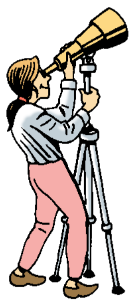
Lesson 2: Wireless Networks

At a Glance



This lesson will introduce some typical applications for wireless networks. It also covers the advantages and disadvantages of deploying a wireless LAN instead of a traditional wired network and the techniques for integrating a wireless network with an existing IP network. The lesson will conclude with a look at some of the exciting technologies that will soon be available by wireless.

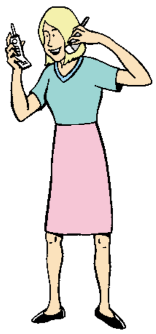
What You Will Learn

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

- Explain several advantages/disadvantages to using a wireless network
- List the basic components of a wireless network and their functions
- Describe wireless configurations for remote bridging, LANs, and WANs

Student Notes:

Tech Talk



- **3G**—Third generation; the next advance in wireless telecommunications
- **Access Point**—(remote bridge) A wireless bridge used to connect wireless devices to a network.
- **Attenuate**—To weaken.
- **Cell**—An area covered by a particular wireless base station.
- **Decibel**—(dB) A logarithmic measure used to describe the difference in power level between two points.
- **Directional antenna**—An antenna that sends a signal out in one direction.
- **Frequency reuse**—A technique for more efficiently using the limited radio spectrum available, two cells can use the same frequency if they are separated by a certain number of other cells.
- **Gain**—The degree of amplification added by an antenna.
- **Hand-off**—Transfer of a mobile user's connection from one cell to another.
- **Modulation**—Change in a radio wave to encode information.
- **MTSO**— (Mobile telephone switching office) An unmanned station that determines which cell a mobile user should connect to.
- **Omnidirectional antenna**—An antenna that sends its signal out in all directions.
- **Propagation pattern**—The coverage of an antenna.
- **PCS**—(Personal Communication Services) A wireless WAN technology that uses very small cells at low power.
- **Remote bridge**—A bridge such as a wireless link that connects two physically distant LAN segments.
- **Transmit power**—The amount of power used to send out a radio signal.
- **WNI**—(Wireless Network Interface) A network interface card that can convert the digital computer signal into a radio wave or infrared light.

Introduction

In warehouses, department stores, hospitals, car rental agencies, schools, and many other places, people need to move around while they work and yet still access files from a server, communicate with others on the network, or transmit information to a database. Wireless technology allows people to be mobile and connected at the same time. Using new versions of the familiar technology of radio, we can build computer networks more rapidly than before, link them to existing networks, and access them from mobile locations.

Why go wireless?

Mobility

There are many reasons for using wireless technology and mobility is one of the most important. Consider these examples:

- Modern hospitals keep records and up-to-the-minute status reports for patients on a master database. As doctors make their rounds they need to check these records and review their patients' progress. A wired workstation on each floor can serve this purpose but a laptop with a wireless connection saves time and allows a doctor much more flexibility.
- One of the first radio-telephone calls was made to a police car. Now police rely on wireless communications to routinely check license plate numbers, criminal records, and other information while on patrol.
- Wireless LANs allow warehouse workers to take inventory without paper. Walking up and down the aisles with a wireless bar code scanner, a warehouse employee can update a central database with the number of items in stock, how long they have been there, and their location.
- "United Parcel Service has developed a cellular system which constantly tracks each package as it is picked up, delivered, and received. Every one of the 70,000 drivers at UPS carries a "cellular clipboard" which has the ability to update UPS headquarters each time it is dropped into its carrying slot within the truck. A cellular link updates all the information the driver has entered while in route. This cellular technology also allows for headquarters to constantly update the driver to newly added pick-ups or deliveries. This technology is essential for UPS to maintain and update all package information immediately." (Bjurmark, B., et al. *Cellular Technology*)

Going where wires cannot

Wireless technology allows the set up a network without risking damage to an older building that was not designed with space for network cables. An older building might have pipes insulated with asbestos in the places where network cables could go. A wireless network would allow the installer to avoid coming in contact with toxic substances. Wireless links are particularly useful for connecting buildings that are relatively close but separated by a highway or railroad tracks or a river, making burying cable much too expensive.

Setting up in a hurry

In August 1999, Hurricane Floyd pummeled the southeast coast of the United States. North Carolina in particular had some of the worst flooding ever. The Federal Emergency Management Administration sent hundreds of workers and used cellular phones to establish a network for providing assistance to the victims.

Expanding the network

When a company expands rapidly, a major expense is connecting the new employees to the network. A wireless LAN can make connecting new workstations as easy as putting them on the desk. It eliminates the possibility of installing cables incorrectly.

Moving the network

Wireless mobility does not just mean that the end users can move around, sometimes a whole network must be mobile. When a company adds a temporary department or moves to a temporary location, a wireless network can sometimes offer a much more economical solution than rewiring a whole building.

Wireless Versus Wired

Wireless networking is not always the perfect solution. There are a number of issues that must be considered before choosing to build a wireless LAN instead of using wired Ethernet or Token Ring.

Power

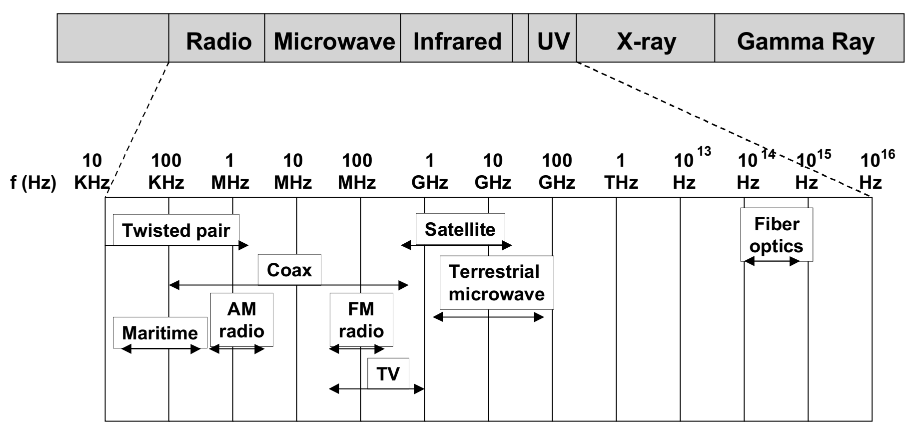
In many cases it is possible to plug in a wireless device to an electrical outlet, but many portable devices rely on battery power. NICs that must transmit radio signals are big power users. Using wireless technology means dealing with recharging batteries and conserving power as much as possible to extend battery life.

The finite spectrum and interference

The radio spectrum is a finite resource. There are only so many frequencies that can be used and there are many, many people who want to use them.

