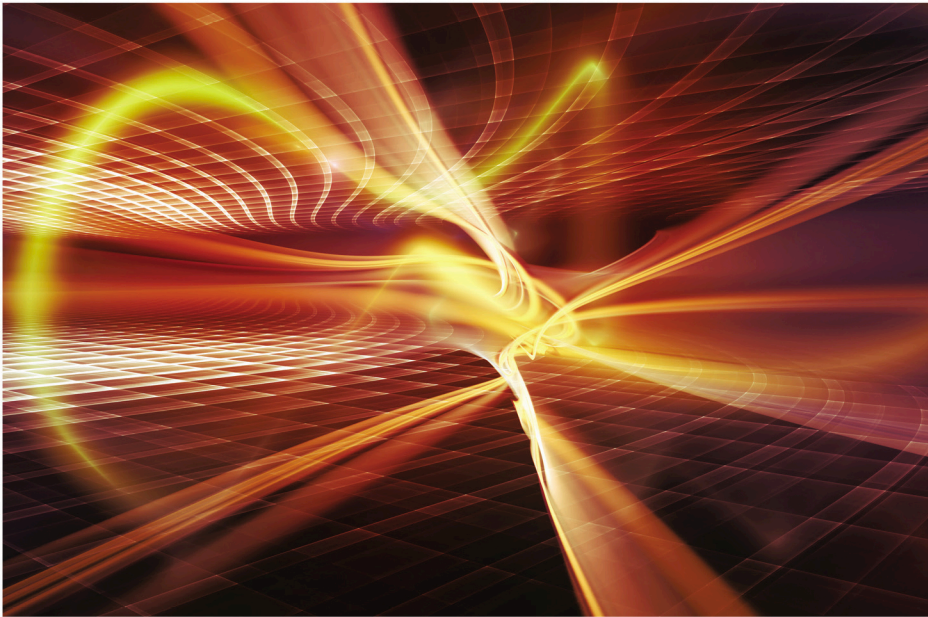


NETWORKING

Guide to Wireless Communication



Fourth Edition

Jorge L. Olenewa

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Guide to Wireless Communications

Fourth Edition

Jorge L. Olenewa



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Guide to Wireless Communications, Fourth Edition

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Library of Congress Control Number: 2016952388

ISBN: 978-1-305-95853-1

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Printed in the United States of America
Print Number: 01 Print Year: 2016

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Introduction

We live in a wireless world! All the technologies and standards that have been released in the past five years, along with the ones that will be released between now and 2020, means that almost everything we do—every aspect of our lives—has a wireless component. In fact, wireless data communication is omnipresent today—in the cordless phones we use in our homes and offices, in the over 6 billion cellular phones that roam the world, even in warehouses, where wireless is used to keep track of inventory. Today, we can purchase nearly all types of products or board a flight with our cellular phones and tablets, thanks to wireless. Furthermore, homes, businesses, and 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 impact of wireless communication devices, an IT professional looking to enhance your understanding of the field by learning more about wireless data communications, or a student taking an introductory course in this topic, *Guide to Wireless Communications*, Fourth Edition, will help you in that journey and prepare you for more in-depth learning.

Approach

Since the introduction, in mid-1995, of infrared data 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 continued to expand at a dramatic pace. This book provides the reader with an in-depth introduction to wireless data communication technologies that are based on standards, along with others that are important components of today's wireless world. The text covers the basics of radio frequency transmissions, transmitters, receivers, antennas, IEEE 802.15.1 and Bluetooth, IEEE 802.15.4 and ZigBee standards for low-rate wireless personal area networks, IEEE 802.11a/b/g/n/ac/ad and the upcoming /ax and /ay standards for wireless local area networking (Wi-Fi), IEEE 802.16 (WiMAX) and Free Space Optics (infrared) wireless metropolitan area networks, the evolution of cellular technology all the way to 5G and satellite wireless wide area networks, and, finally, radio frequency identification (RFID) and near field communication (NFC). Many aspects of coexistence (the ability of two or more of these technologies to work in the same physical space) are also discussed, as are the basics of implementation and security issues for each of the mentioned technologies, along with a comprehensive tour of the various business and residential applications of wireless technologies in Chapter 12.

