

Chapter Three

Conducted and Wireless Media

Data Communications and Computer
Networks: A Business User's Approach
Eighth Edition

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 terrestrial microwave systems, including the advantages and disadvantages

After reading this chapter,
you should be able to (continued):

- 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
- Describe the basics of cellular telephones, including all the current generations of cellular systems
- Outline the characteristics of short-range transmissions, including Bluetooth

After reading this chapter,
you should be able to (continued):

- 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, expandability and distance, environment, and security to various media in a particular application

Introduction

- The world of computer networks would not exist if there were no medium by which to transfer data
- The two major categories of media include:
 - Conducted media
 - Wireless media

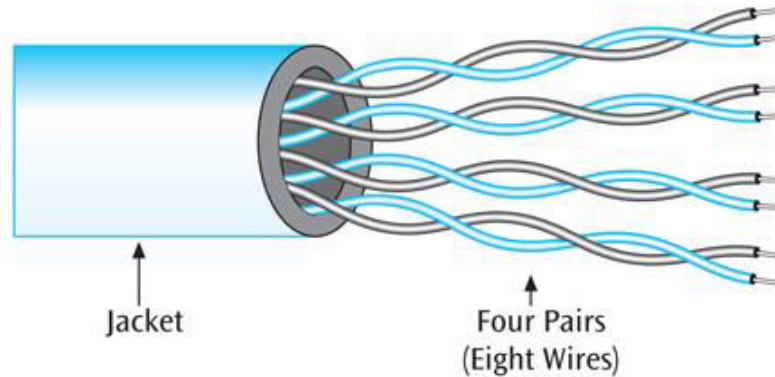
Twisted Pair Wire

- One or more pairs of single conductor wires that have been twisted around each other
- Twisted pair wire is classified by category. Twisted pair is currently Category 1 through Category 7, although Categories 1, 2 and 4 are nearly obsolete
- Twisting the wires helps to eliminate electromagnetic interference between the two wires
- Shielding can further help to eliminate interference

Twisted Pair Wire (continued)

Figure 3-1

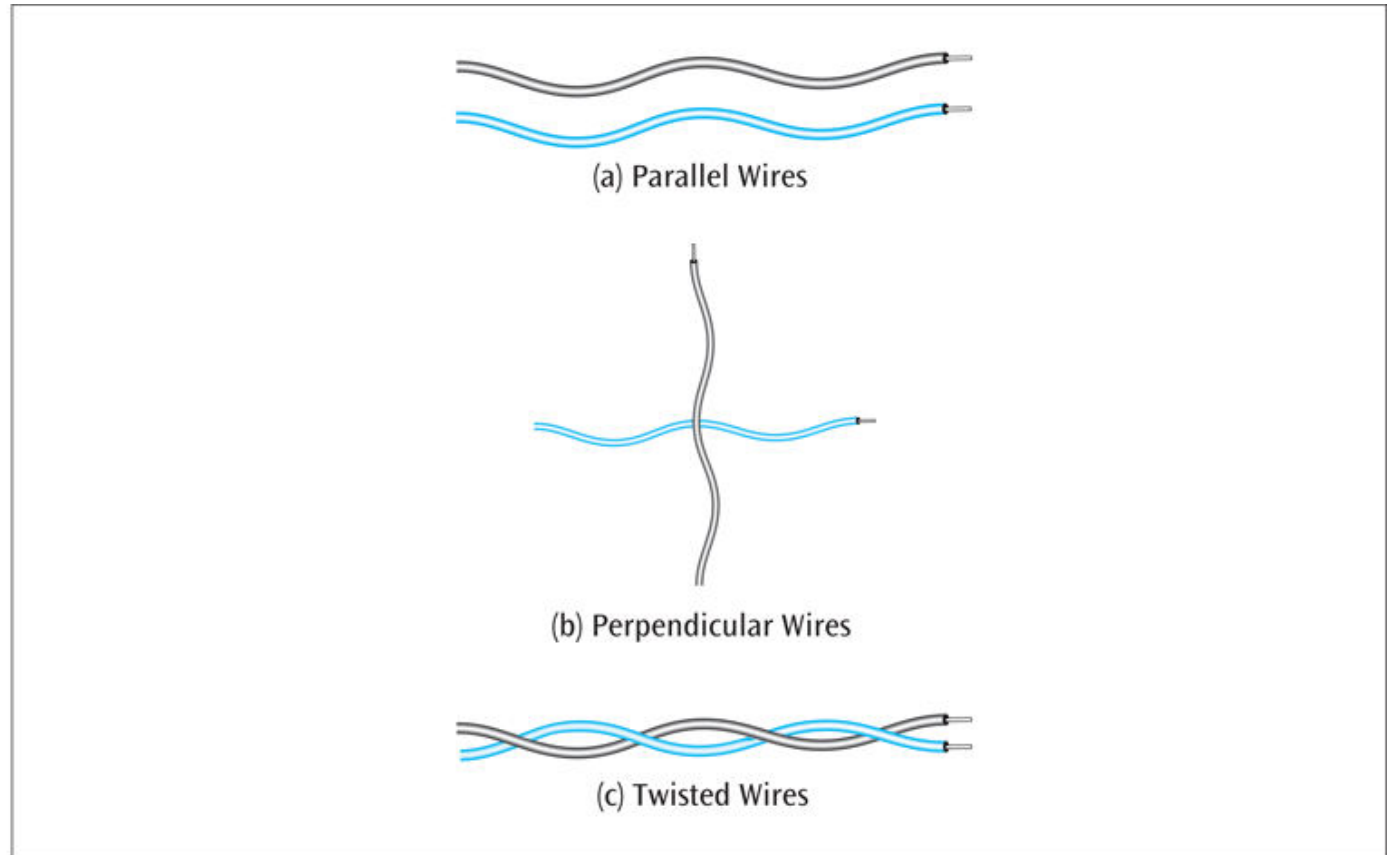
*Example of four-pair
twisted pair wire*



