Data Communications and Computer Networks

A Business User's Approach

Chapter 3

The Media: Conducted and Wireless

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Acknowledgement

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  - William Stallings, “Business Data Communications, 4th Edition”, Prentice Hall publisher

Objectives

- After reading this chapter, you should be able to:
- Outline the characteristics of twisted pair wire, including the advantages and disadvantages
- Outline the differences among Category 1, 2, 3, 4, 5, 5e, 6, and 7 twisted pair wire
- Explain when shielded twisted pair wire works better than unshielded twisted pair wire
- Outline the characteristics, advantages, and disadvantages of coaxial cable and fiber-optic cable
- Outline the characteristics of satellite microwave systems, including the advantages and disadvantages as well as the differences among low-Earth-orbit, middle-Earth-orbit, geosynchronous orbit, and highly elliptical Earth orbit satellites

Objectives (Cont)

- Describe the basics of cellular telephones, including all the current generations of cellular systems
- Outline the characteristics of short-range transmissions, including Bluetooth
- Describe the characteristics, advantages, and disadvantages of Wireless Application Protocol (WAP), broadband wireless systems, and various wireless local area network transmission techniques
- Apply the media selection criteria of cost, speed, right-of-way, distance and expandability, environment, and security to various media in a particular application

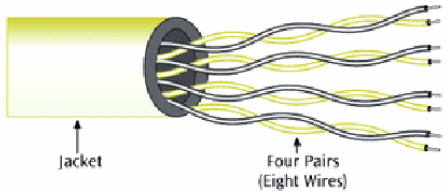
Introduction

- The world of computer networks and data communications would not exist if there were no medium by which to transfer data.

- The two major categories of media include:
  - Conducted (or guided) media
  - Wireless (or unguided) media

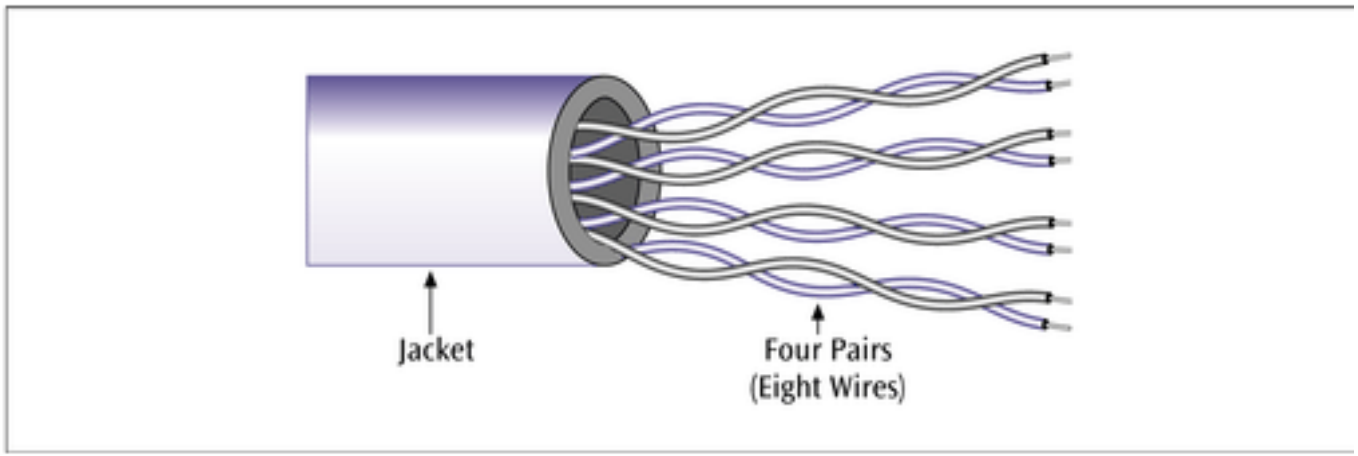
Twisted Pair Wire

- Two or more pairs of single conductor wires that have been twisted around each other.
- Twisted pair wire is classified by category.
  - Category 1 through Category 5e.
- Twisting the wires helps to eliminate electromagnetic interference between the two wires.
- Shielding can further help to eliminate interference.



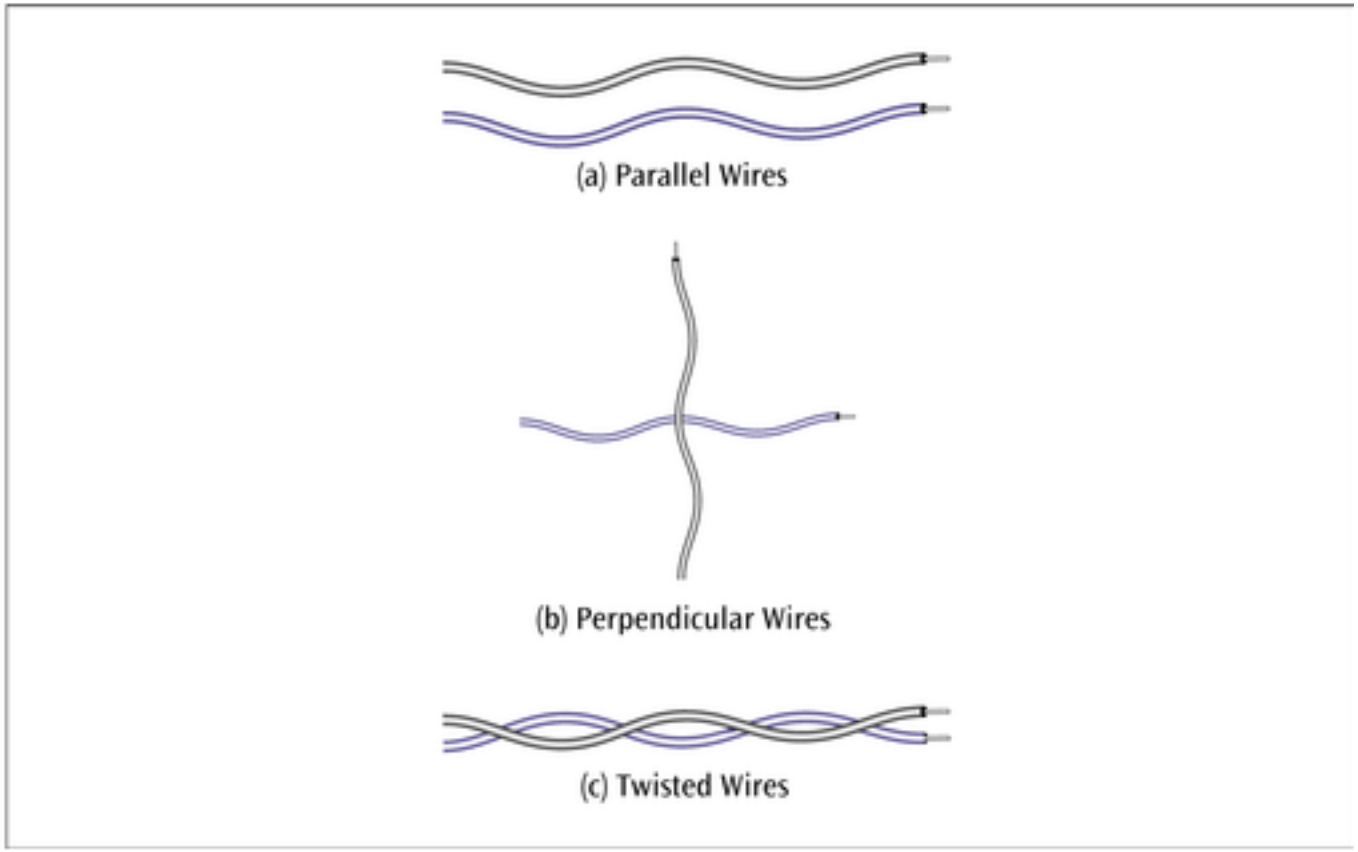
Unshielded Twisted Pair Wire

Figure 3-1
Example of 4-pair twisted pair wire



Twisted Pair Wire

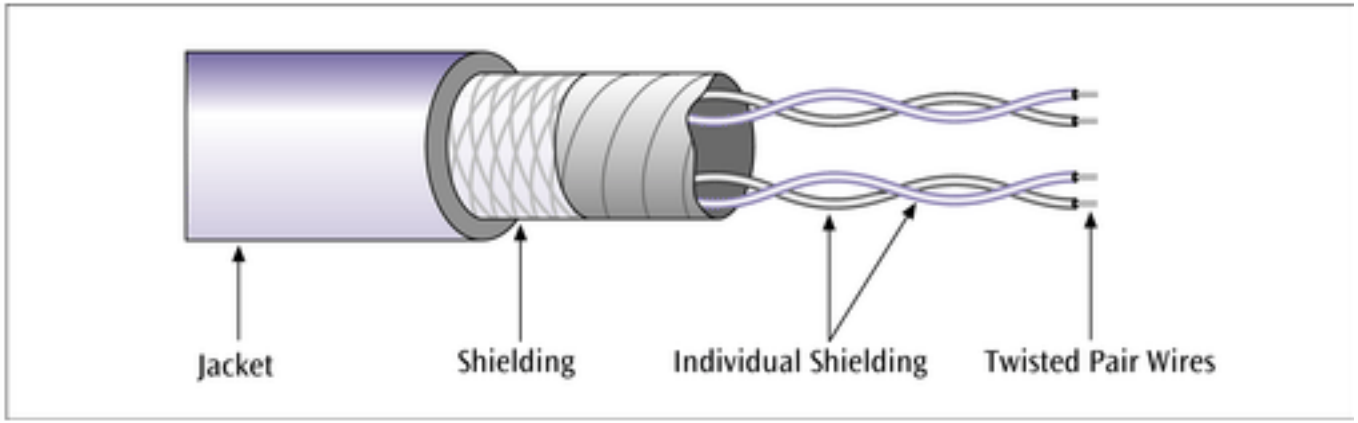
Figure 3-2
(a) Parallel wires — greater chance of crosstalk (b) Perpendicular wires — lesser chance of crosstalk (c) Twisted wires — note how the wires keep crossing each other at perpendicular angles



