The Freedom of Wireless:

Proving the Business and Industry Case for Wireless Connectivity

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Introduction

Companies in just about every industry are turning to wireless technology to connect serial devices and avoid the high cost of installing cable. Low-cost wireless links reduce installation and maintenance costs. They also provide mobility. However, designing an effective wireless networking solution requires an understanding of today's complex wireless technologies, their benefits, and their trade-offs.

Knowledge is power. This has been historically true in the computer industry and its true today as wireless technologies become pervasive in the marketplace.

This paper provides technical information to help you understand the available wireless technologies for embedded solutions. It starts by describing the motivation to go wireless and provides real-world success stories. Next, it overviews the various wireless networking standards available and includes a description of 900 MHz technology. This paper includes a discussion on WiPort™ and WiBox™, Lantronix's revolutionary solutions for network enabling serial devices via wireless technology. A glossary at the end of this paper defines the technical terms appearing in **bold red** throughout this paper.

Wireless is Worth the Investment

Local Area Networks (LANs) run on wire cable. Wire is expensive to install and difficult to reconfigure for changes in the production environment. It does not allow for mobility and it simply cannot go in certain places. For instance, running cable throughout a factory floor is extremely difficult (if not sometimes impossible). On account of these limitations, WLANs (wireless LANs) are a hot commodity, revolutionizing the way we work and do business today.

Data applications running over wireless networks are found everywhere in our daily lives — from the department store using wireless devices for inventory control to the hospital using wireless to check patient test results. The following sections illustrate how wireless networks are transforming the business process and removing roadblocks to productivity.

Medical/Healthcare and Wireless

The medical and healthcare industries aggressively seek productivity gains as a result of the current nursing and doctor shortage. With this situation expected to worsen as baby boomers age and require more care, an increasing number of medical and healthcare industries are modifying their processes by building convincing wireless return on investment (ROI) models. Use of computer-based physician order entry (CPOE) and bar-code scanning for medications is expected to expand over the next few years and wireless communications networks are essential to their success.

Wireless networks are also realizing significant growth in the healthcare industry from an increased emphasis on work efficiency. As news of medical mistakes become more public, wireless applications are becoming a key component in the fast-growing initiative to improve accuracy and quality of care in hospitals. Now hospital emergency-room doctors can examine a seriously injured patient, order x-rays, transfer the patient to surgery, and receive the x-rays electronically in the operating room. In addition, physicians can remotely check a patient's status, test results, medication schedules, or other information based on up-to-date entries made by nurses on their rounds. Quality of care improves dramatically as patient information is more accessible wirelessly and as more accurate information is recorded by immediate record keeping.

Doctors in outpatient offices or portable screening labs are already accessing high-resolution images, including Magnetic Resonance Imaging, Ultrasound, and Computed Tomography, wirelessly from remote labs.

Real-world example: The University of Maryland Medical Center in Baltimore, Maryland, installed an IEEE 802.11 WLAN in all patient-care areas. Using hand-held Portable Digital Assistants (PDAs) and personal computers mounted on mobile carts, care teams of physicians and residents can now access electronic medical records as they conduct rounds and perform patient care. Physicians, nurses, and therapists use the mobile technology to check test results, order medications and tests, and document care while they are with the patient, instead of returning to a central station to view and enter this information after interacting with the patient. Mobile access to data saves time every day for all types of clinicians and makes innovative new software applications such as CPOE possible, which in turn reduces errors when ordering medication and other critical services.

Rental Cars and Wireless

Before wireless, checking in a rental car was an extensive procedure. Customers often became angry due to delays and occasionally even missed flights, which ultimately cost car rental companies return business. In addition, the mass of paperwork manually entered on a daily basis was cumbersome. Worse yet, returned vehicles sometimes would stay on the premises for hours before being turned around and re-rented. Car-rental companies needed a real-time solution to improve their rental return process. WLANs allow car rental companies to accomplish strategic business goals in new and innovative ways.