Twisted Pair Wire (continued)

Figure 3-2

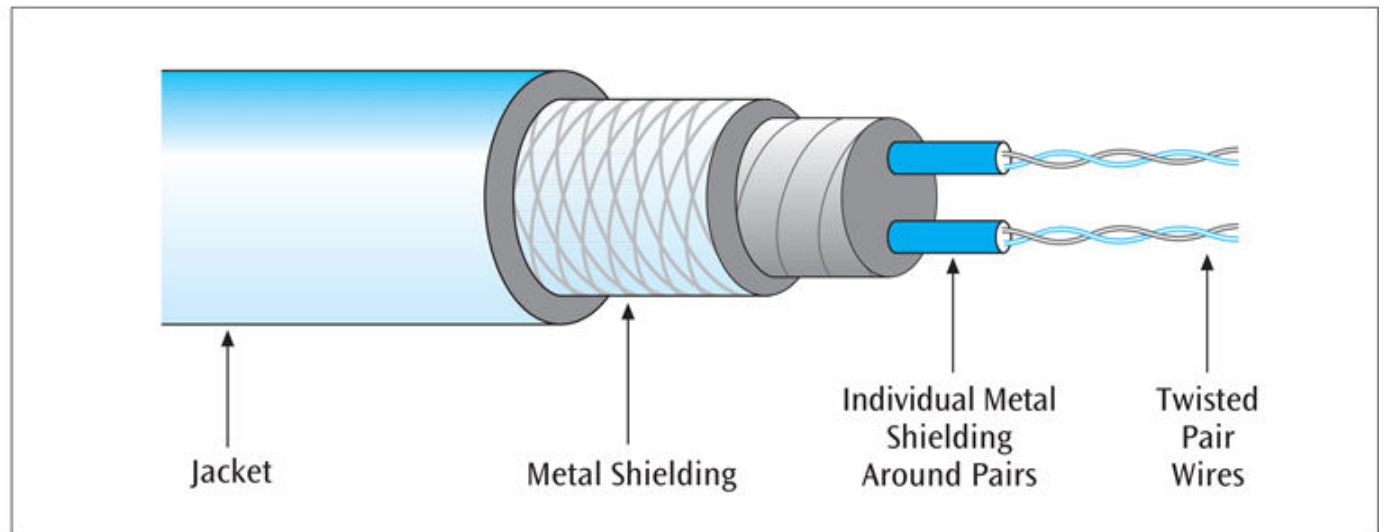
- (a) Parallel wires—greater chance of crosstalk*
- (b) Perpendicular wires—lesser chance of crosstalk*
- (c) Twisted wires—crosstalk reduced because wires keep crossing each other at nearly perpendicular angles*



Twisted Pair Wire (continued)

Figure 3-3

An example of shielded twisted pair



Twisted Pair Wire (continued)

Table 3-1

A summary of the characteristics of twisted pair wires

UTP Category	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
Category 1	Telephone wire	<100 kbps	5–6 kilometers (3–4 miles)	Inexpensive, easy to install and interface	Security, noise, obsolete
Category 2	T-1, ISDN	<2 Mbps	5–6 kilometers (3–4 miles)	Same as Category 1	Security, noise, obsolete
Category 3	Telephone circuits	10 Mbps	100 m (328 ft)	Same as Category 1, with less noise	Security, noise
Category 4	LANs	20 Mbps	100 m (328 ft)	Same as Category 1, with less noise	Security, noise, obsolete
Category 5	LANs	100 Mbps (100 MHz)	100 m (328 ft)	Same as Category 1, with less noise	Security, noise
Category 5e	LANs	250 Mbps per pair (125 MHz)	100 m (328 ft)	Same as Category 5. Also includes specifications for connectors, patch cords, and other components	Security, noise
Category 6	LANs	250 Mbps per pair (250 MHz)	100 m (328 ft)	Higher rates than Category 5e, less noise	Security, noise, cost
Category 7	LANs	600 MHz	100 m (328 ft)	High data rates	Security, noise, cost

Twisted Pair Summary

- Most common form of wire
- Relatively inexpensive
- Easy to install
- Carries high data rates (but not the highest)
- Can suffer from electromagnetic noise
- Can be easily wire-tapped
- Comes in shielded and unshielded forms

