chapter 1

Introduction to Wireless Communications

After reading this chapter and completing the exercises, you will be able to:

- Describe how wireless communications technologies are used today
- List various applications of wireless communications technology
- Outline the advantages and disadvantages of wireless communications technology
- List several types of wireless technologies and their purposes

We all know that wireless communications technologies have had a huge impact around the world, especially in the last five years. Today, wireless communications affects almost everything we do on a daily basis, from using the ever-present cellular phones to making voice calls and accessing information, to the counting of inventory in large retail stores, to buying public transit system tickets, to locating hotspots for Internet access and wireless remote sensors installed in locations that are difficult to access, to using credit and debit cards that just need to be placed near a device instead of swiped or inserted, and many, many other uses. There should be no question in anyone's mind that the use of wireless devices will continue to expand into virtually every aspect of our lives.

Wireless communications has completely revolutionized the way we live, just as personal computers forever altered how we worked in the 1980s and the Internet dramatically changed how we obtained and accessed information in the 1990s. Lately, the Internet has also changed how we communicate around the world. Using wireless devices to send and receive short messages as well as to browse the Internet and access corporate applications and databases from any location in the world is now an integral part of our daily lives. And numerous devices—notebook computers, tablets, digital still picture and video cameras, printers, portable digital music players, even refrigerators, washing and drying machines, and electricity meters—are equipped with the ability to communicate without wires.

Today, we can all be in touch with the digital resources we need, no matter where we may find ourselves. Nearly everyone has experienced dramatic changes based on wireless technologies, to the extent that we don't even think about what we are doing, we just expect devices to work without being connected by a cable.

Using an electronic book reader or e-reader, you can view the cover, sample some pages, and purchase a book simply by visiting an online bookstore. On an Amazon Kindle device, for example, all you need is access to either a wireless network or to the cellular telephone network (in over 100 different countries), depending on which model you have. The book will be automatically downloaded to your reader within a couple of minutes. See *www.amazon.com/kindle*.

How Wireless Technology Is Used

Before we continue, let's define precisely what we mean by *wireless communications*. The term *wireless* is often used to describe all types of devices and technologies not connected by a wire. A garage door opener and a television remote control can be called "wireless devices," but they have little in common with the technologies discussed in this book. Because the term *wireless* is sometimes used to refer to any device that has no wires, people can be puzzled about the exact meaning of *wireless communications*. A cordless phone can be considered a wireless communications device—for communicating with the human voice, that is. But for the purposes of this book, **wireless communications** is defined as the transmission of digital data without the use of wires, meaning devices that can be interconnected using some kind of data networking technology. Digital data may include e-mail messages, spreadsheets, and messages transmitted to or from a digital cellular phone. However, note that devices that use a computer network to transmit voice conversations are also included here.

One example of a device that can be used to transmit voice conversations over a computer network is an Apple iPod Touch. This device is generally used to listen to music but can also be used to make calls to telephone numbers anywhere in the world while it's connected to a wireless network, using an application such as Skype. (Go to *www.apple.com/ipodtouch*. Also go to *www.skype.com*, place the mouse cursor over Get Skype, then click iPhone.) When using such devices, your voice is first converted to digital data and then transmitted first over a wireless network and then over the Internet. At the receiving end, the stream of data that is your voice is converted back to sound. You will read more about this in Chapter 10.

The next section talks about the various forms that wireless data communications can take. You will learn about Bluetooth, WirelessHD, WiGig, satellite, cellular, **Wi-Fi**-based wireless LANs, and fixed broadband wireless communications technologies. The specific details of each of these technologies are covered in later chapters. Let's take a look at a day in the life of a typical couple, Joseph and Ann Kirkpatrick, which will provide a quick overview of some of today's wireless communications and how they can be used.

A Wireless World

Joseph and Ann get ready for a typical day. Before Ann leaves for the office, she must first print a copy of a spreadsheet that she finished working on late last night. Because there are several computers in their house, the Kirkpatricks have set up a wireless network that uses a specific networking standard to allow all the digital-data-enabled devices around the house to communicate with one another. Computers and other devices that are compatible with the standards can be as far as roughly 330 feet (100 meters) apart from each other and can send and receive data at speeds up to 300 million bits per second (300 megabits per second or Mbps), depending on which specific standard they are compatible with. The devices that can be part of the network include not only computer equipment but also **Voice over Internet Protocol (VoIP)** telephones, which carry digitized voice over the Internet, home entertainment and gaming equipment, and even some digital music players, such as an Apple iPod Touch.

To get a better idea of the speed of wireless transmission of data, consider that each alphanumeric character transmitted typically uses 16 bits of data. This means that at 300 Mbps, which is the speed of the fastest wireless network today, a computer can transmit over 9,000 letter-sized pages per second, with approximately 2,000 letters and spaces in each. Can you read that fast?

Ann pulls a tablet computer out of her briefcase and opens a spreadsheet. She then selects the print command. A device called a **wireless network interface card** (or **wireless NIC**) is built in on the tablet computer. This interface card sends the data over radio waves directly to the wireless-enabled laser printer downstairs, which has its own wireless NIC. This wireless network is ideal for the Kirkpatricks. They can have all their home computing and electronic devices interconnected without the trouble and expense of installing cables; this network enables all of their devices to share printers, files, and even the home Internet connection. Figure 1-1 illustrates the home wireless network.

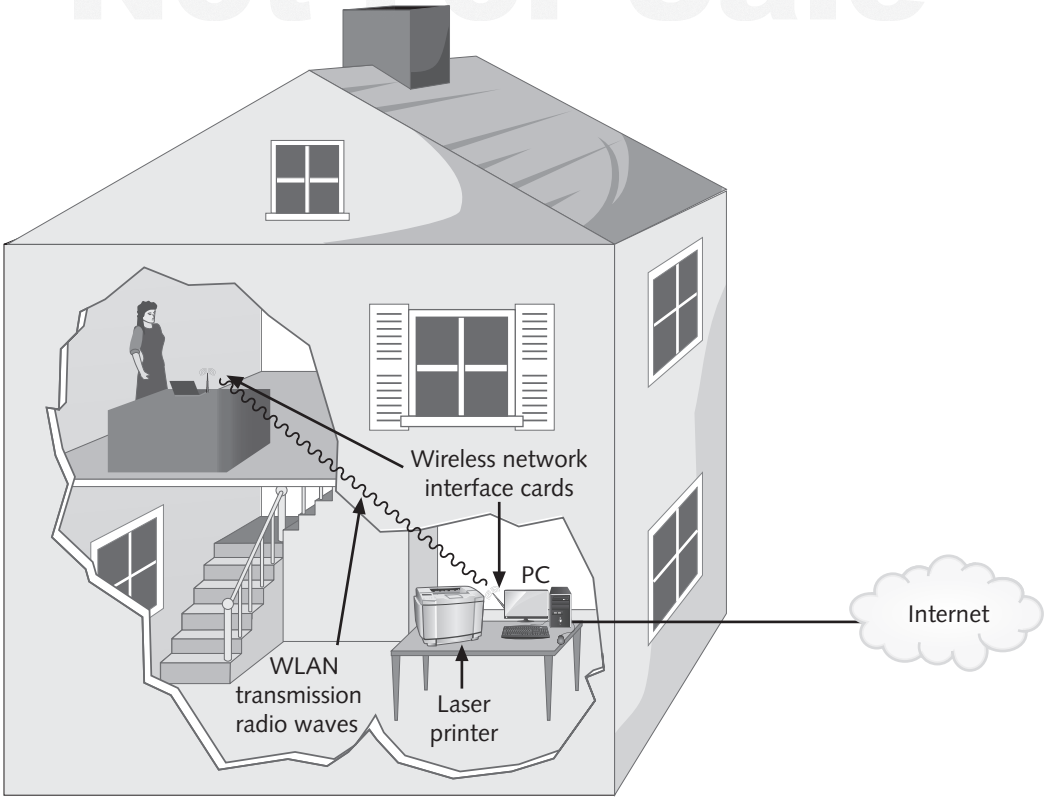

Figure 1-1 Home wireless network (WLAN)

Ann places a call to her office to pick up her messages using her **smartphone**, a combination of a mobile phone and **personal digital assistant** (**PDA**) that also provides an appointment calendar, a to-do list, a phone book, and a notepad as well as many other useful business and entertainment applications. Although most mobile phones today include some of these features, smartphones can connect to other devices, such as personal computers, and synchronize the data between the two devices; they can also electronically store and transmit business cards and other types of information, even word-processing files and spreadsheets. In addition, almost all models of smartphones today can connect directly to the same kind of wireless network that we use to interconnect computers. Because Ann is inside the home, the smartphone automatically connects to the wireless network to access and store data. While they are inside the house, both Ann and Joseph's smartphones can use software that enables them to make calls using VoIP over their wireless network and the Internet instead of their cellular provider. They even have separate phone numbers that people can dial to call them from a landline phone. After Joseph and Ann leave home, their mobile phones disconnect when they are out of range of the wireless network; then they use the cellular network to make and receive voice calls. Being able to use VoIP over the Wi-Fi network helps them save money by cutting down on their cellular phone bills.

As early as 2004, runners in the Boston Marathon covered the 26.2-mile course with tiny wireless chips clipped to their shoelaces. The chips transmit an identification code that is detected at several stations along the marathon course, and the code is used to track the runners' times as well as to e-mail updates to the runners' friends and relatives regarding their locations and progress. For a full description of the technology employed, search the Internet using the keywords "Boston marathon wireless."

Shortly after finishing their breakfast in the kitchen, Joseph hears a short beep and notices that a shopping list has been e-mailed to his smartphone from the refrigerator. A computer system installed in the refrigerator door automatically generates a grocery list by scanning the **radio frequency identification** (**RFID**) tags attached to almost every product package. RFID tags are small chips containing radio transponders that can be used to identify products and track inventory. At predetermined dates and times, the refrigerator computer compares the remaining food items with a list of minimum quantities for those items. If the items are running out, it adds them to a list and sends an e-mail over the Internet to both Ann and Joseph, which they receive on their smartphones. Joseph or Ann can also use the wireless network to connect to the refrigerator's computer and find out what they need to buy. Because the refrigerator is also connected to the Internet, the same function can be accomplished regardless of where they are, at any time.

To watch a video demonstration of a refrigerator computer in action, search the Internet or YouTube using the keywords "Samsung Internet fridge." The refrigerator in this video does not include RFID, but it allows you to manage a family calendar, leave notes for family members, send e-mails and tweets, and connect to Facebook. You can also access recipes online, create a shopping list, etc.

Bluetooth and Other Short-Range Wireless Technologies

Bluetooth is a wireless standard designed to transmit data at very short ranges—typically, from a few inches to 33 feet (10 meters). The main purpose of short-range technologies such as Bluetooth is to eliminate cables between devices such as smartphones and computers, which allows data to be transmitted wirelessly between, say, a computer and a printer or a mobile telephone and a music player or a computer and a smartphone. Figure 1-2 shows two examples of Bluetooth headsets that are typically used with mobile phones or digital music players like the iPod Touch but that can also be used with computers. Bluetooth communicates using small, low-power transceivers called **radio modules**, which are built into tiny circuit boards and contain very small microprocessors. Bluetooth devices use a **link manager**, which is software that helps it identify other Bluetooth devices, create a link between them, and send and receive music and voice in the form of digital data; it can also send other types of data.