Shielded Twisted Pair Wire

- Used when electromagnetic interference is excessive, STP are used

Figure 3-3
An example of shielded twisted pair



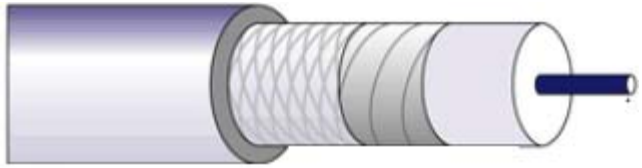
Twisted Pair Wire

Table 3-1

A summary of the characteristics of twisted pair wires

UTP Category	Typical Use	Signaling Technique	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
Category 1	Telephone wire	Analog and digital	<100 kbps	3–4 miles	Inexpensive, easy to install and interface	Security, noise
Category 2	T-1, ISDN	Digital	<2 Mbps	3–4 miles	Same as Category 1	Security, noise, obsolete (?)
Category 3	LANs, telephone circuits	Analog and digital	10 Mbps	100 m (328 ft)	Same as Category 1, with less noise	Security, noise
Category 4	LANs	Digital	20 Mbps	100 m	Same as Category 1, with less noise	Security, noise, obsolete
Category 5	LANs	Digital	100 Mbps (100 MHz)	100 m	Same as Category 1, with less noise, very common	Security, noise
Category 5e	LANs	Digital	125 Mbps (125 MHz)	100 m	Same as Category 5 but includes connectors, patch cords, and other components	Security, noise
Category 6	LANs	Digital	200 MHz	100 m	Higher rates than Category 5, less noise	Security, noise, more expensive
Category 7	LANs	Digital	600 MHz (?)	100 m (?)	Draft standard in early stages	Security, noise

Coaxial Cable



- A single wire wrapped in a foam insulation surrounded by a braided metal shield, then covered in a plastic jacket.
  - Cable can be thick or thin.
- Baseband coaxial technology uses digital signaling in which the cable carries only one channel of digital data.
- Broadband coaxial technology transmits analog signals and is capable of supporting multiple channels of data.

Coaxial Cable

Figure 3-4
Example of coaxial cable showing metal braid

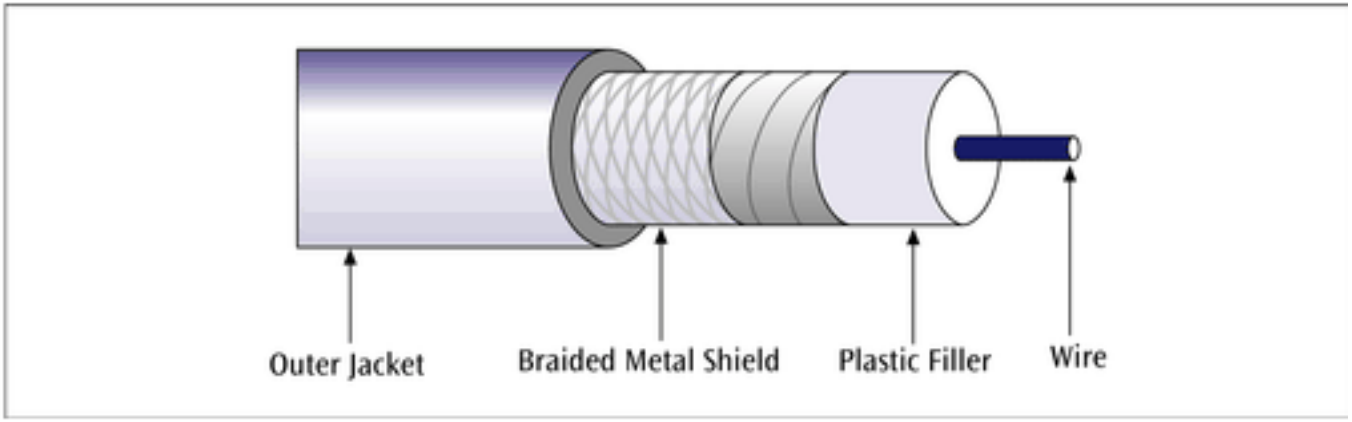
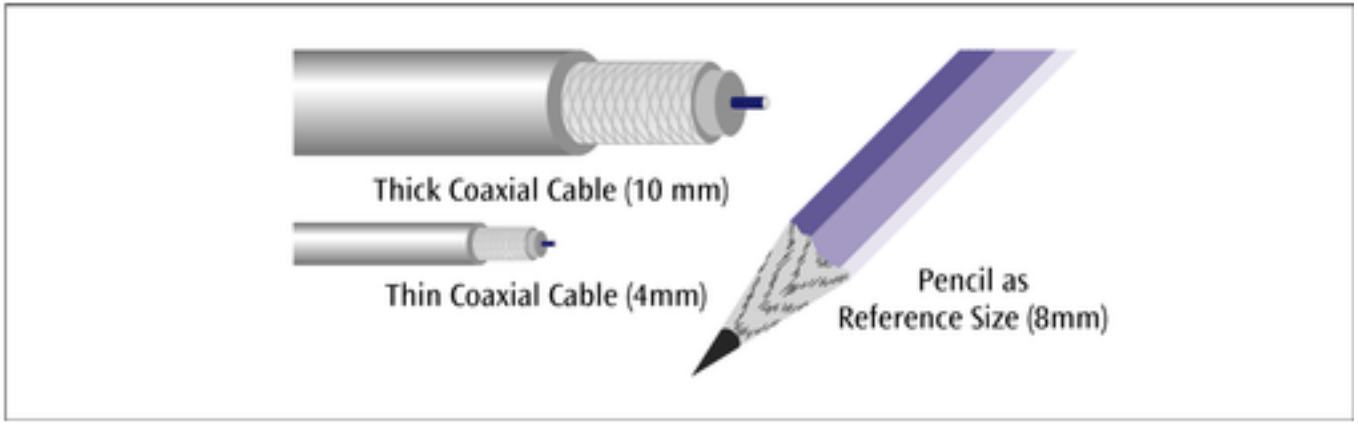


Figure 3-5
Examples of thin coaxial cable and thick coaxial cable



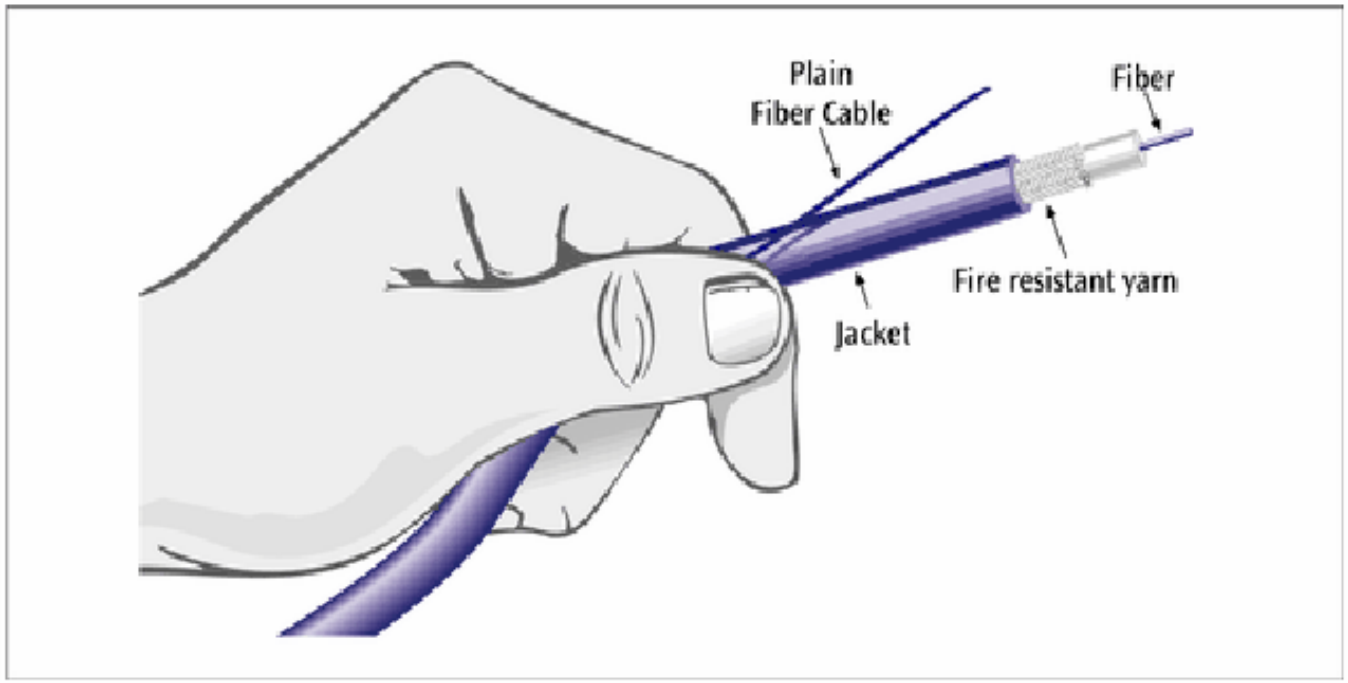
Fiber Optic Cable

- A thin glass cable approximately a little thicker than a human hair surrounded by a plastic coating and packaged into an insulated cable.

- A photo diode or laser generates pulses of light which travel down the fiber optic cable and are received by a photo receptor.