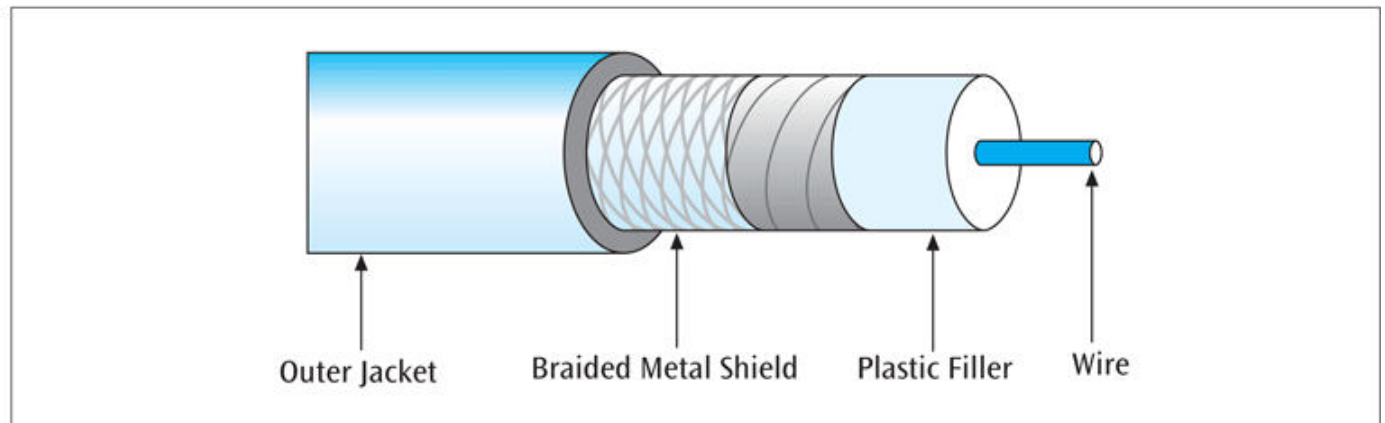
Coaxial Cable

- A single wire wrapped in a foam insulation surrounded by a braided metal shield, then covered in a plastic jacket. Cable comes in various thicknesses
- 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

Coaxial Cable (continued)

Figure 3-4

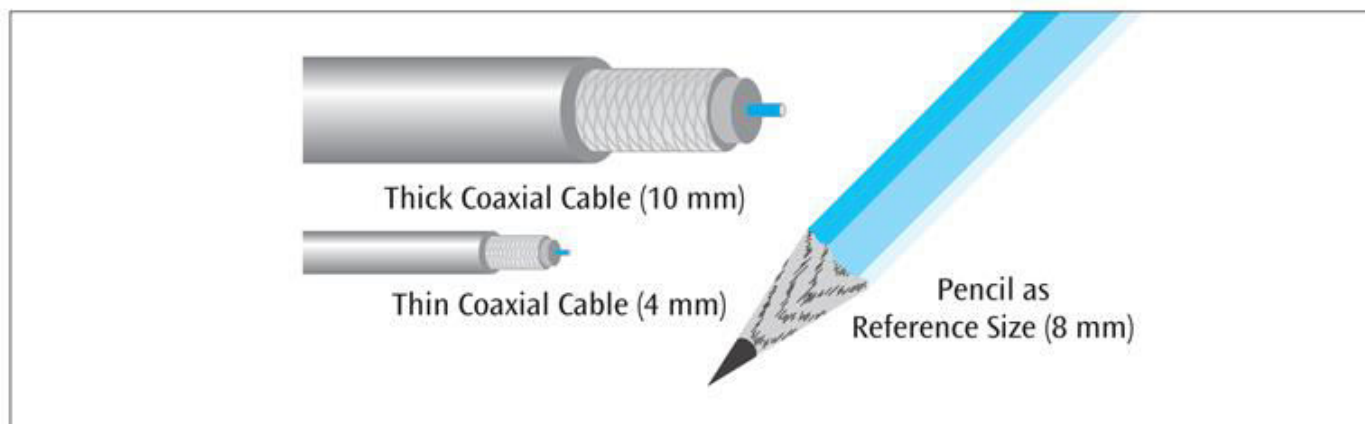
Example of coaxial cable showing metal braid



Coaxial Cable (continued)

Figure 3-5

Examples of thick coaxial cable and thin coaxial cable



Coaxial Cable Summary

- A single wire surrounded by a braided shield
- Because of shielding, can carry a wide bandwidth of frequencies
- Thus is good with applications such as cable television
- Not as easy to install as twisted pair
- More expensive than twisted pair