Figure 1-2 Two examples of Bluetooth headsets: mono (left) and stereo (right)

There are other short-range wireless technologies designed for use primarily in the home, which are similar to Bluetooth but can handle a lot more data at much higher speeds. For example, **WirelessHD** and **WiGig** can send CD-quality audio and DVD or Blu-ray disk high-definition video to multiple receivers around the house at the same time. Most Bluetooth devices can transfer a maximum of between 1 Mbps and 3 Mbps at distances of up to 33 feet (10 meters), but the latest version covers transmission at data rates up to 24 Mbps. WirelessHD and WiGig can transfer video and sound at speeds between 7 Gbps and 10 Gbps (gigabits or billions of bits per second) using a radio transmission technology called **Ultra Wide Band (UWB)**. Bluetooth can send data through physical barriers like walls. These wireless devices don't even have to be aimed at each other the way a TV remote control usually has to be aimed at the TV set when changing channels or adjusting the sound. UWB WirelessHD and WiGig generally have a range of up to 10 meters, but only within a room with few or no obstacles between devices. In addition, the greater the distance, the slower the transmission. The gigabit per second speeds above can only be achieved at distances of up to 6 feet (approximately 1.8 meters). Plus, the more obstacles, including people, that there are in a room, the shorter the transmission range of UWB.

Nearly 14,000 different computer, telephone, and peripheral vendors create products based on the Bluetooth standard. Both WirelessHD and WiGig also have an impressive list of well-known member companies.

To check out the range of available products, visit the WirelessHD Consortium Web site at *www.wirelesshd.org*. When the main page opens, place the mouse cursor over the Consumers tab, then click Product Listing.

Joseph and Ann both work for Federated Package Express (FPE), a package delivery service. To send a package, a customer telephones the local FPE call center. An FPE customer service representative receives the call using her VoIP telephone handset, which is connected to the

WLAN and to a Bluetooth telephone headset. Ann doesn't even have to be at her desk; her Bluetooth device automatically establishes a connection with the wireless telephone handset as soon as both devices are turned on. She can immediately answer a call by simply tapping a small button on the headset, without having to pick up the receiver. In addition, the tablet computer she carries around keeps her connected to the office network at all times, no matter where she is in the building. For example, the address list and calendar that Ann updated last night at home are transmitted to the office, and the information is immediately refreshed.

The automatic connection between various Bluetooth devices creates a **piconet**, also sometimes called a **wireless personal area network** (**WPAN**). A piconet consists of two or more Bluetooth devices that are exchanging data with each other. Up to seven devices can belong to a single Bluetooth WPAN.

The customer service representative at FPE answers the call while she is moving around her cubicle, without having her movements not limited by a telephone wire. She can also enter the package pickup information on her computer or, when she is not at her desk, on her tablet. Figure 1-3 illustrates a Bluetooth wireless network.

Bluetooth is named after the tenth-century Danish King Harald Bluetooth, who was responsible for unifying Scandinavia. You can read more of his story on the Internet by searching for the king's name.

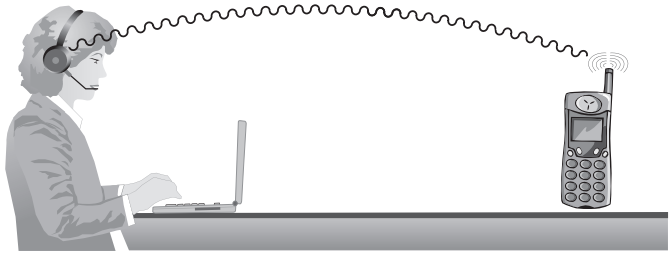

Figure 1-3 Bluetooth network (piconet) or WPAN between a cordless handset and a headset

Satellite Networks

FPE, the company that Joseph and Ann work for, has connectivity needs that go far beyond the walls of its headquarters building. The company uses a combination of a satellite-based network and the cellular wireless network to stay in touch with its delivery vehicles while they are on the road. Where cellular networks (discussed in the next section) are not available, the drivers can use satellite phones to connect their handheld computers to FPE's head office.

After the FPE customer service representative has entered the pickup information into the computer, the data needs to get to the pickup driver—in this case, Joseph. FPE's satellite network is sometimes responsible for this data transmission. From the main head-office computer, the pickup data is transmitted to a satellite orbiting the Earth and then back down to the handheld satellite phone and finally to Joseph's handheld computer. Figure 1-4 shows a satellite retransmitting the signal between the main office and the satellite phone in Joseph's van.

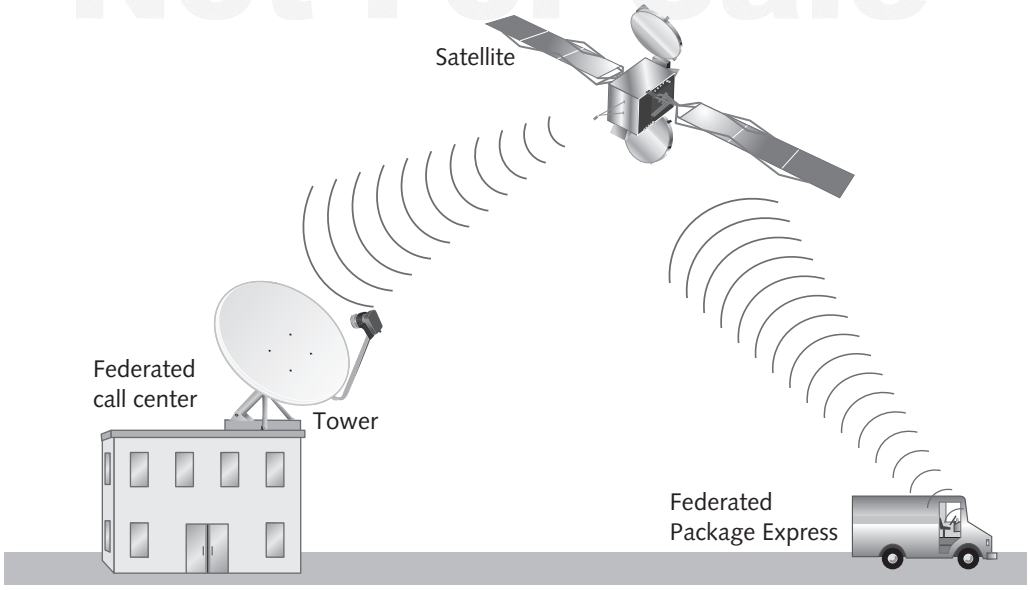

Figure 1-4 Satellite data network

In satellite communications, a device called a **repeater** is located in the satellite itself. A repeater simply "repeats" the same signal to another location down on the surface. An Earth station transmits to the satellite at one frequency band, and the satellite regenerates and transmits (repeats) the signal back to Earth on a different frequency. The transmission time needed to repeat a signal from one Earth station to another can be up to 250 milliseconds. This is illustrated in Figure 1-5.

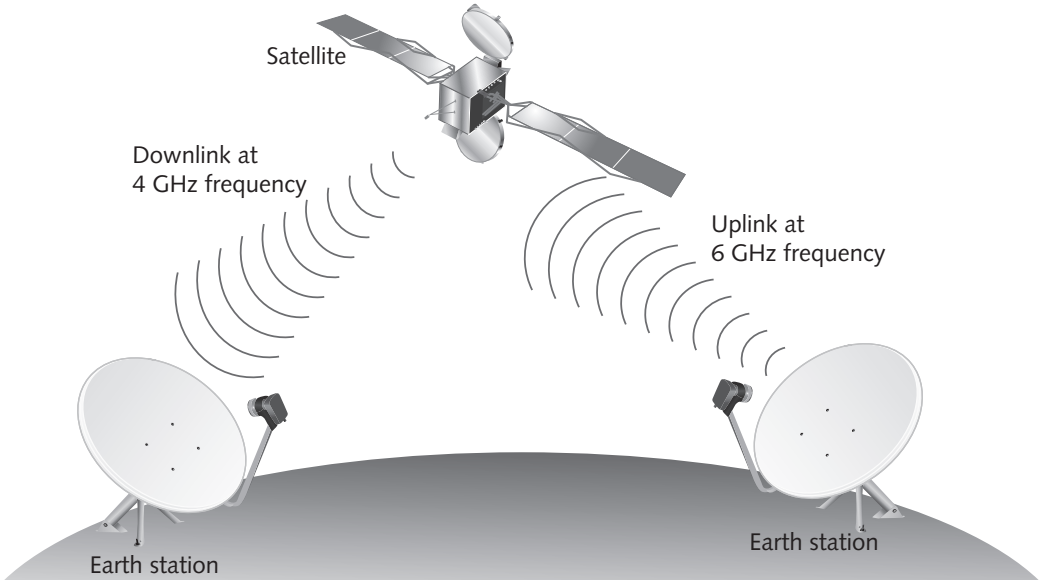

Figure 1-5 Satellite repeating a signal to another Earth station

FPE uses an outside vendor that provides international satellite communications.

The first satellite to orbit Earth successfully, called Sputnik, was launched by the Soviet Union in 1957. Today, there are more than 900 operational satellites in orbit around the planet and reportedly over 5000 that are no longer functional. It's only due to some truly amazing mathematical calculations that they don't continually crash into one another, but on February 10, 2009, a nonoperational Russian satellite did crash into the Iridium 33 communications satellite, which is used for satellite phones.

Cellular Networks

Cellular digital technology provides another link between the various components that make up the FPE package pickup process. A modern cellular telephone network is built around the concept of low-power transmitters, with each "cell" handling a number of users. With transmission towers spread throughout a city, the same radio frequency channel can be used by towers located a few miles away from each other, thereby avoiding interference. This concept maximizes the use of a limited range of frequency channels and is made possible by low-power digital transmission technology, which permits another transmitter to use the same frequency a relatively short distance away, without causing interference problems. This topic is discussed in greater detail in Chapter 10. Figure 1-6 shows examples of two smartphones.

Figure 1-6 Smartphones—Blackberry Bold (left) and Apple iPhone (right)

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Joseph is equipped with a handheld smart wireless terminal, and his truck is equipped with a wireless printer. Joseph's handheld terminal receives the pickup order via the cellular phone network and can also receive time-sensitive information, such as route alerts warning of traffic delays or changes in pickup schedules; Joseph can also access route maps online. The van's engine computer, which monitors engine performance and other

vehicle systems, can perform diagnostic checks and transmit the results back to FPE over the same cellular connection. GPS tracking technology installed in the truck allows FPE to monitor the location of the delivery trucks, sending pickup orders to the one that is closest to the customer.

With the pickup order transmitted through the cellular network to the handheld terminal, Joseph swings onto the highway and reaches the address in about 15 minutes. He leaves the van carrying his handheld terminal, and then walks into the building to retrieve the package. The customer has already filled out a package label called a *waybill* that includes the sender's information as well as the recipient's name, address, and other information. A unique, 12-digit tracking number is printed on the waybill along with a barcode that corresponds to the tracking number. Using his smart terminal, which includes a barcode scanner and keyboard, Joseph scans the barcode on the waybill and then types in the destination of the package, the type of service delivery (such as Priority or Standard Overnight), and the delivery deadline. If necessary, when Joseph returns to the van, the terminal connects to the printer and can output a more detailed routing label that contains all this information, which Joseph can then place on the package before putting it in the back of his truck.

The information Joseph enters on his handheld terminal after picking up the package is immediately transmitted back to the office using wireless digital cellular technology. The data is actually transmitted to a cellular tower, which retransmits the data to the office via the cellular carrier's central office and eventually through the Internet. This cellular technology is based on a standard commonly known as **4G** (**fourth generation**) technology, which uses 100 percent digital transmission for both voice and data. On a 4G cellular phone, the technology allows the user to make a voice call at the same time data is being transmitted or received.

Check out the range of RFID-equipped and barcode-scan-equipped mobile computers at the Motorola Solutions Web site—for example, the MC65 model at *www.motorola.com* or the Intermec 70 series devices (that can be used for parcel delivery and pick-up) at *www.intermec.com*. Some of these devices can also be used as a cellular phone anywhere in the world. For portable wireless printers, check out *www.maxatec-europe.com* or *www.zebra.com*. You can also search the Internet using the terms in this tip to find other products.

