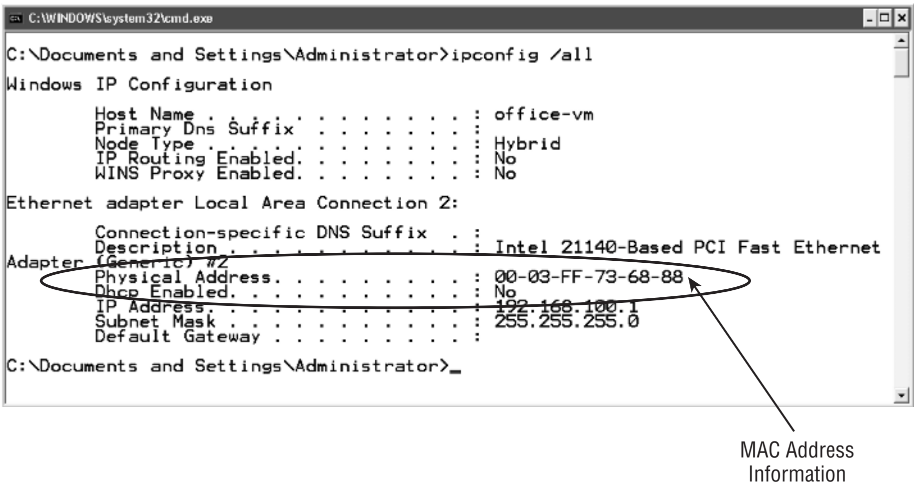
The streets shown—1st, Main, and 2nd—represent local area networks. The numbers 10, 20, 123, 131, and 120 represent the unique address of each structure on the streets just as MAC addresses would represent devices on a LAN.

FIGURE 1.21 Example of a Layer 2 MAC address shows the OUI and unique physical address


MAC Address: AA-BB-CC-11-22-33
Organizationally Unique Identifier
Unique Address

The MAC address of a device is usually stamped or printed somewhere on the device. This allows the device to be physically identified by the MAC address. By typing the simple command **ipconfig /all** in the command-line interface of some operating systems, you can view the physical address of the network adapter. Figure 1.22 shows an example of the information displayed by using this command-line utility in the Microsoft Windows operating system.

FIGURE 1.22 The **ipconfig** command-line utility displaying a physical/MAC address in Microsoft Windows



```
C:\Documents and Settings\Administrator>ipconfig /all

Windows IP Configuration

        Host Name . . . . . . . . . . . . : office-vm
        Primary Dns Suffix  . . . . . . . :
        Node Type . . . . . . . . . . . . : Hybrid
        IP Routing Enabled. . . . . . . . : No
        WINS Proxy Enabled. . . . . . . . : No

Ethernet adapter Local Area Connection 2:

        Connection-specific DNS Suffix  . :
        Description . . . . . . . . . . . : Intel 21140-Based PCI Fast Ethernet
Adapter (Generic) #2
        Physical Address. . . . . . . . . : 00-03-FF-73-68-88
        Dhcp Enabled. . . . . . . . . . . : No
        IP Address. . . . . . . . . . . . : 192.168.100.1
        Subnet Mask . . . . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . . . . :

C:\Documents and Settings\Administrator>_
```

Logical Addressing

Network devices can also be identified by a logical address, known as the Internet Protocol (IP) address. The Layer 3 IP protocol works with a Layer 4 transport protocol, either User Datagram Protocol (UDP) or Transport layer Protocol (TCP). You learned earlier in this chapter that UDP is a connectionless protocol, and using it is analogous to sending a postcard through the mail. The sender has no way of knowing if the card was received by the intended recipient. TCP is a connection-oriented protocol, used for communications analogous to a telephone call, and provides guaranteed delivery of data through acknowledgements. During a telephone conversation, communication between two people will be confirmed to be intact, with the users acknowledging the conversation. Routable logical addresses such as TCP/IP addresses became more popular with the evolution of the Internet and the Hypertext Transfer Protocol (HTTP) that is used with the World Wide Web (WWW) service. IP moves data through an internetwork such as the Internet one router (or hop) at a time. Each router decides where to send the data based on the logical IP address. Figure 1.23 shows a basic network utilizing both Layer 2 and Layer 3 data traffic.

Logical addresses (IP addresses) are 32-bit dotted-decimal addresses usually written in the form www.xxx.yyy.zzz. Figure 1.24 illustrates an example of a logical Class C, 32-bit IP address. Each of the four parts is a byte, or 8 digital bits. There are two main IP address types: private addresses and public addresses. Private addresses are unique to an internal network, and public addresses are unique to the Internet. These addresses consist of two main parts: the network (subnet) and the host (device). Logical addresses also require a subnet mask and may have a gateway address depending on whether the network is routed. IPv4 addresses fall under three classes: Class A addresses, Class B addresses, and Class C addresses.