Real-world example 1: A number of car rental agencies provide portable terminals that transfer customer check-in information wirelessly to a central location. Others equip attendants with hand-held units used to access customer account information from a wired LAN through access points around each lot and instantly print a receipt.

Real-world example 2: Lightly damaged vehicles are costly for car rental companies. To reduce costs, a major rental car agency is using a wireless system allowing damaged cars to be inspected and an appraisal prepared within two minutes. The company estimates that it potentially saves approximately $30 million a year on unrecovered costs. It also ensures crucial customer information and signatures are not lost.

Retail and Wireless

In an increasingly competitive environment, retailers are seeking ways to improve productivity, reduce costs, and generate incremental revenue. WLANs and the applications that run over them offer proven solutions. Popular examples include multimedia kiosks and self-service displays that employ audio, video, animation, and graphics to run point of sale (POS) and information applications. By improving the timeliness and flow of information, these wireless solutions lead to better overall customer satisfaction and increased profitability.

Real-world example 1: A major music store has set up wireless kiosks that provide real-time streaming of music videos, seasonal fashion displays, ticket-selling services, local web access, on-line music sampling, and other content residing on a video server.

Real-world example 2: A number of museums use wireless kiosks for educational applications. The space and distance requirements associated with these kiosks make wireless the only cost-effective solution.

Real-world example 3: In the future, retailers will be able to install RFID (Radio Frequency Identification Device) readers into their store shelves. With these readers, retailers will have the capability to detect when the shelves are empty and need to be restocked – all via wireless communication.

Industrial Automation

Productivity improvements. Inventory management. Quality control. All are common challenges found in virtually every manufacturing facility today. From automotive to warehouse environments, the need to attach essential devices (new or legacy) such as PLCs, CNC/DNC equipment, process and quality control equipment, pump controllers, barcode operator displays, scales and weighing stations, printers, machine vision systems, and many other types of manufacturing equipment is common. Wireless networks offer the solution for all these challenges.

Wireless applications are particularly attractive to industries where certain functions are difficult to perform because of large areas, harsh operating conditions, or other restrictions. For example, wireless applications are ideally suited for pharmaceutical manufacturing applications where an uncontaminated environment is required to monitor, control, and configure equipment.

Real-world example 1: In the past, a major facility control center operated process-control equipment on a legacy network that was independent of the LAN. To network-enable all of the process control equipment at the support center would have required more than 1,500 feet of wiring and conduit spanning multiple buildings, both a costly and time-intensive project. Instead, wireless device servers were integrated to Ethernet-enable all of the equipment in the support center. This solution also delivers significant time-savings, as over 500 PCs in the support center have access to real-time information as it is generated by the process control equipment. This eliminates the need for a technician to patrol the floor and monitor each device individually, and speeds the response time when a failure occurs.

Real-world example 2: Prior to implementing a wireless solution, a major company had adopted a complex procedure for measuring and reading the concentration of contaminants in water samples. This process involved transferring a signal from a water analyzer to a programmable logic controller to a human/machine interface (HMI). When reading this information, the opportunity for error increased as the signal passed through each separate device, with measurements so small that any degree of error can be detrimental. Going wireless enabled this company to measure contaminants directly at the source of the water sample. A device server communicates directly with the HMI, reducing the risk for errors and providing information on the process in real time.

Surveying the Wireless Landscape

As the previous examples show, businesses of all types are finding that wireless networks meet the high availability and capacity requirements needed for their specific applications. Once a decision is made to deploy a wireless system, the overriding question then becomes one of standards.

Table 1 summarizes today's popular wireless-networking standards. The sections that follow describe these standards in greater detail.

