

NETWORKING

**Guide to
Wireless Communications**

Third Edition

Jorge L. Olenewa





Guide to Wireless Communications

Third Edition

Jorge L. Olenewa



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Guide to Wireless Communications, Third Edition

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Introduction

We live in a wireless world! All the technologies and standards that have been released in the past six years, along with the ones that will be released between now and 2014, mean that almost everything we do—every aspect of our lives—has a wireless component. In fact, wireless data communications is omnipresent today—in the cordless phones we use in our homes and offices, in the nearly 6 billion cellular phones that roam the world, even in warehouses, where wireless is used to keep track of inventory. Today, we can even purchase products or board a flight with our cellular phones and tablets, thanks to wireless. Furthermore, homes, businesses, even whole towns are now equipped with wireless networks that allow residents, employees, and visitors to access the Internet from anywhere using laptop computers, mobile phones, and tablets.

Whether you are a manager who needs a better understanding of the implementation of wireless communication devices, an IT professional looking to enhance your understanding of the field by adding wireless data communications, or a student taking an introductory course in this topic, *Guide to Wireless Communications*, Third Edition, will help you gain a basic understanding of the technical and business aspects of wireless data communications technologies and prepare you for more in-depth learning.

Approach

Since the introduction, in mid-1995, of infrared interfaces in laptop computers, which allowed two computers to communicate without wires, along with the publication, in 1997, of the first IEEE 802.11 wireless local area network standards, the field of wireless data

communications has expanded dramatically. This book takes you on a virtual tour of all the wireless data communication technologies, covering the basics of radio frequency transmissions, antennas, infrared, Bluetooth, the IEEE 802.15.4 (ZigBee) standard for low-rate wireless personal area networks, the IEEE 802.15.3c standard for high-rate wireless personal area networks, ultra wide band (UWB), WiGig, WirelessHD, Wireless Home Digital Interface, IEEE 802.11a/b/g/n wireless local area networks, IEEE 802.16 (WiMAX), free-space optics, LMDS and MMDS wireless metropolitan area networks, cellular and satellite wireless wide area networks, and, finally, radio frequency identification (RFID). Coexistence (the ability of two or more of these technologies to work in the same physical space) is also discussed, as are the basic implementation and security issues for each of the mentioned technologies as well as the various business and residential applications.

Using straightforward language, this text introduces the most important technical aspects of each technology and can be used in either classroom settings or for distance education. It features extensive linking to Web sites, where the reader can find additional materials. Please note, however, that although the addresses of these Web sites were accurate at the time this book was printed, some of them may no longer be available.

This text's pedagogical materials include Real-World Exercises, which further your learning outside the classroom setting, and Hands-On Projects, which take you through the often step-by-step process of performing tasks relevant to working in wireless communications. The Hands-On Projects, which can be performed in the lab or at home, use inexpensive, consumer-class equipment as well as freeware and demo versions of popular software. Finally, there are Challenge Case Projects, team-based research projects that help expand the student's knowledge of the technologies discussed and direct him or her to additional learning resources.

Intended Audience

Guide to Wireless Communications, Third Edition, is intended to meet the needs of students and professionals who want to gain a better understanding of the fundamental concepts, scope, and penetration of wireless data communications technologies. It assumes a basic knowledge of computers and networks at a CompTIA A+ and Network+ level. The pedagogical features provide a realistic, interactive learning experience to help prepare students for the challenges of working in the field of wireless data communications.

Chapter Descriptions

Here is a summary of the topics covered in each chapter of this book:

Chapter 1, Introduction to Wireless Communications, provides an overview of a range of applications of wireless data communications in personal, local, metropolitan, and wide area networks. This chapter follows the way the industry is classifying wireless data communications today and looks at the advantages and disadvantages of wireless data communications.

Chapter 2, Wireless Data Transmission, introduces you to wireless data transmission techniques by discussing various techniques used with infrared light and radio waves to transmit data without wires.

Chapter 3, Radio Frequency Communications, looks at the individual components and design of radio systems and how they are used to transmit data. It also provides an overview of standards and their role in the wireless data communications industry.

Chapter 4, How Antennas Work, takes a simplified but in-depth look at antennas and the important role they have in the successful implementation of a wireless data communications system.