Using straightforward language, this text introduces the most important technical aspects of each technology and can be used in classroom settings in technical colleges, early year university courses, or for distance education. It features extensive linking to websites where the reader can find additional materials. Please note, however, that although the URLs for some of these sites were accurate at the time this book was printed, these web resources can change frequently.

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 students' knowledge of the technologies discussed and direct them to additional learning resources.

Intended Audience

Guide to Wireless Communications, Fourth Edition, is designed to meet the needs of students and professionals who want to gain a better understanding of the fundamental concepts, scope, and issues surrounding the implementation of wireless data communications technologies. The text assumes a basic knowledge of computers and networks at CompTIA A+ and Network+ levels. 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 also looks at some of the advantages and challenges 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 component blocks used in the 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, which is important knowledge for anyone working in the 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, Introduction to Wi-Fi WLANs, provides essential knowledge of the basics of Wi-Fi LANs by taking an in-depth look at the early design and implementation of IEEE 802.11, Wi-Fi, and prepares the reader to learn about the more complex enhancements to the standard covered in later chapters.

Chapter 7, Enhancing WLAN Performance, details all of the IEEE 802.11 amendments that have helped make WLAN performance competitive with wired LANs, from 802.11a/g to 802.11ac and introduces 802.11ax and ay.

Chapter 8, Expanding WLANs and WLAN Security, covers implementation enhancements that have been created to expand WLANs and make them easier to manage. It also introduces core WLAN security concepts.

Chapter 9, Wireless Metropolitan Area Networks, is an introduction to Free Space Optics, microwave, and WiMAX, wireless technologies that can interconnect LANs, provide last-mile connectivity, and also make it possible to deploy data networks in remote areas, across and in between cities and even covering entire continents.

Chapter 10, Wireless Wide Area Networks, takes a look at the evolution, design, and the basics of implementation of cellular networks, as well as satellite technologies and how these 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. It then introduces NFC, the technology that enables wireless payments such as Apple Pay, enables tap-to-pay using credit and debit cards, and can simplify the establishment of connections between devices like cellular phones, tablets, wireless speakers, cameras, and other devices.

Chapter 12, Wireless Communications Everywhere, takes learners on a comprehensive tour of how wireless data communication technologies are being used today and introduces some potential future applications.

Appendix A, Completing Hands-On Projects Using Windows 10, outlines some of the differences between the text's Hands-On Projects in Microsoft Windows 7 and completing them using Windows 10 to guide users who might be using the latest version of the operating system.

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 operating system as well as software downloaded from the Internet.
- **Real-World Exercises**—In these 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 third edition was published. It also covers several new topics and provides enhanced coverage of ongoing topics. New areas include:

- IEEE 802.11ac and IEEE 802.11ad/ax/ay
- LoRa (Long Range Wide Area Network)
- Microwave
- Expanded coverage of cellular technologies with LTE Advanced and 5G
- A chapter dedicated to current and future wireless data communication applications

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

Everything you need for your course is in one place! The following supplemental materials are available for use in a classroom setting. All the supplements available with this book are provided to the instructor online. Please visit login.cengage.com and log in to access instructor-specific resources on the Instructor's Companion Site.

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

Cengage Learning Testing Powered by Cognero. This flexible, online system allows you to do the following:

- Author, edit, and manage test bank content from multiple Cengage Learning solutions.
- Create multiple test versions in an instant.
- Deliver tests from your LMS, your classroom, or wherever you want.

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. 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 16 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. Jorge L. Olenewa is also the author of the second and third editions of *Guide to Wireless Communications*. In addition, he is actively involved in applied research at George Brown College, working on building automation and is also involved in teaching courses related to the Internet of Things, helping industry adopt and develop new wired and wireless data communications products for building and residential control systems.