Signals on a wired network are protected from interference by transmissions on other wires because the wires are insulated. Wireless transmissions are radiated throughout the open space with no insulation; they can interfere with other transmissions using the same frequency.

The Radio Frequency Spectrum



All wireless devices must transmit on frequencies in the allocated ranges, but the government does not decide who gets to use the specific frequencies in that range, so it is possible that signals could interfere with one another. Microwave ovens, elevator motors, cordless phones and other devices, not to mention other wireless networks, can all interfere with a network's radio signal. For example, microwave ovens operate in the 2.4 GHz range that is also used by many wireless LANs.

In cases of interference, it is up to the two parties involved to work out the problem. Wireless networks use transmission technologies that are resistant to interference. One way to avoid interference is to transmit low power signals that only reach a small geographic area, or "cell." Another way is to use a multiplexing or spread spectrum technology that allows many users to share a range of frequencies.

Changing addresses

Because a wireless user moves around, connecting to the network from various locations, his or her address does not always correspond to his/her physical location. A routed IP network assigns a device an IP address based on how that device is connected to the network. If a user changes locations, he or she might connect to the network by a different port, which may result in connecting to a different subnet with a different IP address range. Wireless networks must be able to manage mobile users' IP addresses.

Security

Signals that travel over wires can be intercepted, but only if the listener is in proximity to the actual wire. Wireless signals, however, can be captured from the air, anywhere between the sender and the receiver. This is an important factor when the data traveling by wireless must be kept secret. Encryption is necessary for wireless networks to remain secure. Some multiplexing techniques, such as Frequency Hopping Spread Spectrum, make it very difficult for a non-authorized listener to intercept and understand the wireless signals.

Installing the network

Buildings, mountains, weather, the curvature of the Earth, and other factors affect the propagation of radio signals, how far they reach. The footprint of a wireless signal must be carefully planned so that it reaches everywhere it needs to. Some wireless LANs require line-of sight transmissions, that is, there must be an unobstructed space between the transmitting and receiving antennas. Managing the signal's reach is an ongoing process because new buildings get built and trees grow. Important questions that should be asked before designing a wireless LAN include (Greer, 1999):

- What is the building made of? Will the radio waves be able to pass through the walls and floors?
- Are there any trees that might block line-of-sight radio waves?
- Does it ever snow or rain heavily?
- Where can access points be located in the building? Where will the signals from these omnidirectional antennas reach?
- Can a directional antenna be installed on top of the building?

Compatibility

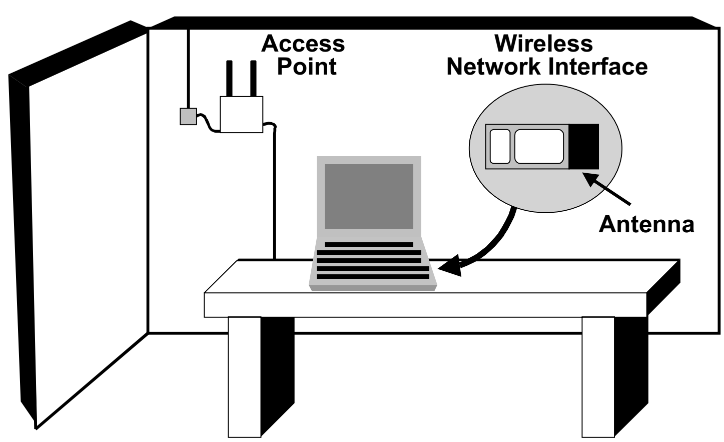
Only recently (1997) did the IEEE issue the 802.11 standard for wireless technologies. Before that, each company that built and sold hand-held devices, base stations, and the software to run them, used its own proprietary wireless system. This made it very difficult for companies that used wireless to upgrade because they had to wait for their particular vendor to make a better product. Incompatibility also made it difficult to integrate equipment from different vendors. The IEEE standard should alleviate those problems.

Wireless Network Components

End-user devices on a wireless network include workstations, laptops, palmtops, handheld PCs, and data collection devices such as bar code scanners. These devices are gaining more and more capabilities as the technology improves.

A workstation on a wired network must use a network interface card to convert the digital signal in the computer into a signal that can travel over wires. Similarly, a device on a wireless network uses a Wireless Network Interface (WNI), which is usually a NIC that can convert the digital computer signal into a radio wave or infrared light. The WNI includes a transceiver and a software driver appropriate for the device's operating system.

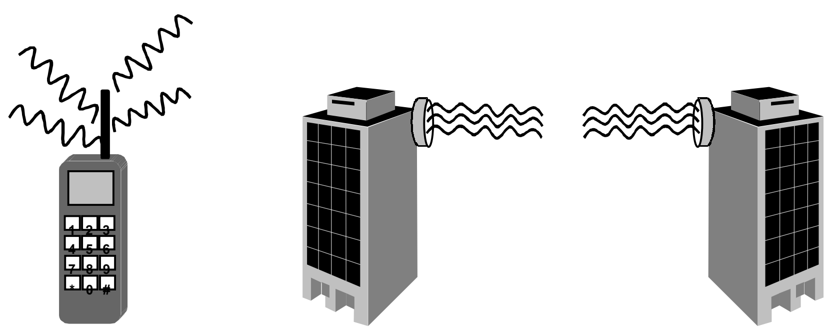
A wireless workstation



The WNI connects to an antenna that transmits and receives the radio signal. The transmit power of an antenna is measured in watts. Many radio stations use 50,000 watts of power. Wireless networks do not need to send their signals as far as a broadcast radio station and so they require much less power. Typically, the transmit power for a wireless network is one watt or less.

An antenna can increase the power of the radio signal so that it can travel farther. A good analogy is a sprinkler that sprays water in many directions. If all but one of the holes is covered, the water will spray out of the one open hole with much greater power and will travel much farther. An antenna increases the power of a radio signal by keeping the radio waves from going up but allowing them to go out toward the receiver, that is, the antenna compresses the vertical propagation to increase the horizontal propagation. The increase in power provided by an antenna is called gain and measured in decibels (dB). As a rule of thumb, a 6dB antenna will increase the power of a signal by 4 and a 9dB antenna will multiply the power by 8. A typical cellular phone antenna has a 3dB gain.

Types of antennas



Omnidirectional Antenna **Directional Antenna**

An omnidirectional antenna transmits radio waves in all directions. Its gain is equal to one, also called unity gain. For cellular phones unity gain antennas are good to use in cities where there are tall buildings or in the mountains because they allow the signal to travel up and over the buildings or mountains. Omnidirectional antennas are also good for indoor wireless networks.

A directional antenna concentrates its power in a certain direction and therefore has higher gain. A directional antenna is good for point to point connections.

