lated signal into a demodulator, which derives the information signal from the radio signal carrier.

One of the simplest forms of modulation is amplitude modulation, which varies the amplitude of a signal in order to represent data. This is common for light-based systems whereby the presence of a 1 data bit turns the light on, and the presence of a 0 bit turns the light off. Actual light signal codes are more complex, but the main idea is to turn the light on and off in order to send the data. This is similar to giving flashlights to people in a dark room and having them communicate with each other by flicking the flashlight on and off to send coded information.

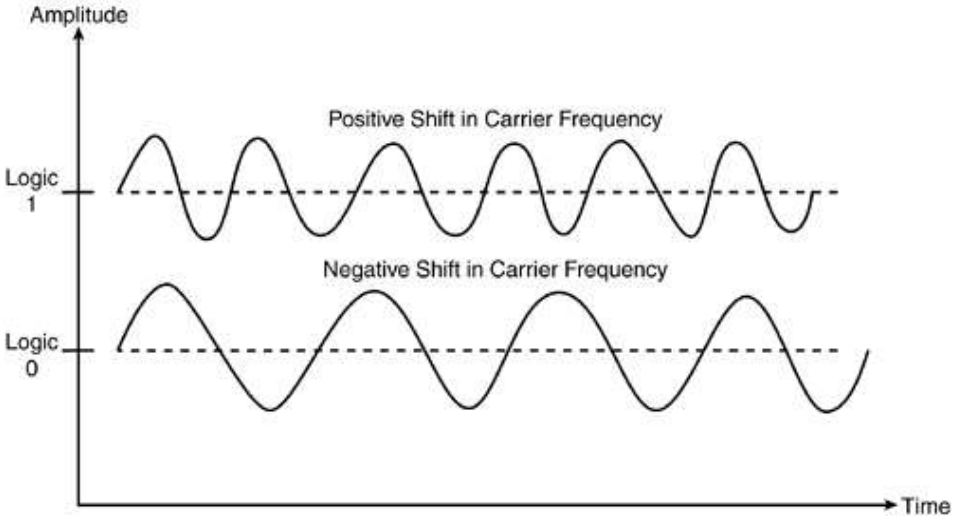
Modulation for RF systems is more complex and covered in the following sections.

Frequency Shift-Keying

Frequency shift-keying (FSK) makes slight changes to the frequency of the carrier signal in order to represent information in a way that's suitable for propagation through the air. For example, as shown in Figure 3-7, modulation can represent a 1 or 0 data bit with either a positive or negative shift in frequency of the carrier. If the shift in frequency is negative, that is a shift of the carrier to a lower frequency; the result is a Logic 0. The receiver can detect this shift in frequency and demodulate the results as a 0 data bit.

Figure 3-7. FSK Makes Use of Changes in Frequency to Carry Information

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Phase Shift-Keying

Similar to FSK, some systems utilize phase shift-keying (PSK) for modulation purposes. With PSK, data causes changes in the signal's phase while the frequency remains constant. The phase shift, as **Figure 3-8** depicts, can correspond to a specific positive or negative amount relative to a reference. A receiver is able to detect these phase shifts and realize the corresponding data bits.