4G sends data at rates that can theoretically reach over 150 Mbps when the devices are not moving and located in an area with few concurrent users, over 45 Mbps for slow-moving pedestrians, and over 20 Mbps in a fast-moving vehicle. 4G technologies are expected to harmonize all the different digital cellular specifications used around the world into a single standard. If Joseph happens to be located in an area outside the reach of the current 4G cellular networks, the terminal can use the interim technology known as **3G** (**third generation**), which has a theoretical maximum data transmission rate of up to 21 Mbps and can realistically reach speeds between 3 to 11 Mbps. The latest cellular technology

standard that is being deployed by carriers around the world is capable of even higher speeds and will be discussed in greater detail in Chapter 10. A digital cellular network is illustrated in Figure 1-7.

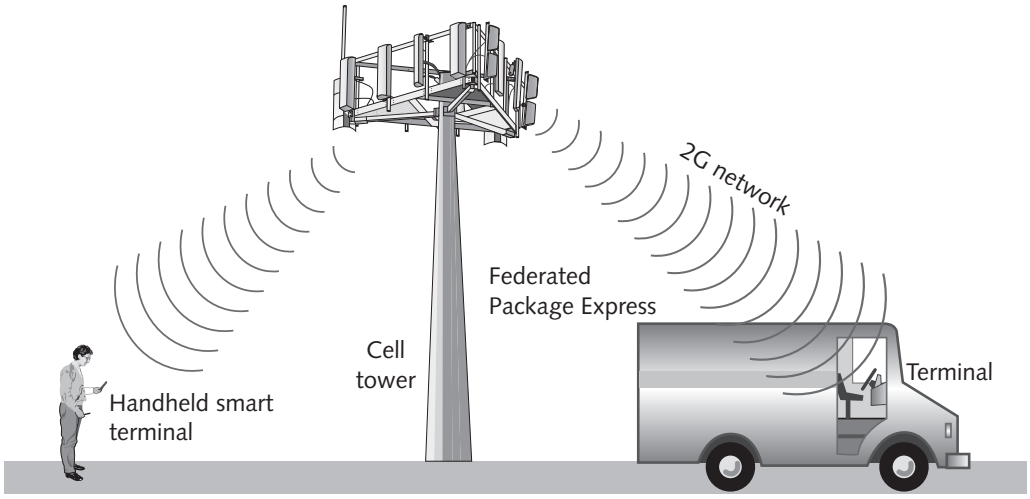

Figure 1-7 Digital cellular network

Wireless Local Area Networks

Joseph pulls his van into the FPE distribution warehouse, where packages are unloaded and sorted for delivery. His handheld terminal may still contain a large amount of important data, including shipping receipts and electronic customer signatures for deliveries. As soon as he pulls the van up to the loading dock, the terminal begins communicating with the computer network in the warehouse through a **wireless local area network** (**WLAN**). A WLAN is an extension of a wired LAN, connecting to it through a device called a **wireless access point** (also **AP** or **wireless AP**). The AP relays data signals among all the devices on the wired network, including file servers, printers, and even other access points and the wireless devices connected to them. Each computer on the WLAN has a wireless network interface card (NIC). This card performs the same basic functions and looks similar to a traditional NIC except that it does not have a cable that connects it to a network jack in the wall. Instead, the wireless NIC has an antenna built into it. The AP is fixed in one place, although it can be moved when necessary, whereas the computing devices with wireless NICs have the freedom to move around the office area or sometimes an entire campus complex. An access point and wireless NIC are illustrated in Figure 1-8, but keep in mind that the wireless NIC in Joseph's handheld terminal is built in and is much smaller.

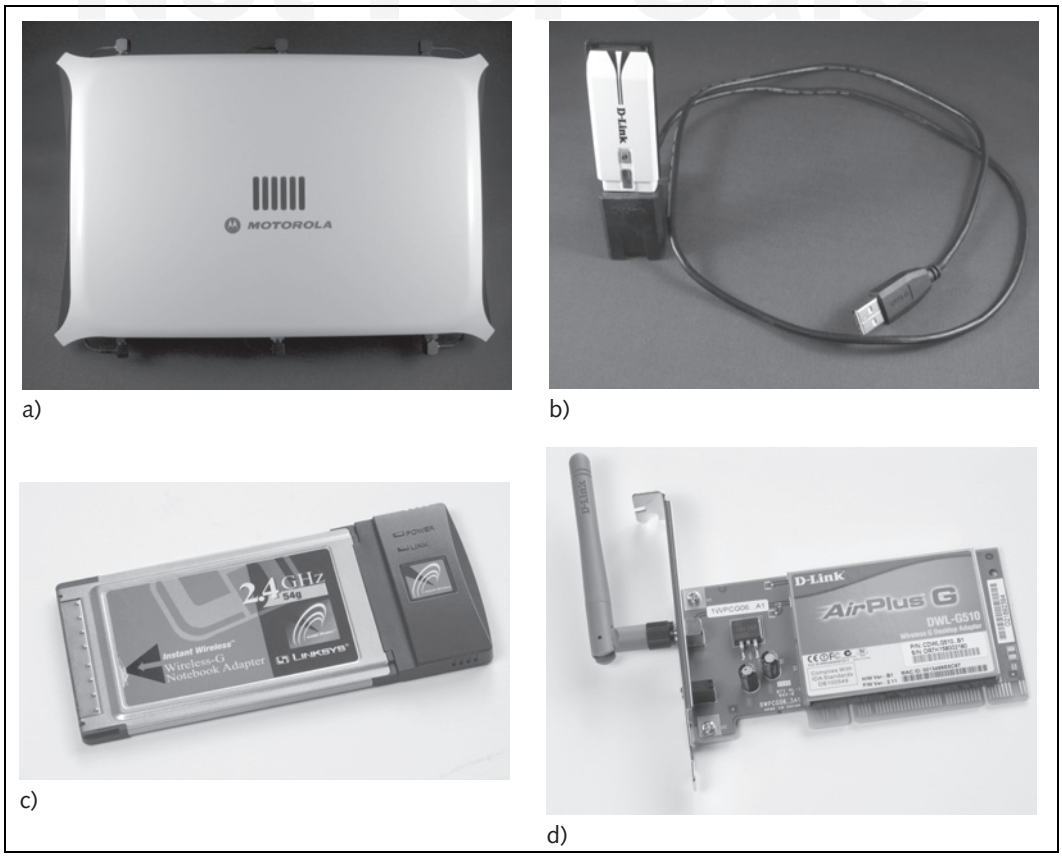

Figure 1-8 Clockwise from top left: a) access point with built-in antennas, b) USB Wireless N NIC, c) PCMCIA, and d) PCI Wireless NICs

WLANs operate based on networking standards established by the Institute of Electrical and Electronics Engineers (IEEE). The IEEE has published a series of standards, including the more recent **IEEE 802.11n-2009** (more commonly known as **IEEE 802.11n**), which provides for data transmission speeds of up to 600 Mbps and distances much greater than those of earlier versions of the standard. Depending on the standard used, most WLANs can transmit at speeds anywhere from 1 Mbps to 300 Mbps and cover distances of up to 375 feet (114 meters), under ideal conditions. In fact, even with some inexpensive 802.11n devices, today's WLANs can reach speeds of up to 450 Mbps. See Table 1-1 on page 18 of this chapter for a breakdown of the standards and their capabilities.

Throughout this book, "IEEE 802.11," "802.11," and "Wi-Fi" are used interchangeably, with or without a letter after the main standard number, 802.11. Although this may not be the most correct way to refer to these standards, it is the way everyone in the industry usually refers to them.

FPE currently uses an 802.11g network and is in the process of updating its WLAN to the higher capacity and faster 802.11n standard. The transmission of data from the handheld smart terminal, which includes all the important information regarding each pickup, is completed before the first package is unloaded from Joseph's van (see Figure 1-9).

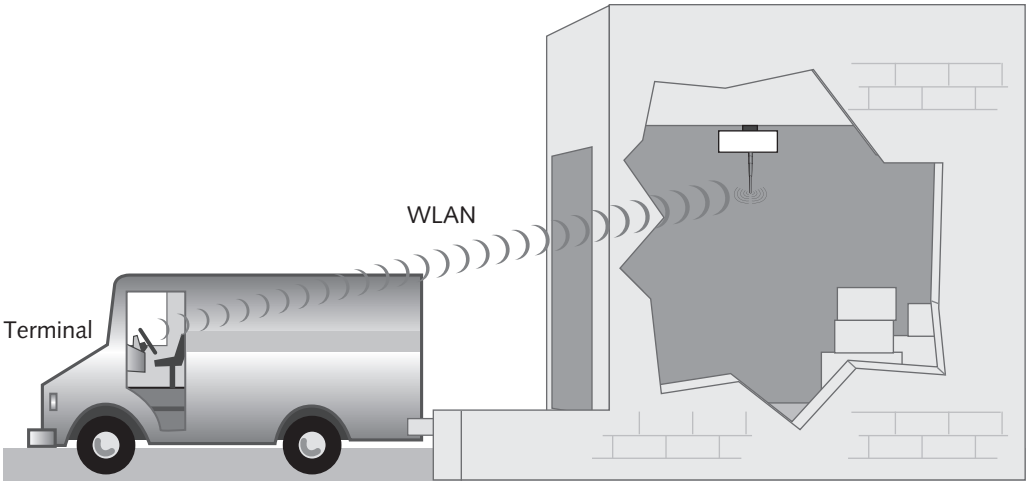

Figure 1-9 Warehouse WLAN

Joseph's wife, Ann, who also works for FPE, uses WLANs at her office, too. She does not have a desktop computer in her cubicle. Instead, FPE provides employees with portable notebook computers or tablet computers that they use while traveling, at home, and in the office. None of the notebook computers and tablets in the office are connected to the local area network by cables or wires. Instead, a WLAN provides connectivity among devices.

The WLAN renders devices portable. When Ann turns on her notebook computer at her desk, it establishes an automatic, preconfigured connection with the access point. She can now perform any network activity as if she were connected to the network with a cable. She can bring her notebook to a conference room for meetings. Once there, her notebook is still connected to the network, as are the notebooks of the other staff members in the meeting. Figure 1-10 illustrates the office WLAN.

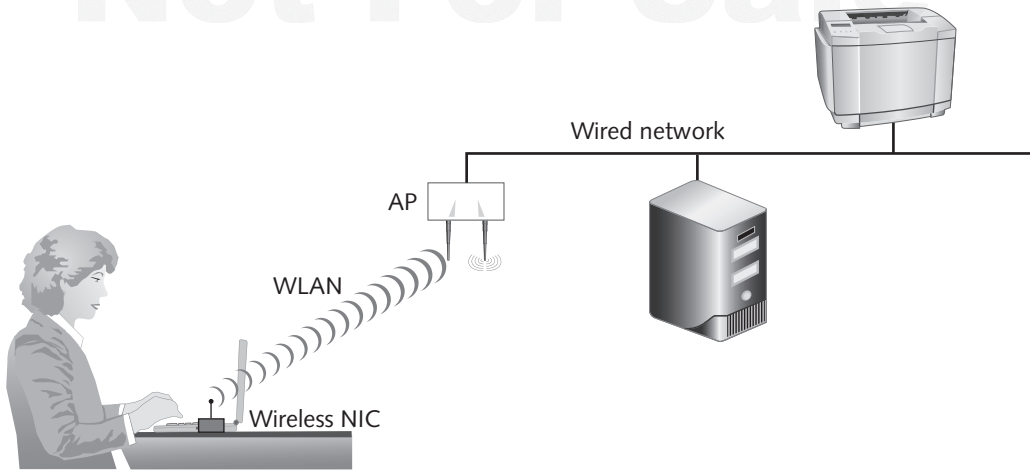

Figure 1-10 Office WLAN

Fixed Broadband Wireless

FPE's offices are spread over three locations: the main office, which is downtown; the warehouse, which is in a small industrial park; and the call center, which is at the edge of town. Through the years, FPE has tried a variety of connection types to link the three sites. Initially, FPE used expensive transmission lines leased from the local telephone company. **Integrated Services Digital Networks** (**ISDN**), which transmits at up to 256 Kbps over regular phone lines, was soon replaced with **T1** lines, which transmit at 1.544 Mbps, which was itself replaced with **optical fiber**. However, both of these types of communication lines cost several thousands of dollars per month. Technologies such as **cable modems**, which use a television cable connection, are generally only available in or near residential areas. **Digital subscriber lines** (**DSL**), which use either regular or special telephone lines, are sometimes available, but the speed is dependent on the distance between FPE's main office and the nearest telephone switching office (CO, for "central office").

