Lesson 1: Wireless Technology

At a Glance

This lesson will look at the underlying technology that allows transmitting data through the air. It begins with a review of the radio frequency spectrum. The 802.11 Standard defines how wireless networks should make the best use of limited frequencies, how they should handle data, and how they should connect to existing networks.

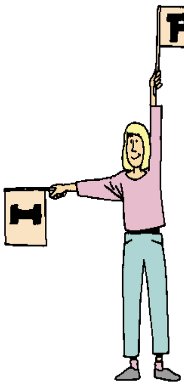
What You Will Learn

After completing this lesson, you will be able to do the following:

- Explain the basics of wireless transmissions and frequency allocation
- Explain the purpose of the IEEE 802.11 Standard and describe several wireless issues that it addresses
- Describe several technologies for improved wireless transmissions including multiplexing, spread spectrum, collision avoidance protocol, and Mobile IP

Student Notes:

Tech Talk



- **CDMA**—(Code division multiple access) A multiplexing technique that allows all users to share all channels at the same time. Each user's data is transmitted in pieces and each piece is coded to identify it as belonging to that particular user.
- **DSSS**—(Direct signal spread spectrum) A transmission technique that replaces each bit of data to be transmitted with a long pseudo-random pattern of bits. The receiver must decode the patterns to demodulate the data.
- **FHSS**—(Frequency hopping spread spectrum) A transmission technique that rapidly changes channels in a pseudo-random pattern while sending the signal. The receiver must change channels in the same pattern.
- **Hopping pattern**—The sequence of channels used in FHSS.
- **Middleware**—The software on a wireless network that improves the interface between the end-user devices and the wired network running TCP/IP.
- **Mobile IP**—A protocol that provides a temporary forwarding address for mobile wireless users so that the IP network can continue to send them data when they change their physical location.
- **Modulation**—Changing a radio wave to carry information.
- **Spread spectrum**—One of a number of techniques for wireless transmission that spreads a signal over a wide range.
- **TDMA**—(Time division multiple access) A multiplexing technique that divides a frequency into a repeating sequence of timeslots, each of which can be assigned to a different user.

Basic Concepts

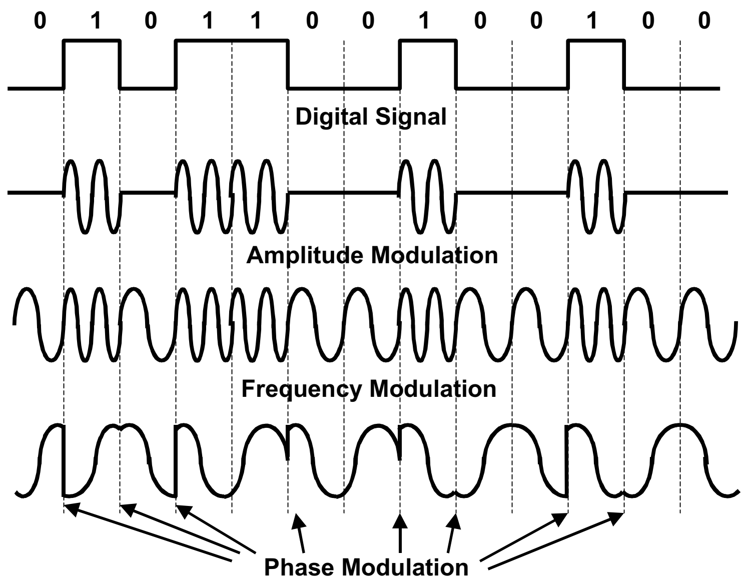
Before learning about the various ways that data is transmitted over wireless networks, there are some basic concepts about radio transmissions that must be understood.

Radio transmissions

Radio transmissions use the electromagnetic waves generated by an electrical circuit. The German physicist Heinrich Hertz first observed these waves in 1887. In 1893, in St. Louis, Nikola Tesla connected an antenna to an electrical circuit and transmitted the electromagnetic waves to a receiver. Guglielmo Marconi was the first to put together a viable "large scale" transmission system and in 1901 he transmitted the three-dot Morse code symbol for ``S'' from Cornwall, England, to St. John's, Newfoundland. Marconi won the Nobel Prize in 1909 and he is generally considered the father of radio even though the Supreme Court eventually decided that Marconi had infringed on Tesla's patents.

Marconi managed to generate radio waves and then modulate them to communicate information. He modulated the waves manually, by turning them on and off. Modern wireless transmissions still work on the same principle but modern techniques of modulation are much more complicated.

Modulation Techniques

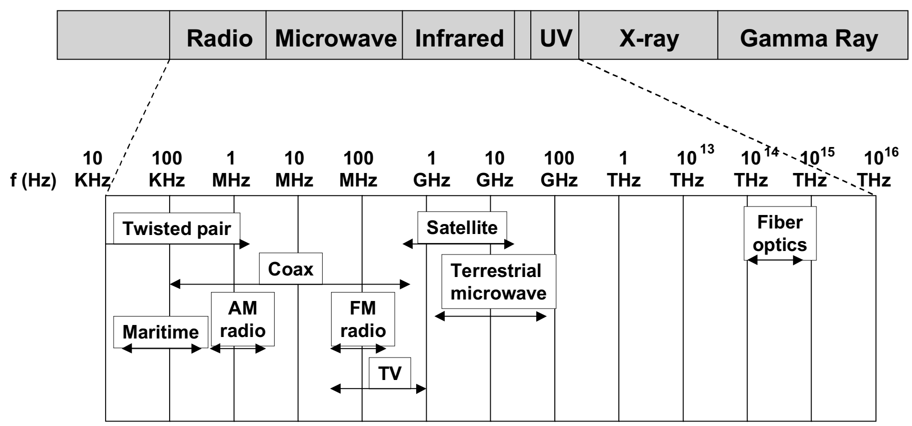


Modulation techniques are classified into amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM). AM and FM radio use the modulation types they are named for. Wireless data transmission uses versions of frequency modulation and phase modulation.

How much information can a wave carry?

Modulation allows electromagnetic waves to carry information. The electromagnetic spectrum is the complete range of frequencies from cosmic and gamma rays found in space, to sub-audible radio waves with wavelengths of thousands of kilometers. Within this range are radio, microwave, visible light and infrared waves, which can all be modulated.