Figure 3-8. PSK Makes Use of Changes in Phase to Carry Information

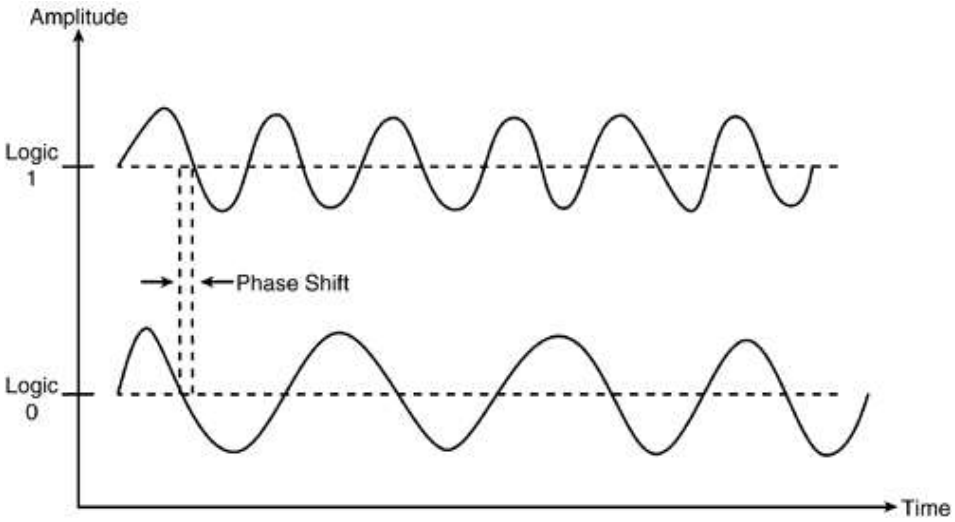
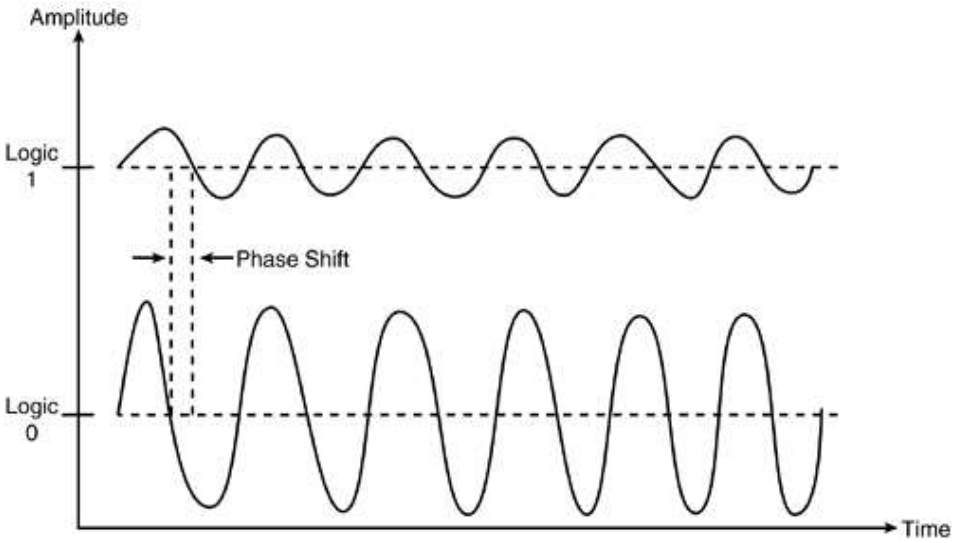


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Quadrature Amplitude Modulation

Quadrature amplitude modulation (QAM) causes both the amplitude and phase of the carrier to change in order to represent patterns of data, often referred to as symbols. (See **Figure 3-9**.) The advantage of QAM is the capability of representing large groups of bits as a single amplitude and phase combination. In fact, some QAM-based systems make use of 64 different phase and amplitude combinations, resulting in the representation of 6 data bits per symbol. This makes it possible for standards such as 802.11a and 802.11g to support the higher data rates.

Figure 3-9. QAM Makes Use of Changes in Amplitude and Phase to Carry Information



Spread Spectrum

In addition to modulating the digital signal into an analog carrier signal using FSK, PSK, or QAM, some wireless networks also spread the modulated carrier over a wider spectrum in order to comply with regulatory rules. This process, called **spread spectrum**, significantly re-

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duces the possibility of outward and inward interference. As a result, regulatory bodies generally don't require users of spread spectrum systems to obtain licenses.

Spread spectrum, developed originally by the military, spreads a signal's power over a wide band of frequencies. (See **Figure 3-10**.) Spread spectrum radio components use either direct sequence or frequency hopping for spreading the signal. Direct sequence modulates a radio carrier by a digital code with a bit rate much higher than the information signal bandwidth. Frequency hopping quickly hops the radio carrier from one frequency to another within a specific range. **Figures 3-11** and **3-12** illustrate direct sequence and frequency hopping, respectively.