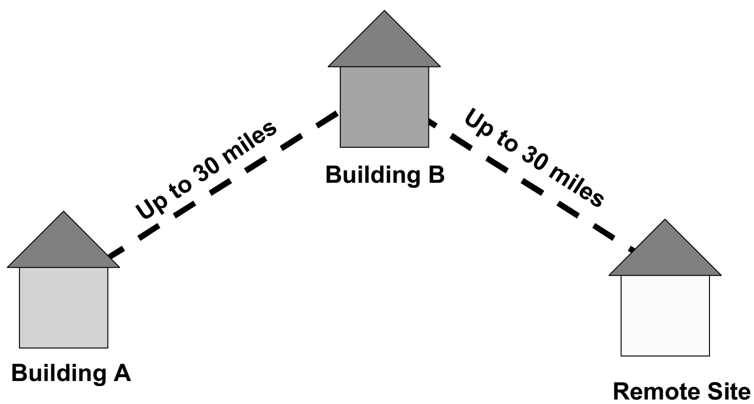
Check Your Understanding

- List three advantages and three disadvantages that wired networks have in comparison to wired networks.
- Why do newer cordless phones operate at 900 MHz?
- If you were using a cellular phone in a remote rural location, far from the nearest base station, what type of antenna would you want to use?

Wireless Point-to-Point Networks

One basic use of wireless technology is to take the place of a wired link in a wired network. A company that needs to connect computers in separate buildings to a single network could use a wireless link between buildings. A wireless link can be much less expensive than stringing or laying cable. A wireless link can also save a company the monthly fee of using the phone company's lines to connect remote sites. A wireless link acts as a bridge, called a remote bridge, segmenting the network to keep data from crossing the wireless link unless it is addressed to a destination on the other side.

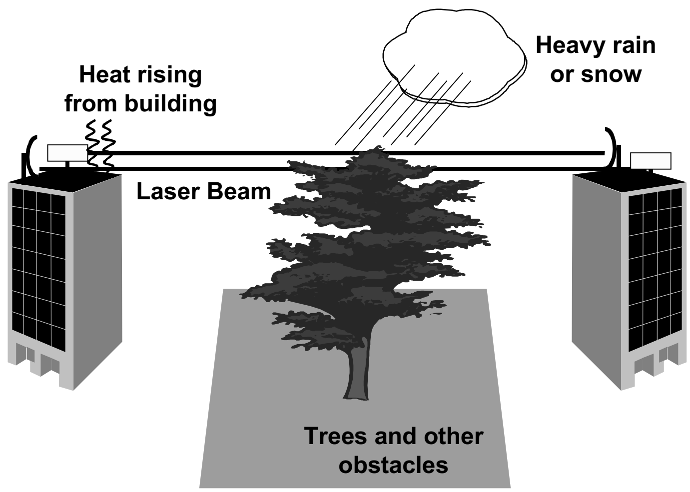
Wireless point-to-point network



Wireless point-to-point networks use radio or infrared waves with highly directional antennas to transmit signals up to about 30 miles. Microwave links can use narrowband transmission in which they concentrate all of their power at one frequency. More commonly they use spread spectrum transmission in which the signal is distributed over a wide range of frequencies and collected at the receiving end. A typical microwave radio link transmits data at 4-5 Mbps.

Lasers can be used to create an infrared light link. Infrared light can handle much higher data rates than microwave radio—10 Mbps Ethernet is not a problem. Infrared links however are susceptible to interference by weather and even by the sun. Heavy rain, snow, or even fog or smog can weaken or attenuate the signal. If the sun shines directly into the receiving dish antenna, the receiver could mistakenly interpret the sun's light as a signal. Infrared links are rarely used over distances greater than one mile and they should not be oriented east west. If a bird flies through a laser link it will temporarily disrupt the transmission but it will not get hurt, the laser is not powerful enough.

Infrared remote bridge and possible causes of transmission problems



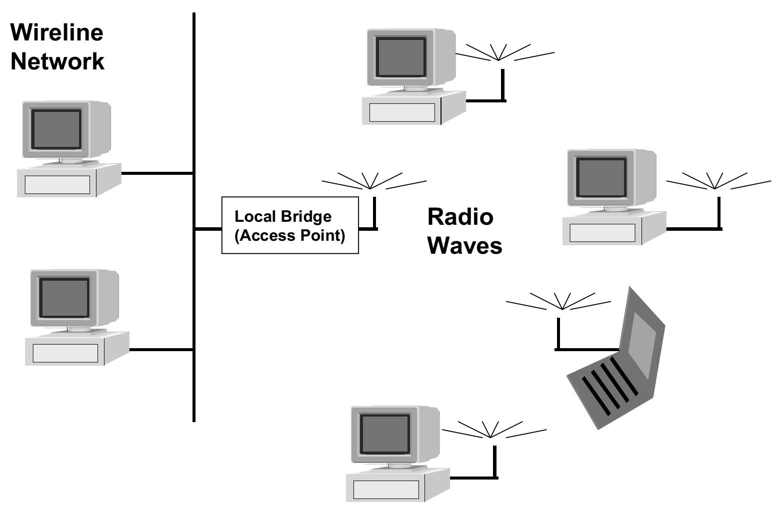
Because point-to-point wireless links transmit across outside areas where there are likely to be many other radio transmissions, they are susceptible to interference. There are several ways of dealing with this problem. An organization using narrowband radio transmission can apply to the Federal Communications Commission for a license to use a specific frequency. This takes time to fill out the paperwork and wait for the government to approve the request. If one holds a license and someone else's transmission causes interference, it is possible to ask the government to make them use a different frequency. Another solution is to use an infrared link. Because infrared light has a frequency higher than 300 GHz, an infrared link doesn't have to be licensed by the FCC and because an infrared receiving antenna is so tightly focused, infrared is much less likely to be interfered with by other transmissions being received by the antenna.

A third solution is to use spread spectrum transmissions. A wireless link using spread spectrum sends out a signal over a wide range of frequencies but with very low power at each frequency. This type of transmission is much less susceptible to interference and does not require a license from the FCC. Another advantage is that it is very difficult to intercept spread spectrum transmissions and so they are more secure.

Wireless LANs

A company may have employees who need to move around and yet still be connected to the network. For example, a manager of a large manufacturing plant may need to walk around on the assembly floor. A wireless LAN usually serves to extend an existing wired network and make it accessible to mobile users. A company might connect a wireless bridge, which is also called an access point, to the Ethernet network. Employees could then move about the company's premises with their wireless NIC equipped laptops or palmtop computers that communicate with the access point.