The best and lowest-cost way for FPE to link its office locations was to use a **wireless metropolitan area network** (**WMAN**). A single WMAN link can cover an area of about 25 square miles, and it can be used to carry data, voice, and video signals. WMANs today are mostly based on the **IEEE 802.16 WiMAX Fixed Broadband Wireless** standard and use radio waves for data communications instead of optical or telephone wires. These networks use small custom antennas on the roof of each building in the WMAN. The signal is transmitted to the antenna of the receiving building. The transmission speed can be as high as 75 Mbps at distances of up to 4 miles (6.4 km), and 17 to 50 Mbps (depending on link quality) at distances over 6 miles (10 km) in a straight line, which is enough to interconnect all of FPE's offices. Newer versions of the IEEE 802.16m standard, which should be approved by the time this book is published, can achieve average speeds up to 100 Mbps, and up to 1 Gbps in a point-to-point link. The use of antennas substantially reduces the cost when compared to traditional wired connections, which require an infrastructure under city roads, are more prone to damage, and are more expensive to maintain.

Ironman triathlons, which can encompass a wide geographical area, can now be viewed live online using an IEEE 802.16 WMAN to connect cameras along the race route to the competition's Web site. Several channels of video are sent out, allowing enthusiasts to check what is happening at different race checkpoints simultaneously.

FPE has antennas on each of its three buildings in the area. Once the data from Joseph's van is transmitted to the network in the warehouse, it is sent to the main office by fixed broadband wireless. This process is illustrated in Figure 1-11.

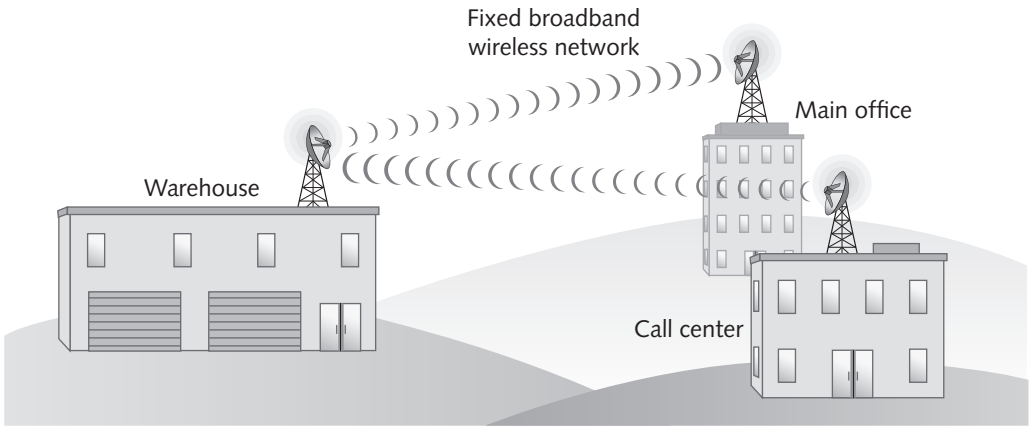

Figure 1-11 IEEE 802.16 wireless metropolitan area network (WMAN)

Wireless Wide Area Network

Personal computers use Web browsers to display Internet data. Based on user input, a Web browser requests Web pages to be displayed on the user's computer screen. The requested page is transmitted from a file server to the user's Web browser in **Hypertext Markup Language** (**HTML**), the standard language for displaying content from the Internet. This model is illustrated in Figure 1-12.

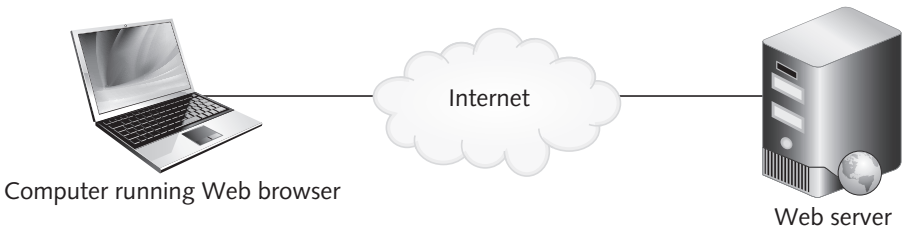

Figure 1-12 Browsing the World Wide Web on a PC

As Joseph's van is unloaded, he takes his afternoon break. Joseph pulls out his smartphone to surf the Internet. He can do this because his phone is a late model that includes an HTML version 5-compatible Web browser, which displays Web content the same way a computer does. Older cellular phones may be equipped with a **microbrowser**, a miniaturized version of a Web browser program that is based on version 1 of the **wireless application protocol** (**WAP**) and cannot display graphics or pictures. Newer types of phones that are not smartphones use the **wireless application protocol version 2.0** (**WAP2**), which provides a standard way to transmit, format, and display Internet data for small wireless devices such as cellular phones.

WAP2 follows the standard Internet model, allowing compatible cellular phones to display Internet content directly. The microbrowser in a WAP2-compatible cellular phone is a tiny program much like the browser on a PC, but the Web pages can be reformatted by the microbrowser for cellular phone screens, which usually have much less space. WAP2 is compatible with HTTP, the protocol used by Web server software to format data into Web pages, but it uses an earlier, simpler version (1.1) of HTTP rather than the version (4.1) in use by most of today's full-featured browsers. Most smartphones are also equipped with WAP2 browsers, which are used when they cannot access high-speed digital cellular services but still need to be able to access the World Wide Web.

When a Web server sends a Web page back to a PC, it is sending HTML code and any files (such as graphics) required to assemble the page. The Web browser application program on the receiving device is responsible for interpreting the code and displaying the results on the screen; in other words, the Web server does not send a fully formatted image of the page. Rather, it sends only HTML code and text along with formatting instructions, images and graphics, and the relative positions where they should be displayed on the screen. It is the receiving device itself that is responsible for formatting and displaying the Web pages.

Some newer cellular phones can even display live television and can be used to access a variety of business applications. Most cellular phones today still use a version of **J2ME** (**Java 2 Micro Edition**) and are designed and optimized to display text, graphics, and even some limited animations on the small screens, as seen in Figure 1-13. Several business applications that support common file formats such as Microsoft Word or Excel spreadsheets can be downloaded and displayed on some mobile devices or can be available on demand on the Web. Using cellular phone technologies, companies can create a **wireless wide area network** (**WWAN**) that enables employees to access corporate data and applications from virtually anywhere—across the country, an entire continent, or, depending on the type of cellular phone or mobile device, anywhere around the world.

Figure 1-13 Displaying Web content on a smartphone

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Joseph uses his cellular phone to connect to a Web server. Actually, the cellular phone connects to the nearest cell tower, which connects to the local telephone company, which in turn connects to an Internet provider and completes the link to the Web server. The contents of the Web page are then sent back and displayed on the screen of Joseph's phone.

The previous version of wireless application protocol (WAP) allowed Web browsing from cellular phones using text only, and it required a gateway server between the Web server and the cellular phone. In the original version of WAP, the text information (but not the images) contained in a Web page was extracted and translated by the WAP gateway (or WAP proxy) server from HTTP into a WAP-specific format called wireless markup language (WML) and broken down into a series of pages called "cards." These cards could be displayed on the small screen of a cellular phone, one at a time.

The Wireless Landscape

Most of the Kirkpatrick's activities, in a typical day, could not be attempted—much less completed—without wireless technology. It's clear that wireless communication is no longer reserved only for high-end users. Instead, it has become a standard means of communication for people in many occupations and circumstances, as shown in Figure 1-14. As new wireless communications technologies are introduced, they will become even more integral to our lifestyle and will continue to change how we live. Table 1-1 summarizes these technologies; Figure 1-15 compares their capabilities.

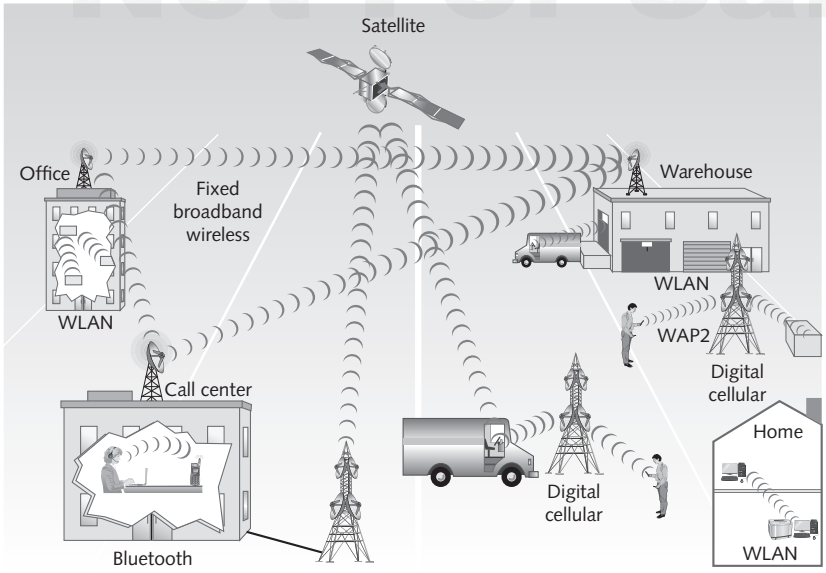

Figure 1-14 Wireless communications

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Wireless Technology	Range (Transmission Distance)	Maximum (Average) Speed
RFID	1 inch (2.5 centimeters) to 300 feet (100 meters), depending on frequency and type of tag	A few thousand bits-per-second (Kbps)
Bluetooth version 4	Class 3: 3.3 feet (1 meter) Class 2: 33 feet (10 meters) Class 1: 330 feet (100 meters)	1 Mbps (721.2 Kbps) to 24 Mbps (version 4 only)
WiGig and WirelessHD	150 feet (50 meters)	7–10 Gbps (3–5 Gbps)
WLAN 802.11n	375 feet (114 meters)	300–600 Mbps (140–400 Mbps)
WLAN 802.11g	300 feet (90 meters)	54 Mbps (22–26 Mbps)
WMAN 802.16 WiMAX	35 miles (56 kilometers)	75 Mbps (20–40 Mbps)
WMAN 802.16m WiMAX	35 miles (56 kilometers)	100 Mbps (40–60 Mbps) to 1 Gbps (point-to-point)
3G digital cellular	16 miles (up to 25 kilometers to tower), then anywhere in the world via other networks	21 Mbps (2–11 Mbps)
4G digital cellular	Typically, 16 miles (up to 25 kilometers) to tower, then anywhere in the world via other networks	20 Mbps–150 Mbps (4–25 Mbps)
Satellite	Worldwide	Greatly varying speeds, with each transmission experiencing about a quarter second (250 milliseconds) delay

Table 1-1 **Wireless data communications technologies**

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The speeds of wireless networks vary greatly, depending on the number of users connected, the amount of data traffic, the amount of interference present at the time, and many other factors that will be discussed in later chapters.