Acknowledgments

Writing a textbook, especially one covering so many different technologies, is a huge undertaking that requires the involvement of a large team of people. The folks at Cengage Learning are undoubtedly one of the very best teams I have ever worked with. A special thank you is due to Product Team Manager Kristin McNary and Associate Product Manager Amy Savino, for supporting the creation of this edition. Product Manager Michelle Ruelos Cannistraci was wonderful in helping to keep this project on track and was always helpful and supportive. Developmental Editor Deb Kaufmann provided wonderful insight into my writing but also wonderful suggestions to improve the readability of the book. Content Project Manager Brooke Baker worked tirelessly behind the scenes to ensure that this edition would be released to readers as soon as possible. Technical Editor Danielle Shaw's sharp skills and knowledge helped me correct many oversights, mistakes, and inconsistencies in the text. She caught many of my "slips" and made excellent suggestions to improve the technical content. I hope to get a chance to work with this team again in a future edition of this book. A very special thank you is also due to Albert Danison, Chair of the School of Computer Technology at George Brown College in Toronto, Ontario, Canada, for his support; Hisham Alasady for sharing his in-depth knowledge of Microwave systems and LTE technology; Lei Li and Wilson Liu from Huawei in Canada for their contributions on LTE and 5G cellular technology; and James West from the University of Washington, who has been in touch with me several times since the second edition of this book with excellent questions and suggestions based on courses that he teaches and who also participated as a reviewer, for a few of the chapters. Carolyn

Duarte, from Nelson Canada, our Cengage Learning representative in Canada, also deserves a special mention here for caring and being supportive of this project. In addition, I would like to thank our team of peer reviewers, many of whom use the text in their courses and who also evaluated each chapter and provided extremely helpful suggestions and comments:

Feng Li—Indiana University Purdue University Indianapolis

Donna M. Lohn—Lakeland Community College

Babak Shoraka—Northeastern University

Sammy J. Van Hoose—Wayland Baptist University

Garrett C. Whelan—Long Beach City College

The entire Cengage Learning staff was always helpful and worked very hard to create this finished product. I feel privileged and honored to be part of such an outstanding group of professionals, and to these people and everyone on the team I extend a very sincere thank you.

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.

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. However, you may find it useful to follow Chapter 1 with Chapter 12 as a means of sparking additional interest in learning about all the technologies mentioned throughout the book. For additional information on hardware, software, and specialized requirements, as well as extra labs, or to exchange ideas and suggestions for lab exercises, please visit the author's website at <http://faculty.georgebrown.ca/~jolenewa>.

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 2.1 or 4.X adapter (supported by Windows 7 or Windows 10)
- Any consumer-class wireless residential gateway or access point, such as Linksys or DLink, and preferably a dual-band router compatible with 802.11ac. If possible, try to acquire a few new or used enterprise-class access points (APs) to provide learners with a higher-end perspective on the available configuration options. In my opinion, the standards supported by the AP are not as important as the differences between configuring a home wireless router and an enterprise AP.

- Wi-Fi-certified IEEE 802.11a/b/g/n/ac and, if possible, /ad wireless network adapter
- Windows 7 Professional or Windows 10 Professional
- An Internet connection and the most current version of a web browser such as Google Chrome or Firefox

Specialized Requirements

Whenever possible, the need for specialized equipment was kept to a minimum. However, Chapters 5, 6, 7, and 8 require the following specialized hardware:

- Laptop or desktop computers with USB version 2.0+ ports, a dual-band Wi-Fi adapter that supports 802.11n/ac, and Bluetooth (USB Bluetooth is acceptable)
- Dual- or tri-band wireless router that supports the same standards as the wireless adapter mentioned above
- One or more enterprise-class wireless access points (APs) if possible

Free downloadable software is required for some of the Hands-On Projects. Instructions for downloading the software are given in each chapter, as required. Although not mentioned specifically in the text, an Android smartphone with a Wi-Fi scanner application can prove very useful for scanning the RF Wi-Fi environment in the classroom as well as for around the campus.