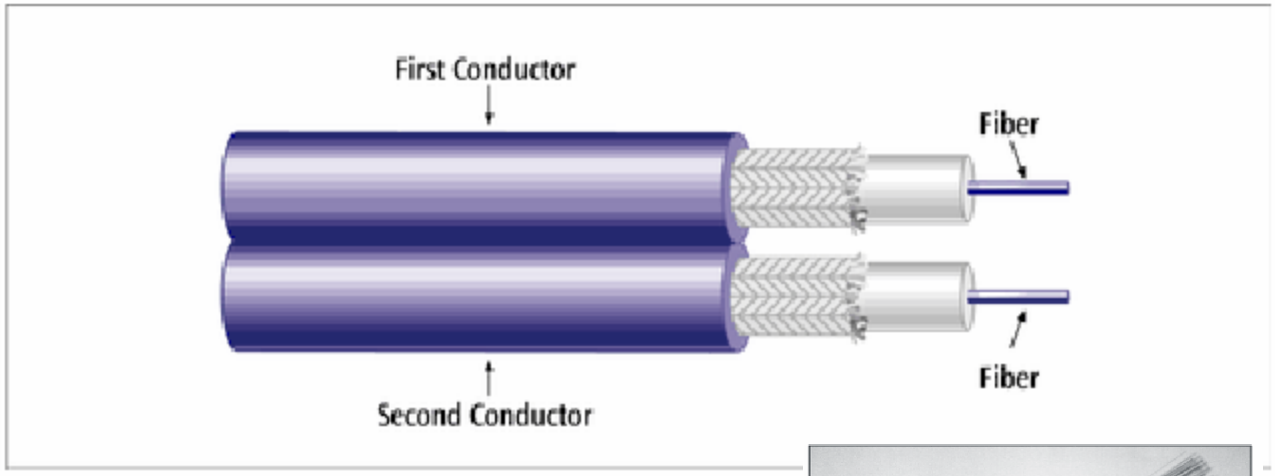
Fiber Optic Cable

Figure 3-6
A person holding plain fiber optic cable and fiber optic cable in an insulated jacket



Fiber Optic Cable

Figure 3-7
A fiber optic cable with two strands of fiber, one for each direction of transmission



Fiber-Optic Cable

- Fiber-optic cable is capable of supporting millions of bits per second for 1000s of meters
- Thick cable (62.5/125 microns) causes more ray collisions, so you have to transmit slower. This is step index multimode fiber. Typically use LED for light source, shorter distance transmissions
- Thin cable (8.3/125 microns) – very little reflection, fast transmission, typically uses a laser, longer transmission distances; known as single mode fiber

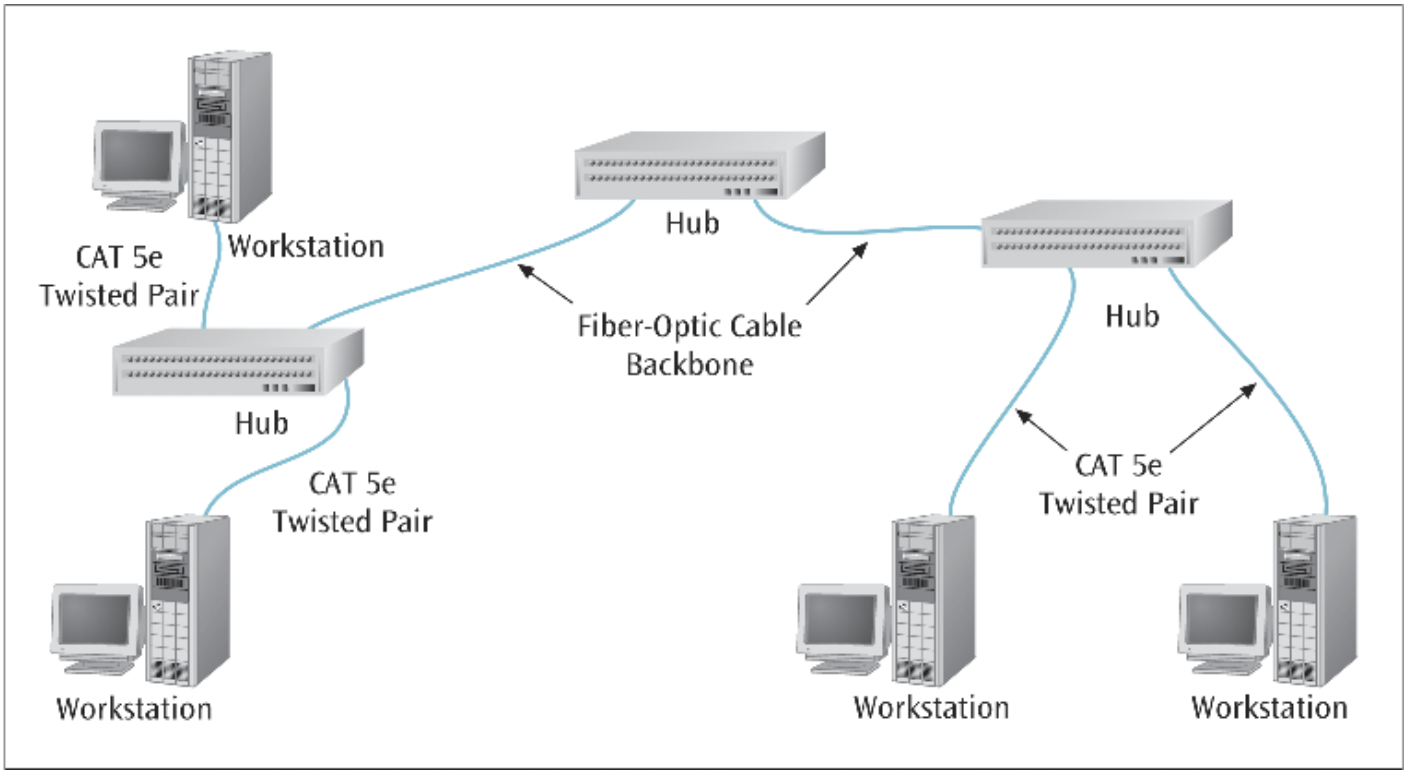
Fiber-Optic Cable

- Fiber-optic cable is susceptible to reflection (where the light source bounces around inside the cable) and refraction (where the light source passes out of the core and into the surrounding cladding)
- Thus, fiber-optic cable is not perfect either. Noise is still a potential problem

Fiber Optic Cable

- It is very common to mix fiber with twisted pair in LANs.

Figure 3-8
A fiber-optic backbone with Category 5e twisted pair running to the workstations



Fiber-Optic Cable (continued)

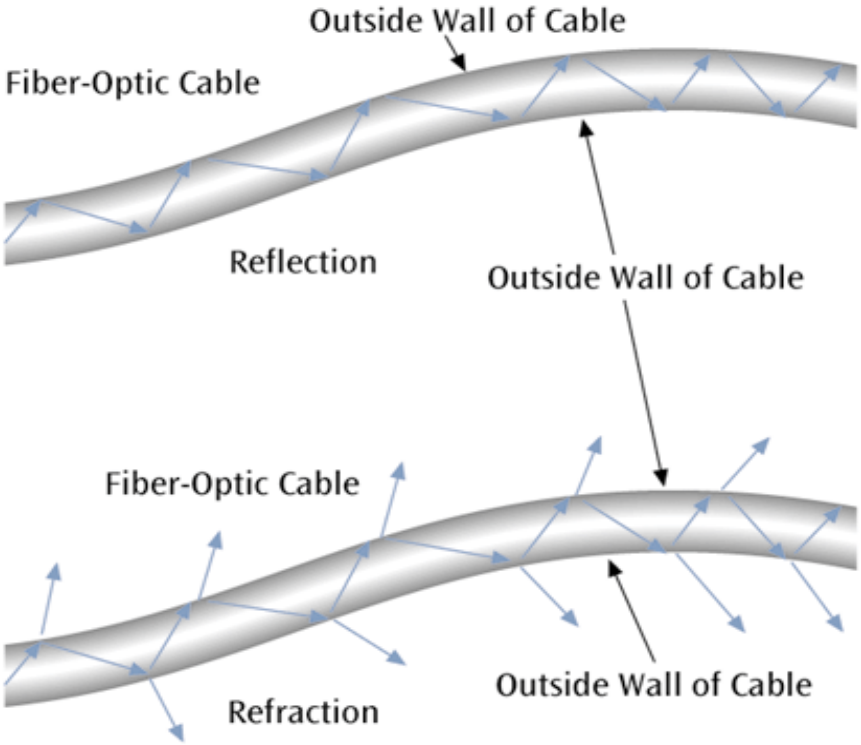


Figure 3-9 *A simple demonstration of reflection and refraction in a fiber-optic cable*

Conducted Media

Table 3-3

A summary of the characteristics of conducted media

Type of Conducted Media	Typical Use	Signaling Technique	Maximum Data Rate	Maximum Range	Advantages	Disadvantages
Twisted Pair						
Category 1 – 2	Telephone systems	Analog, digital	<2 Mbps	2 – 3 miles	Inexpensive, common	Noise, security
Category 3 – 6	LANs	Digital	200 Mbps	100m (328 feet)	Inexpensive, versatile	Noise, security
Coaxial Cable						
Thin baseband single channel	LANs	Digital	10 Mbps	100m	Low noise	Security
Thick broadband multi-channel	LANs, cable TV, long distance telephone, short-run computer system links	Analog	10 Mbps	2 – 3 miles	Low noise, multiple channels	Security
Fiber Optic	Data, video, audio, LANs, WANs	Light pulses	10 Gbps	100 miles	Secure, high capacity, very low noise	Interface expensive, but coming down in cost

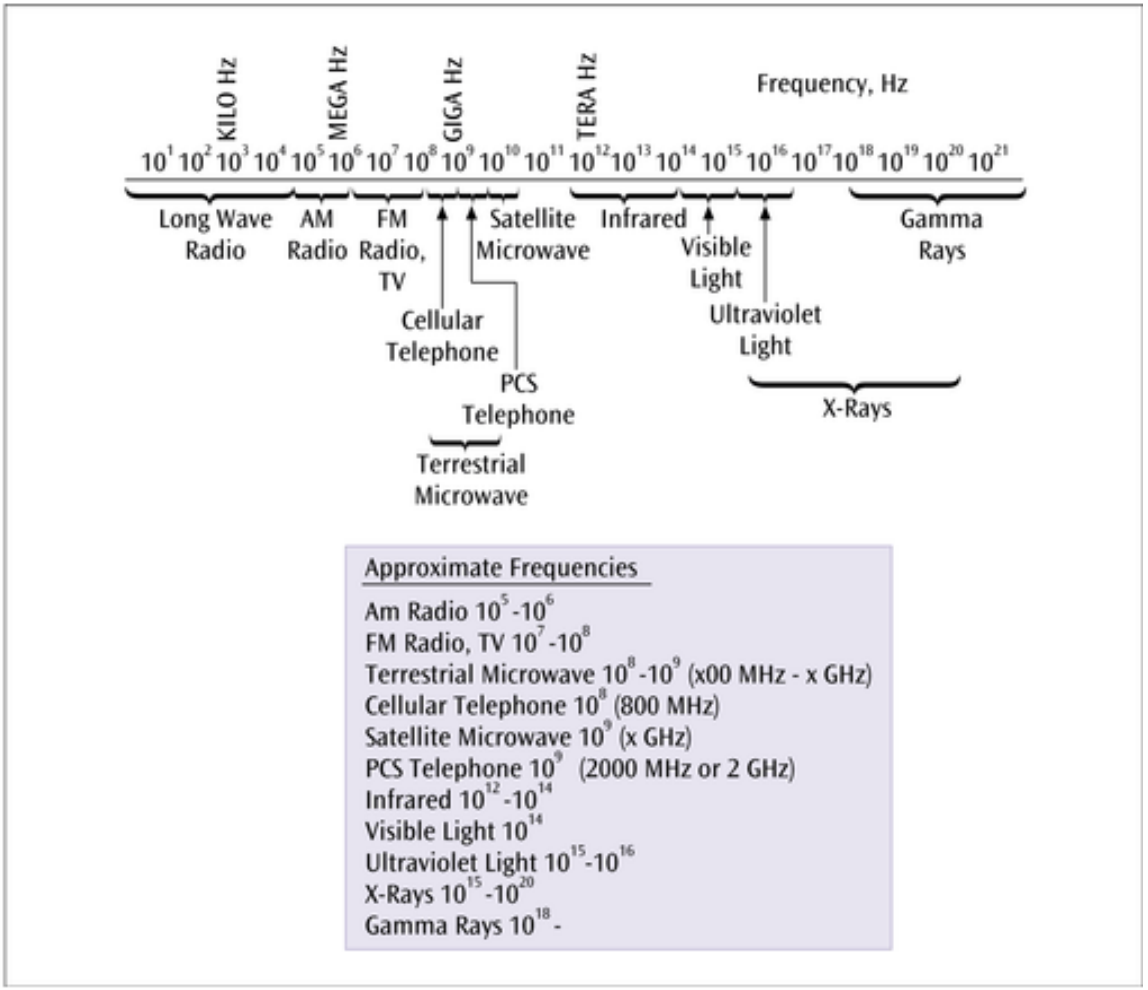
Wireless Media

- Radio, satellite transmissions, and infrared light are all different forms of electromagnetic waves that are used to transmit data.