Table 1. Wireless Networking Standards

Standard	Data Rate	Frequency Band	Modulation Scheme	Typical Range	Pros/Cons
IEEE 802.11 (see page 9)	Up to 2 Mbps	2.4 GHz	FHSS or DSSS	20m	♦ This specification is extended into 802.11b.
IEEE 802.11a (see page 9)	Up to 54 Mbps	5 GHz	OFDM	40 ft at 54 Mbps 300 ft at 6 Mbps	♦ Supports eight channels. ♦ Less potential for RF interference than 802.11b and 802.11g. ♦ Better than 802.11b at supporting multimedia voice, video, and large-image applications in densely populated user environments. ♦ Relatively shorter range than 802.11b. ♦ Not interoperable with 802.11b.
IEEE 802.11b (see page 9)	Up to 11 Mbps	2.4 GHz	DSSS with CCK	100 ft at 11 Mbps 300 ft at 1 Mbps	♦ Not interoperable with 802.11a. ♦ Requires fewer access points than 802.11a for covering large areas. ♦ Compatible with 802.11g. ♦ Offers high-speed access at up to 300 feet from base station. ♦ Supports 14 channels, 11 of which can be used in the U.S. due to FCC regulations, with only three non-overlapping channels.
IEEE 802.11g (see page 9)	Up to 54 Mbps	2.4 GHz	OFDM above 20 Mbps, DSSS with CCK below 20 Mbps	50 ft at 54 Mbps 150 ft at 11 Mbps	♦ Improved security enhancements over 802.11. ♦ Compatible with 802.11b. ♦ Supports 14 channels, 11 of which can be used in the U.S. due to FCC regulations, with only three non-overlapping channels.
Bluetooth (see page 10)	Up to 2 Mbps	2.45 GHz	FHSS	10 m	♦ No native support for IP, TCP/IP, and wireless LAN applications. ♦ Not originally created to support wireless LANs. ♦ Best suited for connecting PDAs, cell phones, and PCs in short intervals.
Not Applicable (see page 11)	Not Applicable	900 MHz	Not Applicable	500 to 2,200 feet (typical)	♦ Frequency range, not a networking standard. ♦ Requires a network over which it can run.

IEEE Standards

The IEEE 802.11 standard does not specify a single method of implementing wireless data communications. Rather, it comprises a family of standards — some ratified and others working their way through the ratification process.

802.11 specifies the parameters of both the physical (PHY) and medium-access control (MAC) layers of the WLAN.

- The PHY layer handles the transmission of data between **nodes**. Transmission can occur using **direct sequence spread spectrum** (DSSS) or **frequency-hopping spread spectrum** (FHSS), transmission technologies that support RF transmissions that can penetrate walls.
- The MAC layer is a set of protocols that maintain order in the use of a shared medium. The 802.11 standard specifies a protocol known as **carrier sense multiple access with collision avoidance** (CSMA/CA).

IEEE 802.11 is based on the same standards framework as Ethernet. This provides a high level of interoperability and ensures that Ethernet/WLAN internetworking functions and devices can easily be implemented.

The initial 802.11 specification for WLANs was finalized in June 1997. This standard specified a 2.4 GHz operating frequency, with data rates of 1 and 2 Mbps. Table 2 summarizes the 802.11 standard and the subsequent standards that have evolved from it.

Table 2. IEEE WLAN Standards

	802.11	**802.11a**	**802.11b**	**802.11g**
Standard Approved	July 1997	September 1999	September 1999	June 2003
Available Bandwidth	83.5 MHz	300 MHz	83.5 MHz	83.5 MHz
Unlicensed Frequencies of Operation	2.4 – 2.4835 GHz DSSS, FHSS	5.15 – 5.35 GHz OFDM 5.725 – 5.825 GHz OFDM	2.2 – 2.4835 GHz DSS	2.2 – 2.4835 GHz DSS or OFDM
Number of Non-overlapping Channels	3 (indoor/outdoor)	4 indoor (UNII1) 4 indoor/outdoor (UNII2) 4 outdoor (UNII3)	3 (indoor/outdoor)	3 (indoor/outdoor)
Data Rate per Channel	2, 1 Mbps	54, 48, 36, 24, 18, 12, 9, 6 Mbps	11, 5.5, 2, 1 Mbps	54, 36, 33, 24, 33, 12, 11, 9, 6, 5.5, 2, 1 Mbps
Modulation Type	DQPSK (2 Mbps DSSS) DBPSK (2 Mbps DSSS) 4GFSK (2 Mbps FHSS) 2GFSK (1 Mbps FHSS)	BPSK (6, 9 Mbps) QPSK (12, 18 Mbps) 16-QAM (24, 36 Mbps) 64-QAM (48, 54 Mbps)	DQPSK/CCK (11, 5.5 Mbps) DQPSK (2 Mbps) DQPSK (1 Mbps)	OFDM/CCK (6, 9, 12, 18, 24, 36, 48, 54 Mbps) OFDM (6, 9, 12, 18, 24, 36, 48, 54 Mbps) DQPSK/CCK (5.5, 11, 22, 33 Mbps) DQPSK (2 Mbps) DBPSK (1 Mbps)