Chapter 5, Wireless Personal Area Networks, looks at the first two technologies developed for short-range wireless data communications: Bluetooth, and ZigBee (IEEE 802.15.4).

Chapter 6, High-Rate Wireless Personal Area Networks, wraps up the discussion of short-range wireless data communications with IEEE 802.15.3c, a technology developed for interconnecting multimedia devices and entertainment systems in homes and businesses, WiGig from the Wireless Gigabit Alliance, WirelessHD, and WHDI. It also looks at ultra wide band (UWB) technology and the impact it has in wireless communications in general.

Chapter 7, Low-Speed Wireless Local Area Networks, introduces the IEEE 802.11 WLAN technology, including its infrared variant, and IEEE 802.11b for transmission at up to 11 megabits-per-second.

Chapter 8, High-Speed WLANs and WLAN Security, discusses IEEE 802.11a, the different frequency bands that 802.11 networks operate in, as well as all the enhancements to 802.11 technology designed to boost its data transmission speed and usability. It also introduces 802.11ac and 802.11ad multi-Gigabit wireless standards, as well as the security techniques and issues in WLANs.

Chapter 9, Wireless Metropolitan Area Networks, addresses medium-range wireless data communications, from infrared free-space optics to the latest WiMAX (IEEE 802.16) technology.

Chapter 10, Wireless Wide Area Networks, takes a look at cellular and satellite technologies and how they are used to extend the reach of wireless data communications networks across the entire world.

Chapter 11, Radio Frequency Identification and Near-Field Communication, describes the RFID technology that is being used today to help identify, count, and track everything from small packaged products to the entire contents of large warehouses automatically and without wires. The chapter then introduces NFC, the technology that enables wireless payments, enables wireless information exchange between cellular phones and tablets, and enables handheld devices to read RFID tags.

Chapter 12, Wireless Communications in Business, outlines the advantages and challenges of wireless data communications and discusses the steps that a typical business must go through to identify, evaluate, and implement the wireless data communications technology that is the best solution for its needs, including developing RFI, RFP, and RFQ documents as well as performing wireless site surveys.

Appendix A, History of Wireless Communications, details the history of wireless communications in addition to the histories of television, radar, and cellular technologies.

Features

This book includes many features designed to enhance your understanding of wireless data communications technology:

- **Chapter Objectives**—Each chapter begins with a detailed list of the concepts to be mastered within that chapter. This list provides you with both a quick reference to the chapter's contents and a useful study aid.
- **Illustrations and Tables**—Numerous illustrations of wireless LAN concepts and technologies help you visualize theories and concepts. In addition, the tables provide details and comparisons of practical and theoretical information.
- **Chapter Summaries**—Each chapter's text is followed by a summary of the concepts introduced in that chapter. These summaries provide a helpful way to review the ideas covered in each chapter.
- **Key Terms**—The important terminology introduced in each chapter is summarized in a list at the end of each chapter. The Key Term list includes definitions for each term.
- **Review Questions**—The end-of-chapter assessment begins with a set of review questions (including multiple choice, fill-in-the-blank, and true/false) that reinforces the ideas introduced in each chapter. These questions help you evaluate and apply the material you have learned. Answering these questions will ensure that you have mastered the important concepts.
- **Hands-On Projects**—Although it is important to understand the theory behind wireless networking technology, nothing can improve on real-world experience. Toward this end, each chapter provides several Hands-On Projects that provide you with a practical wireless network experience. Some of these projects require Internet and library research to investigate concepts covered in the chapter; others let you put into practice the chapter's content using Linksys and D-Link equipment and the Windows XP operating systems as well as software downloaded from the Internet.
- **Real-World Exercises**—In these extensive exercises, students implement the skills and knowledge gained in the chapter by doing research and working on real design and implementation scenarios.
- **Challenge Case Projects**—These group exercises take students even further, posing questions that emulate real-life situations, thereby helping students apply their knowledge, initiative, and in-depth research.