FIGURE 1.23 A network with Layer 3 network device logical addressing

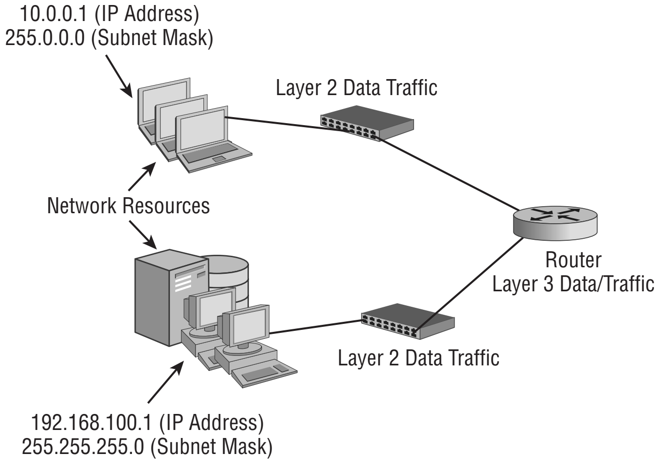
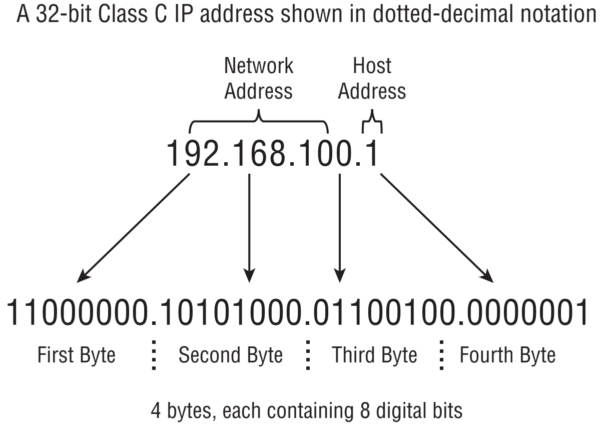


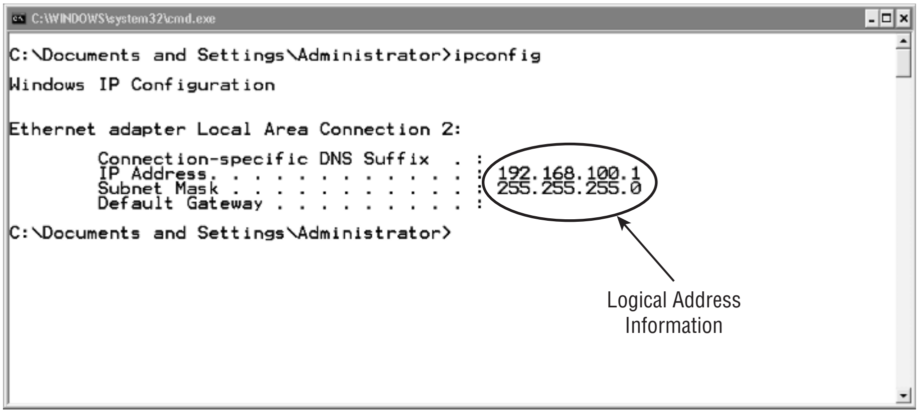
FIGURE 1.24 Example of a Class C logical IP address



The logical IP addresses you just learned about are known as IPv4 addresses. Newer addresses called IPv6 addresses also exist and are discussed in Chapter 2.

Unlike a MAC address, an *IP address* is logical and can be either specified as a static address assigned to the device manually by the user or dynamically assigned by a server. However, the same command-line utility used to identify the physical address of a device can be used to identify the logical address of a device. Typing **`ipconfig`** at a command prompt displays the logical address, including the IP address, subnet mask, and default gateway (router) of the device. The `ipconfig /all` command illustrated earlier in the chapter will yield additional information, including the physical or MAC address of the device's network adapter. This command is for a computer using the Microsoft Windows operating system. For some Apple and Linux devices, the `ifconfig` command will yield similar information. Figure 1.25 shows the `ipconfig` utility displaying the logical address information, including the IP address and subnet mask.

FIGURE 1.25 The Microsoft Windows **`ipconfig`** command-line utility showing logical address information



```
C:\Documents and Settings\Administrator>ipconfig
Windows IP Configuration

Ethernet adapter Local Area Connection 2:

        Connection-specific DNS Suffix  . :
        IP Address. . . . . . . . . . . . : 192.168.100.1
        Subnet Mask . . . . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . . . . :

C:\Documents and Settings\Administrator>
```