This book is dedicated to the memory of my best friend ever, our toy poodle, who was my most loyal companion for just over 12 years. I will always love and remember you Charlie, and in my heart, you will live forever.

Introduction to Wireless Communications

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

- Describe the various types of wireless communications technologies used today
- Discuss some trends in wireless data communications
- Outline the advantages and challenges of wireless communications technology

We all know that wireless communications technologies have had a huge impact around the world. Today, wireless communications affects almost everything we do, from using our ever-present smartphones to make voice calls, to access information on the Internet, shop, keep up with friends and family, watch videos and play games, listen to music, buy movie and event tickets, and thousands of other applications, to business uses such as counting inventory using handheld wireless scanners and using portable credit or debit card readers that communicate over the cellular phone network and can also read the cards simply by having them placed near the device. There should be no question 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. The Internet has also changed how we communicate around the world. Using wireless devices to send and receive messages through a variety of apps, as well as to connect to 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—laptop computers, tablets, digital still picture and video cameras, printers, portable digital music players, even refrigerators, washers and dryers, watches, 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, without even thinking about it, we expect devices to be connected at all times, without using wires or cables.

Wireless Communications Technologies

Before we continue, let's define precisely what we mean by wireless communications. The term *wireless* is often used to describe all types of electronic devices and technologies not connected by a wire. A garage door opener and a television remote control can be called "wireless devices," and although they do transmit data, 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 sometimes be puzzled about the exact meaning of wireless communications. A home or office cordless phone can also 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 while connected to some type of data network, without the use of wires. **Smartphones**, for example, can be used to make a simple voice call, but these devices have capabilities that extend far beyond that, and are also able to connect to data networks. Digital data in this case may include email messages, spreadsheets, and short messages transmitted to or from a digital cellular phone.

The next sections discuss the various forms that wireless data communications can take. You will read about Wi-Fi-based wireless LANs, Bluetooth, ZigBee, WiGig, radio frequency identification (RFID) and near field communication (NFC), as well as satellite, cellular, and fixed broadband wireless communications technologies. The specific details of each of these technologies are covered in later chapters. Let's first take a look at a few examples of technologies and what it is like to use a variety of wireless data devices.

Wi-Fi (Wireless LAN)

We begin with Wi-Fi, because it is the most common and most recognizable of all the different technologies discussed in this book. Imagine that you are getting ready to leave home for a busy workday. While you are getting ready, using your smartphone's connection to the **Wi-Fi network** or **wireless local area network (WLAN)**, which enables you to access all the digital-data-enabled devices in the house, you play music from your smartphone through wireless speakers. These Wi-Fi-enabled speakers can play music from any of the devices connected to the Wi-Fi network and can be installed anywhere in the house without the need for wires, except for power cords. You then open your tablet and print a spreadsheet on your Wi-Fi printer to take to work, and place a call to your office to pick up your messages using your smartphone with a **Voice over Internet Protocol (VoIP)** app, which allows you to make calls over the Internet.

Figure 1-1 illustrates a home wireless network.