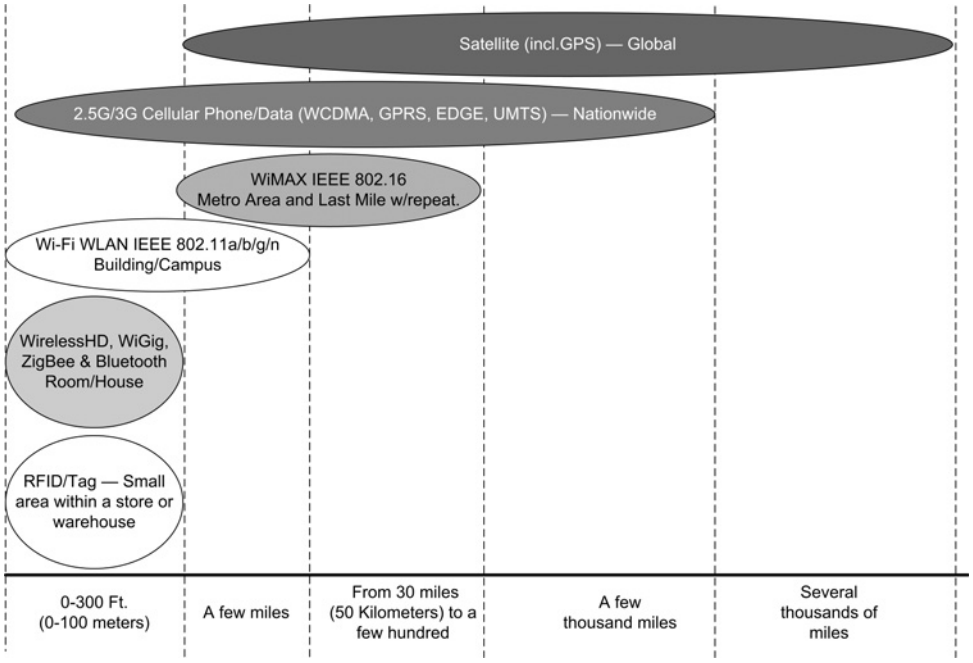

Figure 1-15 Comparing wireless communications technologies

Just as the number of wireless devices will dramatically increase, so will the number of job opportunities to support these new technologies. Professionals such as wireless engineers, wireless local area network managers, and wireless technical support personnel will be needed to build wireless networks and assist wireless users. The job market for these new careers is exploding and will continue to grow.

Worldwide expansion of wireless has surpassed all expectations. This has made it difficult for market research companies to provide accurate estimates of growth. In areas of central Africa, for example, where banking systems and a communications infrastructure practically do not exist, customers do not have a credit history, and the majority of the population survives on less than $1.00 a day, a cellular phone operator estimated it might have 36,000 customers by the end of one year. Instead, it had 38,000 subscribers within three weeks.

A team of anthropologists recently studied wireless device usage among people around the world. They noted several cultural differences in how wireless products were perceived. In Sweden, wireless phone devices become an extension of users' personalities. In France, users are more concerned about how the phone looks than the underlying technology or what it can do. In Great Britain, shy people find wireless devices help them overcome their reticence and reach out to others. In Japan, wireless usage helps

citizens break through social barriers, a common obstacle in that culture. In the United States, there's concern about people developing information overload from being available 24 hours a day. And in India, many business appointments and even major transactions are often accomplished using text messaging on cellular phones.

Digital Convergence

Users are constantly demanding more functionality from their computers, and as a result, wireless devices such as cellular phones and PDAs are being combined into single devices, what we today call smartphones. These devices have also continued to add capabilities. Whereas they were initially used only as appointment calendars, phonebooks, and phones, today they can play computer games with sophisticated graphics, play both short- and full-length movies, and play music as well as provide Web access and run business and utility software while connecting via the cellular network or WLANs. Some carriers even provide users with the ability to watch live television programs on their smartphones.

Digital convergence refers to the power of digital devices—such as desk and laptop computers and wireless handhelds like smartphones—to combine voice, video, and text-processing capabilities as well as to be connected to business and home networks and to the Internet. The same concept applies to the development of VoIP networks, which use the same protocols and media (both wired and wireless) that once carried only data to carry two-way voice conversations. Wireless networks in general play an important part in digital convergence as users demand to be connected to their data and voice networks at all times, wherever they may be. Cellular providers in North America and Europe are beginning to introduce TV programming; depending on the device, we can even have access to on-demand movies and Internet radio.

The recent and upcoming advances in wireless technology and standards discussed in this book will enable an ever-wider range of applications for wireless devices. There are now smartphones that incorporate all voice and data communications in addition to providing entertainment functions and allowing the user to make payments and debits directly from a bank or prepaid account, and many more devices with these same capacities will be introduced in the near future. Today, people in Finland can purchase a ticket, pay for a bus or streetcar ride, buy a drink from a pop machine, order movie tickets, and so forth just using their cellular phones. They don't need to carry a wallet.

In China and many other Asian countries, more people use cellular phones than computers to access the Internet and e-mail, check news reports, and watch movies.

Wireless Applications

Almost every type of business needs a computer network, but many are unable to install traditional cabled networks because of the physical limitations of such systems. Wireless networks can go where regular wired networks couldn't. Wireless applications—the use of wireless communications technologies in conducting day-to-day business activities—can be found in any industry whose employees need the mobility and freedom to conduct business without being confined to a specific location. Industries and fields such as education, construction, and health care are among those using wireless technologies to make a number of activities occur more quickly and conveniently.

Education

Wireless technology is ideal for schools. An instructor can create a classroom presentation on a notebook computer in his home or school office, then carry the computer right into the classroom. He does not have to plug and unplug cables to attach to the campus network. Instead, the notebook automatically connects to the classroom network as soon as the instructor walks into the room; it can even connect to multimedia display projectors without using wires. Teachers can also distribute handouts directly to students who have brought their own wireless devices to class, and they can conduct pop quizzes in which students submit their answers directly and immediately.

The wireless connection also frees students from having to go to a specific computer lab or the library to get on the school's computer network. They can access the school network wirelessly from almost any location on campus. As students move to different classrooms in different buildings, they remain connected to the network. Wireless education makes computing resources available to students and teachers from anywhere at any time.

Wireless technology translates into a cost savings for colleges. Traditional classrooms become fully accessible computer labs without the expense of additional wiring and infrastructure. And colleges no longer have to consider the expense of adding open computer labs for students because everyone can access the resources from any building on campus or, in some cases, while outdoors.

You can search YouTube for a video called "Classroom of the Future." This short video provides an overview of many of the wireless advances being employed in today's schools.

Home Entertainment

Since 2006, a number of manufacturers have introduced products designed to enhance the home entertainment experience by enabling people to distribute all forms of digital media throughout the home. From wireless speakers to media players, game consoles, DVD players, televisions, digital video recorders (DVR), and multimedia personal computers, several large manufacturers are adding wireless networking capability to their products. Multimedia PCs enable movie and audio enthusiasts to download, distribute, and control all forms of digital entertainment from anywhere in the house. The specialized wireless networking software and hardware simplifies processing of sound, video, and pictures. You can send music, movies, or pictures to a stereo receiver, TV set, portable device, or PC located anywhere in the house. Begin watching a movie in the family room, if you wish, then move to the bedroom and finish watching the show from there. You can also download the files to your digital media portable devices, such as MP3 and video players, which can be used while roaming throughout the house.

Although there are many such multimedia-capable devices on the market today, three notable ones are Apple TV, WD TV Live Plus, and Boxee. Both Apple TV and Boxee come with built-in wireless, and WD TV Live Plus is compatible with a wide range of USB wireless NICs. Once connected to a television and a WLAN, these devices are able to access and play media stored in networked disk drives or computers, display Internet content directly, and allow users to rent or purchase movies and music from a variety of sources. You can search the Web for more information on these products.

Home Control Systems

In addition to multimedia, several manufacturers are making wireless systems that enable us to control lights, heating, ventilation, air conditioning, drapes, alarms, door locks, and various home appliances from locations throughout the home or even from a smartphone or tablet anywhere in the world. These systems, several of which use the **ZigBee Alliance** communications protocols and the IEEE 802.15.4 standard, enable devices like light switches and wall sockets to communicate with one another, thereby allowing us to control the entire home environment. This can help keep the home secure by turning lights on and off at preset times or by randomly increasing and decreasing the time by up to a half hour, to make the home look "lived-in." It can also make the environment more comfortable when we get home from work. And, finally, it's more "green," given that lights and devices can be automatically turned off and the temperature can be adjusted when no one is home.

Health Care

Administering the correct medication is a major concern in the health care industry. It is estimated that incorrectly administered medication results in hundreds of thousands of medical emergencies annually. Typically, printouts of prescriptions are posted in the pharmacy area of a health care facility. As the medications are dispensed for delivery to a patient, they are crossed off the list. However, because the paper record cannot always be updated immediately, there is a possibility that a patient will get an extra dose of medication before an order for a new or changed medication has been processed. This potential problem necessitates duplicate documentation, with nurses first checking the printout to determine the medication and dosage to be given, then noting on paper that the medication was actually given, then later entering the data into the hospital's database.

Wireless point-of-care computer systems based on smartphones, tablet computers, or wireless-equipped computers mounted on movable carts allow medical staff to access and update patient records immediately. Many hospitals are using portable devices with barcode scanners or RFID and a wireless connection. Without connecting and disconnecting cables, health care professionals can immediately document a patient's medication administration in the computer while moving from room to room. Nurses and doctors can identify themselves to the computer system or be automatically detected by a real-time location system. The patient's barcoded or RFID-enabled armband is then scanned, and all medications that are currently due for that patient are brought up on the screen. The medications to be administered are sealed in pouches that can be read by a device connected to the computer. Nurses identify the medications before opening the package. An alert immediately appears on the screen if the wrong medication or incorrect amount is selected. After administration, the nurse indicates through the wireless network that the medication has been given, electronically signing the distribution form. A hard copy can be printed out as needed.

The system immediately verifies that medication is being administered to the correct patient in the correct dosage, which eliminates potential errors and documentation inefficiencies. The documentation process now takes place at the bedside, where care is delivered, which improves accuracy. In addition, all hospital personnel have real-time access to the latest medication and patient status information.

Select medical groups are now beginning to provide their physicians smartphone software, a portable printer, and prescription-writing software. This technology is intended to reduce errors associated with illegible handwritten prescriptions and can transmit drug orders to the pharmacy via the hospital's WLAN or the Internet.

Even telephones are now being connected to hospital IEEE 802.11 WLANs, employing VoIP technology. Doctors and nurses no longer have to be paged over the PA system, nor do they have to be in an office or nursing station to access lab results. Doctors can also consult with specialists while at a patient's bedside, and the specialists can be more easily reached, no matter where they are in the hospital. Cellular phones have been banned from health care facilities due to their potential for interfering with diagnostic equipment, but handsets that can connect to an IEEE 802.11 WLAN and use VoIP are allowed, and they are making hospitals far more efficient.

Wireless real-time location systems are also being implemented in hospitals around the world to track equipment, staff, patients, and doctors, and to identify the potential spread of contagious diseases in hospitals, a major problem that is made worse by the advent of antibiotic-resistant bacteria (see *www.aeroscout.com*, *www.sonitor.com*, and *www.infonaut.ca*). Some of these wireless systems are also being connected to hand-washing stations and hand-sanitizer stations to track whether doctors and nurses are complying with hospital and government regulations dealing with hand hygiene.