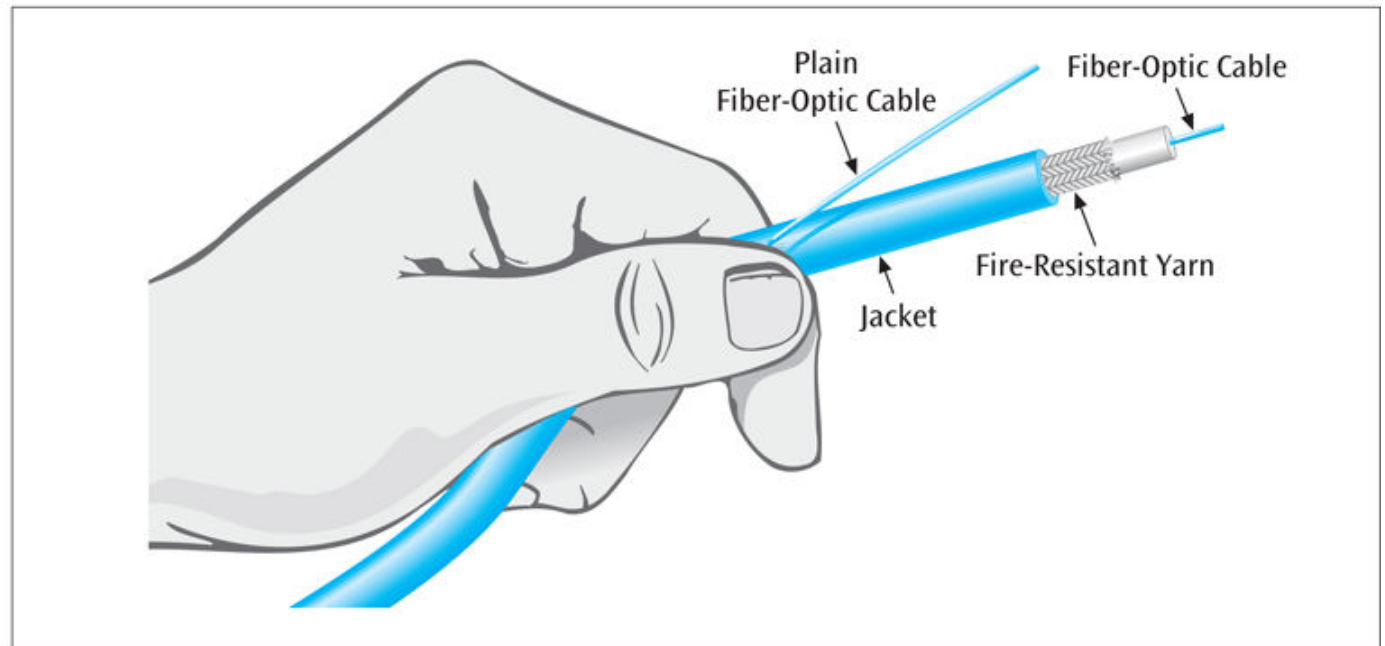
Fiber-Optic Cable

- 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 (continued)

Figure 3-6

A person holding a plain fiber-optic cable and a fiber-optic cable in an insulated jacket



Fiber-Optic Cable (continued)

- 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 (continued)

Figure 3-7

*A fiber-optic cable
with multiple strands
of fiber*



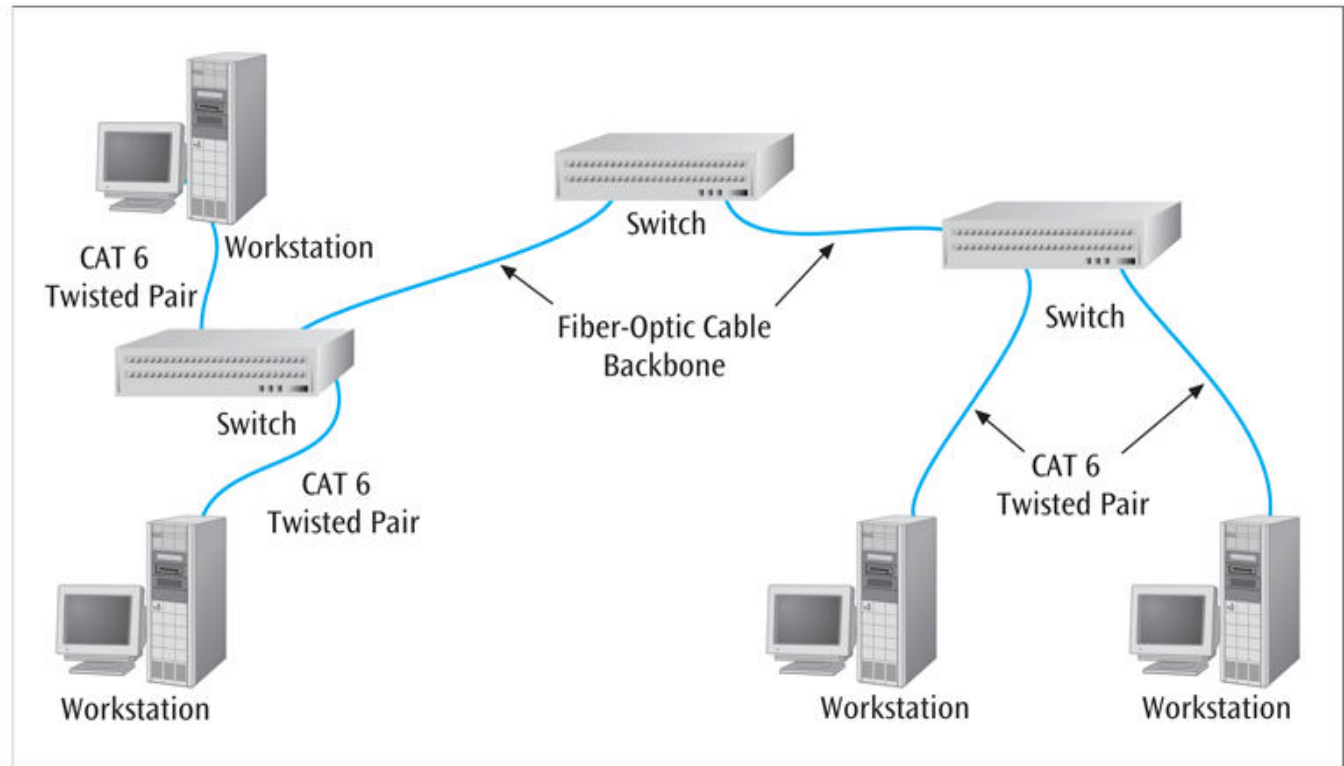
Fiber-Optic Cable (continued)

- 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 (continued)

Figure 3-8

A fiber-optic backbone with Category 6 twisted pair running to the workstations



Fiber-Optic Cable (continued)