The Electromagnetic Spectrum



Bandwidth is the amount of frequency spectrum between the lowest and highest frequencies. The wider the band, the more information can be transmitted. A typical channel is 30 kilohertz wide. This is three times the ten kHz allowed an AM radio station even though the radio station might broadcast with 50,000 watts and the cellular telephone call might transmit with only one watt. More power does not mean more bandwidth. A high-powered signal can use a narrow bandwidth.

Because everyone transmitting data wants the highest data rate possible, everyone wants as much bandwidth as they can get.

Frequency allocation

Within the radio and microwave spectrum, the US Government (specifically, the Federal Communications Commission and the National Telecommunications and Information Administration) regulates which frequencies can be used for which purposes. The governments of other countries have their own regulations. The chart on the next page provides a summary of radio frequency allocation in the United States. For example, the frequencies between 535 kHz and 1605 kHz are allocated to AM radio. FM radio is allocated frequencies between 88 MHz and 108 MHz. Notice that the range called High Frequency is not very high in the overall spectrum. When the names were given, the higher frequencies could not be measured yet. No one knew that frequencies in the gigahertz range would some day be regularly used.

Cellular and PCS data transmissions are allocated various ranges of frequencies in the Ultra High Frequency (300 MHz to 3 GHz) range. Cellular frequencies start at 824 MHz and end at 894 MHz. PCS frequencies start at 1850 MHz and end at 1990 MHz. TV channels 14 to 70 also occupy this band, from 470 to 806 MHz.

Converting between frequency and wavelength

Frequency ranges in the allocation chart are separated at 3, 30, 300, etc because the ranges were originally based on wavelength: 1 to 10 meters, 10 to 100 meters, etc. Because all electromagnetic waves travel at the speed of light in a vacuum, wavelength is converted into frequency using the formula:

(wavelength)x(frequency)=(speed of light)

$$\lambda f = c$$

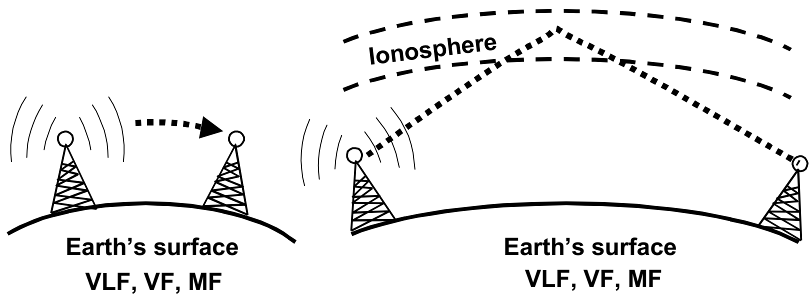
The speed of light is 300,000,000 meters/second. If the wavelength of the light is 1 meter, then 300,000,000 wavelengths pass in one second. Light with a wavelength of one meter has a frequency of 300 megahertz (MHz). When technology made it possible to measure very small wavelengths, it became more practical to measure by frequency.

Band Designation	**Frequency Range**	**Wavelength**	**Usage**
Extremely Low Frequency (ELF) and Super Low Frequency (SLF)	3 Hz – 3 kHz		US military Project ELF (to communicate with submarines).
Very Low Frequency (VLF) Radio	3 kHz – 30 kHz	100 Km – 10 Km	Navigation, Weather, Submarine Communications
Low Frequency (LF) Radio also called Long Wave	30 kHz – 300 kHz	10 Km – 1 Km	Navigation, Maritime Communications,
Medium Frequency (MF) Radio also called Medium Wave	300 kHz – 3 MHz	1 Km – 100 m	Navigation, AM Radio
High Frequency (HF) Radio also called Short Wave	3 MHz – 30 MHz	100 m – 10 m	Citizens Band (CB) Radio
Very High Frequency (VHF) Radio	30 MHz – 300 MHz	10 m – 1 m	Amateur (HAM) Radio, VHF TV, FM Radio, aircraft
Ultra High Frequency (UHF) Radio	300 MHz – 3 GHz	1 m – 10 cm	Microwave Satellite, UHF TV, Cordless phones
Super High Frequency (SHF) Radio	3 GHz – 30 GHz	10 cm – 1 cm	Microwave Satellite, Wireless data networks
Extremely High Frequency (EHF) Radio	30 GHz – 300 GHz	1 cm – 1 mm	Microwave Satellite, Wireless data networks
Infrared			
Visible		700 nm – 400 nm	

Properties of waves

The frequency of a radio wave determines the amount of data it can carry. The frequency also determines how the wave travels through space. Low frequency waves are omnidirectional, they propagate in all directions. VLF, LF, and MF radio (including AM radio) waves follow the curvature of the earth and can travel for long distances. Waves in the HF can travel even longer distances because they bounce off the ionosphere. Ham radio operators use the HF bands.

How radio waves travel



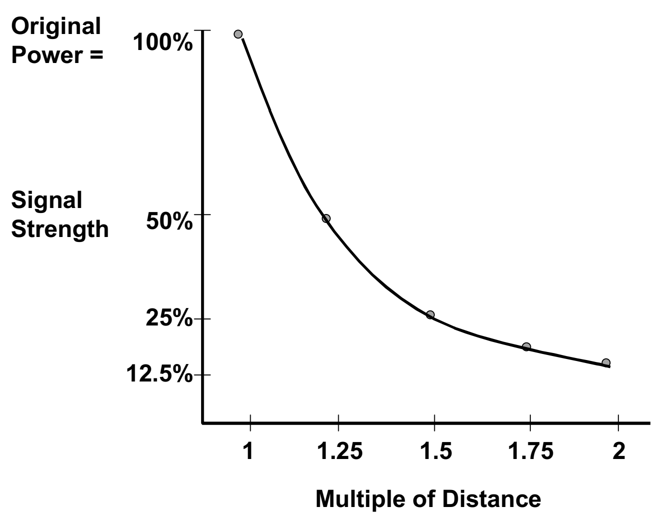
Lower frequency radio waves can pass through buildings, which makes them useful for radio and TV stations. They tend to attenuate sharply as they propagate.