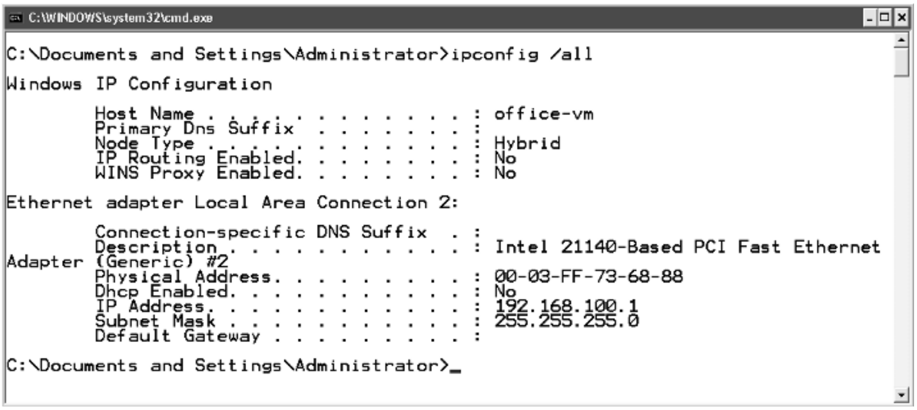
In Exercise 1.1, you will use the `ipconfig` utility from a command prompt on a computer using the Microsoft Windows operating system. This will allow you to see the address information for any available network adapters within the device.

Exercise 1.1 was written using a computer with the Microsoft Windows 7 operating system. If you're using another version of the operating system, the steps may vary slightly. Keep in mind that there are many different shortcuts and ways to get to a command prompt in the Microsoft operating systems. The steps in this exercise use one common method.

EXERCISE 1.1

Viewing Device Address Information on a Computer

1. Click the Start button.
2. Mouse over the All Programs arrow. The All Programs window appears in the left pane.
3. Navigate to and click on the `Accessories` folder. The accessories programs appear.
4. Click the Command Prompt icon. The command window will appear.
5. In the command window, type **`ipconfig /all`**.
6. View the results in the command window. Notice the physical address of the network adapter as well as other information. The results should look similar to that shown here for Microsoft Windows 7 but may vary slightly based on the OS version in use.



```
C:\Documents and Settings\Administrator>ipconfig /all

Windows IP Configuration

        Host Name . . . . . . . . . . . . : office-vm
        Primary Dns Suffix  . . . . . . . :
        Node Type . . . . . . . . . . . . : Hybrid
        IP Routing Enabled. . . . . . . . : No
        WINS Proxy Enabled. . . . . . . . : No

Ethernet adapter Local Area Connection 2:

        Connection-specific DNS Suffix  . :
        Description . . . . . . . . . . . : Intel 21140-Based PCI Fast Ethernet
Adapter (Generic) #2
        Physical Address. . . . . . . . . : 00-03-FF-73-68-88
        Dhcp Enabled. . . . . . . . . . . : No
        IP Address. . . . . . . . . . . . : 192.168.100.1
        Subnet Mask . . . . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . . . . :

C:\Documents and Settings\Administrator>_
```

Summary

This chapter provided a survey of networking topics to help you understand the basics of computer networking as an introduction or a simple review. It began with an outline of the common network technology types:

- Local area networks (LANs)
- Wide area networks (WANs)
- Metropolitan area networks (MANs)

- Campus area networks (CANs)
- Personal area networks (PANs)

The next fundamental networking concept discussed was computer network topologies. You learned about network topologies ranging from the legacy high-speed linear bus and ring to the current star topology, the most common topology used today with both wired and wireless networks. You looked at the following various topologies:

- Bus
- Ring
- Star
- Mesh
- Ad hoc
- Point-to-point
- Point-to-multipoint

You then reviewed the basics and different layers of the OSI model, including a brief overview of each layer illustrating the different protocols and sublayers where applicable. Then I discussed the basics of peer communications and data encapsulation.

The chapter's final topic was device addressing. You explored the concepts of physical (MAC Sublayer) and logical (Network layer) addressing, including the IP address and subnet mask. A simple exercise using a computer with the Microsoft Windows operating system showed how to view device addressing information.

Chapter Essentials

Understand the components of a local area network (LAN). A local area network is a group of computers connected by a physical medium in a specific arrangement called a topology.

Know the different types of networks. The basic networks types are LAN, WAN, CAN, MAN, and PAN.

Become familiar with various networking topologies. Bus, star, ring, mesh, and ad hoc are some of the topologies used in computer networking. Bus is considered legacy, and the star topology is one of the most common in use today.

Understand point-to-point and point-to-multipoint connections. These can consist of both wired and wireless connections and will connect two or more LANs.

Understand the OSI model basics. Each of the seven layers of the OSI model serves a specific function. It's beneficial to have an overall understanding of all seven layers.

Remember the details of the lower two layers of the OSI model. The Physical layer and Data Link layer are the two lowest layers in the OSI model. Wireless networking technology operates at these layers. The Data Link layer consists of two sublayers: the Logical Link Control (LLC) sublayer and the Media Access Control (MAC) sublayer.

Understand device addressing. Devices are assigned a unique physical address by the manufacturer. This address is known as the MAC address. MAC addresses consist of two parts, the organizationally unique identifier (OUI) and the unique physical address. A logical address may also be assigned at the Network layer to identify devices on different internetworks using the Internet Protocol (IP).