Figure 3-10. Spread Spectrum Occupies a Wide Portion of the RF Spectrum

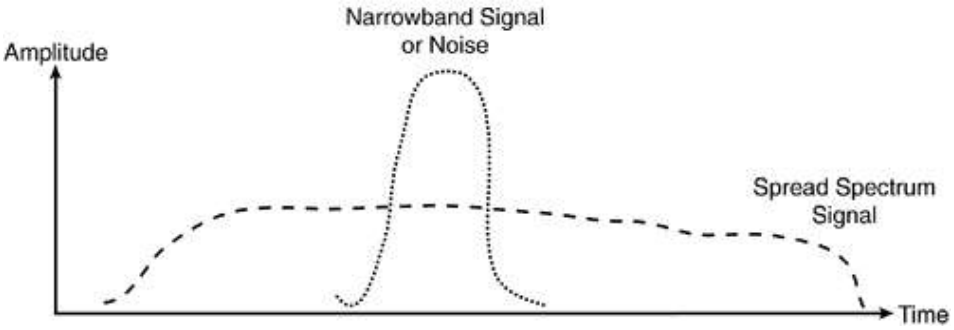


Figure 3-11. Direct Sequence Is a Type of Spread Spectrum

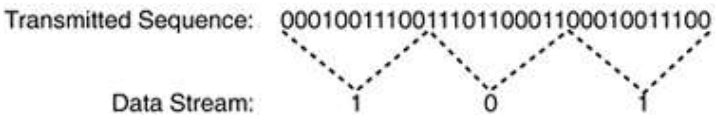
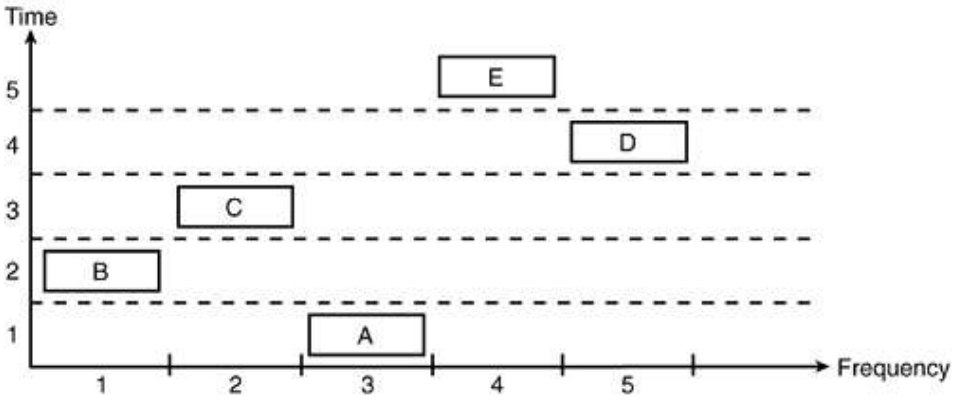


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Figure 3-12. Frequency Hopping Is a Type of Spread Spectrum



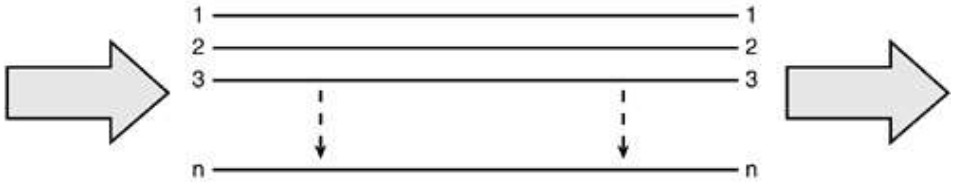
Most spread spectrum systems operate within the Industrial, Scientific, and Medicine (ISM) bands, which the FCC authorized for wireless LANs in 1975. The ISM bands are located at 902 MHz, 2.400 GHz, and 5.7 GHz. RF systems operating in the ISM band must use spread spectrum modulation and operate below 1 watt transmitter output power. Commercial users who purchase ISM band products do not need to obtain or manage FCC licenses. This makes it easy to install and relocate wireless networks because the hassle of managing licenses is eliminated. Because the ISM bands are open to the public, however, care must be taken to avoid RF interference with other devices operating in the same ISM bands.