A radio signal weakens in proportion to the distance. The formula for attenuation is

$$\text{change in signal strength} = (\text{change in distance})^{3}$$

If the distance is doubled from the source of a radio signal, the signal will only be 1/8 as strong. This is why AM radio stations that want to reach a large area must transmit with high power.

AM Radio wave attenuation

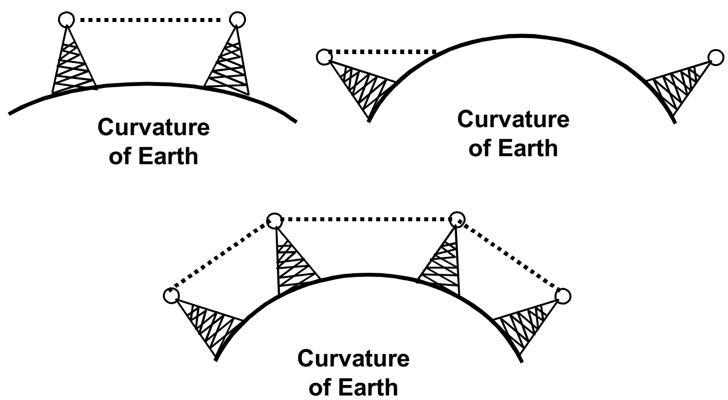


At high frequencies (in the microwave range), radio waves travel in straight lines, which makes them better for transmissions to a focused point, such as an antenna on a building. Telephone companies previously used microwaves to create long distance phone links less expensively than stringing or burying cable. MCI stands for Microwave Communications, Inc. because it began competing with AT&T by using microwave links.

Because the waves travel in a straight line, they cannot travel for very long distances without a repeater to keep the waves above the curvature of the Earth. Higher towers can transmit over longer distances.

Unlike lower frequency radio waves, microwaves bounce off of buildings. Rain and snow can also absorb them. This is how microwave ovens work, the water in the food absorbs the high frequency radio waves and the energy of the waves is transferred into the water molecules in the form of heat.

How microwaves travel



Despite the problems, microwaves are widely used for telephones, cellular phones, wireless LANs, transmissions from satellites, and even microwave ovens and garage door openers operate in these frequency ranges. There simply is not enough frequency for each device to have its own, so it is very important to make the best use of the frequencies allocated.

Analog vs. digital

The first wireless transmissions, before computers, were analog and much of the cellular phone system in the US still uses an analog system called AMPS (analog mobile phone service). In an analog transmission, the signal tries to reflect or imitate the source. If one spoke into a microphone connected to an oscilloscope (a device that displays sound waves as a visual pattern) the pattern would look the same as if one had transmitted their voice by analog transmission and then connected the receiver to an oscilloscope. The only difference would be that the signal that was transmitted would be at a higher frequency.

If one transmitted their voice digitally and then connected the receiver to an oscilloscope, the pattern would look nothing like the wave pattern of their voice. The digital pattern is a code for their voice. The code can be understood by the receiver and translated back into the sound of their voice.

Think of analog and digital watches to understand the difference. The second hand on an analog watch is constantly moving. As the second hand sweeps around the face of the watch, the information that is displayed is constantly changing. It tries to imitate what is really happening. A digital watch, on the other hand, only changes once every second or every minute. It translates the information, time, into a code, the numbers. An analog system is like the watch with a second hand. It attempts to recreate the information as it actually happens. The digital system takes the information and represents it as a series of changes, or "bits," that are represented in code by zeros and ones.

Frequency modulation for transmitting digital signals is called frequency-shift keying because the signal shifts between two frequencies. To send a 1 using digital frequency modulation, the signal is modulated to slightly higher than the middle of the 1 MHz band. To send a 0, the signal is modulated to slightly lower than the middle. The signal always stays within the 1 MHz range of the particular channel.

The convergence of voice and data networks will eventually require that all transmissions be digital. Digital transmission is faster and less expensive that analog transmissions. Because computers are digital devices, it makes sense to use digital transmission for data. This eliminates the need to convert the computer signal into an analog signal for transmission and then back to a digital signal when the computer at the other end receives it. But using digital transmission for analog sources, such as voice, means that the sound must be converted into digital data. The telephone network began converting the lines and switching facilities from analog to digital in the mid-1960s and it is just about entirely digital today. The only analog portion left is the handset on the telephone.

IEEE 802.11 Standard

The IEEE Standard for Wireless LAN Medium Access (MAC) and Physical Layer (PHY) Specifications was introduced in June 1997. Before then, companies manufacturing wireless equipment or providing wireless transmission services had created their own methods for such things as handling data and connecting wireless networks with wired networks. This created problems for customers because they often could not get equipment to work together if it came from different suppliers. It also meant that if another manufacturer came out with a new feature, it probably could not be used without changing the entire wireless network to use that manufacturer’s equipment.

The standard makes it easier to comparison shop for equipment since equipment from different vendors can be combined. Customers can also be sure that the equipment they buy today will work with equipment that comes out next year or even next month. The standard also reduces costs for manufacturers since they do not have to make their equipment work differently with each other vendor's products.

Overview

802.11 standardizes 1 Mbps to 2 Mbps wireless LAN devices. The next version of 802.11 will probably include 10 Mbps wireless networks because 2 Mbps is not enough bandwidth for video. The standard makes the following recommendations for how to deal with those issues:

- To conserve power in battery operated devices, the standard calls for the wireless device to sleep whenever possible to conserve power but to wake up periodically and retrieve messages from a queue where they collect while the radio sleeps.
- Because bandwidth is limited for wireless, the standard calls for compressed data and increased data rates.
- Because wireless signals can be captured from the air, especially when they are transmitted over long distances, the standard calls for added security.
- Because wireless users are moving, their location does not always correspond to their address. The standard defines Mobile IP to handle changing locations

OSI Layers

The primary goal of the 802.11 standard is to define how the MAC layer (OSI Layer 2) and the physical layer (OSI Layer 1) in a wireless network should operate so that they pass data in a standard way to the higher layers.