802.11a (OFDM in the 5 GHz Band)

802.11a is an extension to the 802.11 standard. With basic MAC protocols that rely upon the legacy 802.11 MAC specification, 802.11a specifies operation in the 5 GHz UNII band using **orthogonal frequency division multiplexing** (OFDM). By moving to the 5 GHz frequency band and using OFDM modulation, the IEEE 802.11a standard provides the following benefits over 802.11b:

- It increases the maximum data transfer rate per channel from 11 Mbps to 54 Mbps.
- It increases the number of non-overlapping channels.
- It offers much less potential for RF interference than other PHYs (e.g., 802.11b and 802.11g) that use 2.4 GHz frequencies.

The 5 GHz band (UNII band) consists of three sub-bands:

- UNII1 (5.15-5.25 GHz)
- UNII2 (5.25-5.35 GHz)
- UNII3 (5.725-5.825 GHz)

Up to eight non-overlapping channels are available when UNII1 and UNII2 are both used, compared to three in the 2.4 GHz band. The total bandwidth available in the 5 GHz band is also higher than in the 2.4 GHz band — 300 MHz versus 83.5 MHz. Therefore, an 802.11a-based WLAN supports a larger number of simultaneous high-speed users, without the potential for conflict.

802.11a is not without its drawbacks. One disadvantage is that in the time between when 802.11a became a standard in 1999 and today, the requirements for wireless networking have changed drastically, with a greater need for interoperability and security. Interoperability limitations are evident by the European (ETSI) requirements being omitted from the 802.11a standard. In addition, some tradeoffs in terms of compatibility and range had to be made. Because 802.11a and 802.11b operate in different frequency bands, products that follow either one of these standards are not compatible.

802.11b (High Rate DSSS in the 2.4 GHz Band)

802.11b is an extension to the 802.11 standard and covers devices that operate in the unlicensed 2.4 GHz RF band, from 2.4 to 2.483 GHz. 802.11b supports raw channel signaling rates of 1, 2, 5.5, and 11 Mbps. However, the effective data throughput is typically less than half of the raw channel signaling rate. Typical ranges are from 15 to 75m, depending on the environment, with payload rates decreasing over distance.

802.11b uses DSSS transmission technology, with a chipping code that increases the signal's bandwidth to improve resistance to interference and frequency-selective fading. Please see the 802.11g section for 802.11g interoperability.

802.11g (DSSS at 2.4 GHz / OFDM at Higher Speeds)

802.11g offers high speeds of 20+ Mbps, while maintaining backward compatibility with existing 802.11b equipment. 802.11g works at the same 2.4 GHz frequency band and with the same DSSS modulation types as 802.11b, at speeds up to 11 Mbps, while using more efficient OFDM modulation at higher speeds.

This backward compatibility protects customer investments in various ways. An IEEE 802.11g-capable device, for example, will work with an 802.11b access point, and vice versa, at speeds up to 11 Mbps. To benefit from speeds up to 54 Mbps, both the access point and the device with which it communicates must be 802.11g compliant.