Orthogonal Frequency Division Multiplexing

Instead of using spread spectrum, some wireless systems make use of Orthogonal Frequency Division Multiplexing (OFDM). OFDM divides a signal modulated with FSK, PSK, or QAM across multiple sub-carriers occupying a specific channel. (See **Figure 3-13**.) OFDM is extremely efficient, which enables it to provide the higher data rates and minimize multipath propagation problems.

Figure 3-13. OFDM Sends Multitudes of Data Simultaneously in Parallel

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Multiple subchannels
provide parallel transmission.

OFDM is becoming popular for high-speed transmission. In addition to being part of both 802.11a and 802.11g wireless LANs, OFDM is the basis for the European-based HiperLAN/2 wireless LAN standards. In addition, OFDM has also been around for a while supporting the global standard for Asymmetric Digital Subscriber Line (ADSL), a high-speed wired telephony standard.

Ultrawideband Modulation

Ultrawideband (UWB) modulation is beginning to take a stronger foothold instead of spread spectrum or OFDM in the wireless networking industry. While it has been used for a while by the military, UWB is now going through the necessary authorizations and developments for public and commercial use. Even though the advancement of UWB has been somewhat slow, UWB becoming a superior technology for many types of wireless networks is a possibility.

UWB uses low-powered, short-pulse radio signals in order to transfer data over a wide range of frequencies. A UWB transmission involves billions of pulses spread over several gigahertz. The corresponding receiver then translates the pulses into data by listening for a familiar pulse sequence sent by the transmitter.

UWB should initially deliver bandwidths from about 40 to 600 Mbps, and eventually data rates could be up to (with higher power). UWB systems also consume little power, around one ten-thousandth of cell

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phones. This makes UWB practical for use in smaller devices, such as cell phones, PDAs, and even watches that users can carry at all times.

Because UWB operates at such low power, it has little interference impact on other systems. UWB causes less interference than conventional RF systems. In addition, the relatively wide spectrum that UWB utilizes significantly minimizes the impact of interference from other systems.

Concerns still remain, however, about the interference of higher-power UWB systems. The FCC plans to reevaluate UWB in the near future, and they will take a closer look at the issue of higher-power systems. Until then, you're limited to UWB products with short-range propagation.

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Chapter Summary

RF and light signals are the heart of wireless networks. They offer a means of transmitting information invisibly through air. Interference offers the most critical form of transmission impairment, requiring careful planning when deploying a wireless network. The various modulation techniques—FSK, PSK, or QAM— combine with spread spectrum or OFDM to realize a transceiver, which is a critical element of the wireless NIC.

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Chapter Review Questions

You can find the answers to the following questions in **Appendix A**, "Answers to Chapter Review Questions."

1: RF signals offer relatively short range as compared to light signals. True or false?

2: What type of weather impacts RF signals the most?

3: Why does interference cause errors in wireless networks?

4: What are sources of RF interference?

5: Multipath affects higher data rates more than lower data rates for 2.4 GHz systems. True or false?

6: What is meant by a diffused infrared light system?

7: Approximately up to what range do direct infrared systems operate?

8: How does modulation make it possible to transmit information through the air?

9: What attributes of a signal does QAM change in order to represent information?

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10: Spread spectrum generally requires user licenses. True or false?

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Chapter 4. Wireless PANs: Networks for Small Places

What You Will Learn

After reading this chapter, you should be able to

- **Recognize specific wireless PAN applications**
- **Understand wireless PAN components and standards**
- **Realize the various wireless PAN systems**

Wireless PANs satisfy needs for wireless networking over relatively small areas, such as between a cell phone and a laptop. In most cases, the range of a wireless PAN is less than 30 feet. This makes wireless PANs applicable to a wide variety of solutions, but many of the applications merely replace interfacing cables or allow simple transfers of information directly from one user to another.

This chapter defines each of the primary wireless PAN components, describes how these components interconnect to form a variety of systems, and explores several radio and infrared light technologies.

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Wireless PAN Components

Wireless PANs make use of both radio and infrared light technologies, which manufacturers embed in many different types of devices.

User Devices

Wireless PANs don't require much battery power to operate, making them ideal for small user devices, such as audio headsets, cell phones, PDAs, game controls, GPS units, digital cameras, and laptops. Figure 4-1 illustrates several of these types of devices. For example, a wireless PAN enables someone to listen to music on headsets wirelessly from their PDA. Or a person can transfer his phone book from his laptop to a cell phone. As with these cases, wireless PANs eliminate wires that often frustrate users.