New To This Edition

This edition covers a number of standards and technologies that were not yet approved when the second edition was published. It also covers several new topics and provides enhanced coverage of ongoing topics. New areas include:

- IEEE 802.11n, IEEE 802.11ac, and IEEE 802.11ad
- IEEE 802.15.3c WiGig, WirelessHD, and WHDI
- IEEE 802.16m and WiMAX
- Expanded coverage of cellular technologies such as HSPA, HSPA+, and LTE
- Near-Field Communication (NFC) technology

Text and Graphic Conventions

Wherever appropriate, additional information has been added to help you better understand the topic at hand. The following icons are used throughout the text to alert you to additional materials:



The Note icon indicates helpful material related to the subject being described.



The Tip icon indicates helpful pointers on completing particular tasks.



The Hands-On Project icon indicates lab-setting projects that provide practical wireless network experience.



The Challenge Case Projects icon indicates group exercises that promote further learning by emulating real-life scenarios.

Instructor's Materials

Instructor Resources CD (ISBN: 9781111307578)

Please visit login.cengage.com and log in to access instructor-specific resources. To access additional course materials, please visit www.cengagebrain.com. At the CengageBrain.com home page, search for the ISBN of your title (from the back cover of your book) using the search box at the top of the page. This will take you to the product page where these resources can be found.

The following supplemental materials are available when this book is used in a classroom setting. All the supplements available with this book are provided to the instructor on a single CD-ROM as well as online at the textbook's Web site.

Electronic Instructor's Manual. The Instructor's Manual that accompanies this textbook includes additional instructional material to assist in class preparation, including suggestions for lecture topics, recommended lab activities, tips on setting up a lab for the Hands-On Projects, and solutions to all end-of-chapter materials.

ExamView Test Bank. This cutting-edge Windows-based testing software helps instructors design and administer tests and pretests. In addition to generating tests that can be printed and administered, this full-featured program has an online testing component that allows students to take tests at the computer and have their exams graded automatically.

PowerPoint Presentations. This book comes with a set of Microsoft PowerPoint slides for each chapter. These slides are meant to be used as a teaching aid for classroom presentations, to be made available to students on the network for chapter review, or to be printed for classroom distribution. Instructors are also at liberty to add their own slides for other topics introduced.

Figure Files. All the figures in the book are reproduced on the Instructor Resource CD, in bit-mapped format. Similar to the PowerPoint presentations, these are included as a teaching aid for classroom presentation, to make available to students for review, or to be printed for classroom distribution.

Solutions. Answers to the end-of-chapter material are provided. These include the answers to the Review Questions and to the Hands-On Projects (when applicable).

Syllabus. To help prepare for class, a sample syllabus is provided.

About the Author

Jorge L. Olenewa has been working in and teaching data communications since 1970. With a passion for learning and teaching, Jorge has spent the past 12 years developing and teaching courses in wireless data communications at George Brown College in Toronto, Ontario, Canada. Prior to this, he worked for several large and small IT organizations, beginning with Burroughs (today Unisys), in Brazil, where he supported and trained data communications technologists throughout South and Central America. Olenewa is also the author of the second edition of *Guide to Wireless Communications* and the accompanying lab manual. In addition, he is actively involved in applied research at George Brown College, working in the field of energy management, and helping industry adopt and develop new wired and wireless data communications products for building and residential control systems.

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Writing about such a diverse range of wireless data communications technologies also demands many hours of reading, research, and experimentation. Translating the technical language and standards into text that can be read by virtually anyone with an interest in the field is made far easier when you can count on the assistance of people who work with the various technologies every day and who can provide invaluable help with examples, equipment, and many of the pictures used to illustrate this edition. I would like to especially acknowledge Bob Moroz, the president of RFID Canada, Jeff Mulvey of Redline Communications, Henry White of Bell Mobility, Hisham Alasady from George Brown College, and Allison Csanyi from fSona Networks, for their time and their contributions.

Lab Requirements

To the User

This book is intended to be read in sequence, from beginning to end. Each chapter builds on preceding chapters to provide a solid understanding of wireless data communications.