- Note in the following figure how each source occupies a different set of frequencies.

Wireless Media

Figure 3-10
Electromagnetic wave frequencies



Terrestrial Microwave

- Land-based, line-of-sight transmission
- Approximately 20-30 miles maximum between towers
- Transmits data at billions of bits per second
- Popular with telephone companies and business to business transmissions

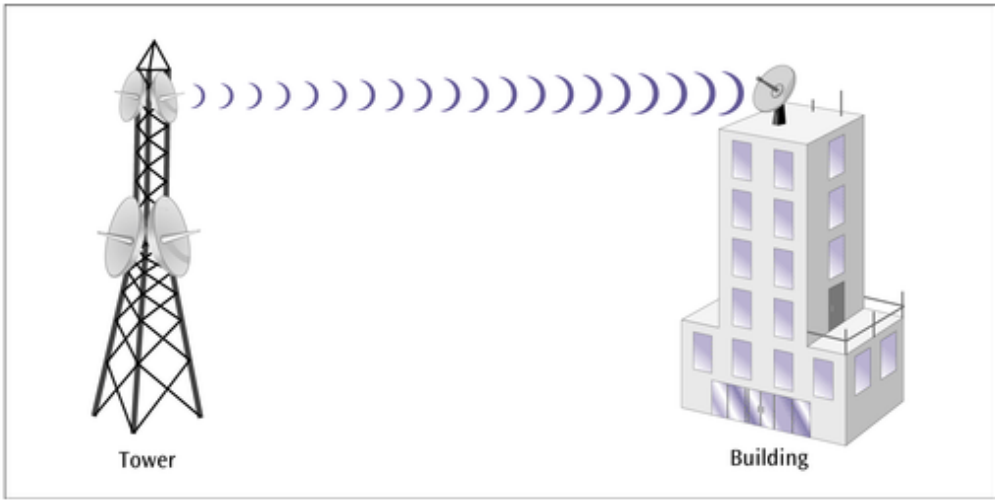
Terrestrial Microwave

Figure 3-11
A typical microwave tower and antenna

Terrestrial Microwave

- Often the microwave antennas are on towers and buildings.
- Advantages: Speed, wireless
- Disadvantage: cost, attenuation, crosstalk (interference)

Figure 3-12
A microwave antenna on top of a free-standing tower transmitting to another antenna on the top of a building



Satellite Microwave

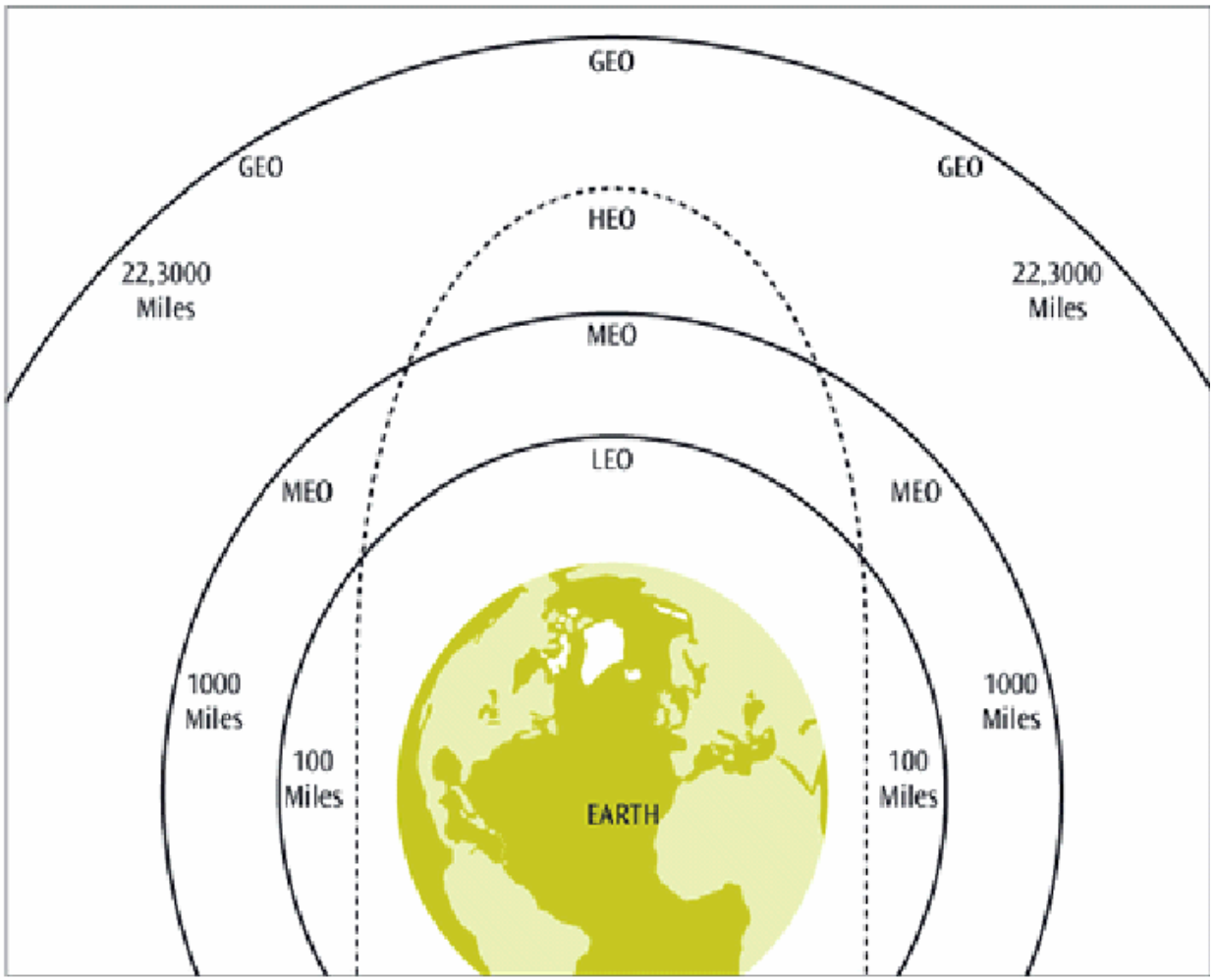
- Similar to terrestrial microwave except the signal travels from a ground station on earth to a satellite and back to another ground station.

- Satellites can be classified by how far out into orbit each one is (LEO, MEO, GEO, and HEO).

Satellite Microwave

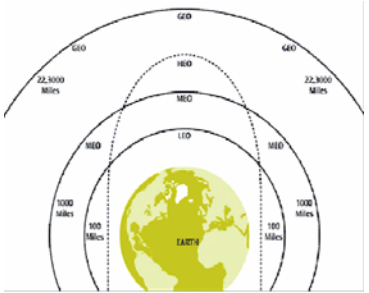
Figure 3-13

Figu The earth and the four
The earth orbits: LEO, MEO,
and GEO, and HEO



Satellite Microwave

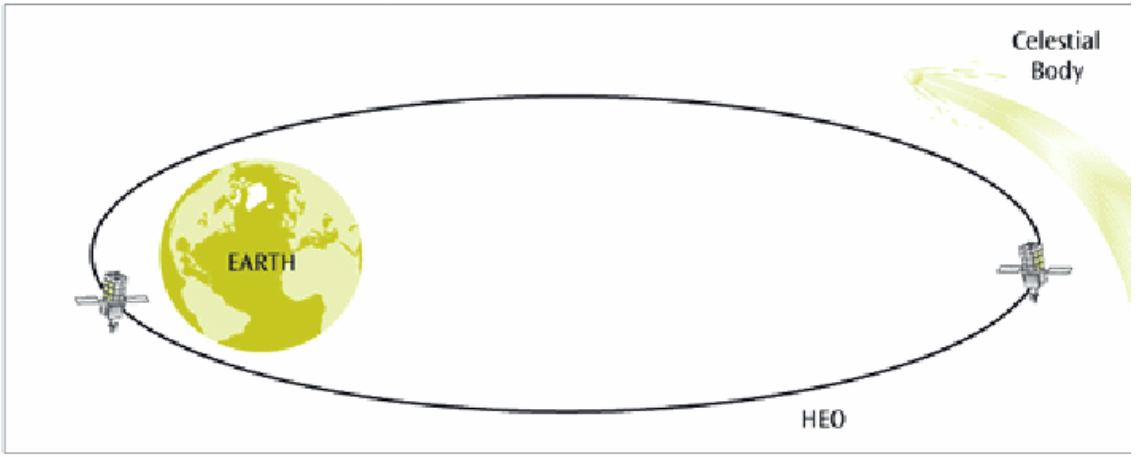
- LEO - Low Earth Orbit - 100 miles to 1000 miles.
  - Used for pagers, wireless e-mail, special mobile telephones, spying, videoconferencing.
  - Approximately 300 LEO satellites going to 700 (2003)
- MEO - Middle Earth Orbit - 1000 to 22,300 miles.
  - Used for GPS and government.
  - Approximately 65 of them, going to 120 (2005)
- GEO - Geosynchronous Orbit - 22,300 miles.
  - Always over the same position on earth (and always over the equator)
  - Used for weather, television, and government operations.