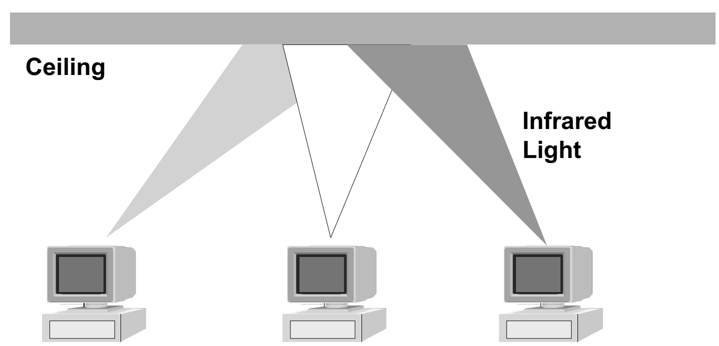
Wireless LAN



Infrared LANs

If the wireless network only has to connect computers in one room, infrared transmission may be a good choice. Infrared devices are used as remote controls for TVs or stereos. Because of its low power, a wireless remote signal will not reflect off a wall, it must be aimed directly at the receiver. An infrared wireless link employs the same technology but with slightly higher power. The higher power allows the signal to bounce off of a ceiling or wall and still reach the receiver. This is called diffused infrared. Collision detection, that is, making sure only one station transmits at a time, on a diffused infrared network works similarly to CSMA/CD on an Ethernet network. Instead of listening to the wire to detect whether another station is transmitting, wireless stations "watch" the ceiling to see if any infrared light is being transmitted.

Diffused infrared wireless LAN



Point-to-point infrared links like those used between buildings can also be used to create a wireless network. Infrared links can be used to replace the wired links in a Token Ring LAN. There must be a clear line of sight between the stations and the access point, and of course, the stations cannot be moved without re-aligning the antennas.

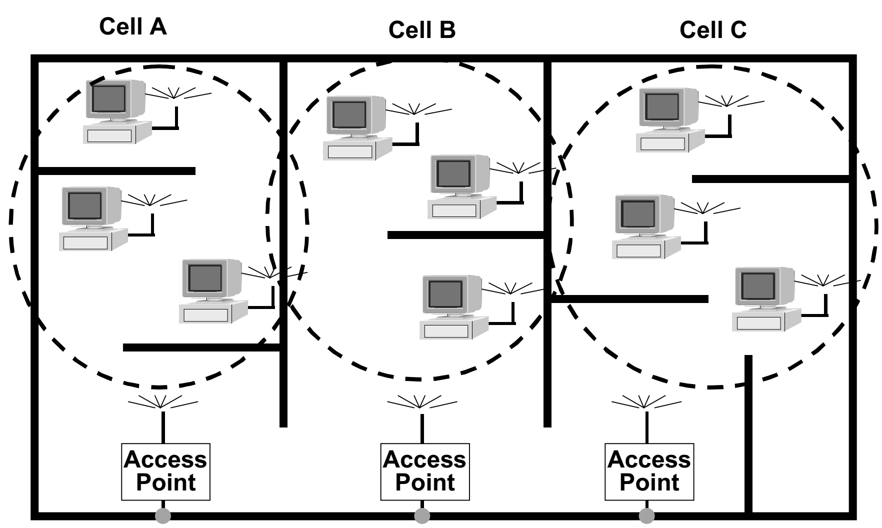
Peer-to-Peer Wireless LANs

Most wireless LAN network interface cards allow users to create a peer-to-peer network for sharing data between a group of workstations without connecting to a larger wired network. Any time two devices with wireless NICs come in range of one another, they can communicate. Most wireless LANs, however, are designed to connect users to a larger wired network. This requires access points that are wired into the network.

Cells and roaming

The access point connects to the network like a traditional bridge, and it must be placed in a location where it can transmit radio signals to the entire area it needs to cover. Because radio waves can travel through most walls there does not need to have an access point in every room, or even on every floor of an office. Larger offices or manufacturing plants or campuses will require multiple access points. Each access point covers a specific area and is connected to a wired backbone. The area covered by a single access point is called a cell. This is a similar configuration used for the wide area networks that you know as cellular telephone.

Cells in a wireless LAN



When a person with a wireless device moves from one cell to another (or even when he or she moves out of a cell and then back in) a roaming protocol tells the device how to find the appropriate access point and connect. The roaming protocol checks the quality of transmission. When it falls below a certain quality, the protocol starts looking for a better access point. If possible, the protocol makes the new connection before losing the old one so that the connection does not drop in between.

Roaming protocols add overhead to wireless transmissions. The more frequently the protocol checks to make sure transmission is ok, the more bandwidth the protocol uses. The less frequently it checks, the more likely it is that the connection will drop (or at least degrade) before the roaming protocol recognizes that it needs to start looking for a new cell.

Check Your Understanding

- Describe a situation in which a company might choose an infrared wireless network instead of one using radio waves.
- Why won't a diffused infrared network work outside?
- Explain how a wireless network knows when to switch a mobile user from one access point to another.

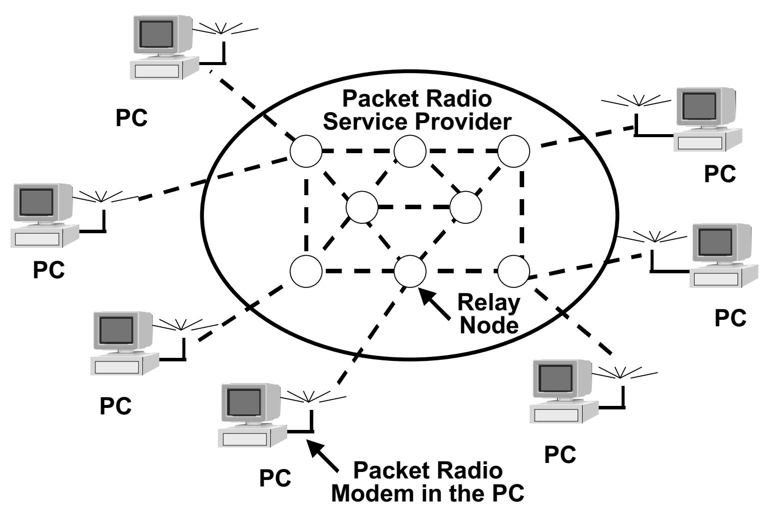
Wireless WANs

Except for large organizations that can afford to put up their own satellites or string their own cables across long distances, wide area networks use a public carrier such as a phone company to carry communications. Commonly used wireless WAN technologies include packet radio, cellular telephone, and satellite.

Packet Radio WANs

Packet radio WANs function much like a wired packet switching wide area network. Users transmit messages to one another across a network of relay nodes. In a wired network these nodes are routers or switches connected by copper or fiber optic lines or satellites. In a wireless network the nodes are connected by radio transmissions.

Packet radio WAN



Packet radio WAN users connect to their computers a packet radio modem with an omnidirectional antenna. These modems are currently relatively slow, not suitable for surfing the web, but sufficient for transmissions like short e-mail messages. An advantage that packet radio has over cellular services is the way users are charged to use the network. Packet radio fees are charged by the packet. Cellular charges are by the minute. For a user sending lots of short messages that take far less than a minute to transmit, packet radio can be less expensive. In a cellular network, each connection is charged a certain rate. ARDIS and RAM Mobile Data are services that provide packet radio networks.