Hardware and Software Requirements

Here are the hardware and software requirements needed to perform the end-of-chapter Hands-On Projects:

- Built-in or USB Bluetooth adapter (supported by Windows XP or Windows 7)
- Any consumer-class wireless residential gateway or access point, such as Linksys or DLink
- Wi-Fi-certified IEEE 802.11a/b/g/n wireless network adapter (the adapter standard should ideally match that of the access point or wireless router)
- Windows XP Professional or preferably Windows 7
- An Internet connection and the most current version of a Web browser application

Specialized Requirements

Whenever possible, the need for specialized equipment was kept to a minimum. However, Chapter 5 requires the following specialized hardware:

- Laptop computers with USB version 2.0+ ports, a Wi-Fi adapter, and Bluetooth (USB Bluetooth is acceptable)

Free downloadable software is required for some of the Hands-On Projects. Instructions for downloading the software are given in each chapter, as required:

- AirMagnet Bluesweep
- MetaGeek inSSIDer
- Ixia QCheck
- Ekahau HeatMapper

To my three grandsons, Tristan, Nathanael, and Logan, who unknowingly inspire me to carry on, and to my best friend, Charlie, our toy poodle, for his constant companionship and affection.

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.

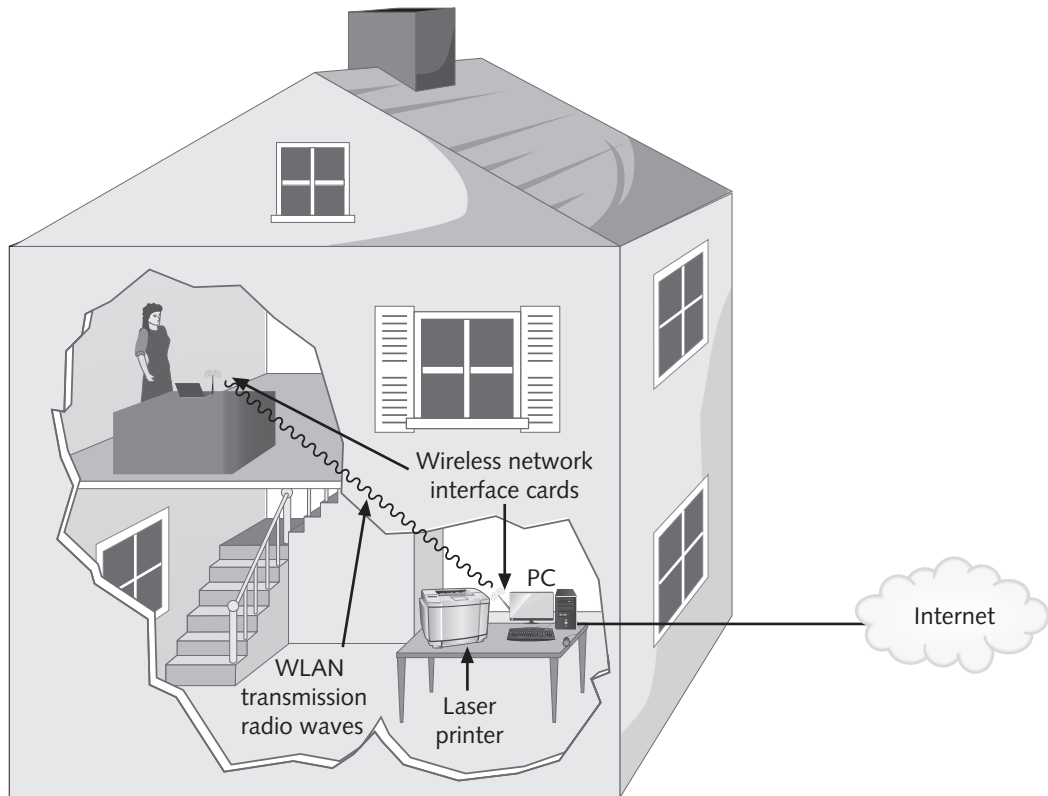


Figure 1-1 Home wireless network (WLAN)

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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.



NOTE

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.



TIP

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)

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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.

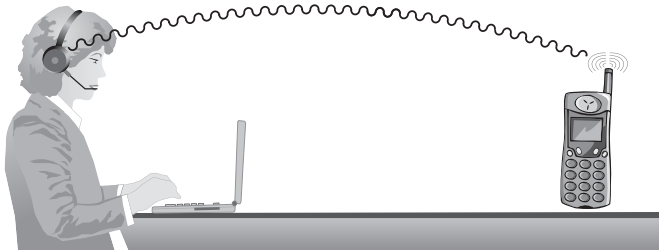


Figure 1-3 Bluetooth network (piconet) or WPAN between a cordless handset and a headset

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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.