Satellite Microwave

- HEO – Highly Elliptical Orbit
- A fourth type of orbit used by the military for spying and by scientific organizations for photographing celestial bodies.
- When satellite is far out into space, it takes photos. When satellite is close to earth, it transmits data.

Figure 3-14
Diagram of a highly elliptical earth orbit satellite



Satellite Microwave

- Satellite microwave can also be classified by its configuration:

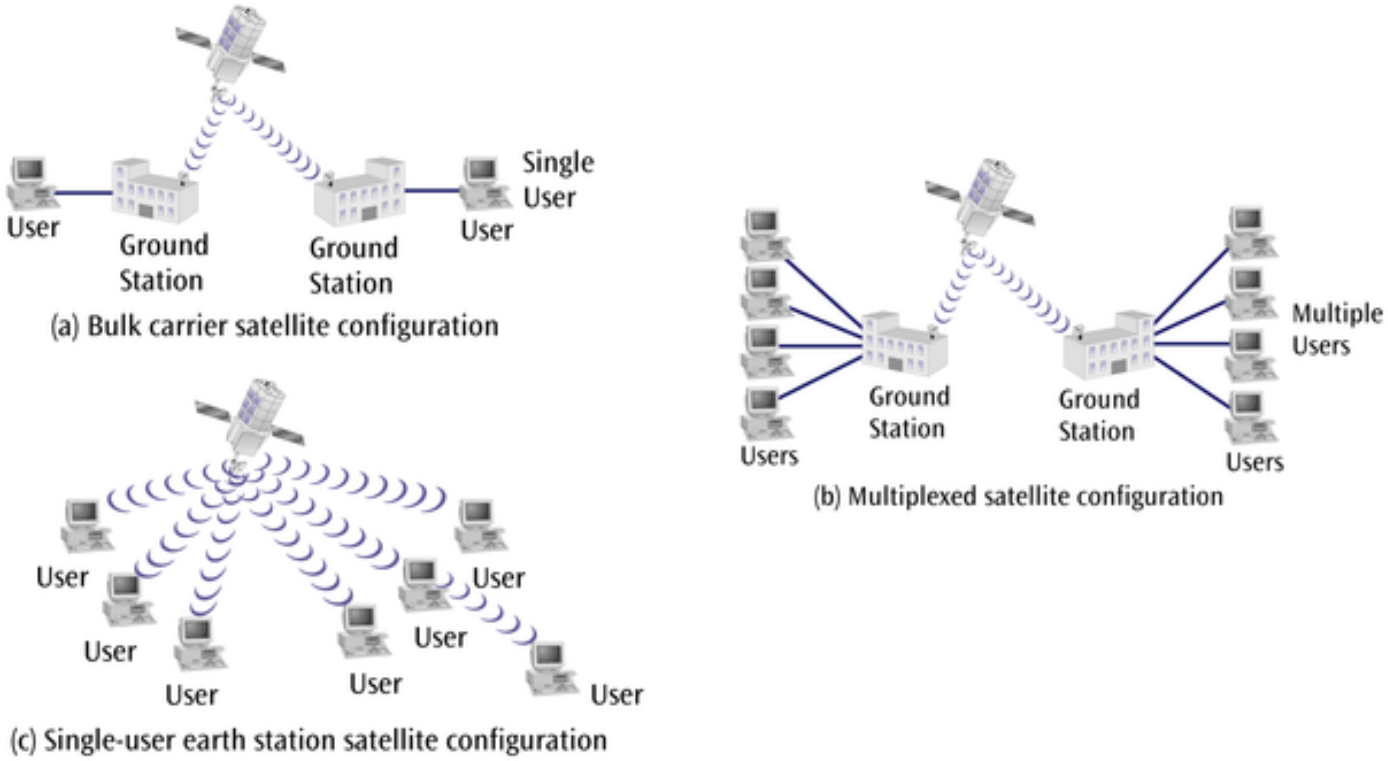
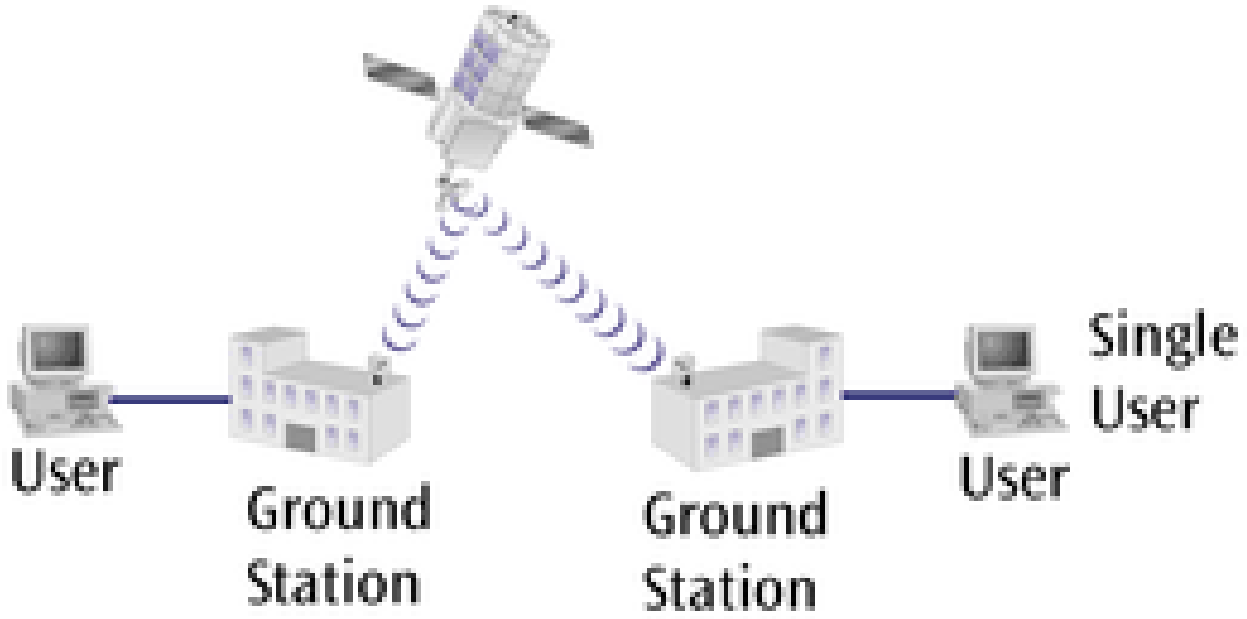


Figure 3-14 *Bulk, multiplexed, and single-user configurations of satellite systems*