A common use of packet radio WANs is for service technicians in the field who need to order parts or check inventory or report how much time they spent on a particular job. The Toronto Sun newspaper uses a packet radio WAN. Each distributor who fills the newspaper vending machines reports each night how many papers were left unsold. Using this data, the newspaper plans how many papers to print the next day. Another application is remote monitoring. For example, a packet radio modem could be connected to a water meter in a hard to reach location. The meter would periodically transmit the current reading.

To transfer data across the network, packet radio WANs follow similar routing protocols to wired networks, maintaining routing tables and sending a packet on in the direction of the destination according to the table. The main difference is that a wireless relay node can only transmit to other nodes within reach of its transmissions, its propagation pattern.

Cellular WANs

The convergence of telephony and computer networking means that cellular telephone networks, designed for voice transmission, will be used more and more for data transmission. Cellular phones currently transmit at about 14.4 Kbps but the technology, and speed is improving rapidly.

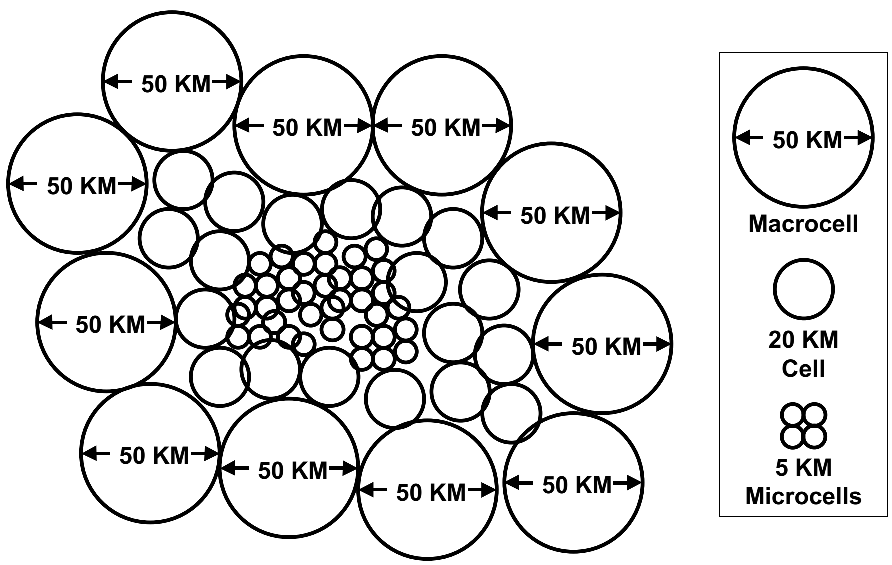
The original cellular telephone system was analog (called Analog Mobile Phone Service, AMPS) because it was designed to carry data from an analog source: people's voices. Telephone companies have invested billions of dollars to create an infrastructure for carrying voice transmissions nearly anywhere in the world. Now that network is being used more and more for data instead of voice. This is pushing the cellular telephone carriers to switch from analog to digital transmissions. Among other advantages, digital signals can be encrypted for better security and can have better error control.

The cellular system uses radio waves to transmit signals. A call on a cellular system uses two frequencies for each call, one frequency for each direction the signal travels between the base station and the mobile user. When a call is made using a cellular phone, the phone searches for the nearest base station. The call is routed through the antenna for that base station to the public switched telephone network where it is transmitted over that network like a regular phone call. As the phone moves from one cell to another during a call, the network automatically roams and switches the call to the next cell.

Cellular technology was developed to overcome the problem of more and more people using mobile phones. In the beginning, engineers would solve the problem of network growth by adding frequencies or by subdividing the frequencies they had into narrower and narrower channels. But it became obvious that there would never be enough individual frequencies to carry all of the calls.

Cellular networks offer a different solution called frequency reuse. Each frequency is only used in a limited area called a cell. Two cells can use the same frequency if they are separated by a certain amount that depends on the power of the transceiver and the topography. This increases the number of "available" frequencies without actually increasing the number of frequencies. The smaller the cells, the more the frequencies can be reused. In fact, when the size of the cell is reduced by 50%, capacity will increase four times. Frequency reuse has always been used for radio and television. Two television stations can use the same frequency if they are at least 150 miles apart. It is not uncommon to experience radio stations reusing frequencies while driving between cities with the car radio tuned to a particular station. At a certain point the signal changed from one station to another with a short time in between when the two signals overlapped.

Cells

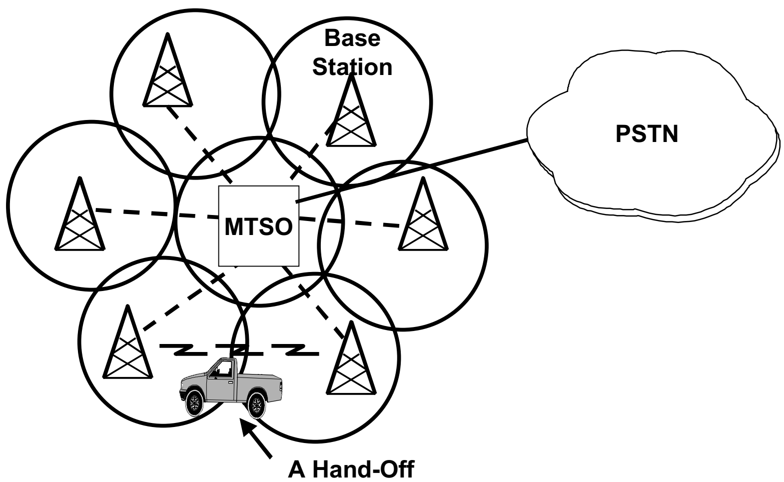


Cell sizes range from one kilometer to 50 kilometers in radius. Larger cells are used for less densely populated places and especially for highways where mobile telephone users are moving so fast that they would pass through smaller cells too quickly. Smaller cells are used in more densely populated urban areas. PCS (Personal Communications Service) is a popular digital cellular WAN that uses very small cells that are no more than 10 kilometers across. For example, the Omnipoint PCS network for the greater New York City area uses over 500 cell sites to cover the 161,300-square-kilometer area

At the center of each cell is a tower called the base station that holds the antennas, and some switching equipment. Each base station uses carefully chosen frequencies that will not interfere with adjacent cells.

Each cell is grouped with seven other cells in an organization called a cluster. Within each cluster is a Mobile Telephone Switching Office (MTSO). The MTSO connects the network to the Public Switched Telephone Network (PSTN), which is the local wire-based telephone company.