Similarly, every 802.11g client and access point must be able to fall back and operate exactly like an 802.11b device. Therefore, migration to 802.11g technology can be smooth and easy. As new 802.11g access points are installed, 802.11b access points can remain in service and be fully interoperable with newer 802.11g clients.

802.11g also specifies optional modulation types such as OFDM/CCK (**Complementary Code Keying**), which are intended to improve efficiency in an all-802.11g installation. In larger installations, the benefit of having approximately the same effective transmission ranges means that existing 802.11b WLAN infrastructure can be upgraded to higher speeds easily, without having to install additional access points in many new locations for covering a given area.

802.11g technology supports higher data rates at longer ranges than 802.11a. The combination of OFDM and the superior wall-penetrating power of 2.4 GHz give 802.11g a clear advantage over other high-speed WLAN technologies. The ability to provide high throughput coverage for a comparatively large area is an important cost factor.

Wi-Fi

In a mixed wireless network environment, it is important to select standards-based wireless products that are interoperable. The main measure of 802.11 equipment interoperability is the Wireless Fidelity (Wi-Fi) certification program.

Wi-Fi is a generic term referring to any type of 802.11 network, whether 802.11a, 802.11b, 802.11g, etc. The term is promoted by the Wi-Fi Alliance (www.wi-fi.org). Any products tested and approved as “Wi-Fi Certified®” by the Wi-Fi Alliance are certified as interoperable with each other, even if they are from different manufacturers. To keep current, the Wi-Fi Alliance tracks standards developments and enhances its interoperability testing to reflect advancements in the 802.11 standards.

The Wi-Fi interoperability program tests for association and roaming capabilities, throughput, and required features such as 64-bit encryption. A user with a Wi-Fi Certified product can use any brand of access point with any other brand of client hardware that also is Wi-Fi certified. Users benefit from this interoperability by not being locked into one vendor’s solution.

Bluetooth

Named for the Viking, Harald Bluetooth, Bluetooth is a short range (10 meter) frequency-hopping protocol that links devices. Designed to operate in noisy frequency environments, Bluetooth uses a fast acknowledgement and frequency hopping scheme to make the link robust. Bluetooth operates in the unlicensed ISM band at 2.4 GHz and avoids interference from other signals by hopping to a new frequency after transmitting or receiving a packet. Compared with other systems in the same frequency band, Bluetooth hops faster and uses shorter packets.

As a short-range, low-cost, wireless solution, Bluetooth operates in the 10-to 20-m range, with a signaling data rate of 1 Mbps (data payload of approximately 700 Kbps). While Bluetooth has a lower throughput and range than 802.11b, Bluetooth-based devices require less operating power than 802.11b devices.

Bluetooth uses an FHSS, full-duplex signal at up to 1,600 hops per second to avoid interference. To obtain a high degree of interference immunity, the signal hops among 79 frequencies at 1 MHz intervals. However, because Bluetooth shares the 2.4 GHz radio spectrum with 802.11b, there is a potential for interference with consumer appliances that operate in the same spectrum, such as cordless phones, microwave ovens, baby monitors, and so on.

Sharing the Air

In 1985, the FCC authorized the use of spread-spectrum radio technology in the 902-928 MHz, 2.400-2.4835 GHz, and 5.725-5.850 GHz frequency bands. FCC Part 15 rules allow unlicensed use of spread-spectrum data communications in these bands. Commonly referred to as 900 MHz, 5.7 GHz, and 2.4 GHz, these frequencies are also known as ISM bands.

Table 3 compares the advantages and disadvantages of the ISM bands. Note that:

- The 900 MHz band is more crowded than other frequency bands and, as a result, prone to more potential interference.
  - In the U.S., for example, this band is used for cordless telephones, devices to extend in-home TV signals, vehicle-locating systems, and other non-spread-spectrum applications.
  - Internationally, the 900 MHz band is widely used for Global System for Mobile Communications (GSM) cellular telephone systems or military communications. As a result, companies with sites around the globe cannot standardize on 900 MHz-based solutions for all locations.
- The 900 MHz band suffers from a lack of interoperability, as vendors employ proprietary radio protocols. The industry, on the other hand, is moving towards standards-based systems, with multi-vendor support for common WLAN infrastructures. By contrast, 802.11/Wi-Fi consumers are not restricted to a single vendor for upgrades and expansion of their WLAN systems.