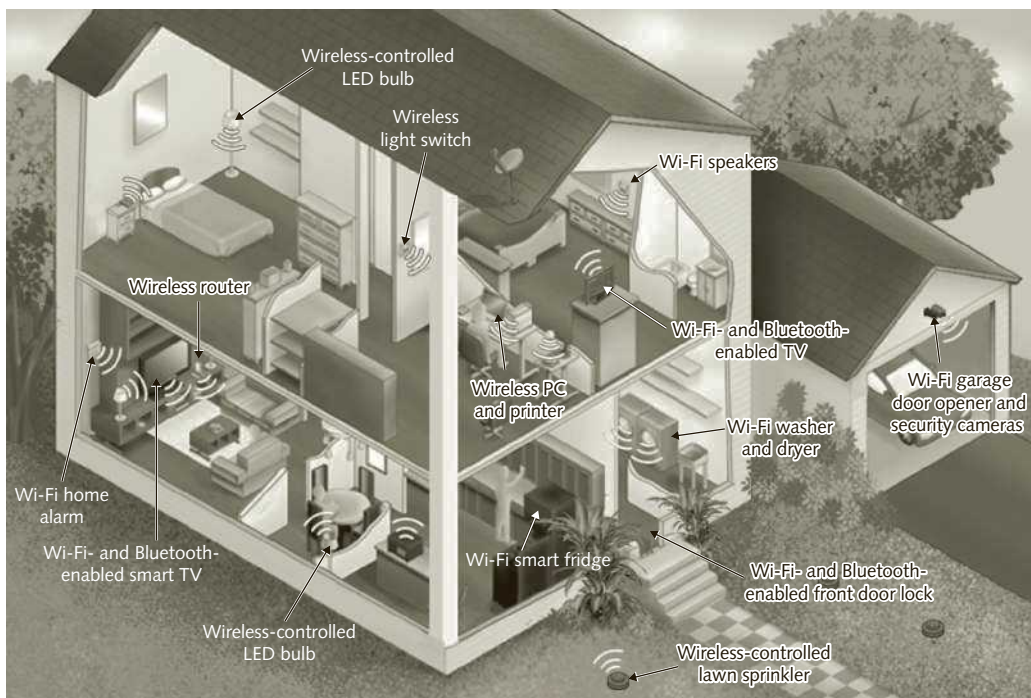


Figure 1-1 Home wireless network

Because you are inside your home using the Wi-Fi network, your smartphone can automatically connect and access the Internet. Using VoIP over your wireless network and the Internet instead of your cellular provider can help you save money on your bills. In fact, many people no longer have or use traditional telephone lines, preferring to have only a mobile phone. Some carriers offer a service that makes the phone automatically switch the call between your wireless network and the cellular network when you are out of range and not connected to a Wi-Fi network. This also helps the cellular carriers by reducing the amount of voice call traffic on their expensive cellular networks.

While you are having breakfast, a short beep sounds and you notice that a shopping list has been emailed to your smartphone from the refrigerator. A computer system installed in the refrigerator door lets you share a family schedule, make shopping lists, as well as exchange information through text messages or email with your computers, smartphones, and tablets. Because the refrigerator is also connected to the Internet through your Wi-Fi network, you can access this information even when you are not at home.



To watch a video demonstration of a smart refrigerator in action, search the web or YouTube using the keywords “Samsung Internet fridge.”

Now let’s take a look at some of the technology behind using your home WLAN.

A WLAN is an extension of a wired LAN. Wireless devices connect to it through a **wireless access point (wireless AP or just AP)**. The AP relays data signals between all the devices on the wired network, including file servers, printers, and even other access points and the wireless devices connected to the AP itself. The AP is fixed in one place, although it can be moved when necessary, whereas the devices that connect to an AP are usually portable and have the freedom to move around the office area or sometimes an entire business or school campus.

In your home, each device that is connected to the Wi-Fi WLAN is equipped with a **wireless network interface card (wireless NIC)**, which communicates with your **wireless residential gateway** (often called a **wireless router**), and some have more than one NIC, to allow connection to different types of wireless networks. A wireless NIC performs the same function as a wired NIC and looks very similar, except that it has one or more antennas instead of a socket for a cable connection. The gateway includes an AP that enables every Wi-Fi-capable device in your home to be interconnected without the trouble and expense of installing cables; this wireless network also enables these devices to share any kind of data that they can process and also allows devices to share an Internet connection.

The devices that can be part of your home or office wireless network include not only computers but also VoIP cordless telephones, home entertainment systems, game consoles, portable digital music players, tablet computers, printers, the home security system, lighting and environment (HVAC) controls, and many other devices.

WLANs operate based on networking standards established by the **Institute of Electrical and Electronics Engineers (IEEE)**. The IEEE has published and is continuing to work on a series of standards used in WLANs. One of the latest standards provides for data transmission speeds of over 1 Gigabit per second or Gbps, that is, over 1,000,000,000 (1 billion) bits per second at distances of up to 375 feet (114 meters). The maximum transmission speeds that can be achieved in WLANs is dependent on the number of radios used simultaneously as well as on the maximum distance. You will learn more about this in the chapters that cover WLANs.