Satellite Configuration

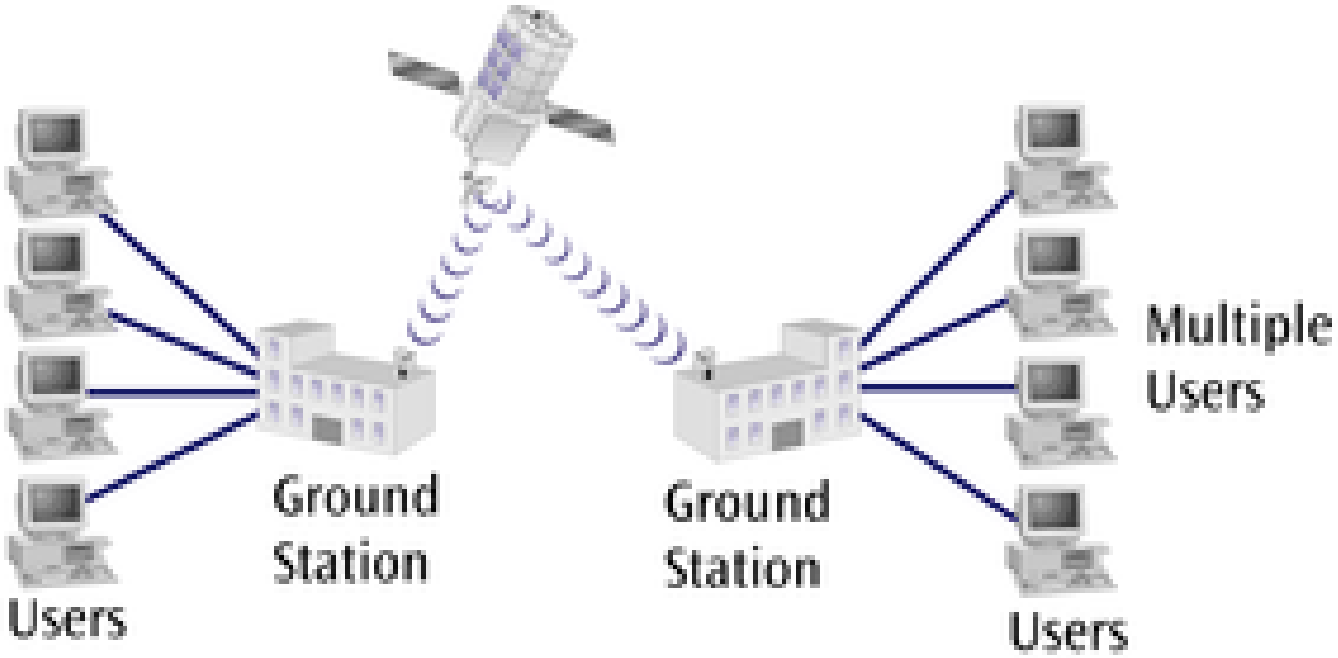
- Bulk carrier configuration



(a) Bulk carrier satellite configuration

Satellite Configuration

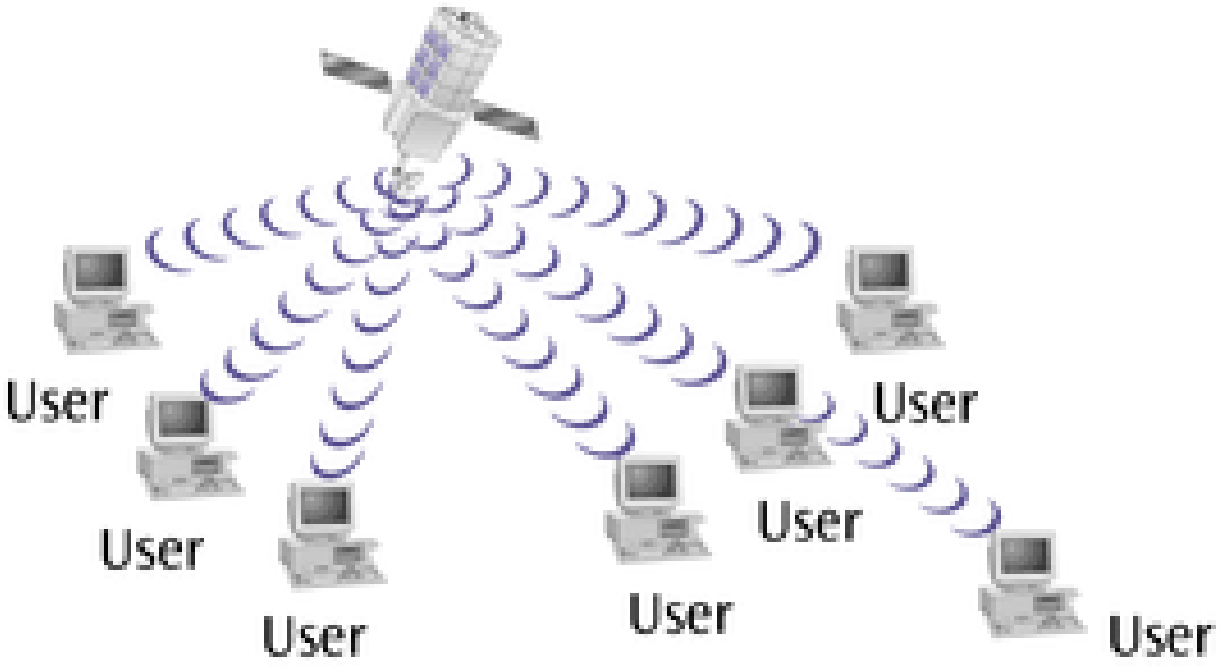
- Multiplexed configuration



(b) Multiplexed satellite configuration

Satellite Configuration

- Single-user earth station configuration (e.g. VSAT: Very Small Aperture Terminal)



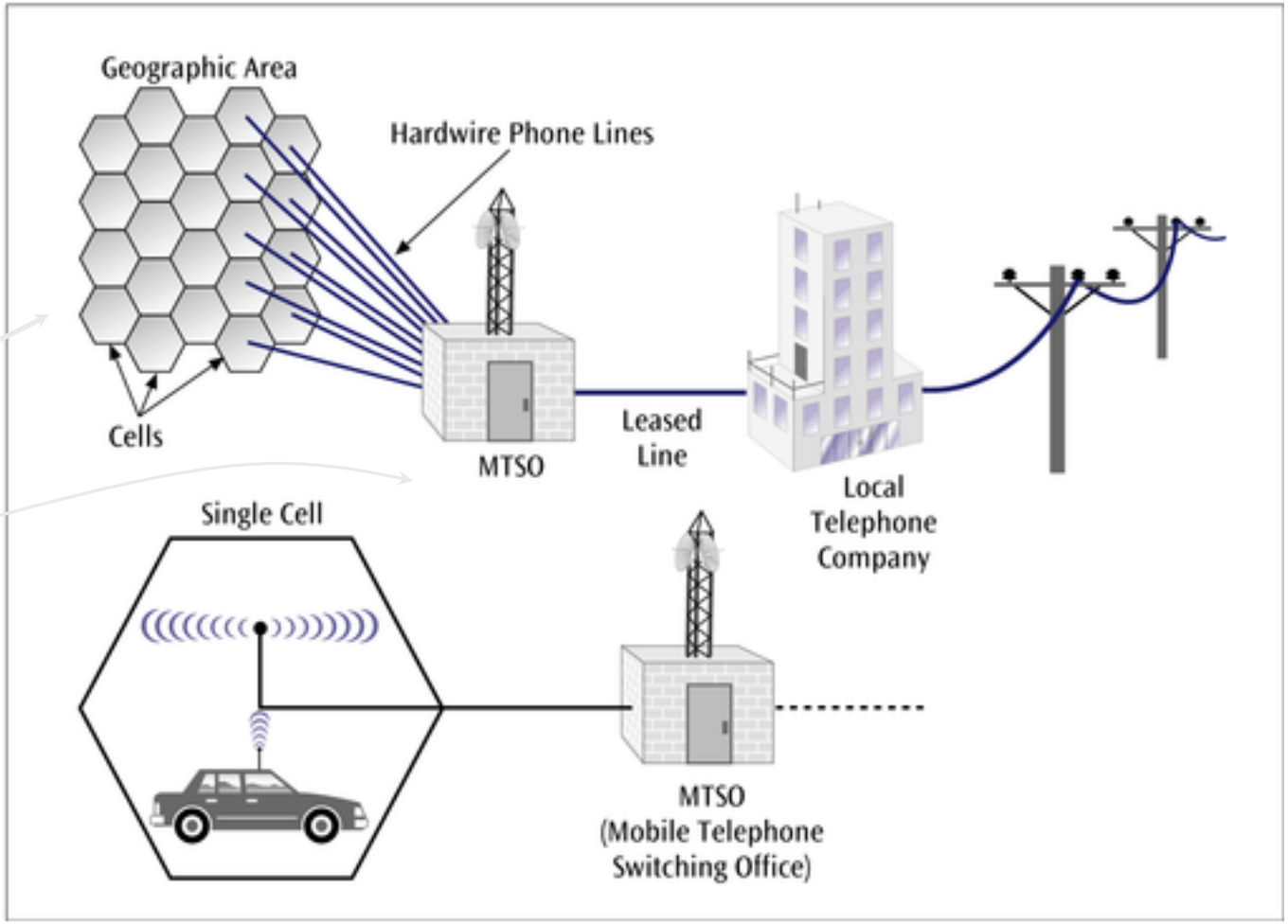
(c) Single-user earth station satellite configuration

Cellular Telephone

- Wireless telephone service,
  - cellular telephone, cell phone, and PCS.
- To support multiple users in a metropolitan area (market), the market is broken into cells.
- Each cell has its own transmission tower and set of assignable channels.

Cellular Telephone

Figure 3-15
One mobile telephone market divided into cells



Cellular Telephone

Figure 3-16
A mobile telephone tower

Cellular Telephone: 1st Generation

- AMPS - Advanced Mobile Phone Service – First (oldest) popular mobile phone service,
  - uses analog signals and dynamically assigned frequency division multiplexing.
- D-AMPS - Digital Advanced Mobile Phone Service –
  - Applies digital time division multiplexing on top of AMPS.

Cellular Telephone: 2nd Generation

- PCS - Personal Communication Systems
  - Newer all-digital mobile phone service (2nd generation)
- 2nd generation PCS phones come in number of technologies:
  - TDMA - Time division multiple access
  - CDMA - Code division multiple access
  - GSM - Global system for mobile communications

Cellular Telephone: 2.5rd Generation

- GPRS (General Packet Radio Service) – now used by AT&T Wireless, Cingular Wireless, and T-Mobile (formerly VoiceStream) in their GSM networks
  - Can transmit data at 30 kbps to 40 kbps
- CDMA2000 1xRTT (one carrier radio - transmission technology) – used by Verizon Wireless, Alltel, U.S. Cellular, and Sprint PCS
  - 50 kbps to 75 kbps
- IDEN technology – used by Nextel

Cellular Telephones (continued)

- 3rd Generation
  - UMTS (Universal Mobile Telecommunications System) – also called Wideband CDMA
    - The 3G version of GPRS
    - UMTS not backward compatible with GSM (thus requires phones with multiple decoders)
  - 1XEV (1 x Enhanced Version) –3G replacement for 1xRTT
    - Will come in two forms:
      - 1xEV-DO for data only
      - 1xEV-DV for data and voice

Cellular Telephone: Future

- GPRS should eventually be replaced with EDGE 110
  - 130 kbps possibly followed by WCDMA at 200 kbps – 300 kbps
- 1xRTT should eventually be replaced with 1xEVDV at 300 – 400 kbps and 1xEVDO at 150 Kbps to 250 kbps

Cellular Digital Packet Data (CDPD)

- Technology that supports a wireless connection for the transfer of computer data from a mobile location to the public telephone network and the Internet.
  - Can be used in conjunction with mobile telephones and laptop computers.
  - All digital transfer but relatively slow at 19,200 bps.
- Emergency services make use of CDPD.

Pagers

- Typically one-way communication service that uses ground-based and sometimes satellite-based systems.
- Some systems are two-way.
- Some systems can transmit small text messages (up to 208 characters).
- Uses LEO class satellites.

Infrared Transmissions

- Special transmissions that use a focused ray of light in the infrared frequency range.
  - 10^{12}-10^{14} Hz
- Very common with remote control devices,
- Can also be used for device-to-device transfers, such as PDA to computer, and Notebooks.
  - IrDA standards
- Will infrared last?

WAP (Wireless Application Protocol)