Table 3. Advantages and Disadvantages of 900, 5, and 2.4 GHz Technologies

Radio Frequency Band	Advantages	Disadvantages
900 MHz	♦ Good balance of range and data rate. ♦ Greater range than 2.4 GHz for in-building WLANs. ♦ Data rates of 100,000 to 450,000 bps are sufficient for many WLAN applications. ♦ Typically larger coverage areas than similar 2.4 GHz systems.	♦ Maximum data rate 1 Mbps. ♦ Limited bandwidth. ♦ Crowded band. ♦ No interoperability.
5 GHz	♦ Relatively uncrowded (less interference than 2.4 GHz) ♦ Global market. ♦ Data rates up to 54 Mbps.	♦ Higher cost RF components.
2.4 GHz	♦ Worldwide acceptance for installation and use in most countries. ♦ Data rates up to 54 Mbps.	♦ Limited range (systems transmit less power, typically 1/10th of a Watt). ♦ Poor propagation characteristics can limit coverage area. ♦ Susceptible to interference from other 2.4 GHz devices such as microwave ovens and cordless phones ♦ Decreased range can increase system-infrastructure costs for large facilities, multi-story buildings, and campus environments.

Lantronix 802.11b-based Solutions

WiPort™

As this paper has shown, there are an abundance of complexities associated with wireless connectivity. The effort involved in understanding this technology and bringing it to embedded solutions is daunting, time-consuming, and expensive. WiPort, Lantronix's wireless embedded device server, simplifies this effort by providing a "drop-in" solution that adds wireless connectivity to products while slashing development costs and accelerating time to market.

WiPort is a fully integrated module that can be easily added to OEM products without any expensive RF and software development. By simply adding WiPort to your design, you can now add wireless connectivity within a few months, not years.

WiPort offers the highest level of integration available in a device server. Within its compact package, the WiPort contains a finely tuned x86 processor, memory, 802.11b transceiver, 256KB of SRAM, 16KB of boot ROM, 2048KB of flash memory for maintenance-free nonvolatile storage of web pages and future system firmware upgrades, and dual high-speed (920Kbaud) serial ports. All of these parts work in concert to give you a complete networking solution. The flexibility and speed are there for you to develop as fast or as slow as your markets dictate.

Lantronix includes installation and configuration software utilities free of charge. DeviceInstaller™ allows you to detect WiPort on the Ethernet and configure it to your needs. Com Port Redirector allows the creation of virtual COM ports (such as COM17) to link your equipment across the network and through gateways to access the WAN as if the equipment was connected directly to your PC. In most cases, you do not need to change your existing interface software application at all.

WiBox™

Lantronix also offers an alternative for those who do not currently have a need for an embedded wireless solution. The WiBox is a two-port device server that allows you connect serial devices to 802.11b wireless networks, quickly and easily. By merging wireless communications and Lantronix device server technology, the WiBox simplifies connectivity to devices where cabling is prohibited or mobility is required.

Serial RS-232/422/485 flexibility, WEP security, robust data handling capabilities and high serial speeds are all built in. The included DeviceInstaller configuration software simplifies setup. Flash memory provides maintenance-free, non-volatile storage of web pages, and allows future system software upgrades.

WiBox is a transparent, cost-effective and scalable means to network-enable any serial device. You will not need to change the way you work or develop special software to take advantage of wireless networking capabilities. By connecting two WiBox units via a network, virtual serial connections can be extended across any facility or around the world.