Cellular telephone network



The MTSO decides when to "hand-off" a call to another cell. MTSOs may also hand off calls when the cell has a lot off call traffic. The MTSO will scan the airwaves looking for a channel from an adjacent cell that can be used, then hands off the call. If the network is overloaded and the MTSO cannot find another channel to “borrow,” the caller may get a busy signal while trying to make a call. Hand-offs present a problem when transferring data as the connection sometimes drops briefly during a hand-off.

Cellular Digital Packet Data

CDPD allows mobile users to transmit digital signals over the analog cellular telephone network in the 800 MHz band. It can achieve data rates up to 19.2 Kbps, much faster than a typical analog cellular phone link being used for data. CDPD transmits very short bursts of data on the cellular channels when no one is using them. Analog cellular networks are idle about 20 percent of the time, even when networks that get very heavy use. For example, the time between one call being disconnected and the next one being connected is idle time for an analog network. A CDPD modem searches for an idle channel and then transmits the data in 128-byte packets.

Personal Communications Services (PCS)

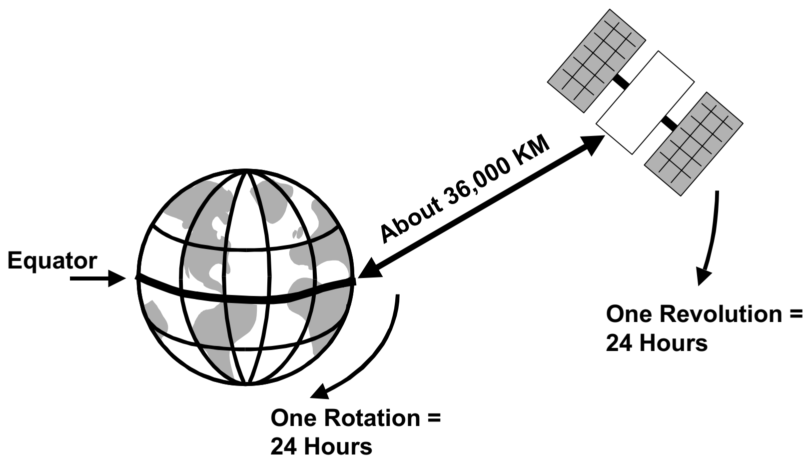
PCS is a fully digital version of cellular wireless that uses very small cells called microcells. Because it is fully digital, PCS has enhanced features, better encryption, and uses less power. Because they use less power, hand-held PCS devices can be smaller and lighter. PCS uses a digital cellular standard called GSM, Global System for Mobilization. GSM is widely used in Europe. The frequency band between 1.850 and 1.990 GHz was recently allocated to PCS in the United States. The frequencies were auctioned to companies that planned to provide PCS. These companies paid the government $7.7 billion for a band of frequencies in 1995 and additional frequencies were auctioned for $6 billion in 1996.

Satellite Networks

A step further in telecommunications networks is the use of satellite networks.

Satellites that orbit the Earth at an altitude of 22,237 miles revolve around the Earth at the same speed that the Earth rotates. This means that the satellites remain over the same area on the ground at all times. This is known as a geosynchronous orbit and was proposed by the physicist and science fiction writer Arthur C. Clarke. Satellites in geosynchronous orbit can relay signals from one part of the Earth to another and can therefore take the place of wired links between distant locations.

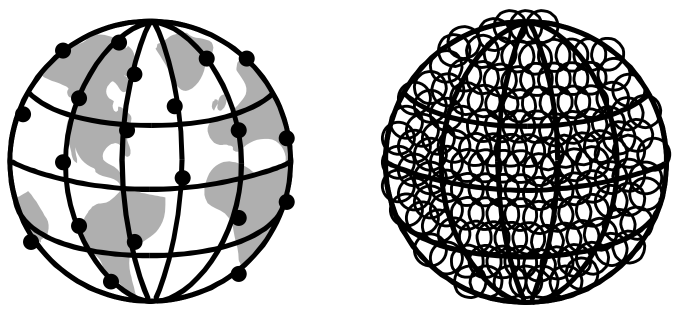
Geosynchronous orbit



Because geosynchronous orbit satellites are so far away from the Earth, it takes a lot of power to transmit a signal that will reach them. This makes them less suitable for use by small wireless networks or mobile users. Another problem with geosynchronous satellites is latency. It takes a relatively long time for a signal to reach a satellite, get processed, and then travel back to Earth. This delay is called latency and can create problems for data transmissions. A third problem arises because the signals are more susceptible to interference since they are transmitted over such a long distance.

One way to overcome the power, latency, and interference problems is to use satellites closer to Earth. But satellites in lower orbits do not maintain their position relative to the ground. If a low orbit satellite were relaying data, the transmission would be interrupted when the satellite moved out of range. The only way to use lower orbit satellites is to put enough of them in orbit so that when one satellite moves out of range, another satellite has already moved into range and can pick up the transmission. Think of this system as a cellular system in which the base stations are moving as well, and hand-offs happen as the base stations and the mobile users move.

Low Earth Orbit (LEO) satellite network



A system of low Earth orbit (LEO) satellites requires so many satellites that the price has been prohibitive until very recently. With the explosion of wireless users, consortiums of companies have invested huge sums of money to create LEO satellite networks.

The Iridium system uses 66 satellites in LEO (750 kilometers). The satellites act as the base stations for more than 1,600 cells that cover the entire surface of the globe. Each cell has 174 channels; the system can handle over 280,000 calls simultaneously.

Another system called Teledesic will have 288 LEO satellites by 2002. The goal is to have systems that can transmit (downlink) at 64 Mbps to the users and can receive (uplink) at 2 Mbps.

Check Your Understanding

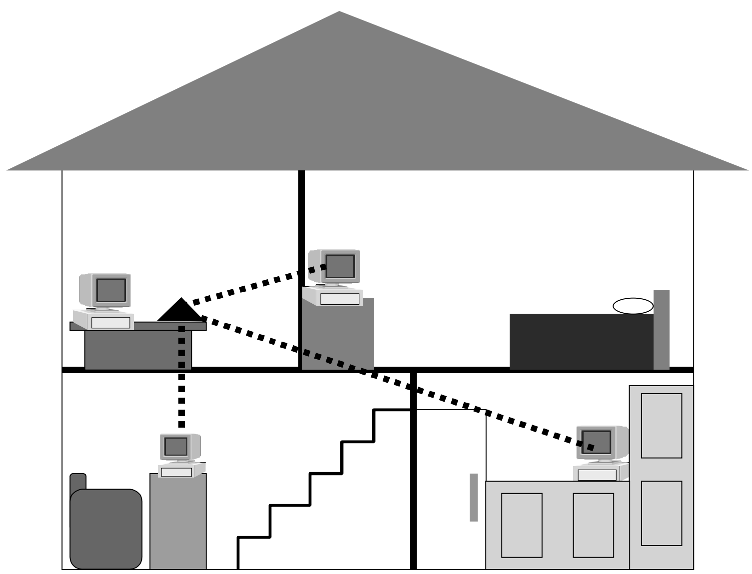
- What determines which packet relay nodes can be reached by what others in the network?
- How does a cellular network reuse frequencies?
- What is the difference between geosynchronous and low earth orbits?