Figure 4-1. Many Different Types of User Devices Operate on Wireless PANs



Radio NICs

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Radio NICs are available for wireless PANs in PC Card and Compact Flash (CF) form factors. If you have a laptop, for example, it's easy to add wireless PAN connectivity by installing a PC Card. These products are available from different vendors. Many of the newer PDAs and laptops come equipped with one or more wireless PAN interfaces. This makes these wireless devices ready to connect with other devices, such as printers, PDAs, and cell phones that also have wireless PAN interfaces. The larger PC Cards are uncommon for wireless PANs, mainly because wireless PAN technologies are ideal for small devices.

USB Adapters

Several companies offer a wireless PAN USB adapter (see **Figure 4-2**), which is also called a wireless dongle. For example, you can purchase a USB Bluetooth adapter and connect it to a USB port on your PC. This makes the PC able to synchronize with other devices having Bluetooth connectivity. Bluetooth—which is discussed later—is a specification developed for short-range, radio-based transceivers.

Figure 4-2. Bluetooth Wireless USB Adapters Enable PCs and Laptops to Interface with other Bluetooth Devices



A PDA utilizing Bluetooth can wirelessly interface with the Bluetooth-enabled PC and synchronize without placing the PDA in a synchronization cradle. A USB connection over Bluetooth, however, is generally slower than having a directly wired interface through the PC's USB port. This is because the wireless USB adapter is mapped to the

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PC's serial port, which runs slower than the USB port. The wireless solution might be more convenient, but you might need to wait twice as long before synchronization is complete.

Routers

Most wireless PAN applications simply involve cable replacement, but some vendors sell Bluetooth-equipped routers to support wireless connections to the Internet. Because of limited range, though, these wireless PAN routers are primarily for home and small office use. In order to satisfy more connectivity needs, some wireless PAN routers also support wireless LAN interfaces, such as 802.11.

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Wireless PAN Systems

Wireless PAN systems generally apply to individual users, and some offer support for multiple users. Take a closer look at several wireless PAN system configurations.

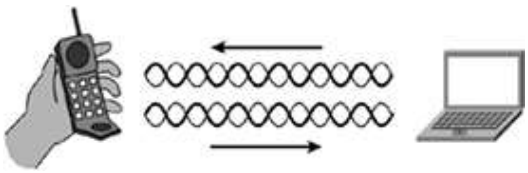
Home and Small Office

Many different system configurations of wireless PANs exist in the home and small office.

Synchronization

One of the most common uses of wireless PANs is PDA and cell phone synchronization with a laptop or PC. Figure 4-3 illustrates the interconnection of components for this type of system. When the user presses a sync button on the handheld device, the radio NIC within the handheld device sends the corresponding data to the radio NIC in the laptop or PC. Likewise, the laptop or PC will send data to the handheld device. In most cases, the wireless connection extends the serial RS-232 port wirelessly to the handheld device.

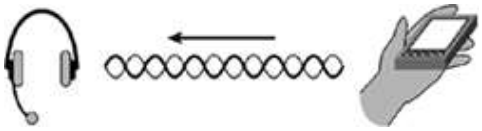
Figure 4-3. Synchronization Transfers Information in Both Directions Between Two Devices



Streaming Multimedia

A large number of wireless PAN applications involve streaming audio and video. For example, a user can easily listen to streaming MP3 files stored on an MP3 player. (See **Figure 4-4**.) Many PDAs have the capability of playing MP3 audio files by installing one of the popular media players, such as the RealOne media player from RealNetworks, Inc. With a wireless PAN, the user doesn't need to carry around the MP3 player and mess with wires or stay within the same area to listen to music. A similar configuration involves the use of a wireless audio earpiece and microphone for a hands-free operation of a cell phone. A drawback to this approach, however, is that batteries will not last as long when using the wireless connections.