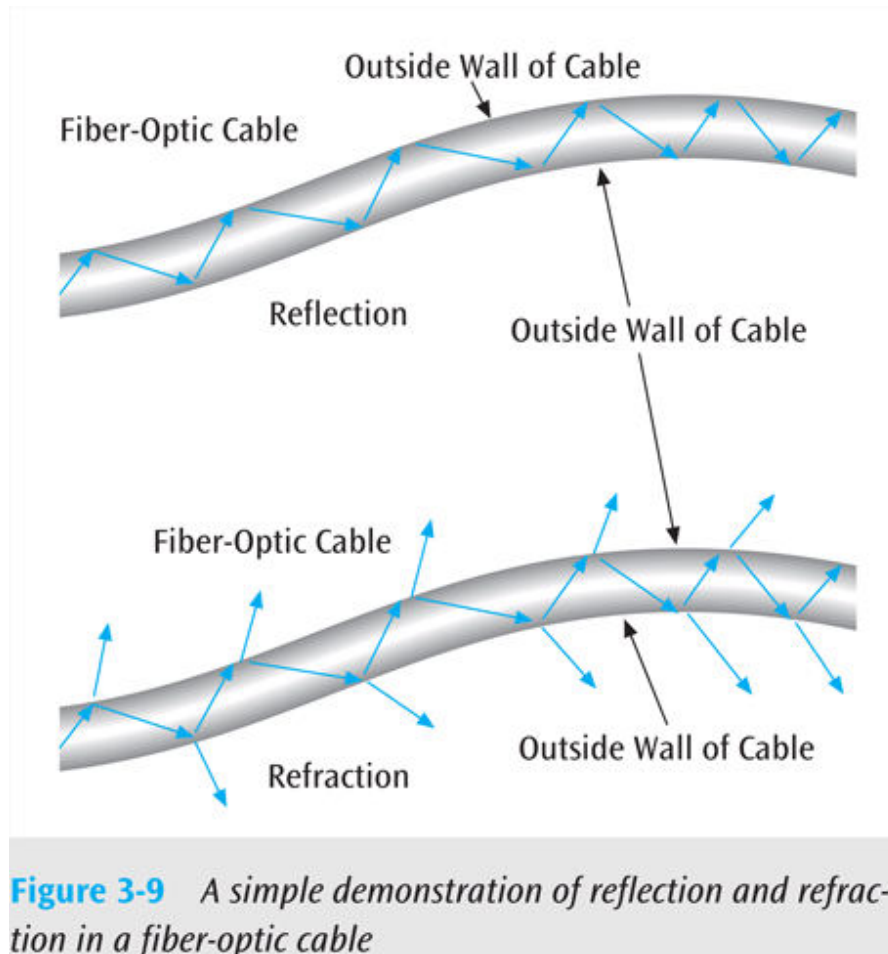


Figure 3-9 A simple demonstration of reflection and refraction in a fiber-optic cable

Fiber-Optic Cable Summary

- Fiber optic cable can carry the highest data rate for the longest distances
- Initial cost-wise, more expensive than twisted pair, but less than coaxial cable
- But when you consider the superiority of fiber, initial costs outweighed by capacities
- Need to fibers for a round-trip connection
- Not affected by electromagnetic noise and cannot be easily wiretapped, but still noise

Conducted Media

Table 3-3 A summary of the characteristics of conducted media

Type of Conducted Medium	Typical Use	Maximum Data Rate	Maximum Transmission Range	Advantages	Disadvantages
Twisted pair Category 1, 3	Telephone systems	<2 Mbps	5–6 kilometers (3–4 miles)	Inexpensive, common	Noise, security, obsolete
Twisted pair Category 5, 5e, 6, 7	LANs	100–1000 Mbps	100 m (328 feet)	Inexpensive, versatile	Noise, security
Thin Coaxial Cable (baseband single channel)	LANs	10 Mbps	100 m (328 feet)	Low noise	Security
Thick Coaxial Cable (broadband multichannel)	LANs, cable TV, long-distance telephone, short- run computer system links	10–100 Mbps	5–6 kilometers (3–4 miles) (at lower data rates)	Low noise, multiple channels	Security
LED Fiber-Optic	Data, video, audio, LANs	Gbps	300 meters (approx. 1000 feet)	Secure, high capacity, low noise	Interface expensive but decreasing in cost
Laser Fiber-Optic	Data, video, audio, WANs, MANs	100s Gbps	100 kilometers (approx. 60 miles)	Secure, high capacity, very low noise	Interface expensive