The Future of Wireless Networks

The next wave of telecommunications technology is often called "third generation" or 3G. The first generation was the analog wireless mobile phone service, which is still widely used. The second generation is the digital wireless technologies including digital cellular and PCS. Third generation technology will bring higher bandwidth access to more people in more places at anytime.

The use of wireless LANs will expand tremendously. Hotels, airports, and other places where many mobile users gather will install high bandwidth "hot spots." Wireless LANs will also replace cables in the home. Apple's iMac is already being sold with an optional wireless base station; it's an access point for up to 10 devices within 150 feet.

A wireless LAN in the home



Upgrades to mobile phone networks will bring transmission rates up to the speed of multiple ISDN lines, 384 Kbps. Other systems, such as Nortel's experimental Skytel system will bypass the public phone system and connect wireless users directly to the Internet. Low earth orbit satellite systems will improve transmission speed and these may be supplemented with blimps, and even low-flying planes that will hover over metropolitan areas to provide cellular coverage.

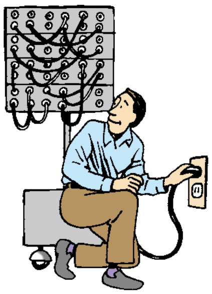
With improved bandwidth, more people will want to use wireless services and the increased demand will cause the price of connection time to decrease. People may be able to stay always connected, making wireless devices as available as a wired network. With a hand-held computer that is always connected, the user will not have to wait to startup, log in, and establish a wireless link. Information will be available instantly.

Tied in with Global Positioning System (GPS), a wireless device could determine the user's exact location. It would know where the user is in relation to others. It could inform the user of others near by. In Japan, a new service called Personal allows users to type a cellular phone number into a web site and find out the exact location of that cellular phone. By connecting wireless service with GPS and the Internet, the user could find out what stores are nearby and which one has the lowest prices or which restaurant in the area serves vegetarian food.

Third generation will improve the connection process to the Internet and allow users to connect directly with other devices. With a limited range low-power radio network, devices could talk to one another without being physically connected. A proposed system called Confinity will let anyone make payments to anyone else using a mobile phone. The payment data is encrypted and transmitted using infrared light.

In time wireless devices will probably be as common as wristwatches and people will wonder how anyone used the Internet when they had to find a place to plug in.

Try It Out: The Mathematics of Cells



Materials Needed:

- Pen/Pencil and Paper
- Scissors
- Calculator (optional)

The idea of using cells for wireless telecommunications has been around since 1947 when engineers for Bell Telephone created a cellular system for radio. In this exercise you can discover how effectively a cellular system uses the limited radio frequency spectrum.

Cellular systems allow you to reuse frequencies within an area. Two cells can use the same frequency if they are not adjacent. To understand how this makes the best use of frequencies, you will experiment with circles of various sizes.

1. Use the circle templates below. The large circle on the paper represents a metropolitan area. The small circles represent cells of different sizes that can be used to cover the metropolitan area. Each cell, no matter what the size, uses one frequency.

2. Complete the first row in the table for a single large cell covering the entire metropolitan area.

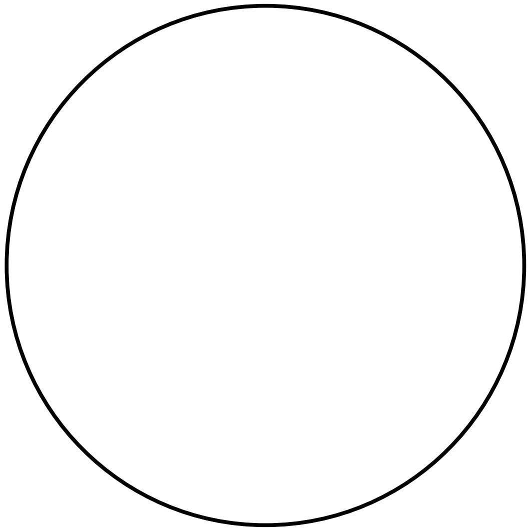
3. Using only size B circles, cover as much of the large circle as possible without extending beyond the edge of the circle. You can cut out circles of size B and place them on the larger circle or simply draw the circles. Be sure to draw in pencil and to have a good eraser handy. Number the circles beginning with 1. Adjacent cells cannot use the same frequency so they cannot have the same number. Cells can use the same frequency if they are separated by at least *the full diameter of one cell*. For example, if you had four cells arranged as shown below, the first cell would be 1, the second cell would have to be 2 because it is adjacent to the first. The third cell is adjacent to both 1 and 2, so it must be cell 3. The fourth cell is adjacent to cells 1, 2, and close enough to 3 so that there would be interference if both cells used the same frequency. So the fourth cell must be 4.

4. Try to find the fewest number of frequencies that you can use to number all the cells you have fit in the "metropolitan" area. Complete the second row of the chart below.

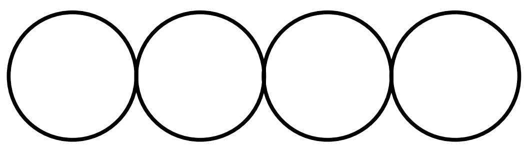
5. Repeat step 3 using only size C circles. Complete the next row of the table.

6. Try to write a formula that expresses the relationship between the number of cells and the number of frequencies used.
7. If you had another set of circles with radiuses one half that of circle #2, how many would it take to cover the metropolitan area? Use your formula to determine how many frequencies you would need to use. Check your answer using circle D.
8. One cell can handle 12 channels, which means 12 simultaneous conversations. How many conversations can take place at one time for each of the cell sizes in your table?
9. What conclusions can you make about the use of cells?
10. Fill in the table below with your results.

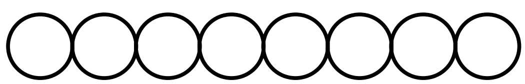
Cell sizes	Number of cells to cover metropolitan area	Minimum number of different frequencies that must be used
A (one cell for entire metropolitan area)		
B		
C		



A



B



C

D

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
Packing circles experimentation, table completed	40	
Correct answers	15	
Conclusions	45	
TOTAL	**100**	

Stretch Yourself: Debate the Allocation of Frequencies

Materials Needed:

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

In this lesson you read that the US government auctioned certain frequencies to companies that planned to provide PCS. These companies paid the government $7.7 billion in 1995 and $6 billion in 1996. Hold a debate in your class on the issue of how the frequency spectrum should be allocated. Consider the following:

- What would happen if anyone could use any frequency?
- Should the government auction the frequencies to the highest bidder or should there be another way to distribute the rights?
- How are radio frequencies similar or different from other resources such as air and water?