Conclusion

Over the past decade, wireless local area networks have played a key role in revolutionizing the use of technology in our society. In the office and at home, and now in medical/healthcare, car rental, retail, industrial automation, and other business infrastructures, wireless connectivity is permeating every aspect of our lives. Designers who want to capitalize on this growth need a convenient, cost-effective, and easy-to-install solution for adding wireless connectivity to their embedded designs.

WiPort provides that solution. Boasting easy installation and high performance with a fraction of the footprint, WiPort adds to your bottom line by significantly reducing product development time, risk, and cost. And best of all, it's backed by Lantronix, the industry leader in wireless and wired connectivity solutions.

Lantronix continues to receive recognition from the industry as well. Leading U.S.-based embedded electronics publications that include EE Times ("Product of the Week") and Electronic Products Magazine ("Product Highlights") have recognized Lantronix's innovative solutions.

Additionally, Lantronix maintains a staff of highly skilled networking specialists who possess in-depth knowledge of serial and network connectivity. Support ranges from basic configuration and troubleshooting to guidance in creating custom web pages and using configurable I/O pins to read or set triggers for unique signal indicators. Technical support is available to customers at no additional charge via phone, e-mail, and the Web. Real-time phone support is available for US domestic clients from 6:00 am to 5:30 pm PST via our toll-free support phone number. Lantronix also provides an online knowledge base, video-configuration tutorials, chat support, and “live assist” — a virtual onsite systems engineer that allows secure, shared control of your personal computer.

To learn more about our WLAN and other solutions, please visit www.lantronix.com.

Glossary

Complementary Code Keying (CCK)	A set of 64 eight-bit code words used to encode data for 5.5 and 11Mbps data rates in the 2.4GHz band of 802.11b wireless networking. The code words have unique mathematical properties that allow them to be correctly distinguished from one another by a receiver even in the presence of substantial noise and multipath interference.
Carrier sense multiple access with collision avoidance (CSMA/CA)	A protocol that works as follows. When a node receives a packet to be transmitted, it listens to ensure no other node is transmitting. If the channel is clear, it transmits the packet. Otherwise, it chooses a random "backoff factor" that determines the amount of time the node waits until it is allowed to transmit its packet. During periods in which the channel is clear, the transmitting node decrements its backoff counter. (When the channel is busy it does not decrement its backoff counter.) When the backoff counter reaches zero, the node transmits the packet. Since the probability that two nodes will choose the same backoff factor is small, collisions between packets are minimized.
Direct sequence spread spectrum (DSSS)	DSSS works by transmitting simultaneously across several different frequencies. This increases the probability that transmitted data will reach the destination. In addition, redundant bit patterns, called "chips," are included in the signal. At any given time, parts of the signal are received simultaneously on the different frequencies at the receiver. To receive and decode the complete signal successfully, the receiving station must know the correct decoding pattern. To trace and decode data during the transmission is extremely difficult. The disadvantage of DSSS relative to FHSS is its higher vulnerability to narrowband interferences.
Frequency hopping spread spectrum (FHSS)	FHSS uses a set of narrow channels from 2,402-2,480 MHz and "hops" through all of them in a predetermined sequence every 20-400 ms. FHSS is superior to DSSS in terms of immunity to interference. Strong interference in a segment of the band may hamper some transmissions, but FHSS transmitters will use the remainder of the band effectively. Users may see a decrease in throughput, but the network will continue to operate.
IEEE	Abbreviation of Institute of Electrical and Electronics Engineers, pronounced I-triple-E. Founded in 1884, the IEEE was formed in 1963 as an organization composed of engineers, scientists, and students. The IEEE is best known for developing standards for the computer and electronics industry. In particular, the IEEE 802 standards for Local Area Networks are widely followed.
Nodes	A computer or other device. Every node has a unique network address, sometimes called a Data Link Control (DLC) address or Media Access Control (MAC) address.
Orthogonal Frequency Division Multiplexing (OFDM)	A frequency-division multiplexing modulation technique for transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. OFDM reduces the amount of crosstalk in signal transmissions. 802.11a WLAN technology uses OFDM.