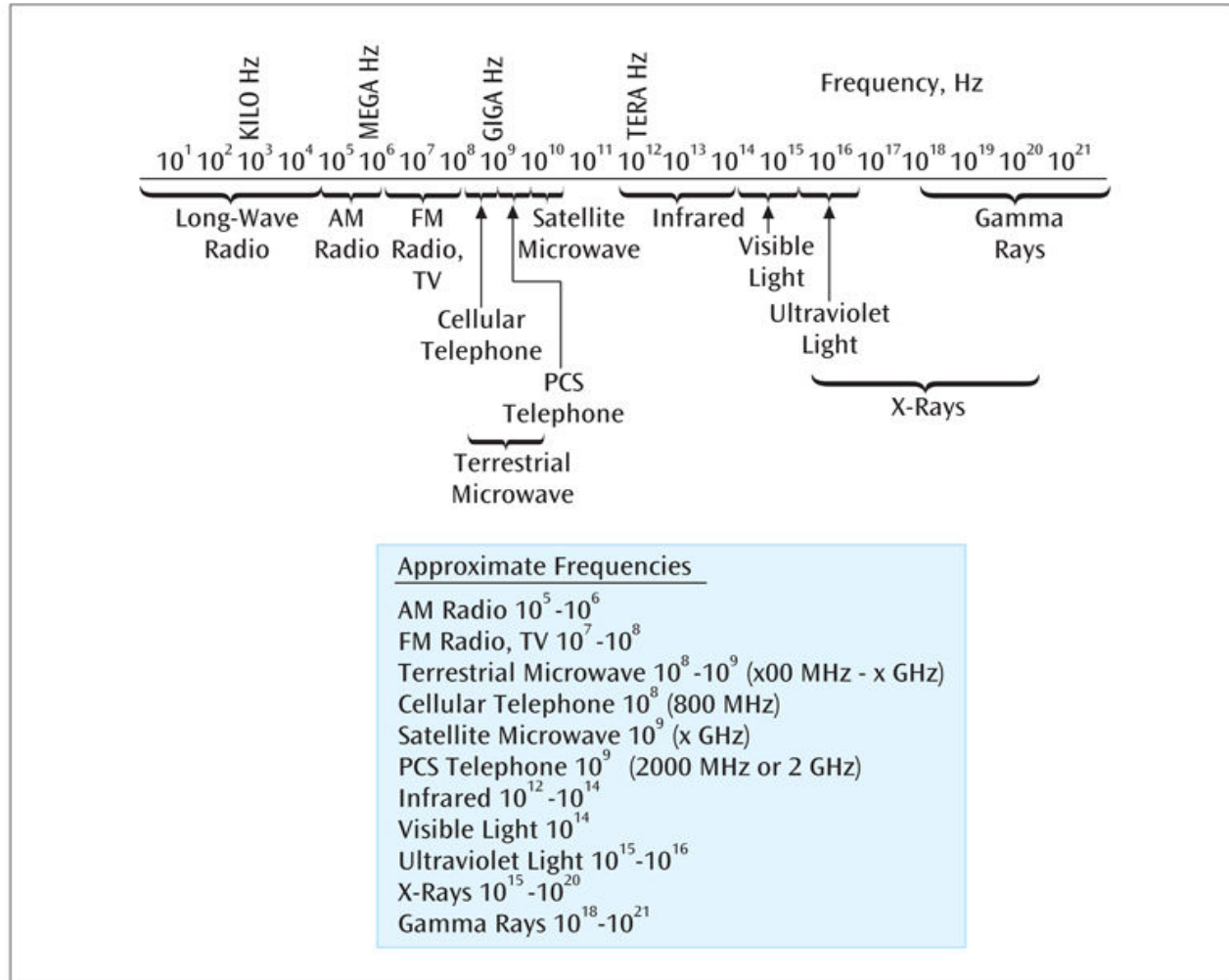
Wireless Media

- Radio, satellite transmissions, and infrared light are all different forms of electromagnetic waves that are used to transmit data
- Technically speaking – in wireless transmissions, space is the medium
- Note in the following figure how each source occupies a different set of frequencies

Wireless Media (continued)

Figure 3-10

Electromagnetic wave frequencies



Terrestrial Microwave Transmission

- Land-based, line-of-sight transmission
- Approximately 20-30 miles between towers
- Transmits data at hundreds of millions of bits per second
- Signals will not pass through solid objects
- Popular with telephone companies and business to business transmissions

Terrestrial Microwave Transmission (continued)