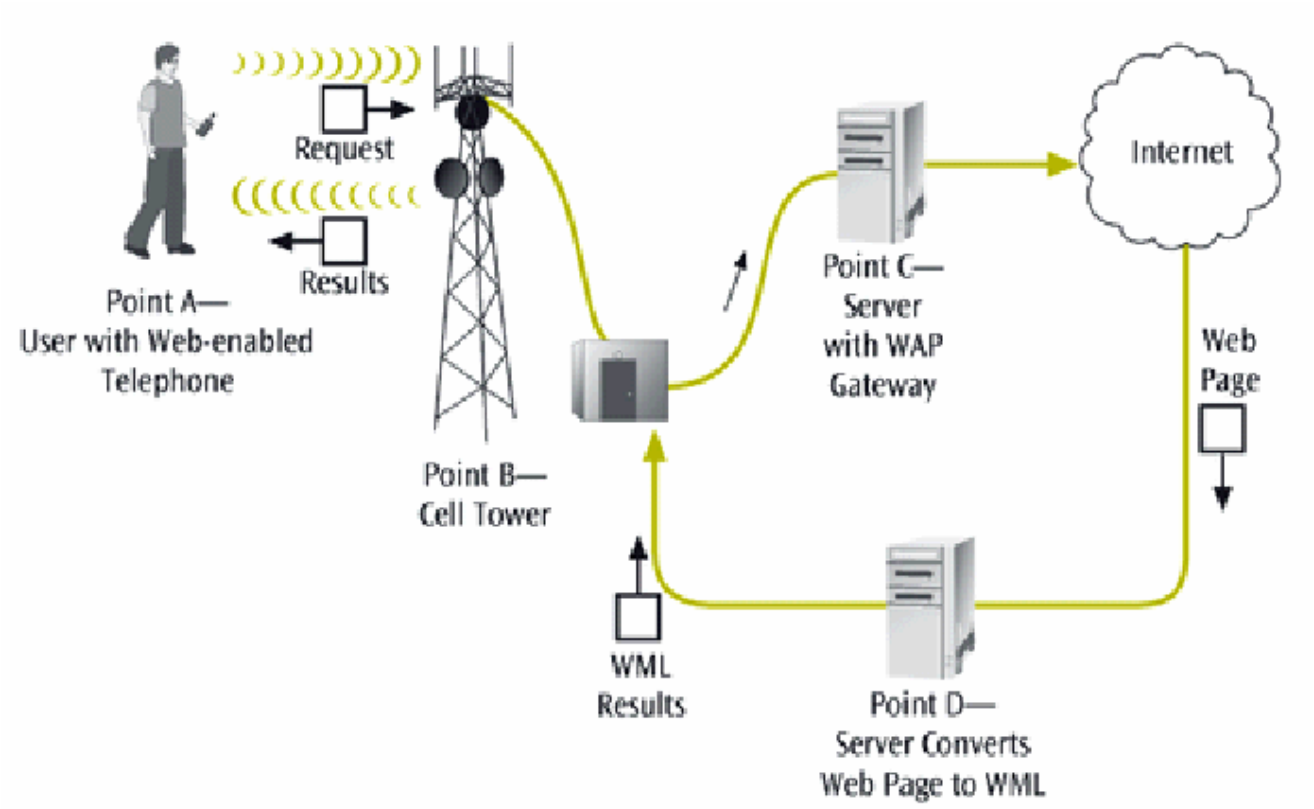
- WAP allows wireless devices such as mobile telephones, PDAs, pagers, and two-way radios to access the Internet.
- WAP is designed to work with small screens and with limited interactive controls.
- WAP incorporates Wireless Markup Language (WML) which is used to specify the format and presentation of text on the screen.

WAP (Wireless Application Protocol)

- WAP may be used for applications such as:
  - travel directions
  - sports scores
  - e-mail
  - online address books
  - traffic alerts
  - banking
  - news
- Possible shortcomings of WAP include
  - Low speeds,
  - Security, and
  - Very small user interface.

WAP (Wireless Application Protocol)

Steps involved in a WAP-enabled transmission

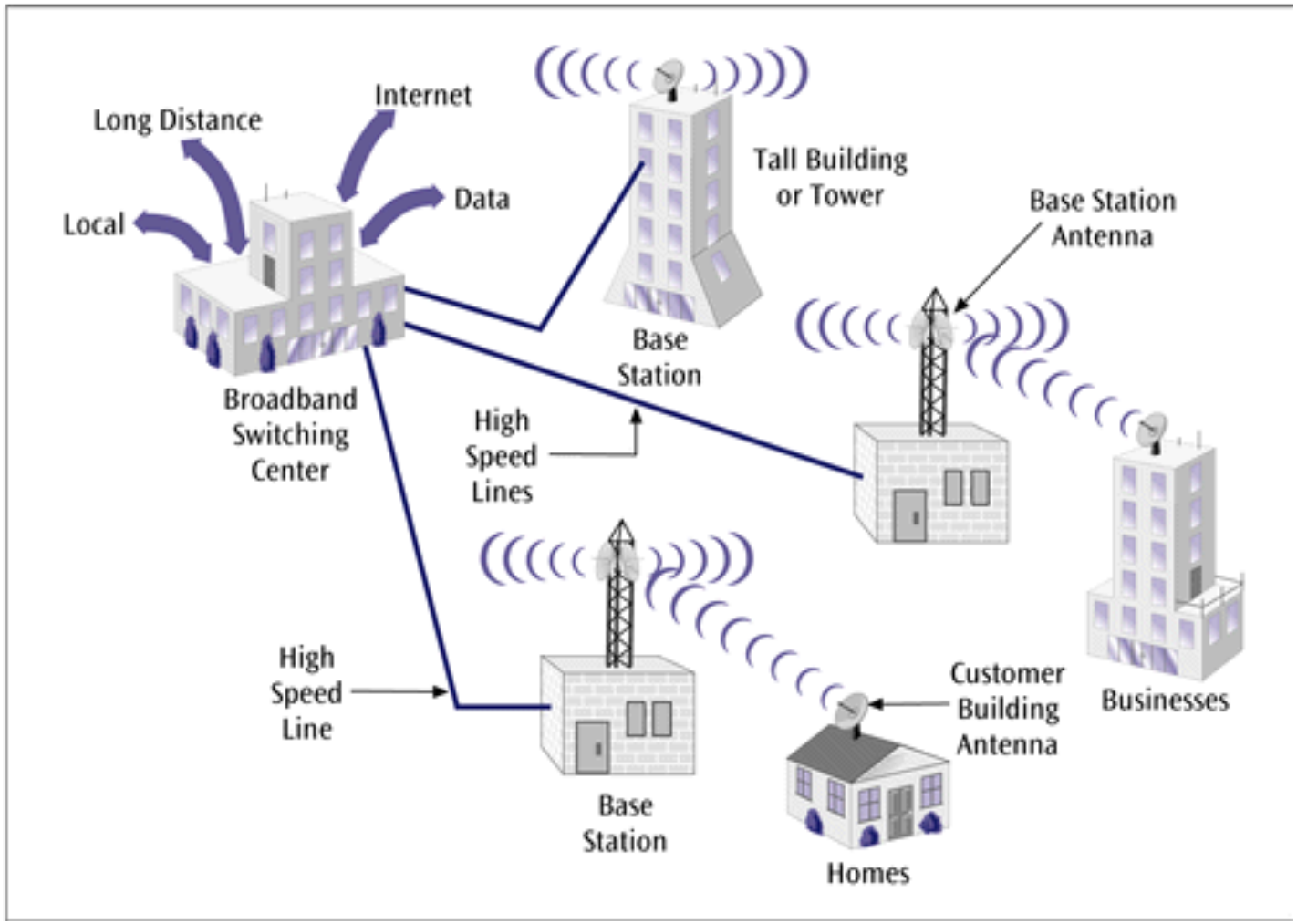


Broadband Wireless Systems

- Delivers Internet services into homes and businesses.
- Designed to bypass the local loop telephone line.
  - Very high frequencies (2500 MHz)
- Transmits voice, data and video over high frequency radio signals.

Broadband Wireless Systems

Figure 3-17
Broadband wireless configuration in a metropolitan area



Broadband Wireless Systems

- Two basic technologies, both support digital data, video, Internet access
- MMDS: Multichannel Multipoint Distribution Service
  - Very high speed (10 Mbps down, 512 Kbps up)
  - Transmits on super high frequency, SHF, 2.5 GHz, 30-35 miles
  - Suitable for rural areas, home use
- LMDS: Local Multipoint Distribution System
  - Millions bps (45 Mbps)
  - 28 GHz – 30 GHz, but covers an area of 5 miles
  - Suitable for metropolitan areas, commercial use

Bluetooth

- Bluetooth is a Radio Frequency specification for short-range, point-to-multipoint voice and data transfer.
- Bluetooth can transmit through solid, non-metal objects.
- Its typical link range is from 10 cm to 10 m,
  - Can be extended to 100 m by increasing the power.

Bluetooth

- Will enable users to connect to a wide range of computing and telecommunication devices without the need of connecting cables.

- Typical uses include phones and pagers, modems, LAN access devices, headsets, notebooks, desktop computers, and PDAs.

Wireless LAN (IEEE 802.11)

- This technology transmits data between workstations and local area networks using high speed radio frequencies.
- Current technology (and protocol) allows for 11 Mbps (11.b) and 54 Mbps (11.g) data transfer at distances up to hundreds of feet.
- More on this in Chapter Seven (LANs)

Free Space Optics

- Uses lasers, or more economical infrared transmitting devices
- Line of sight between buildings
- Typically short distances, such as across the street
- Newer auto-tracking systems keep lasers aligned when buildings shake from wind and traffic

Free Space Optics (continued)

- Current FSO speeds go from T-3 (45 Mbps) up to OC-48 (2.5 Gbps) with faster systems in the lab
- Major weakness is fog
- Typical FSO has link margin of about 20 dB
- Under perfect conditions, air reduces system's power by approx 1 dB/km

Free Space Optics (continued)

- Heavy fog can cause a loss of 400 db/km (rendering 20 dB systems to 50 meters)

- Scintillation is also a problem (especially in hot weather)
  - Scintillation: a flash of light produced in certain materials when they absorb ionizing radiation

Ultra-wideband

- Not limited to fixed bandwidth
  - Broadcasts over wide range of frequencies simultaneously
  - Many of these frequencies are used by other sources
  - Uses such low power that it “should not” interfere with these other sources
- Can achieve speeds up to 100 Mbps (unshared) but for small distances such as wireless LANs

Ultra-wideband (continued)

- Proponents say UWB gets something for nothing since it shares frequencies with other sources
- Opponents say too much interference
- Cell phone industry very against UWB because CDMA most susceptible to interference
- GPS may also be affected
- One solution may be have two types of systems
  - Indoor (stronger)
  - Outdoor (1/10 the power)

Wireless Media: Summary

Summary of wireless media

Type of Wireless Media	Typical Use	Signaling Technique	Maximum Data Transfer Rate	Maximum Range	Advantages	Disadvantages
Microwave	Long-haul telecommunications, building to building	Analog	n-Gbps	20-30 miles	Reliable, high speed and high volume	Long-haul expensive to implement, potential interference
Satellite						
GEO	Signal relays for cable and direct television	Analog	n-Gbps	One third the earth's circumference (8000 miles)	Very long distance, high speed and high volume	Expensive to lease, some interference

Wireless Media: Summary

Summary of wireless media (continued)

Type of Wireless Media	Typical Use	Signaling Technique	Maximum Data Transfer Rate	Maximum Range	Advantages	Disadvantages
MEO	GPS-style surface navigation systems	Analog	n-Gbps	Nationwide	High speed transfers, wide distance	Expensive to lease, some interference
LEO	Communications such as email, paging, worldwide mobile phone network, spying, remote sensing, video-conferencing	Analog	n-Gbps	Worldwide	High speed transfers, very wide distance, some applications inexpensive	Some applications expensive, some interference
Cellular (AMPS and D-AMPS)	Wireless telephones	Analog and digital	19.2 Kbps	Each cell: 0.5-50 mile radius, but nationwide coverage	Widespread, inexpensive applications	Noise
CDPD	Mobile data transfer	Digital	19.2 Kbps	Each cell: 0.5-50 mile radius, but nationwide coverage	Uses existing cellular systems	Limited speeds
PCS						
TDMA	Wireless telephones	Digital	56 Kbps	Each cell 0.5-25 mile radius, spotty nationwide coverage	All digital, low noise	Not everywhere
CDMA	Wireless telephones	Digital	56 Kbps	Each cell 0.5-25 mile radius, spotty nationwide coverage	All digital, low noise	Not everywhere
GSM	Wireless telephones	Digital	56 Kbps	Each cell 0.5-25 mile radius, spotty nationwide coverage	All digital, low noise	Not everywhere, least popular PCS technology in U.S.
Pagers	Wireless paging system	Analog		Local and global systems available	Inexpensive use, wide popularity, some systems two-way	Limited text transfer capabilities
Infrared	Short distance data transfer	Infrared light	16 Mbps	1.5 miles	Fast, inexpensive, secure	Short distances
Local Multipoint Distribution Service	Cable television and Internet service	Digital	1 Gbps	Same as microwave	Relatively inexpensive to use	Expensive to implement, not yet widespread

Media Selection Criteria

- Cost –
  - Initial cost,
  - ROI,
  - Maintenance/support cost
- Speed –
  - Data transfer speed,
  - propagation speed
- Distance and expandability
- Environment –
  - Noise level
- Security –
  - Wiretap possible?
  - Need encryption?