Figure 4-4. Wireless PANs Permit Easy Use of Headphones



Another benefit of wireless PANs in streaming applications is flexible connectivity between video cameras and a server. A homeowner could, for example, place web cams in strategic places for security monitoring purposes. A hidden camera aimed at the front door area allows the homeowner to screen visitors before opening the door. The use of wireless, in this case, simplifies the installation because it eliminates the need to run wires to the camera. Electrical current or batteries are still necessary to power the camera, of course, but electrical outlets are available throughout a home.

Control

Wireless PANs eliminate wires for computer peripherals, such as a wireless mouse, keyboard, and telephone connection, making it easier

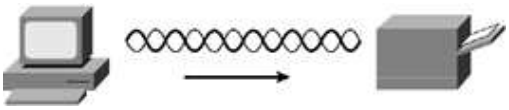
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to move and set up PCs. A user, for example, can use a full-sized keyboard wirelessly with a laptop or PDA. In addition, wireless PANs reduce the tangle of cables surrounding a desktop computer. Reliability is higher because of less cable breakage and less risk of someone inadvertently kicking a cable loose.

Printing

Wireless connections between your PC and printer are made possible within the same room through a wireless PAN connection. (See **Figure 4-5**.) Printer cables are often too short, and you're stuck setting the printer in a less than ideal location. The wireless PAN connection allows the movement of the printer to a better location.

Figure 4-5. Printing Is Easy with a Wireless PAN

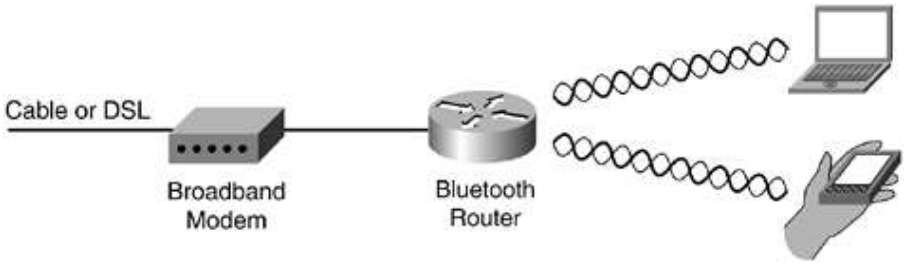


Internet Connections

A user can access e-mail and browse the web from anywhere within the room with a wireless PAN interface to the Internet. Instead of sitting at a desk, for example, a person can relax in a lounge chair or couch. This freedom makes computing much more enjoyable. **Figure 4-6** shows the system configuration that makes this possible.

Figure 4-6. A Wireless PAN Router Allows Connectivity to the Internet

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Enterprise

The use of wireless PANs in enterprise is common; however, the applications and system configurations are similar to homes and small offices. Employees use wireless PANs to synchronize PDAs with desktop computers and take advantage of wireless peripherals. Instead of using a wireless PAN router for connecting users to the Internet however, an enterprise makes use of wireless LANs for Internet connectivity. Enterprises span too large of an area to make wireless PANs practical because of the rather large number of required base stations.

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Wireless PAN Technologies

Wireless PAN technologies utilize both radio frequencies and infrared light, depending on the application.

802.15

The IEEE 802.15 standards working group focuses on the development of standards for wireless PANs and coordinates with other standards, such as 802.11 wireless LANs.

The 802.15 standards working group contains the following elements:

- 802.15.1— This working group, Task Group 1, defines a wireless PAN standard based on Bluetooth v1.1 specifications, which uses frequency hopping spread spectrum (FHSS) and operates at up to 1 Mbps. The 802.15 group published 802.11.1 in June of 2002, and it is meant to serve as a resource for developers of Bluetooth devices.
- 802.15.2— The group responsible for this standard, Task Group 2, is defining recommended practices to facilitate the coexistence of 802.15 and 802.11 networks. An issue is that both networks operate in the same 2.4 GHz frequency band, making coordination between operations necessary. The group is quantifying the interference and proposing methods to counter the interference.
- 802.15.3— This is Task Group 3, which is drafting a new standard for higher-rate wireless PANs. Data rates include 11, 22, 33, 44, and 55 Mbps. Combined with these higher data rates, quality of service (QoS) mechanisms make this standard good for satisfying needs for multimedia applications. This group is also focusing on lower cost and power requirements. A draft of the 802.15.3 standard is now available for purchase.