Doctors can now monitor a patient's vital signs remotely. A graphical application running on a smartphone can display a patient's heart rate and electrocardiogram and can monitor a patient's blood pressure and other vital signs. This can be done via Wi-Fi if the doctor is in the hospital, or through the cellular network after she leaves the facility, or from anywhere in the world where cellular phone service is available (see *www.airstriptech.com*).

Government

Many cities around the world are deploying broadband and Wi-Fi wireless networks that let residents, city employees, contractors, and utility staff access the Internet, collect and transmit data to central databases, and so forth. For example, building inspectors can update permit data while at the construction site. City employees can locate and monitor municipal vehicles. Police officers can watch live streaming video feeds to help them fight crime. And visitors to the city can access the Internet in key areas, which promotes tourism and stimulates the local economy. Nearly every day, there's another news report that a city is either planning or deploying a wireless network.

Allegany County in western Maryland has been reaping the benefits of an IEEE 802.16 network since before the 802.16 standards were ratified. The county's $4.7 million AllCoNet2 project uses 16 radio towers configured in a ring to deliver broadband connectivity to schools, libraries, and government buildings. To avoid conflict with Internet service providers, the city allows them to resell the excess capacity of the county's broadband network at a reduced rate to commercial users, which further stimulates economic development in the region.

Many other cities use wireless technology to provide free Internet access to residents and to attract visitors and businesspeople. The city of Fredericton in the Canadian province of New

Brunswick deployed a system that covers the entire downtown business district and uses a mix of technologies. IEEE 802.16 wireless broadband connects all the major points, and an IEEE 802.11 WLAN is available in the major downtown streets as well as in restaurants, bars, and many other retail businesses. These options provide residents with free Internet access from notebook computers, tablets, and smartphones. In 2005, the city won a major award for innovation as a result of this project. The city of Hamilton in Ontario, Canada uses an IEEE 802.11 WLAN to read smart electrical meters. These meters monitor business and residential hourly electricity consumption and report back to the city's utilities commission.

Military

Military forces around the world use a large variety of both commercial and dedicated wireless communications devices. The latest devices allow military personnel in the field to use voice and the Internet as well as receive and transmit full-motion video, maneuver remote control survey drones, use digital battlefield maps, and so on. Most military technology is considered part of national security, and detailed information about it is generally available only to military personnel or to those with the proper security clearances.

Office Environments

Thanks to wireless technologies, employees in all lines of work never have to be away from the data they need to help them make decisions. In addition to the accessibility of networked data, wireless technologies allow businesses to create an office where the traditional infrastructure doesn't exist. Typically, an office space must be wired with computer cables for network connections and telephone wires for telephones. With wireless technologies such as WLAN and Bluetooth, that expensive cabling infrastructure, which is difficult to troubleshoot and modify, is no longer necessary. This means that an office can be created in a very short period of time with minimum expense. For example, a hotel conference room that may not have the infrastructure to support a wired network can quickly be turned into a wireless networked office environment. During office renovations or reorganization, employees can move to another location in the building or to a completely different place and can be connected immediately, saving businesses the expense of rewiring the entire office.

Event Management

Managing spectators attending a sporting event or concert can be a daunting task. Each attendee has a ticket, and there are special passes for the press and team officials. However, tickets can be lost, stolen, or counterfeited. Attempting to identify a stolen or counterfeit ticket as thousands of spectators are waiting to be admitted has until now been almost impossible. But several large arenas and stadiums are now turning to wireless systems to facilitate this process.

Event tickets are printed with a unique barcode and have an RFID tag embedded that is then scanned at the venue's point of entry using handheld or integrated turnstile hardware, which in turn is connected to a wireless network. The network instantly validates the ticket and then sends a signal back to the turnstile that permits the patron to enter the arena. This

technology is very difficult to reproduce, can prevent the use of counterfeit tickets and can also be used to identify stolen or duplicated tickets.

The wireless point-of-entry turnstiles can provide organizers with a real-time look at traffic flow, thus helping a venue effectively manage its staff and determine where additional people are needed. Advertisers can also tailor their marketing based on who is entering at which gate on wireless display screens installed near the entry points.

In addition, wireless technologies are changing the entertainment experience itself. In several major stadiums, wireless transmissions of in-progress game statistics are available to any fan in the stadium with a wireless device, such as a notebook or tablet computer, or even with a portable media player or video-enabled smartphone. Fans can also view instant replays of the event they are attending or watch replays from other games around the country. In the Arizona Cardinals' football stadium, fans can use their wireless devices to play fantasy football or order concessions and have them delivered to their seats.

Travel

Because wireless technology creates mobility, the travel industry was one of the first to embrace it widely. Wireless global positioning systems (GPS) that tie into emergency roadside assistance have become standard features on many automobiles sold today. **Satellite radio** transmission of over 150 music and talk stations solves the problem of losing a station outside its transmission range. Satellite radio is a subscription service, meaning that users pay a monthly fee for the privilege of listening to the stations without any commercial interruptions. The OnStar roadside assistance service uses GPS and cellular technology to link the vehicle and driver to a central service center. Users can also use the system to make phone calls using the cellular network. Although the system has been exclusively available to GM vehicle owners for several years, electronics and auto accessory retailers now sell it to the general public as OnStar FMV (For My Vehicle), with a user interface built into the rearview mirror (see Figure 1-16).

Figure 1-16 OnStar user interface mounted on the rearview mirror

Courtesy of General Motors

Airport terminals are likewise turning to wireless technologies. Most large airport terminals in North America transmit wireless signals that passengers can pick up on their wireless notebook and tablet computers or smartphones while waiting for their flights. For a nominal fee (or at no cost in some airports, such as Pearson International in Toronto, Canada), they can also surf the Internet or read e-mail as well as check or change flight schedules, and so forth.

Even the airplanes themselves are being equipped with wireless data access. Several large airlines—Lufthansa, Scandinavian Airlines, Singapore Airlines, China Airlines, Korean Air, and many others—are offering wireless Internet capabilities to passengers on cross-country or long-haul flights. Like their Earth-bound counterparts, these passengers can access the Internet or view their corporate data and e-mail from their seats while in flight. Air Canada began a pilot project to offer wireless Internet access on short flights between Toronto, Montreal, and New York City.

City transit systems are also "going wireless." People in Finland can purchase bus, train, and movie tickets (not to mention a can of soda) without ever needing to show a piece of paper. The cost is debited automatically from their bank accounts, and in most cases they simply present a two-dimensional barcode on their phone screens when entering the cinema or bus. Tram tickets in Amsterdam, Holland are equipped with an RFID chip and antenna. Although they look and feel like a regular cardboard ticket, to use them you simply wave the ticket by a box placed near the doors when you board and exit the tram. The unit makes a sound to indicate that your ticket is still valid (usually for one hour) or to let you know that you will need to purchase a new one if your current one has expired.

Construction

Although at first glance the construction industry may not seem to be a prime candidate for wireless technologies, in reality it benefits greatly. Special rugged tablet computers are being manufactured to allow engineers and architects to review drawings and plans at the job site. One challenge for builders is that each construction phase must be completed before the next can begin. For example, if the concrete footings for a new building cannot be poured, then the entire project must be put on hold. This series of events often means idle construction employees and last-minute schedule adjustments. Information from the job site, such as a tardy subcontractor or a problem with materials, could be relayed back to the main office for rescheduling of workers to other sites to prevent idle time.

Because foremen are often at multiple sites during a day's work, filing daily payroll paperwork can be a challenge. Payroll clerks often wrestle with scrawled or illegible notes and are unable to contact the foreman on the job for clarification. The paperwork problems can be eliminated when foremen enter time sheet information on a tablet computer and transmit it to the main office.

Construction equipment such as bulldozers and earth graders also participate in wireless networks by being fitted with wireless terminals, turning them into "smart" equipment. A GPS on a bulldozer can provide location information accurate to within a foot or, in some cases, an inch. The exact location of the dig coordinates can be transmitted to a terminal on the bulldozer, which displays a color-coded map to guide the operator. Smart equipment can be connected through wireless transmissions back to the home office, which tracks engine hours and equipment location. Wireless terminals in the engine's diagnostic system can send an alert when the oil needs to be changed or other maintenance operations are due.

Warehouse Management

Managing a warehouse stocked with inventory can be a nightmare. New products arrive continually and must be inventoried and stored. When products are shipped out of the warehouse, they must be located and then transferred to the correct loading dock so they can be placed on the right truck. Then, employees must update the stock database to reflect the outgoing shipment. A mistake in any one of these steps can result in a warehouse stocked with products that it cannot locate, irate customers receiving the wrong items, or a store running out of goods to sell.

Implementing wireless technology is essential in many warehouse operations. By equipping all of the warehouse's machinery and personnel with wireless networking devices, managers can use warehouse management system (WMS) software to supervise all the activities, from receiving through shipping. And because this network is tied into the front-office computer system, managers can have statistics that are always current.

Pallet loads arriving from locations outside the receiving warehouse come with barcoded pallet labels. The bar coding includes product identification numbers, product code dates or expiration dates, originating plants and lines of manufacture, and sequentially assigned serial numbers. As pallets arrive, a forklift operator scans the barcode label with his portable wireless device. This device sends the data to the wireless network, where the warehouse software immediately designates a storage location for the pallet and relays the information back to the computer on the forklift. A warehouse employee prints out a barcode and fixes it to the pallet. The forklift operator then transports the pallet to the designated storage location. A barcode label suspended from the ceiling for floor locations or attached to a rack face identifies every storage location. The operator scans that barcode to confirm that the pallets are being put in the correct location before depositing the load.

In the front office, orders for merchandise to ship out are received and entered into the computer that connects to the WLAN in the warehouse. The WMS software manages order picking, balances workloads, and selects pick sequences for forklift operators. The dock control module of the WMS then releases orders for picking. A forklift operator locates the correct storage location, scans the barcode of the pallet, and then ferries it to the shipping dock to be loaded onto a truck.

In the near future, most of the barcode functions, including inventory counting, will be replaced by RFID tags, removing the need for printing and affixing labels. Many large retailers already have instructed their suppliers to implement RFID in all the products they purchase. Some highly sophisticated warehouses are operating with fully automated pallet machines and forklifts that can process the storing and retrieving of products completely without human intervention.

Environmental Research

One of the most challenging aspects of documenting research while in the field is that it is difficult and dangerous to extend long cables or install heavy equipment inside, say, deep caves or on the tops of trees. Today, in places that were previously difficult to access and monitor, scientists are using small, battery-powered or solar-cell-powered sensors that can connect to a WLAN. For example, transmitter-equipped sensors located at the tops of tall trees monitor the effects that ultraviolet rays are having on our forests due to the holes in the ozone layer. The computer equipment that records the sensor readings can be installed

in a much more accessible location nearby, along with large, heavy batteries or generators, and it can communicate with the sensors using wireless technology. This capability has proven to be a major breakthrough in many scientific fields and has helped collect data that, until recently, was very difficult—if not impossible—to record.

Industrial Control

Because of their size and complexity, large manufacturing facilities, such as automotive assembly plants, find that it is often impossible to install a full-featured network using very long cables. If machines need to be monitored, it can take hours or even days for a technician to access every machine and record or download the status of each piece of equipment. Wireless networking can solve that problem. Remote sensors called **motes** can connect to a WLAN, then collect data and transmit it to a central location. Manufacturing managers can monitor their equipment from an office, detecting problems instantly. Technicians in a control room can monitor the status of every machine or device and dispatch a technician to perform work on the equipment when necessary.

Wireless Advantages and Disadvantages

As with any new technology, wireless communications offers both advantages and disadvantages.