As on a wired network, a wireless network device that wants to transmit must monitor the transmission medium and wait for a time when no other device is transmitting. On an Ethernet network this procedure is called Carrier Sense Multiple Access /Collision Detection (CSMA/CD). For wireless networks, the standard defines that the MAC layer should use Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). Detecting collisions requires that the device listen for a collision after it transmits. But a wireless device cannot "listen" to the same frequency it transmits on. Wireless transmissions require two channels, one for sending and one for receiving. So, wireless devices cannot detect collisions, they can only attempt to avoid them.

To make the most efficient use of available frequencies, the 802.11 standard defines three allowable physical layers: Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS), and Infrared Light.

The standard does not cover every aspect of wireless technology. For example, it does not specify how roaming from one access point to another should work. Companies that manufacture wireless equipment have developed their own roaming protocols.

Check Your Understanding

- Why might the 802.11 Standard encourage more people to invest in wireless technology?

Multiplexing

Wired networks try to achieve the highest bandwidth possible by using multiplexing technologies and advanced switching technologies, and high capacity media such as fiber optic. Wireless systems also try to achieve the highest bandwidth possible.

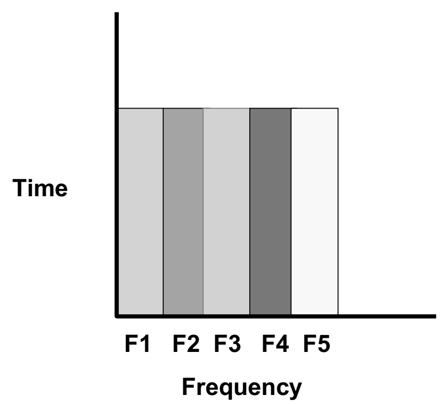
Cellular systems try to make the most efficient use of a limited number of frequencies by dividing frequency use geographically. Different cells can transmit on the same frequencies as long as the cells are distant enough so that their transmissions do not reach one another. Frequency reuse is not sufficient in places like large cities where there are large numbers of people using wireless telecommunications. Additional technologies must be used. Multiplexing (just as on a wired network) can allow many users to share the same frequencies. Multiplexing allows a wireless network to get the most use out of each frequency.

Frequency Division Multiple Access

The first multiplexing technique that was used for analog cellular systems divided the particular cellular frequency into a certain number of channels. A channel is a pair of radio frequencies, one to receive on and one to transmit.

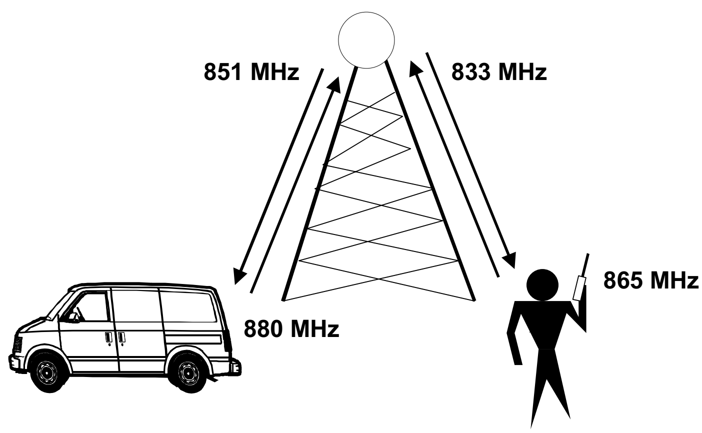
Frequency Division Multiple Access

Frequency Division Multiple Access



This technique called Frequency Division Multiple Access (FDMA) requires two channels, one for transmission and one for receiving, for each call. An AMPS network might have 666 channel pairs for handling 666 calls at a time. FDMA was an adequate technology until mobile phone use skyrocketed in the 1980s. Then cellular networks needed a way to pack more calls into the same frequency band.

Frequencies and channels

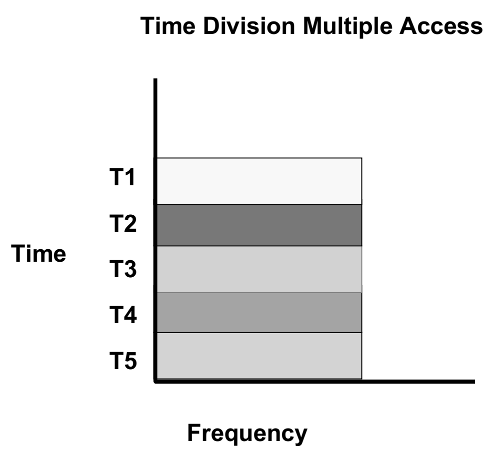


The solution was to switch from analog to digital. Digital transmissions break a message into frames. Each frame contains part of the data and is identified as to where that data fits into the whole transmission. Using this identifying information, the receiver reassembles the data from the frames. Data from multiple users can share the same frequency because the frames identify which data belongs to whom. The two main underlying schemes for dividing a digital signal are Time Division and Code Division.

Time Division Multiple Access

Time Division Multiple Access allows many users to transmit on the same frequency by taking turns. Each device gets its turn, called a time slot, at a specified time in a cycle that repeats endlessly. For example, there might be eight time slots on a particular channel. A device that is assigned time slot 1 can transmit data each time that time slot comes around. If the device is finished sending data, that time slot becomes available and another device can start using it. Each frame can carry a certain number of slots. TDMA is the basis GSM (Global System for Mobilization), which is the standard used for Personal Communication Services (PCS).

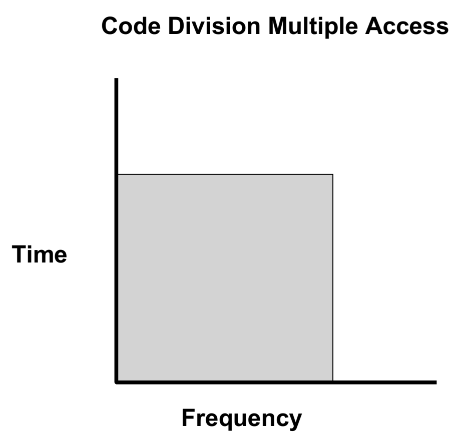
TDMA



Code Division Multiple Access

Code Division Multiple Access (CDMA) is the most advanced technology. In CDMA, all users share all channels at the same time. Each user's data is transmitted in pieces and each piece is coded to identify it as belonging to that particular user. All of the pieces from all users are transmitted at the same time using the entire spectrum of frequencies available. At the receiving end, the signal is decrypted with a matching code. Without the code, one would only hear a type of white noise on the channel. Code Division Multiple Access is also known as spread spectrum, the physical layer defined by the 802.11 standard.