Throughout this book, “IEEE 802.11,” “802.11,” and “Wi-Fi” are used interchangeably, with or without a letter after the standard number, IEEE 802.11. If there is a letter after the number, it indicates an amendment to the standard.

**TIP**

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

Virtually all smartphones, tablets, and laptop computers today are able to connect to a Wi-Fi network, and most of the latest home security, environmental control systems (heating and air conditioning), a few of the newer home appliances like refrigerators, washers and dryers, door locks, and garage doors now include the ability to connect to the Internet. This enables you to control an ever-growing number of devices in your home from wherever you may be. You can also add wireless NICs to desktop computers that may not be equipped with Wi-Fi when you purchase them and eliminate the need for network wires.

Bluetooth

Bluetooth is a wireless technology that is part of standards designed to transmit data at typically very short ranges, from a few inches to 33 feet (10 meters). The main purpose of technologies, such as Bluetooth, is to eliminate the cables between devices such as smartphones and computers, which allows data to be transmitted wirelessly between, say, a computer and a printer, as well as to synchronize your smartphone and computer. 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 a software that helps it identify other Bluetooth devices, create a link between them, and send and receive digital data, including music and voice. Bluetooth can also be used to share many other types of data.

Bluetooth headphones and headsets are popular because they avoid annoying wires that can get caught on clothing, door handles, other people, etc., and can easily be damaged. There are also portable speakers that use Bluetooth to connect to your smartphone or tablet so you can play and share music, and some of these wireless speakers are equipped with a microphone, which allows you to use them to make hands-free phone calls.

Bluetooth is now also common in many other devices, such as smart TVs, which have web browsers and can be connected to the Internet. For example, you could connect a Bluetooth keyboard to a smart TV set and enter a web addresses from the comfort of your couch. Bluetooth is also used for connecting many other types of devices, such as a keyboard and mouse to your computer, which eliminates cables and the need to use **USB** interfaces for these devices. Tablets running on the Google Android operating system can also use Bluetooth to transfer pictures and files and you can use Bluetooth to transfer other types of files between two computers. Bluetooth is also extensively used to connect smartphones to car audio systems. This provides support for hands-free cellular phone calls as well as for playing and controlling music stored in Bluetooth-equipped smartphones and other types of music players.

**NOTE**

Bluetooth is named after the tenth-century Danish King Harald Blåtand (or in Old Norse *Bláötnn*, which means Bluetooth) who was responsible for unifying Scandinavia. You can read more of his story on the web by searching for the king's name.

Among other technologies that use Bluetooth is iBeacon. Originally developed by Apple, iBeacon-enabled apps can not only be used in shopping malls and stores to deliver coupons and direct regular customers of a store to sale items, but it can also be used to help visually impaired persons to more easily find their way around a subway station. iBeacon uses small, inconspicuous, usually battery-powered Bluetooth transmitters that can be installed on walls and issue voice instructions from an app. Most Bluetooth devices can transfer a maximum of between 1 and 3 Mbps at distances of up to 33 feet (10 meters), but one of the latest versions of this technology is capable of transmitting data at rates of 20+ Mbps. Bluetooth is also used to connect **smartwatches** to smartphones and laptops. Most smartwatches can display notifications, who is calling, and email messages right on your wrist, so you do not have to always take your smartphone out of your pocket or purse to check it. Wearable fitness and sleep tracking devices also connect to smartphones via Bluetooth.



Take a look at some iBeacon applications at www.iBeacon.com or by searching for “iBeacon” on the web.



Search the web for more information on smartwatches such as those from Pebble, Apple, Motorola, Samsung, and Asus. Even a few of the traditional watch manufacturers such as Breitling are now producing smart versions that can give you notifications via your smartphone over a Bluetooth connection.