Figure 3-11

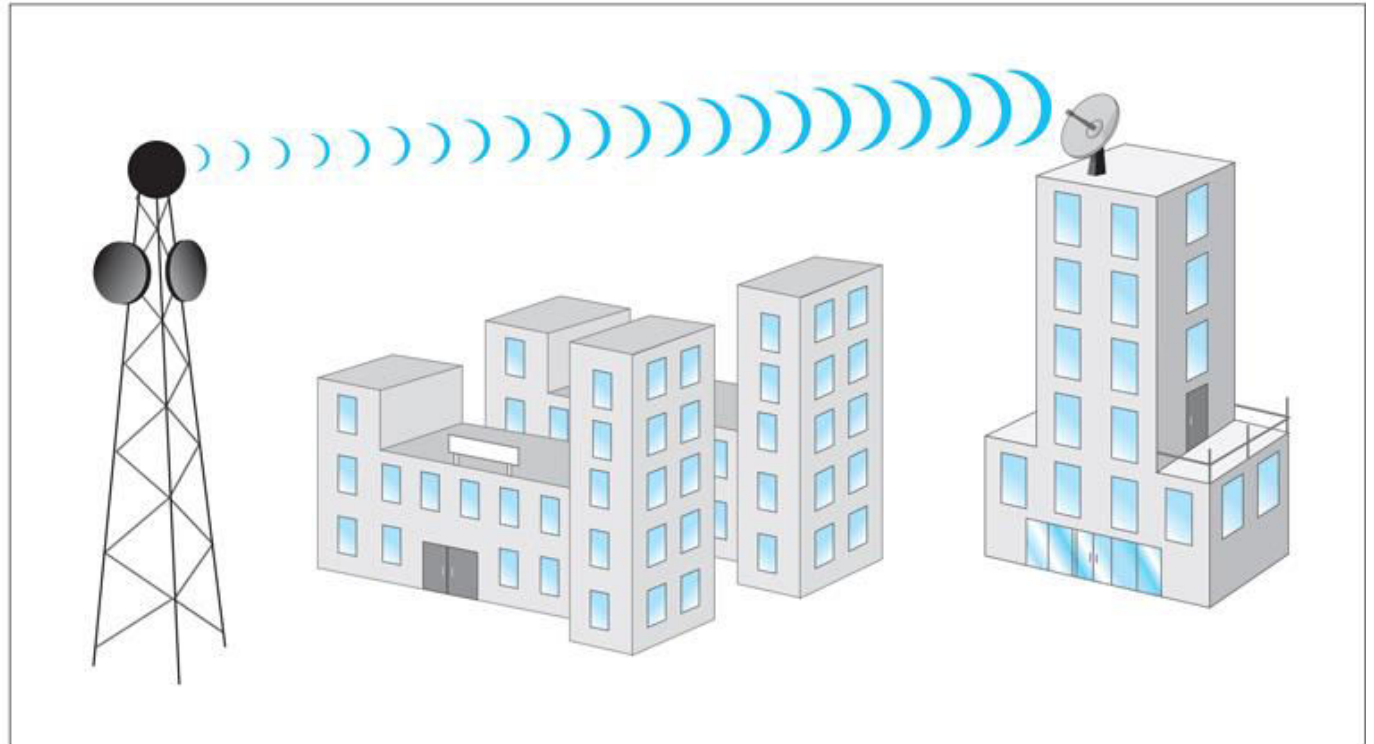
*A typical microwave
tower and antenna*



Terrestrial Microwave Transmission (continued)

Figure 3-12

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



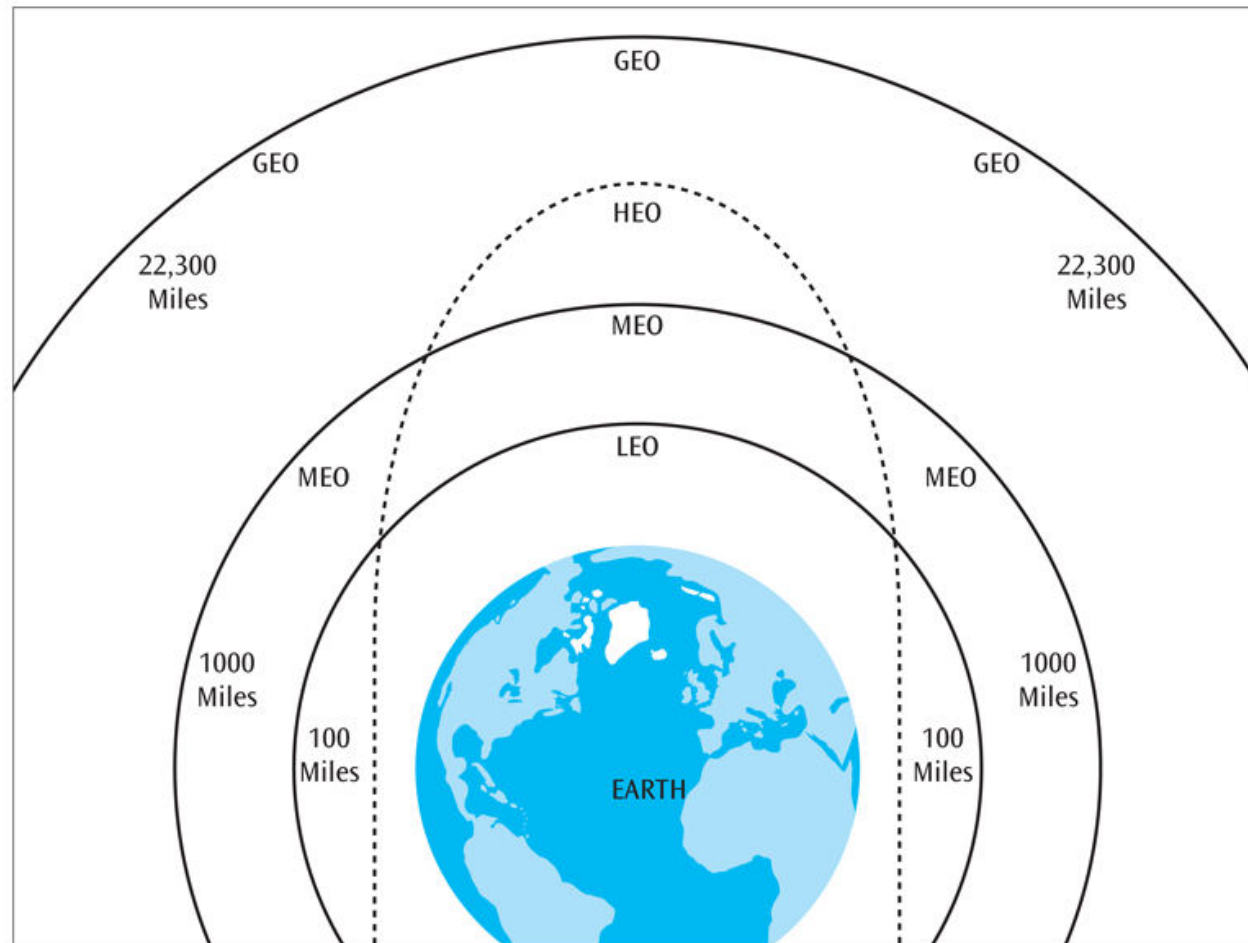
Satellite Microwave Transmission

- Similar to terrestrial microwave except the signal travels from a ground station on earth to a satellite and back to another ground station
- Can also transmit signals from one satellite to another
- Satellites can be classified by how far out into orbit each one is (LEO, MEO, GEO, and HEO)