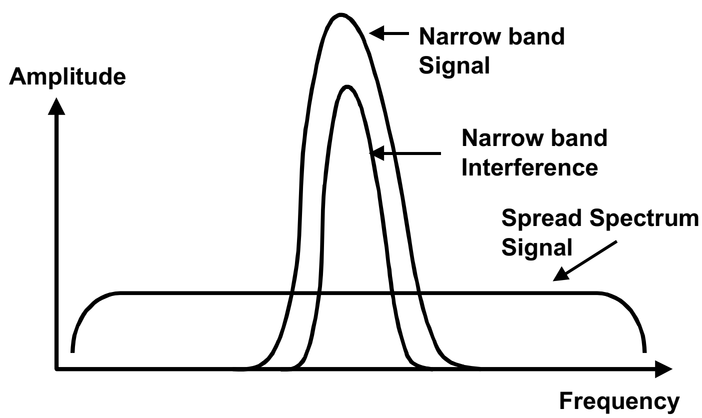
CDMA



Spread Spectrum

In general, spread spectrum distributes a signal over a wide range of frequencies, often 200 times the bandwidth of the original signal. The receiver has prearranged information about how to collect the signals. Most technologies try to use the least amount of bandwidth possible but spread spectrum intentionally uses much more bandwidth. Spread spectrum spreads the signal over a wide range of frequency but at such low power that it does not interfere with anything else transmitting at that frequency. To another device using the same frequency range, spread spectrum transmissions are nothing more than low level background noise. But the signal is clear to a receiver that knows how to decode the spread spectrum transmission.

Spread Spectrum Modulation

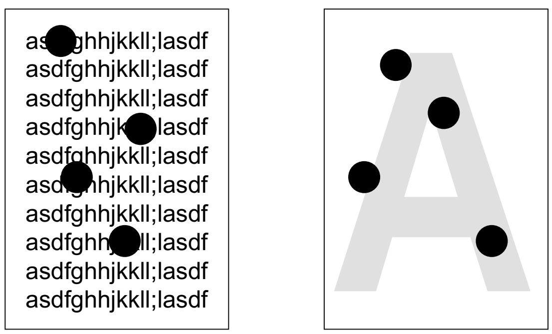


To understand spread spectrum, think of a broken laser printer or photocopier that puts black spots in random places on every page it prints. Imagine the need to print a message to someone on that laser printer. It is better to write using huge letters rather than small ones. If black spots get on a page with a message printed in huge letters, the message will probably still be legible. Whereas, if black spots get on a page with small letters they might completely cover some of the letters and one might have a difficult time figuring out what the message said.

The black spots are like interference caused by other transmissions. Printing huge letters is like transmitting a signal over a wide range of frequencies. If interference affected one or a few frequencies, the signal would still be understandable from the data on the unaffected frequencies.

To transmit a radio signal over a wide range of frequencies would require much more power than transmission using a single frequency. Using more power for one signal will likely cause it to interfere with others. Using more power is also much more expensive, not permitted by the FCC, and not compliant with the 802.11 standard. So, simply transmitting over a wide range of frequencies is not a suitable way to overcome interference and share the radio frequency spectrum with others.

How spread spectrum works



The solution is to print huge letters but using very little ink—huge light gray letters. If black spots get on a page with huge gray letters, the message will still be readable. This is the equivalent of spreading a signal across a wide range of frequencies but using very low power. Because the transmit power is so low, the signal will not interfere with any other signal using that frequency. To other signals, the low power transmission will sound like the background noise that is present all the time anyway. Spread spectrum offers two ways to use transmit a radio signal over a wide range of frequencies using very low power.

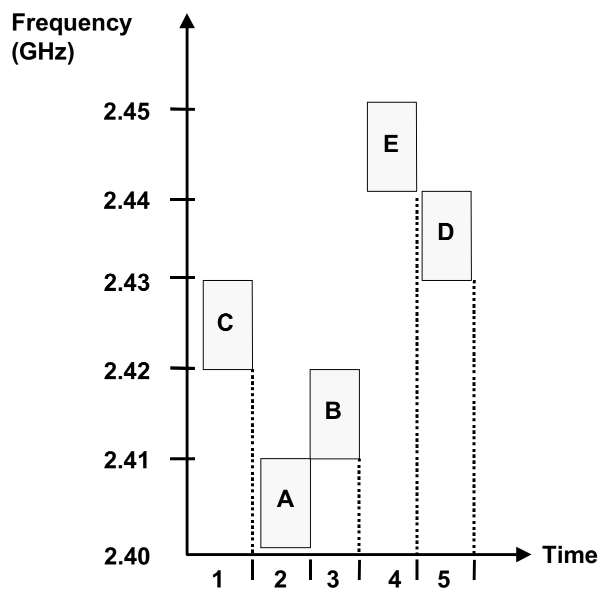
FHSS

Hedy Lamarr, a famous actress, and film score composer George Antheil invented frequency hopping spread spectrum (FHSS) technology during World War II to provide jam-proof communication for guided torpedoes. They received a patent, but the Navy never used the technology because it used player piano rolls, which the Navy thought would not work. The technology had to wait until it could be done electronically rather than mechanically. It was first actually used during the Cuban Missile Crisis in 1962.

FHSS changes frequencies at split second intervals as it transmits. The sender and receiver change frequencies together following a table called a hopping pattern. Imagine talking on a 90-channel cordless phone with a friend also talking on a 10-channel cordless phone. As the conversation progresses, a table is consulted that directs each speaker to talk for 15 seconds on channel 1 then switch to channel 5 for 15 seconds then to channel 8 then to channel 4, etc. That is the basis of FHSS, except that the channel switching happens much faster.

FHSS divides the frequency range into a certain number of channels. In the United States, the frequency range from 2.402 to 2.480 GHz is divided into 79 channels, each 1 MHz wide.

Frequency Hopping Spread Spectrum (FHSS)



The hopping pattern appears to be a randomly ordered sequence of those 79 channels. If interference happens on any particular channel, the chance is very low that it will significantly affect the transmission because the signal only transmits on that frequency for a split second at random intervals.