The automatic connection between various Bluetooth devices creates a **piconet**, also 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. Although Bluetooth can send data through physical barriers like walls, its limited range is more suitable for replacing cables and wires at short ranges. More than 15,000 different computer, smartphone, peripheral, and other equipment vendors today create products based on the Bluetooth standard.



The IEEE standards with the numbering beginning with 802.15 cover WPAN technologies.

ZigBee

Over the past few decades, several home automation or “smarthome” technologies have appeared on the market. Most of them were implemented as systems that depended on house electrical wiring. Later, wireless capabilities were added in the form of devices that bridged between wireless and the house’s power wires. Practically none of these legacy systems are based on standards ratified by organizations like the IEEE, and although there are many compatible devices on the market that support these technologies, they will not be covered in this text.



A notable exception is **ZigBee**, a wireless communications specification based on IEEE standard 802.15.4, which is also intended for short-range transmissions. The ZigBee Alliance is the organization that creates and maintains the specification covering the upper protocol communication layers. The ZigBee Alliance also certifies compatible products.

The ZigBee specification is designed for applications that require devices with long battery life and can transmit data at distances of between 33 and 50 feet (10 to 15 meters). To pass certification, the battery life on ZigBee devices must be at least 2 years. Devices can reach others that are located farther than the maximum 50 feet (15 meters) by making use of a mesh network where devices can pass or “route” data through other devices, similar to how a router in a TCP/IP network can pass data to other routers. The maximum data rate for ZigBee is 250 Kbps (kilobits per second).

When ZigBee-enabled devices are not being used (e.g., think of a typical house light switch), they can save power by turning off their transmitters for long periods of time and only wake up periodically to check the status of the network.

Most smart LED light bulbs being produced today by large manufacturers like General Electric, Philips, and others support the ZigBee protocol and can be controlled by central hub (a kind of wireless AP), which is accessed from a smartphone app.

In addition to home automation, ZigBee is used for automating entire commercial buildings, dramatically reducing the need for control wires from every office to a central control room on the ground level or basement. This can represent major cost reductions for builders and lower maintenance expenses for the building management or owners, in addition to the potential energy savings that can be realized by making it easier for lights to be turned off at night and during holidays and weekends.

The ZigBee specification covers several other applications in addition to home and building automation. Among these are environmental sensors, medical data collection devices, smoke detectors, and security systems as well as controlling industrial equipment.



Find out more about ZigBee products by visiting the Alliance website at www.zigbee.org and selecting ZigBee Products. You can also learn more about smart LED lighting that works with ZigBee networks by visiting lighting.cree.com (search for ZigBee), www2.meethue.com (Philips), or www.gelinkbulbs.com (GE). To learn more about home automation, visit www.wink.com or search the web for “home automation.”

WiGig

WiGig is another short-range wireless technology designed for use primarily in the home; it can transmit larger quantities of data at much higher speeds. WiGig can send and receive CD- and DVD-quality audio and video as well as Blu-ray high-definition movies from entertainment equipment, computers, or mobile devices to a TV, for example. WiGig can transfer video and sound at speeds of up to 7 Gbps (much slower from mobile devices that need to conserve battery power), using a technology called **Ultra Wide Band (UWB)**. However, WiGig can transmit up to a distance of only 2 meters at these high speeds. Thus, its use is confined to the space within a room with few or no obstacles between transmitter and

receiver devices, which is similar to using a TV remote control that uses infrared light, and cannot be used from a different room than the TV because light does not go through walls. In addition, the more obstacles, including people, that there are in a room, the shorter the transmission range of WiGig.

WiGig products are just beginning to be introduced into the home entertainment market. Wireless routers that support WiGig also include Wi-Fi and are able to switch automatically between the two types of connection when the devices are out of the 2-meter range of each other. You will learn more about radio frequency and WiGig in later chapters.



WiGig was originally created by the WiGig Alliance. In 2013, this organization merged with the Wi-Fi Alliance. You can visit the Wi-Fi Alliance website to search for the latest information about WiGig and compatible products at www.wi-fi.org.