Conducted Media In Action

- Remember : Using Category 5 unshielded twisted pair, the maximum segment length is 100 meters.
- A wall jack is a passive device and does not regenerate a signal.
- Hub to hub connections are often fiber optic cable.

Conducted Media In Action

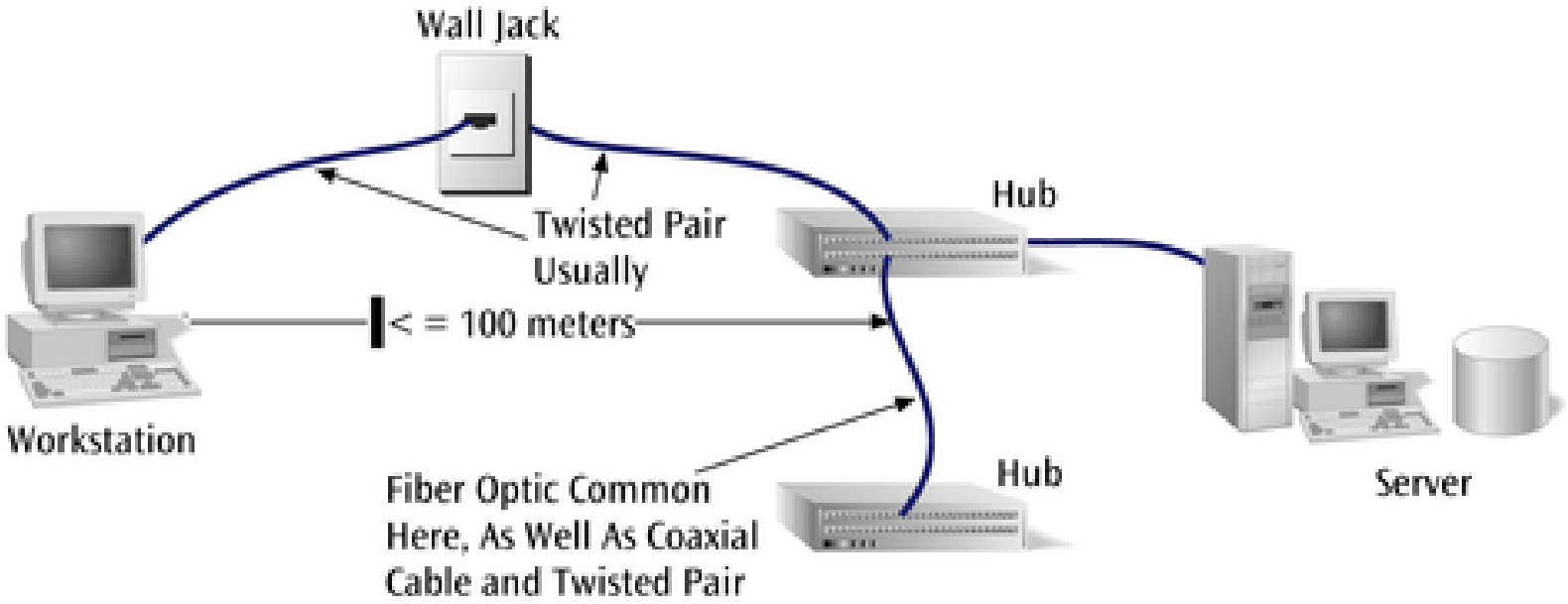


Figure 3-18
Example wiring situation involving a microcomputer and a local area network

Interconnecting Two Buildings

- Two buildings are separated by 400 meters. How do we interconnect them?
  - Twisted pair? (Do we even have access?)
  - Coaxial cable?
  - Fiber?
  - Wireless?
  - Other? (Chapter 12)

Wireless Media In Action

- DataMining Corporation has one office in Chicago and one in Los Angeles.
- There is a need to transmit large amounts of data between the two sites.
- DataMining is considering using a Very Small Aperture Terminal satellite system.

Wireless Media In Action

- Cost-Cost is proportional to high amount of traffic with very high reliability.
- Speed- Speed is high enough to support company's needs.
- Distance- Distance can easily expand across the U.S.
- Environment- Satellite systems are robust in most environments, but a backup can be considered.
- Security- Security can be very good with encryption.

Wireless Media In Action

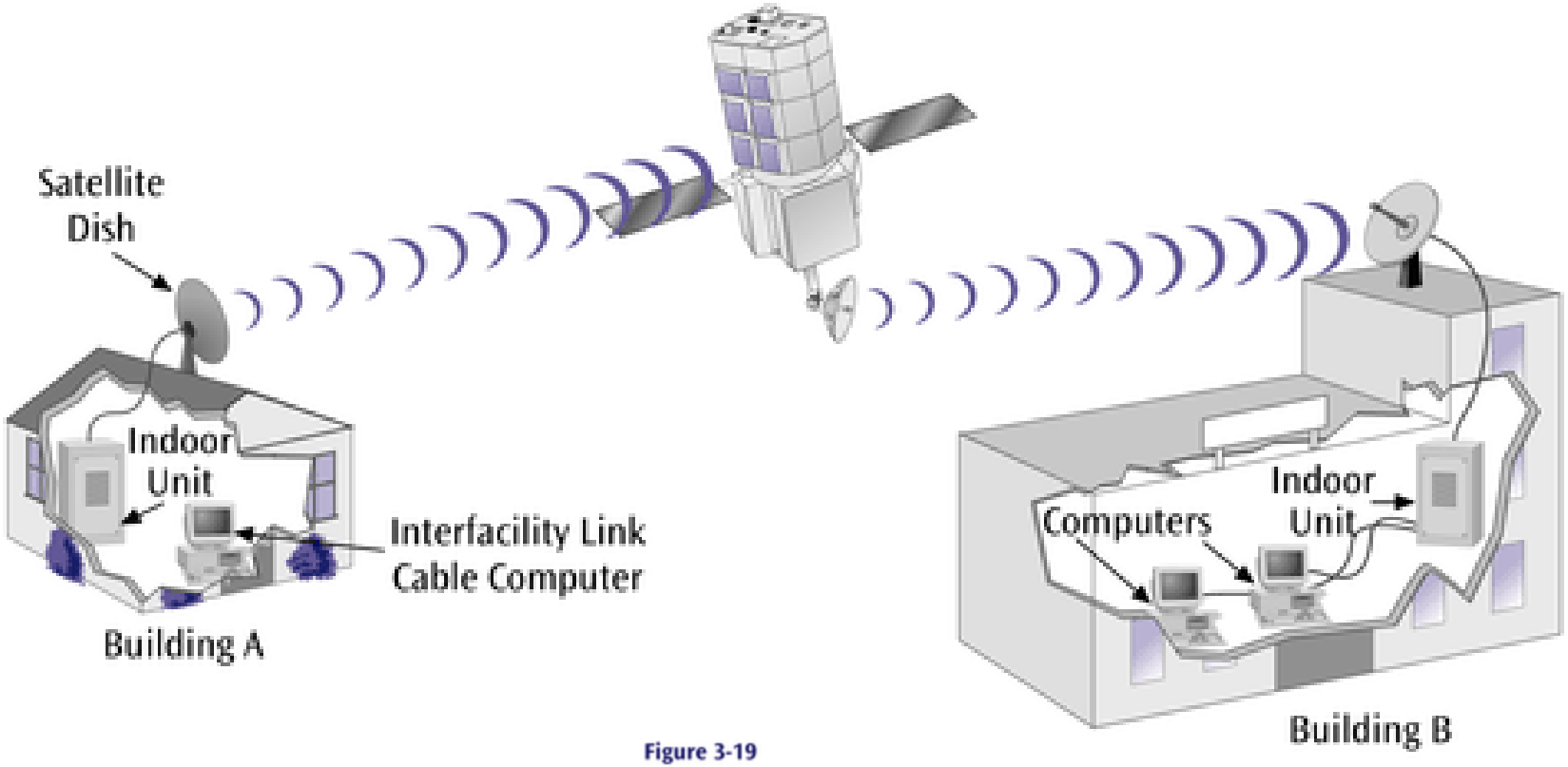


Figure 3-19
VSAT satellite solution for DataMining Corporation

What we learned in this chapter

- the differences between Category 1, 2, 3, 4, 5, 5e, 6, and 7 twisted pair wire.
- the characteristics of coaxial cable including the advantages and vantages.
- Outline the characteristics of fiber optic cable including the advantages and disadvantages.
- Outline the characteristics of terrestrial microwave systems including the advantages and disadvantages.
- Outline the characteristics of satellite microwave systems including the advantages and disadvantages as well as the differences between low earth orbit, middle earth orbit, geosynchronous earth orbit, and highly elliptical earth orbit satellites.
- Describe the basics of wireless radio, including AMPS, D-AMPS, PCS systems, and third generation wireless systems.
- Outline the characteristics of pager systems including the advantages and disadvantages.
- Outline the characteristics of short-range transmissions, including Bluetooth
- Describe the characteristics, advantages, and disadvantages of wireless application protocol
- Outline the characteristics of broadband wireless systems including the advantages and disadvantages.
- Apply the media selection criteria of cost, speed, distance and expandability, environment, and security to various media in a particular application.