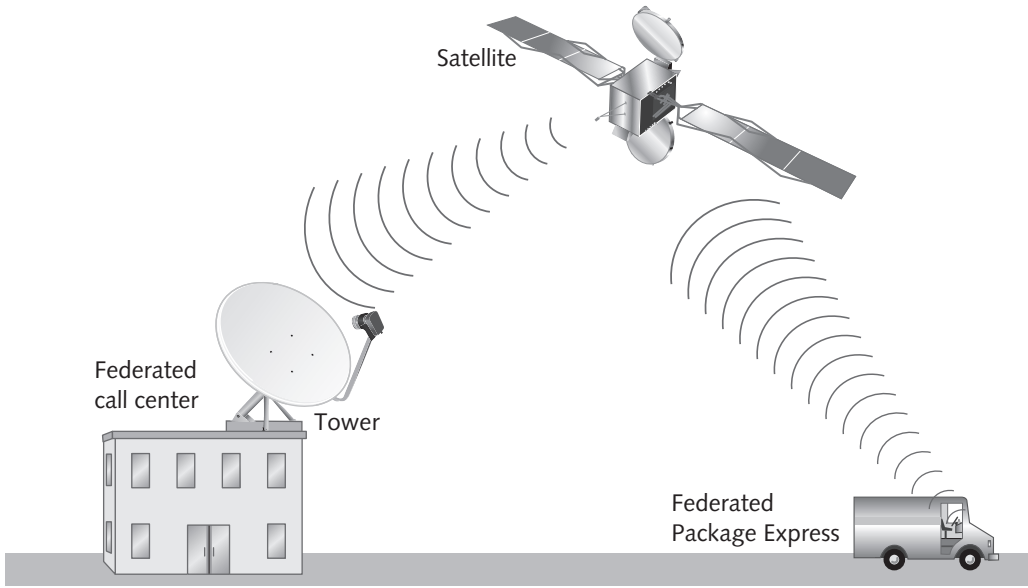


Figure 1-4 Satellite data network

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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.

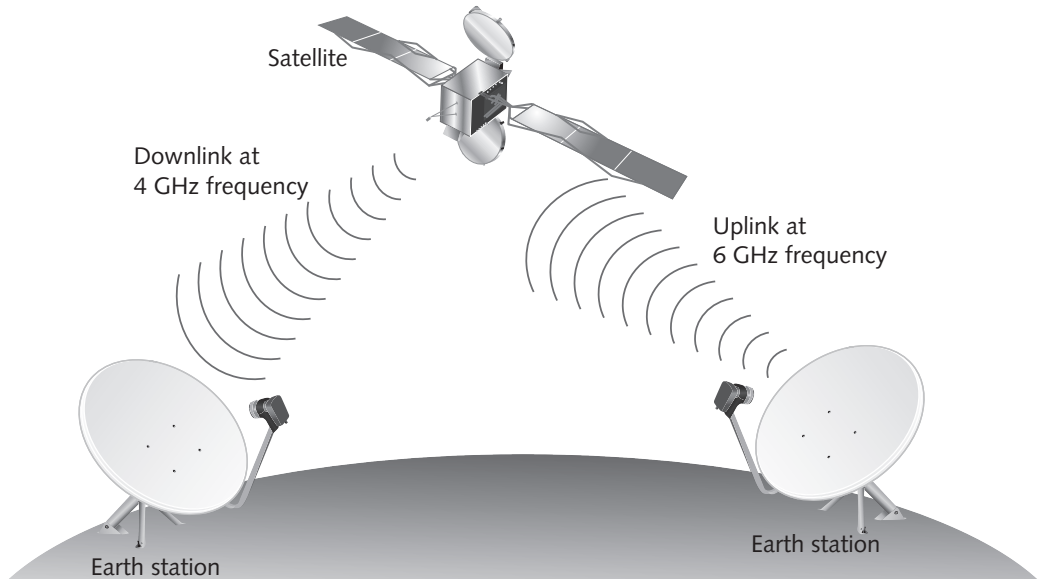


Figure 1-5 Satellite repeating a signal to another Earth station

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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