There are many different hopping patterns and they are designed so that they interfere with one another as little as possible. This allows multiple access points to be grouped in a single area to increase bandwidth. Of course the access points must use different hopping patterns so that they do not interfere with one another.

During the split second that the signal spends on a particular 1 MHz channel, the data transmits using FM (frequency modulation). Of the three physical layers specified by 802.11, FHSS uses the least power and has the lowest cost. It is the most tolerant to interference and it provides good security. Someone trying to intercept the data would need to know the hopping pattern.

DSSS

Direct Sequence Spread Spectrum costs more than FHSS and uses more power but it can achieve higher data rates. It is also much more complicated. In DSSS, the sender's device modulates the data by sending a pseudo-random pattern of bits in place of each bit of the original data.

Direct Sequence Spread Spectrum (DSSS)

Replacement Code: 0 = 11101100011
1 = 00010011100

Data Stream: 101

Transmitted Sequence:

000100111001110110001100010011100

The string of bits that replace each original bit makes the transmission much longer but it also makes it very unlikely that interference will significantly affect the transmission. The receiver knows the patterns that replace each actual data bit. If some of the bits in a pattern are lost, the receiving end can recreate the pattern based on what does get through. From the pattern, the receiver can demodulate to get the actual data.

Check Your Understanding

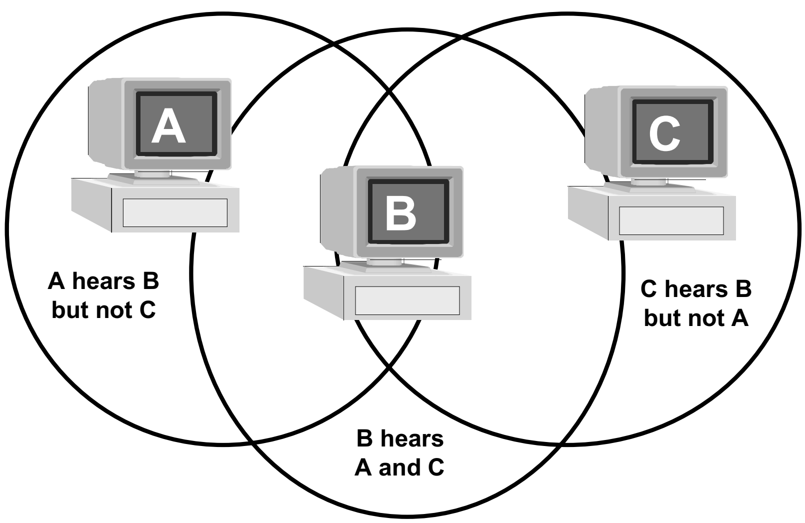
- Why does the FCC require that FHSS hop at a minimum rate of 2.5 hops per second and a minimum hop distance of 6 MHz?
- To a receiver that does not have the hopping sequence for FHSS or the bit patterns for DSSS, what does a spread spectrum signal sound like?

Wireless LAN Protocols

A device on a wired Ethernet network uses CSMA (Carrier Sense Multiple Access) to detect whether another station is transmitting. This works well when the device can listen for transmissions from any other device. However, in a wireless network, two transmitting stations may be out of range of one another. They might both try to transmit to a third station at the same time, with the result being that the receiving station cannot understand either transmission.

To handle this, devices on wireless networks, use a protocol called MACA (Multiple Access with Collision Avoidance). In this protocol, when a receiving device receives a request to send (RTS), it responds with a Clear to Send (CTS). Other devices in the range of the sending device hear the RTS so they wait before transmitting. Devices in the range of the receiving device that did not hear the RTS still hear the CTS so they also wait to transmit until the sending device is finished. In contrast to a wired network, collision avoidance is handled by the receiver rather than by the sender.

Hidden station problem



Wireless IP

The TCP/IP protocol suite enables connections to the Internet and to other networks. Wireless technologies provide the lower level connections over which Transmission Control Protocol/Internet Protocol (TCP/IP) operates.

High bandwidth

TCP is connection-oriented. That means it sends a lot of messages whose purpose is to set up or break off a logical connection or to control the flow of data or to acknowledge that a message has been received. All of these messages add to the bandwidth needed for the actual data being sent. Because wireless networks have (for now) more limited bandwidth than wired networks, using TCP/IP can overwhelm a wireless network, resulting in data loss. Another problem is that wireless networks are more likely to experience transmission interruptions than wired networks. For example, when a mobile user moves from the area of one access point to another, an interruption might occur during the hand-off. When TCP experiences an interruption, it requests that the data be resent. Many requests for resending increase the bandwidth demand even more. If TCP experiences too much data loss, it will terminate the connection. This is a particular problem during hand-offs from one access point and when the signal weakens as a user moves through the farthest reaches of an access point antenna's propagation area.

Middleware is additional software that runs in between the wireless device and the wired TCP/IP network. It might reside on a separate server that lives between the access point of a wireless LAN and the backbone of the TCP/IP network. Middleware improves the performance of wireless devices with TCP/IP networks through various techniques including the following.

- Compressing data to reduce the bandwidth demand on the wireless network.
- Keeping track of transmissions so that if they are interrupted they can start again where they left off instead of from the beginning.
- Bundling small packets into larger ones.
- Storing messages for a wireless user who is temporarily off the network.
- Mobile IP.

Middleware can be much more expensive to buy for each wireless device, but the increase in performance can save money in the long run. Of course, as the bandwidth capacity of wireless networks increases, the need for middleware should decrease.

IP Addresses

IP addresses identify devices on an IP network. Usually when a user logs onto an IP network, he or she is assigned an IP address (by a protocol called DHCP) that is used until he or she logs off. Routers run protocols that learn the location of devices by listening for which router port (that is, which subnet) the devices are connected to. From this information, routers build tables matching IP addresses with specific ports on the router. When a mobile device changes locations, it can confuse the router.

Mobile IP provides a solution to the moving IP address problem. It works like a temporary forwarding address from the post office. When one takes a wireless device into a different subnet, Mobile IP assigns the device an “in care of” address in the current subnet and notifies the home network where to send messages. Now all messages sent to the computer will be forwarded to the user at the “in care of” address.