1. Form debate teams. In groups of two teams together decide upon a specific question to debate. Once the question is agreed upon, each team chooses one side of the issue.

2. Prepare for the debate by researching the following topics:
   - How much of the radio spectrum is allocated to certain uses. You can find the US Frequency Allocation Chart at http://www.ntia.doc.gov/osmhome/allochrt.html)
   - How the frequency spectrum is allocated for telecommunications. For comparison, how radio and television stations received the rights to use certain frequencies. Two web sites that can help your research are:
     - The US Department of Commerce National Telecommunications and Information Administration, http://www.ntia.doc.gov/
     - The Federal Communications Commission (www.fcc.gov) and its Wireless Telecommunications Bureau (http://www.fcc.gov/wtb/).
   - Effects of recent legislation such as the Telecommunications Act of 1996
   - How much the companies providing PCS expect to earn each year

3. Each team writes a one minute opening statement.
4. Each team delivers its opening statement. Teams then alternately take two turns of 30 seconds each to argue their side of the issue.
5. Each team presents a closing statement.
6. The rest of the class votes to decide which side won the debate.

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
Written opening statement	30	
Preparedness	40	
Participation in debate	30	
TOTAL	**100**	

Network Wizards: Electronic Data Collection

Materials Needed:

- Pen/Pencil and Paper
- Student Network Design Proposal Working Draft

You have learned about a number of options for using wireless links on a network. Your goal in this exercise is to create a questionnaire (also called a site survey tool) that will allow you to collect electronic data about various configurations of wireless bridges, LANs and WANs. For each of the questions, write a brief, two to three sentence plan for how you could gather that information. For example, for item 2 you might suggest transferring files of different sizes across the wireless link and monitoring the throughput using Sniffer Basic. Do not worry if you are unable to come up with the "correct" measurement, there are multiple correct answers. This exercise is intended to get you to think about the various measurements you can make and the need to develop a testing plan before you begin making measurements.

Part One: Wireless Data

1. What information would you gather to indicate the *size* of the network?
2. How would you measure how fast data is normally transmitted across the network?
3. How would you measure the range of a wireless access point? How far away does the signal reach?

4. How would you measure the capacity of a wireless access point? How many wireless end users can it handle?

5. How would you measure how well a network's wireless access points cover an area? How well does roaming work?

6. How could you measure the typical battery use of a wireless end user device?

7. A wireless network phenomenon called *near/far* can cause a user device to fail to communicate with an access point if there is another nearer device transmitting at the same time. The access point may not recognize the farther device. How could you test for this problem?

8. In a diffused infrared wireless network (as well as other configurations) there can be a problem called *hidden terminal*. Two stations might be too far apart to transmit to one another but both might be close enough to transmit to a third station. Both stations might transmit to the third station at the same time because they can't sense when the other is transmitting. The third station will not be able to receive either transmission because they come at the same time. How could you test for this problem?

9. What kind of interference would you want to test for and how could you do it?

10. Create a planning chart of the process you would go through to collect the necessary electronic data from a wireless environment.

Rubric: Suggested evaluation criteria and weightings:

Criteria	**%**	**Your Score**
Correct answers	50	
Thorough chart	50	
TOTAL	**100**	

Part Two: Network Design Portfolio Case Study

Electronic data collection provides you with detailed information about the network topology, the components' configurations, and existing performance.

Data is collected using various methods. Network analyzers, such as Basic Sniffer, collect data about performance statistics on mission-critical LAN segments. Other tools, such as Optivity and Site Manager, allow you to determine the network topology, including device configurations. If there are problems detected, these tools can be used to reproduce the problems, so that you can determine the solutions.

It is doubtful that your organization will allow you access to their network to run a sniffer or other tools. In your case, it is best to ask for the statistics on paper. If your organization is resistant to releasing this information, you will have to complete your proposal without the information. Note to your organization during the presentation that you are making certain assumptions since you do not have specific data on which to base your recommendations.

Summary

Wireless Networks

In this unit, you learned the following:

- Advantages and disadvantages to using a wireless network
- The basic components of a wireless network and their functions
- Wireless configurations for remote bridging, LANs, and WANs

Review Questions

Wireless Networks

Part A:

1. A wireless network device typically transmits with a power of
   a. 50,000 watts
   b. Approximately 100 watts
   c. Less than 1 watt
   d. Anywhere from 1 to 1000 watts
2. Cordless phones operate at 900 Mhz because
   a. That's the frequency at which the human voice transmits the best
   b. No other devices use that frequency
   c. The manufacturers have licensed that frequency from the government
   d. No license is needed to use that frequency
3. The radio frequency spectrum regulated by the US government ranges from
   a. 0 to 3 GHz
   b. 900 MHz to 2.4 GHz
   c. 3 kHz to 300 GHz
   d. 3 kHz to 3 GHz

4. Choose the true statement
    a. Making popcorn in a microwave oven could affect a wireless network
    b. All wireless signals can transmit through rain and snow
    c. You can’t transmit wireless signals if there’s any chance that they’ll interfere with an existing network’s transmissions
    d. All wireless LANs require an unobstructed view between the user device and the access point
5. An antenna increases the distance a signal can reach because
    a. It increases the transmit power to 1 watt
    b. It keeps the signal from propagating vertically
    c. It forces the signal to propagate vertically
    d. All antennas increase the gain

Part B:

Matching

1. ________	Segments a network	A. Remote Bridge
2. ________	Transmission rate of typical microwave point-to-point link	B. 4-5 Mbps
3. ________	Often licensed by the FCC	C. Infrared light
4. ________	Higher frequency than microwave	D. Cosmic Rays
5. ________	More tolerant of interference than narrowband	E.. Narrowband Transmissions
		F. Spread spectrum transmission
		G. 1 Mbps
		H. 900 Mhz

6. Explain how a mobile user on a wireless LAN connects to the network.
7. Describe two ways that infrared light can be used to create a wireless LAN.

Part C:

1. Compare a packet radio WAN to a cellular WAN. Give a situation in which each one would be the better choice.

2. Sketch a diagram of a typical cellular telephone network and label the following: mobile user, cell, base station, MTSO

3. Define LEO and explain the advantages and disadvantages that a LEO satellite system has when compared to a network of geosynchronous satellites.

Scoring

Criteria	%	Your Score
Part A: Explain several advantages and disadvantages to using a wireless network.	25	
Part B: List the basic components of a wireless network and their functions.	30	
Part C: Describe wireless configurations for remote bridging, LANs, and WANs.	45	
TOTAL	**100**	
Try It Out:	**100**	
Stretch Yourself:	**100**	
Network Wizards:	**100**	
FINAL TOTAL	**400**	

Resources

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

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