RFID and NFC

Radio frequency identification (RFID) is another short-distance wireless technology, developed primarily to replace the barcodes you see on nearly every product sold today. Barcodes can only store a limited amount of information, the long numbers, and sometimes letters, that are usually printed below the black and white vertical bars of the code. A key advantage of RFID over barcodes is that the information can be read from the tag regardless of whether it is visible, unlike barcodes, which require the vertical bars to be exposed to a laser beam to be read. **RFID tags** are small chips containing a CPU, memory, and other electronic circuitry plus an antenna. RFID tags offer a way to store and access additional information right on the product or the packaging, which makes it easier to identify the product type, serial number, where it was manufactured and when, as well as other information. An **RFID reader** or **RFID interrogator** emits electromagnetic waves that produce a small amount of current in the tag antenna. This current powers the chip in the tag, which in turn transmits the information stored in the tag's memory back to the reader. You will learn more about RFID technology in Chapter 11.

RFID tags are available in a large variety of types and sizes, from self-adhesive labels to key fobs, in plastic nails that can be driven into trees to help identify and track them during their lifetime, in buttons that can be sewn on clothes, and in many other forms. Automobiles that can be started by simply pressing a button on the dashboard incorporate an RFID tag in the key fob and only require the key to be inside the car for the engine to start. Some RFID tags, called active tags, are battery-powered and have a longer range. These tags can include sensors that measure and record environmental parameters that can be used to track if perishable products have been exposed to damaging temperatures or humidity, for example.

Some airports use RFID to identify luggage, a system that vastly reduces the possibility of bags being lost or redirected. As shipments are unloaded from a truck and carried into a warehouse, boxes that include an RFID tag can be read right at the loading dock, updating inventory and also directing the forklift operator where to place the products. It is also possible to tag each individual product and have inventory counted automatically.

One of the most common uses for RFID today is for inventory control. Instead of employees counting inventory manually, an extremely time-consuming and often inaccurate task, RFID readers can be installed throughout the building and inventory can be counted automatically by a computer operator located in an office, as frequently as desired.

Tags can be read at varying distances depending on the type of tag and reader, from less than 1 inch (2.54 centimeters) up to about 330 feet (100 meters). Data rates are usually only few kilobits per second, but this is more than enough for the small amount of data contained in the typical tag.

Near field communication (NFC) is very similar to RFID and, in fact, some RFID equipment is also able to read NFC tags. NFC is intended to work at an average distance of about 2 to 4 inches (about 5 to 10 centimeters) between a single tag and a device or between two capable devices. The transmission speed is approximately 250 Kbps, so it is suitable for reading items like credit or debit cards and for some types of wireless communications between two NFC-enabled devices. The NFC communication protocols allow battery-powered devices to exchange information and, if authorized, both read and write data to each other using secure, encrypted communications. While most RFID tags are passive and designed to store fixed numbers in a predetermined format, NFC tags can include more flexible information like web addresses, commands, or instructions. This technology has been incorporated in many smartphones and tablets today. When two NFC-equipped devices are brought close to each other, they can read data containing instructions, like how to automatically configure a Bluetooth connection between them or set up a peer-to-peer Wi-Fi network to transfer larger amounts of data.



Search the web for “NFC enabled Bluetooth speakers” to view an example of devices that use NFC to configure a connection.

Smartphones and tablets equipped with NFC are sometimes able to write on the tags. For example, you could configure an NFC tag to open your email app on your tablet, so that you would not have to search for the tag icon on the screen and tap it to access your email account. Payment systems like Google Wallet and Apple Pay use NFC to read information from an app on your phone that allows you to pay for purchases without needing to access your wallet and use a credit or debit card. Tap-to-pay debit and credit cards also use NFC to enable you to pay for purchases, usually up to a small value, often without needing to insert a card or swipe the magnetic strip, and enter your PIN code on a keypad, which helps speed the transaction.



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 email updates to the runners' friends and relatives regarding their locations and progress. For a full description of the technology employed, search the web using the keywords “Boston marathon wireless.”