Mobile IP is not simple to implement if one is concerned about security. A firewall is designed specifically to prevent access by devices with addresses from outside the subnet. To allow Mobile IP, firewalls must allow Mobile IP messages to pass.

Wireless Internet

Because web pages use a lot of graphics and require high bandwidth, a mobile device that allows surfing the web as one would through a wired network will have to wait until the bandwidth of wireless links improves. A current example of a wireless Internet application that makes use of middleware, Mobile IP, and digital signals over the cellular telephone network is AT&T's PocketNet service. The middleware is specially designed to extract the information from a web page and send that information over a 19.2 Kbps Cellular Digital Packet Data link. The data is formatted so that it fits on the tiny screen of a hand held wireless device. Users get an IP address when they buy the hand held device and e-mail can be forwarded to that address from anywhere.

Check Your Understanding

- ♦ Why does a mobile user moving from cell to cell cause problems for TCP/IP transmissions over wireless?

Try It Out: Guest Speakers

Materials Needed:

- Windows 95 PC
- Any Word Processor (e.g., MS Word)
- Pen/Pencil and Paper

Invite a representative from one or more of the wireless telecommunication service providers in your area to come to your class and make a presentation.

1. Before you contact each speaker, draw up a list of ten questions you would like to ask. Possible questions might include
   a. What are some of the cutting-edge wireless devices you are now selling?
   b. How do these compare to the technology of one year ago?
   c. What do you see as the next major advances in telecommunications technology?
   d. Where can these devices be used?
2. Contact the speaker and invite him or her to the classroom at a time pre-arranged with your teacher.
3. Take notes during the presentation.
4. At the end of the presentation, compile your notes and write a one or two paragraph summary.

Invite a network administrator from a company that employs wireless technology in its network to describe his or her network. Questions you might ask include:

a. Why did you choose wireless technology over wired

b. How did the initial cost of the wireless components compare with wired components (if you could have used them)?

c. How does the throughput on the wireless portion of the network compare to the rest of the network?

d. Did you encounter any unforeseen problems, for example, interference from radio sources inside or outside the office?

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
List of questions	30	
Participation during presentation	30	
Written summary	40	
TOTAL	**100**	

Stretch Yourself:

Materials Needed:

- Windows 95 PC
- Any Word Processor (e.g., MS Word)
- Lesson Resources
- Internet Connection (optional)
- Pen/Pencil and Paper
- Color Pencils for drawings (optional) or Model materials such as paper mache (optional)

This lesson has only begun to introduce the fundamental concepts of wireless telecommunications. There are many opportunities for further research into topics of interest. Choose a topic from the following list or create your own with approval from your teacher. Use the resources listed at the end of the lesson as a starting point for your research. Prepare a 10-minute oral presentation on your topic. Be sure to use such visuals as drawings or models of equipment (or the real thing if you can supply it), maps, timelines, or diagrams.

1. Choose a product new to market or in development and research its purpose, the equipment it will replace if any, and whether it employs new technology. At the end of your presentation, make a prediction of the effect on computer networking this new product will have.
2. Using the chart of US frequency allocations from the National Telecommunications and Infrastructure Administration, do a presentation on how the frequency spectrum is divided. Note familiar devices and the frequencies at which they transmit (for example, a garage door opener).
3. Research Hedy Lamar and the invention of Frequency Hopping Spread Spectrum.
4. Do a comparison of the various low earth orbit telecommunications networks (Iridium, etc). Who owns them? How much did it cost to launch all those satellites?

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
Research, use of resources	50	
Oral presentation	50	
TOTAL	**100**	

Network Wizards: Wireless Technology Recommendations

Materials Needed:

Pen/Pencil and Paper

You may work individually or in groups on this exercise.

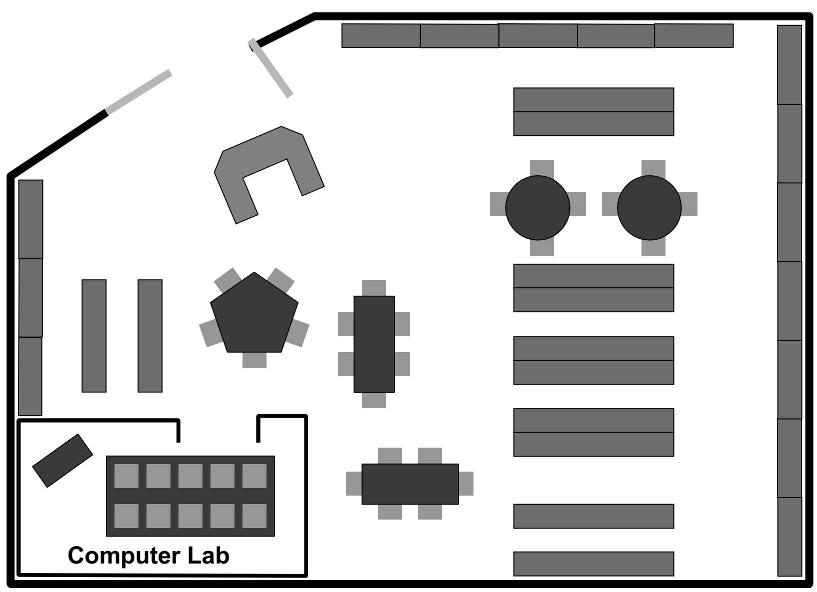
The Red Rock United School District recently received a grant to expand their network to the middle schools to give the middle schools access to the Internet. Currently, only the high schools have access. The grant is sufficient to pay for setting up a LAN in each middle school, but it stipulates that the funding must be used this school year.

The initial plan is to put at least one computer in each classroom connected to a school LAN. The LAN would connect to the high school network to use its Internet connection.

Memorial Middle School was originally built as a high school in the 1920s. The overall middle school building is 300 feet by 200 feet, three stories. The type of construction makes it very difficult to wire Memorial Middle School.

There is a computer lab but the machines are not networked. A plan of the media center is below.