Advantages of Wireless Networking

There are many advantages to using wireless technology compared to wired networks. These include mobility, ease of installation and lower cost, increased reliability, and more rapid disaster recovery.

Mobility The freedom to move about without being tethered by wires is certainly the principal advantage of a wireless network. Mobility enables users to stay connected to the network no matter where they roam within the network's range. Many workers who can't stay tied to a desk—such as police officers who need to access vehicle registration and infraction records or inventory clerks who work in large stores or warehouses—are finding that wireless data communications has become vital to the performance of their jobs.

Wireless technology is also permitting many industries to shift toward an increasingly mobile workforce. Many employees spend large portions of their time away from a desk—whether they are in meetings, working on a hospital floor, or conducting research. Notebook computers—and, more recently, tablet computers, smartphones, and other portable devices—allow these employees to enjoy added convenience, including access to the company network and business applications.

One characteristic of today's business world is "flatter" organizations, meaning there are fewer management levels between top executives and regular employees. Much of the work is done in teams that cross both functional and organizational boundaries, requiring many team meetings away from the employees' desks. The need for immediate access to network resources exists even while these meetings are taking place. WLANs are again the solution to the problem. They give team-based workers the ability to access the network resources they need while collaborating in a team environment.

Easier and Less Expensive Installation Installing network cabling in older buildings can be a difficult, slow, and costly task. Facilities constructed prior to the mid-1980s were built without any thought given to running computer wiring in each room. Thick masonry walls and plaster ceilings are difficult (and messy and loud) to drill holes through and snake cabling around. Some older buildings have asbestos—a potentially cancer-causing insulation material—that has to be completely removed before cabling can be installed. And there are often restrictions on modifying older buildings that have historical value.

In all these instances, a WLAN is the ideal solution. Historical buildings can be preserved, dangerous asbestos doesn't need to be disturbed, and difficult drilling can be avoided by using a wireless system. And, of course, eliminating the need to install cabling can result in significant cost savings for companies.

WLANs also make it easier for any office—in either an old or a new building—to be modified with new cubicles or furniture. No longer does the design for a remodeled office first have to consider the location of the computer jack in the wall when relocating furniture. Instead, the focus can be on creating the most effective work environment for the employees.

The amount of time required to install network cabling is generally significant. Although the cable itself is not very expensive, installers must pull wires through the ceiling and then drop cables down walls to network outlets. This can usually take days or even weeks to complete, and in countries where labor costs are high, this can make it very expensive. And except in the case of brand-new buildings, employees must somehow continue their work in the midst of the construction zone, which is often difficult to do. Using a WLAN eliminates any such disruption.

Using your favorite search engine, look for "installing wireless in a castle." There are a couple of interesting articles by Motorola and Aruba Networks, two of the most successful manufacturers, about their ventures into networking old buildings.

Increased Reliability Network cable failures may be the most common source of network problems. Moisture from a leak during a thunderstorm or a coffee spill can erode metallic conductors. A user who shifts the computer on her desk may break the network connection. When cables are installed in the ceiling or behind walls, a cable splice that is done incorrectly can result in unexplainable errors that are very difficult to identify and locate. Using wireless technology eliminates these types of cable failures and increases the overall reliability of the network.

Disaster Recovery Accidents happen every day. Fires, tornados, and floods can occur with little, if any, warning. Any organization that is not prepared to recover from such disasters will find itself quickly out of business. A documented disaster recovery plan is vital to every business if it is to get back to work quickly after a calamity.

Because the computer network is such a vital part of the daily operation of a business, the ability to have the network up and working after a disaster is critical. Many businesses are turning to WLANs as a major piece of their disaster recovery plans, in addition to using IEEE 802.11n wireless networking as the main connectivity solution. Savvy planners keep laptop computers with wireless NICs and access points in reserve along with backup network servers. Then, in the event of a disaster, managers can quickly relocate the office without needing to find a new facility with network wiring. Instead, the network servers

are installed in the building along with the access points, and the laptop computers are distributed to the resettled employees.

Future Applications Digital wireless communications has expanded almost beyond human imagination since the second edition of this book was published in 2006, and this trend will continue at a very fast pace. Wireless networks have overcome most of the speed limitations since the original standards were approved. At one time, paperless tablet devices like the ones you may have seen in old Star Trek movies were practically unthinkable. Today, they're becoming commonplace in homes and offices and are being used for a very wide range of applications. Patients can swallow tiny wireless cameras installed in capsules that enable doctors to conduct examinations inside a person's body without the need for exploratory surgery. It is virtually impossible to make predictions or to cover every single application here. Every day, a new application for wireless data transmission is thought of or implemented.

Disadvantages of Wireless Networking

Along with the many advantages of wireless technology, there are disadvantages and concerns, including radio signal interference, security issues, and possible health risks.

Radio Signal Interference Because wireless devices operate using radio signals, the potential for two signals to interfere with each other exists. Virtually any wireless device can be a source of interference for other devices.

Several common office devices emit signals that may interfere with the receivers in a WLAN. These devices include microwave ovens, elevator motors, and other heavy electrical equipment, such as manufacturing machines, photocopiers, certain types of outdoor lighting systems, theft protection systems, and cordless telephones. These may cause errors to occur in the transmission between a wireless device and an access point. In addition, Bluetooth, WLAN 802.11b/g/n, and ZigBee devices can all operate in the same radio frequency, potentially resulting in interference between such devices in spite of efforts to design these radios to automatically avoid interference.

Interference is nothing new for a computer data network. Even when using cables to connect network devices, interference from fluorescent light fixtures and electric motors can sometimes disrupt the transmission of data. The solution for wireless devices is the same as that for standard cabled network devices: locate the source of the interference and eliminate it. This can usually be resolved by moving a photocopier or microwave oven across the room or to another room. Most wireless devices can identify that an error has occurred in the transmission and retransmit the data as necessary.

Outside interference from AM or FM radio stations, TV broadcast stations, or other large-scale transmitters is not an issue because they operate on vastly different frequencies and power levels. However, GPS and satellite transmissions can sometimes affect Bluetooth and WLAN transmissions outdoors.

Security Because a wireless device emits radio signals that can cover a wide area, security becomes a major concern. It is possible for an intruder to be lurking outdoors with a

notebook computer and a wireless NIC with the intent of intercepting the signals from a nearby wireless network. Because much of a business's network traffic may contain sensitive information, this is a real concern for many users.

However, some wireless technologies can provide added levels of security. A special coded number can be programmed into an authorized wireless device, which must then transmit this special number prior to gaining access to the network; otherwise, it is denied access. Network managers can also limit access to a wireless network by programming it with a list of approved wireless devices. Only those devices on the list will be allowed access. As a further protection, data transmitted between the access point and the wireless device can also be encrypted or encoded in such a way that only the recipient can decode the message. If an unauthorized user were to intercept the radio signals being transmitted, he or she could not read the messages being sent.

Health Risks Wireless devices contain radio transmitters and receivers that emit radio frequency (RF) energy. Typically, these wireless devices emit low levels of RF while being used. Scientists know that high levels of RF can produce biological damage through heating effects (this is how a microwave oven is able to cook food). However, it is not known if lower levels of RF can cause adverse health effects. Although some research has been done to address these questions, no clear picture of the biological effects of this type of radiation has been found to date.

Most wireless devices also emit very low levels of RF energy when in stand-by mode. These levels are considered insignificant and do not appear to have health consequences.

In the United States, the Food and Drug Administration (FDA) and the Federal Communications Commission (FCC) set policies and procedures for some wireless devices, such as cellular telephones. However, only the World Health Organization (WHO) currently conducts and sponsors research on this topic. In May 2011, the WHO indicated that these devices can be "carcinogenic" but also included a statement that no adverse health effects had been established yet. The announcement was related to the use of cellular handsets, which place the transmitter antenna very close to the user's head during a call. One of the easiest ways to address this issue is to always use a headset when talking on a cellular device.

The FCC and FDA, along with the Environmental Protection Agency (EPA), established RF exposure safety guidelines for wireless phones back in 1996. Before a wireless phone is available for sale to the public, it must be tested by the manufacturer and certified that it does not exceed specific limits. One of the limits is expressed as a specific absorption rate (SAR). SAR relates to the measurement of the rate of absorption of RF energy by a wireless phone user. The FCC requires that the SAR of handheld wireless phones not exceed 1.6 watts per kilogram, averaged over 1 gram of tissue.

Science today does not yet permit anyone to draw a definitive conclusion about the safety of wireless mobile devices. Although there is no proof that using mobile wireless devices has adverse health effects, it is wise to be aware of the possibility and monitor ongoing scientific research.

Chapter Summary

- Wireless communications has become commonplace today and is quickly becoming the standard in the business world. Remote wireless Internet connections and entire wireless computer networks are making many network-based business activities faster and more convenient.
- Wireless networks and devices are found in all circles of life today. Home users can implement WLANs to connect different devices. Meanwhile, Bluetooth, WirelessHD and WiGig are beginning to be implemented on consumer devices, making it possible to connect many different types of home audio and video equipment over short distances. The WAP2 protocol is used along with programming languages such as J2ME to access Web sites and private networks from cellular phones, but HTML version 5 is already being introduced in all new models. WLANs are also becoming the standard in business networks. Fixed broadband wireless is used to transmit data at distances up to 35 miles (56 kilometers), and satellite transmissions can send data around the world. Digital cellular networks are used to transmit data at up to 21 Mbps.
- Wireless wide area networks will enable companies of all sizes to interconnect their offices without the high cost charged by telephone carriers for their landline connections.
- WLAN applications are found in a wide variety of industries and organizations, including the military, education, business, entertainment, travel, construction, warehouse management, and health care.
- Remote sensors capable of communicating using wireless technologies are used in large manufacturing facilities to monitor equipment and for scientific research.
- Mobility—the ability to move around without being connected to the network by a cable—is the primary advantage of a WLAN. Other advantages include easier and less expensive installation, increased network reliability, and support for disaster recovery.
- There are some disadvantages to a WLAN. Radio signal interference, security issues, and health risks may slow down the growth of these technologies for a while, but there are so many advantages that use of wireless data will very likely continue to grow and to be an integral part of our lives.

Key Terms

3G (third generation) A digital cellular technology that can send data at up to 21 Mbps over the cellular telephone network.

4G (fourth generation) A digital cellular technology that can transmit and receive data at theoretical speeds up to 20 Mbps when users are moving fast and up to 150 Mbps (theoretically) when users are moving slowly or are stationary.

access point (AP or **wireless AP)** A device that receives the signals and transmits signals back to wireless network interface cards (NICs).

Bluetooth A wireless standard that enables devices to transmit data at up to 721.2 Kbps over a typical maximum distance of 33 feet. Bluetooth can transmit data farther, but devices that can use this capability are rare.

cable modem A technology used to transmit data over a television cable connection.

digital convergence The power of digital devices such as desktop computers and wireless handhelds to combine voice, video, and text-processing capabilities as well as to be connected to business and home networks and to the Internet.

digital subscriber line (DSL) A technology used to transmit data over a telephone line.

Hypertext Markup Language (HTML) The standard language for displaying Web pages.

Institute of Electrical and Electronic Engineers (IEEE) 802.11n-2009 A set of standards that allows WLAN computers to transmit data at speeds ranging from 1 Mbps to a maximum of 600 Mbps. 802.11n (or 802.11n-2009, as the specification is now called) can also make use of the 5 GHz band in addition to the 24 GHz band.

Institute of Electrical and Electronic Engineers (IEEE) 802.16 Fixed Broadband Wireless A set of standards, some established and some still under development, for fixed and mobile broadband wireless communications that allows computers to communicate at up to 75 Mbps and at distances of up to 35 miles (56 km) in a point-to-point configuration. This set of standards also allows the use of both licensed and unlicensed frequencies.