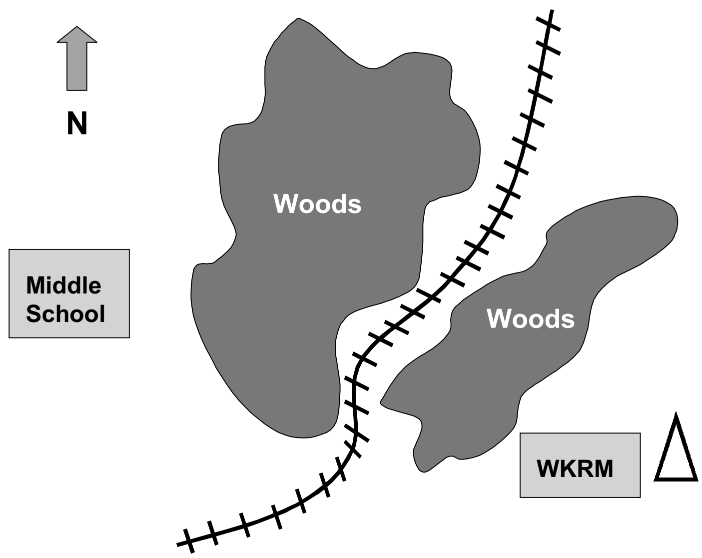
Memorial Middle School Media Center



Library

The middle school is located approximately one mile from the nearest high school. A map of the area is drawn below.

Map of Memorial Middle School local area



The population in the local area is growing rapidly. If it continues at the current pace, there will be far too many students for the middle school in about two years. The school district is already looking for space to build another middle school, which will probably hold just the seventh and eighth grades.

The middle school media director has come to you for information about wireless networking. She needs to make a presentation to the school technology committee in just a few days. Based on the information above, give a preliminary analysis about using wireless technology in Memorial Middle School. Be sure to include the following:

- What kind of wireless technology could connect the middle school to the high school? What would be the advantages and disadvantages compared to a wired link? What are some of the issues that would need to be analyzed before installing a wireless link?

- What kind of wireless technology could be used within the middle school? What would be the advantages and disadvantages compared to wiring the school.

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
Options presented	30	
Advantages and possible problems described	50	
Clarity of presentation	20	
TOTAL	**100**	

Summary

Wireless Technology

In this unit, you learned the following:

- Basic concepts of wireless transmissions and frequency allocation
- The purpose of the IEEE 802.11 Standard and several wireless issues that it addresses
- Technologies for improved wireless transmissions including multiplexing and spread spectrum, collision avoidance protocol, and Mobile IP

Review Questions

Wireless Technology

Part A:

Multiple choice

1. What types of modulation are used for wireless data transmission?
   a. AM
   b. FM
   c. PM
   d. a and b
   e. b and c
2. Which of the following is an advantage to using frequencies in the 2.4 GHz band for a wireless LAN?
   a. Equipment is less expensive
   b. Higher frequency waves travel farther
   c. The 2.4 GHz band complies with the 802.11 standard.
   d. 2.4 GHz is the lowest frequency you can use without a license.
3. Which of the following will not increase the distance a microwave signal can travel?
   a. build taller transmission towers
   b. use repeaters in between towers
   c. use more power
   d. heavy precipitation

4. Visible light can be modulated to transmit data.
    a. True
    b. False
5. A license is required for transmitting at 950 MHz.
    a. True
    b. False
6. A “900 MHz” cordless phone transmits with a power close to one watt.
    a. True
    b. False

Short Answer

7. Why isn’t ultraviolet light used for wireless data transmission?
8. Find the frequency of a 5 mm wave.
9. Find the approximate wavelength transmitted from a 950 MHz cordless phone
10. Radio antennas work best when they are the same size as the wavelength they are receiving. Most antennas are between 1 cm and 5 meters in size. What range of frequencies can be received the best?

Part B:

1. Write a paragraph that summarizes the major issues regarding wireless transmissions that are addressed by the IEEE 802.11 Standard.

Part C:

Matching (There may be more than one answer.)

1. ________	A form of analog multiplexing	A. CDMA
2. ________	Allows several people to use a specific frequency	B. FDMA
3. ________	Invented in World War II	C. FHSS
4. ________	Replaces each bit with a string of bits	D. TDMA
5. ________	Requires a hopping pattern	E. DSSS
6. ________	The standard AM or FM radio dial is an example of this	
7. ________	A form of multiplexing in which all users share all frequencies	
8. ________	A physical layer defined by 802.11 standard	

Short Answer

9. Why can't wireless networks use CSMA/CD like wired networks?

Scoring

Criteria	**%**	**Your Score**
Part A: Explain the basics of wireless transmissions and frequency allocation.	30	
Part B: Explain the purpose of the IEEE 802.11 Standard and describe several wireless issues that it addresses.	30	
Part C: Describe several technologies for improved wireless transmissions including multiplexing, spread spectrum, collision avoidance protocol, and Mobile IP.	40	
TOTAL	**100**	
Try It Out:	**100**	
Stretch Yourself:	**100**	
Network Wizards:	**100**	
FINAL TOTAL	**400**	

Resources

Bjurmark, B., et al. Cellular Technology. Available Online: http://tcbworks.cba.uga.edu/~adennis/t97/cd.htm.

Farley, T. (in progress). Digital Wireless Basics. Available Online: http://www.privateline.com/PCS/splash.htm.

Geier, J. (1999). Wireless LANs. New York: Macmillan Technical Publishing.

Glas, J. (1996). The principles of Spread Spectrum communication. Available Online: http://cas.et.tudelft.nl/~glas/ssc/techn/techniques.html.

Horak, R. (1997). Communications Systems and Networks. New York: M&T Books.

Kobb, B.Z. (1999).SpectrumGuide™ Fifth Edition. Radio Frequency Allocations in the United States, 30 MHz-300 GHz, Available Online: http://www.newsignals.com/sghome.html.

Rysavy, P. (1999) Tech Tutorial: Wireless IP: Ready to Lift Off? Available Online: http://www.data.com/issue/990307/wireless.html.

Silberman, S. (1999). "Just Say Nokia," *Wired*, September 1999, p.134.

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http://www.ntia.doc.gov/
(source for many reports including the US Frequency Allocation Chart, http://www.ntia.doc.gov/osmhome/allochrt.html)

Utility World (1998). The Shortwave Jargon Glossary. Available Online: http://www.ominous-valve.com/jargon.txt.

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