Integrated Services Digital Networks (ISDN) A technology that transmits data over telephone lines at a maximum of 256 Kbps.

J2ME (Java 2 Micro Edition) A variation of the Java programming language designed for use in portable devices such as PDAs and cellular phones.

link manager Special software in Bluetooth devices that helps identify other Bluetooth devices, creates the links between them, and sends and receives data.

microbrowser A tiny browser program that runs on a WAP or WAP2 cellular phone.

motes Remote sensors used for collecting data from manufacturing equipment or for scientific research, which can communicate using wireless technology.

optical fiber A glass strand, about the thickness of a human hair, that carriers data signals encoded in a laser beam.

personal digital assistant (PDA) A handheld computer device used for taking notes, making appointments, creating to-do lists, and communicating with other devices.

piconet A small network composed of two or more Bluetooth devices that are exchanging data with each other.

radio frequency identification (RFID) A small tag placed on product packaging and boxes that can be remotely activated and read by remote sensors. The data about the product is then transferred directly to an information-processing system for inventory control, location tracking, and item counting.

radio modules Small radio transceivers built onto microprocessor chips and embedded into Bluetooth devices, which enable them to communicate.

repeater A device commonly used in satellite communications that simply "repeats" the signal to another location.

satellite radio A pay-for-service radio broadcast system that transmits digital programming directly from satellites to a network of ground-based repeaters and that holds the signal regardless of the listener's location. Users must purchase special receivers and pay a monthly subscription fee to listen to commercial-free music channels. Because the digital transmission is decoded at the receivers, the sound quality is also much better than conventional FM radio.

smartphone A device that combines a cellular phone with the capabilities of a personal digital assistant (PDA). These devices provide the user with the ability to enter appointments in a calendar, write notes, send and receive e-mail, and browse Web sites, among other functions.

T1 A technology used to transmit data over special telephone lines at 1.544 Mbps.

Ultra Wide Band (UWB) A wireless communications technology that allows devices to transmit data at hundreds of megabits or even gigabits per second at short distances—up to 6 feet (2 meters) at the higher speeds and up to 150 feet (50 meters) at lower speeds.

Voice over Internet Protocol (VoIP) A technology that allows voice telephone calls to be carried over the same network used to carry computer data.

Wi-Fi A certification label awarded to IEEE 802.11 WLAN-compatible wireless devices that pass all interoperability tests performed by an organization called the Wi-Fi Alliance. The acronym is often thought to stand for Wireless Fidelity, but this is a common misconception. The name was chosen by the alliance purely for marketing reasons and is not an acronym at all.

WiGig An alliance of companies involved in developing a common wireless specification for connecting computers, communication, and entertainment devices over short ranges, using the 60 GHz band at multi-gigabit speeds.

wireless application protocol (WAP or **WAP2)** A standard for transmitting, formatting, and displaying Internet data on cellular phones. WAP can display only text. WAP2 supports HTML and can display color and pictures.

wireless communications The transmission of user data between devices without the use of wires.

WirelessHD A specification for the wireless transmission of high-definition video (HD), multichannel audio and data between consumer devices such as televisions, stereo systems, and Blu-ray players, using the 60 GHz frequency band.

wireless local area network (WLAN) A local area network that is not connected by wires but instead uses wireless technology. Its range extends to approximately 100 meters and has a maximum data rate of 600 Mbps. Today's WLANs are based on IEEE 802.11a/b/g/n standards.

wireless metropolitan area network (WMAN) A wireless network that covers a large geographical area such as a city or suburb. The technology is usually based on the IEEE 802.16 set of standards and can span an entire city, covering distances of up to 35 miles (56 km) between transmitters and receivers or repeaters.

wireless network interface card (wireless NIC) A device that connects to a PC to transmit and receive network data over radio waves. It includes an antenna for wireless communication between networked devices.

wireless personal area network (WPAN) A very small network that typically extends to 10 meters or less. Due to its limited range, WPAN technology is used mainly as a replacement for cables. *See also* piconet and Ultra Wide Band.

wireless wide area network (WWAN) A WAN that uses cellular phone technologies and encompasses any geographical region, including the entire globe.

ZigBee Alliance An organization that creates protocols and specifications for devices used to wirelessly control lighting, as well as security and energy systems, for home and industry.

Review Questions

1. Ultra Wide Band technology is used primarily for _____.
   a. displaying Web pages on a cellular phone
   b. connecting devices inside the home at very high speeds
   c. finding the location of a car within a city
   d. transmitting data at distances of up to 35 miles
2. Bluetooth devices communicate using small radio transceivers called _____ that are built onto microprocessor chips.
   a. receivers
   b. transponders
   c. radio modules
   d. link managers
3. _____ provides a standard way to transmit, format, and display Internet data on cellular phones.
   a. WLAN
   b. WAP2
   c. HTML
   d. WML
4. IEEE 802.11n devices can be as far as 375 feet apart and can send and receive data at rates up to _____ million bits per second (Mbps).
   a. 75
   b. 600
   c. 100
   d. 54
5. Each Bluetooth device uses a _____, which is special software that helps identify other Bluetooth devices.
   a. frame
   b. link manager
   c. repeater
   d. bridge
6. Bluetooth can send data through physical barriers, like walls. True or False?
7. Most Bluetooth devices can transmit data at up to 1 Mbps over a distance of 33 feet (10 meters). True or False?
8. A wireless network interface card performs basically the same functions and looks similar to a traditional network interface (NIC) card. True or False?

9. An Earth station transmits to a satellite at one frequency, and the satellite regenerates and transmits the signal back to Earth at another frequency. True or False?

10. Eliminating installation costs is a disadvantage of a WLAN. True or False?

11. The automatic connection between various Bluetooth devices creates a network called a(n) _____.
    a. micronet
    b. small net
    c. piconet
    d. Intranet

12. The new fourth generation (4G) cellular technology will allow data to be transmitted at a maximum speed of _____.
    a. 2 Mbps
    b. 1 Gbps
    c. 20 Mbps
    d. 150 Mbps

13. An 802.11 wireless NIC, when configured to communicate with a wired network, sends its signals through invisible radio waves to _____.
    a. another computer directly
    b. an access point
    c. a wireless server
    d. the Internet

14. _____ uses wireless transmissions for data communications as much as 35 miles apart.
    a. Wi-Fi
    b. WirelessHD
    c. WiGig
    d. WiMAX

15. "WAP2" stands for _____.
    a. Wireless Access Protected version 2
    b. Wi-Fi Access Protocol 2
    c. Wireless Application Protocol version 2
    d. Wireless Protected Access II

16. Explain the role of an access point (AP) in a WLAN.

17. Explain how a WAP cellular phone sends and receives Internet data.

18. Explain how a WLAN can be used in a classroom.

19. Describe how wireless networks can reduce installation time.
20. Explain how implementing a wireless network can be helpful in case of disaster recovery.

Hands-On Projects

Project 1-1

Understanding the terminology and being able to explain what something means to a person who does not work in the same field is an essential part of any support technician's job today. Although many of the following terms will be discussed and reviewed in later chapters, you should become familiar with as many of them as possible. Research these terms and write a one-paragraph description of each of them, in your own words.

HSPA+	Ultra Wide Band (UWB)	Parity check
Frequency channel	WiGig	Bandwidth
Free-space optics	Wireless repeater	Wi-Fi protected access
Spread spectrum	Frequency hopping	Yagi
RFID	Personal area network	Metropolitan area network
Wireless bridge	Data encryption	Data integrity

Project 1-2

To be successful in today's job market, wireless technicians and engineers must be familiar with the industry and have a broad knowledge of the various products available. For example, you may have heard about the Verizon Palm Pre smartphone, but who actually makes this phone? If you needed a full set of specifications for this device, you would have to contact Hewlett-Packard because Verizon does not actually manufacture it and may not provide you with all the data that you need. Using the Internet, research one or two manufacturers (not distributors or resellers) of the products listed below, then provide links to information about the products.

Wireless controllers	Enterprise-class access point
RFID tags	RFID readers
Bluetooth access point	Wireless bridge
ZigBee development kits	WiMAX sector controller
Wi-Fi antennas	Free-space optics transceivers
Smartphones	Bluetooth class 1 adapter (300 feet/100 meter range)

Project 1-3

Following the news about the wireless industry is a very good way to learn who uses a particular technology and for what purpose. Use local news services or the Internet to find a school, hospital, manufacturing plant, warehouse, or other business in your area that is switching to wireless technology. If possible, try to interview some of the people involved to determine why they are making the change. Ask what benefits and drawbacks they considered. Write a one-page paper describing what you find out.

Project 1-4

Because a wireless device transmits radio signals over a broad area, security becomes a major concern. What are some of the security concerns with using a WLAN? What security options are available? Write a one-page paper that addresses these concerns. Use the Internet and information from hardware and security vendors as additional resources.

Project 1-5

Using the Internet, find the latest information about health concerns using wireless technologies. What studies are currently under way? What issues are of concern? What are the official positions of the government departments on these issues? Write a one-page paper about your findings.

Real World Exercises

Tenbit Wireless Inc. (TWI) is a company consisting of 50 wireless networking specialists who assist organizations and businesses with network planning, design, implementation, and problem solving. You have recently been hired by TWI to work with one of its new clients, Vincent Medical Center (VMC), a large health care facility, concerning their wireless needs.

Each day, doctors and nurses throughout VMC's facility attend to patients, update medical records, issue prescriptions, and order medical exams. VMC has deployed a sophisticated suite of medical software that stores all patient records, exam results, and diagnoses. The system is also fully integrated with VMC's pharmacy and can process purchase orders, payments, and receipts as well as inventory and shipments, and it meets the tightest patient information protection regulations established by the federal government.

Exercise 1-1

VMC is interested in learning about the possibilities of upgrading its infrastructure and deploying a wireless network to allow doctors, nurses, and all staff members to access information from anywhere within the medical facility (two buildings). VMC does not want to spend money installing additional network cabling connections to every patient room. VMC has asked you to make a presentation to its administrator regarding the use of a WLAN. Create a presentation to deliver to the staff about WLANs. Be sure to cover the following points:

- Greater mobility for doctors and nurses
- Ease and cost of installation

- Easier network modifications
- Increased network reliability
- Radio signal interference
- Security

Exercise 1-2

VMC would like to know about potential interference that medical equipment such as X-ray machines and CT and MRI scanners might cause on the WLAN, or vice versa. Prepare a report to present to the hospital administrators addressing their concerns.

Exercise 1-3

After your presentation, the physicians and nurses seem very interested in the potential of the WLAN. However, VMC also has an outdated telephone system that provides mobile cordless handsets but is no longer supported by the manufacturer. Without the ability to use voice communications from anywhere in the facility, the staff cannot see how a wireless network alone will solve their dilemma. Create a presentation that expands on your first one and proposes a solution based on the existing WLAN.

Exercise 1-4

Although some doctors have notebook computers already equipped with wireless NICs, VMC is also interested in providing other staff members with portable data communication equipment, but at a lower cost than notebooks. The devices should be able to transmit prescriptions directly to the central system. The pharmacy would then deliver medications to patients right away. VMC would also like to be able to check on the status of these pharmacy orders. VMC administrators have asked your opinion regarding using smartphones on the WLAN or tablet computers, and they have told you that their software can handle these requirements through a Web server. Prepare to present your recommendations to VMC's management team.

Challenge Case Project

A syndicated magazine is writing an article about Bluetooth technology and has asked Tenbit Wireless Inc. for information. Form a team of three or four consultants and research Bluetooth technology. Focus on the current specifications and on the future of Bluetooth. Provide information regarding its problems and concerns by some vendors. Also provide estimates regarding how you envision Bluetooth or any other proposed technology will be used in home, office, and personal applications.