Satellite Microwave Transmission (continued)

Figure 3-13

*Earth and the four
Earth orbits: LEO, MEO,
GEO, and HEO*



Satellite Microwave Transmission (continued)

- LEO (Low-Earth-Orbit) – 100 to 1000 miles out
 - Used for wireless e-mail, special mobile telephones, pagers, spying, videoconferencing
- MEO (Middle-Earth-Orbit) – 1000 to 22,300 miles
 - Used for GPS (global positioning systems) and government
- GEO (Geosynchronous-Earth-Orbit) – 22,300 miles
 - Always over the same position on earth (and always over the equator)
 - Used for weather, television, government operations

Satellite Microwave Transmission (continued)

- HEO (Highly Elliptical Earth orbit) – satellite follows an elliptical orbit
 - Used by the military for spying and by scientific organizations for photographing celestial bodies

Satellite Microwave Transmission (continued)

- Satellite microwave can also be classified by its configuration (see next figure):
 - Bulk carrier configuration
 - Multiplexed configuration
 - Single-user earth station configuration (e.g. VSAT)

Satellite Microwave Transmission (continued)

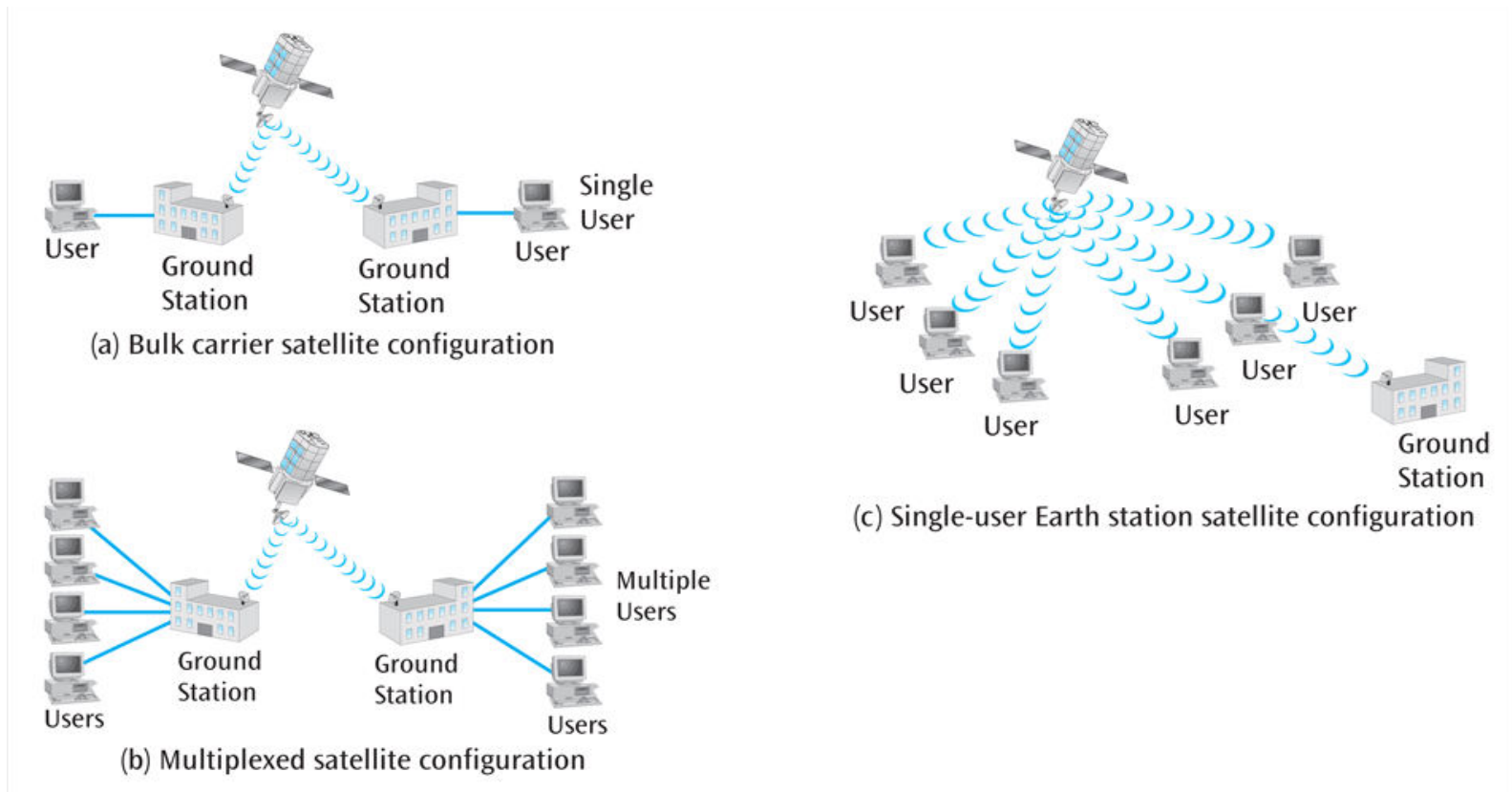
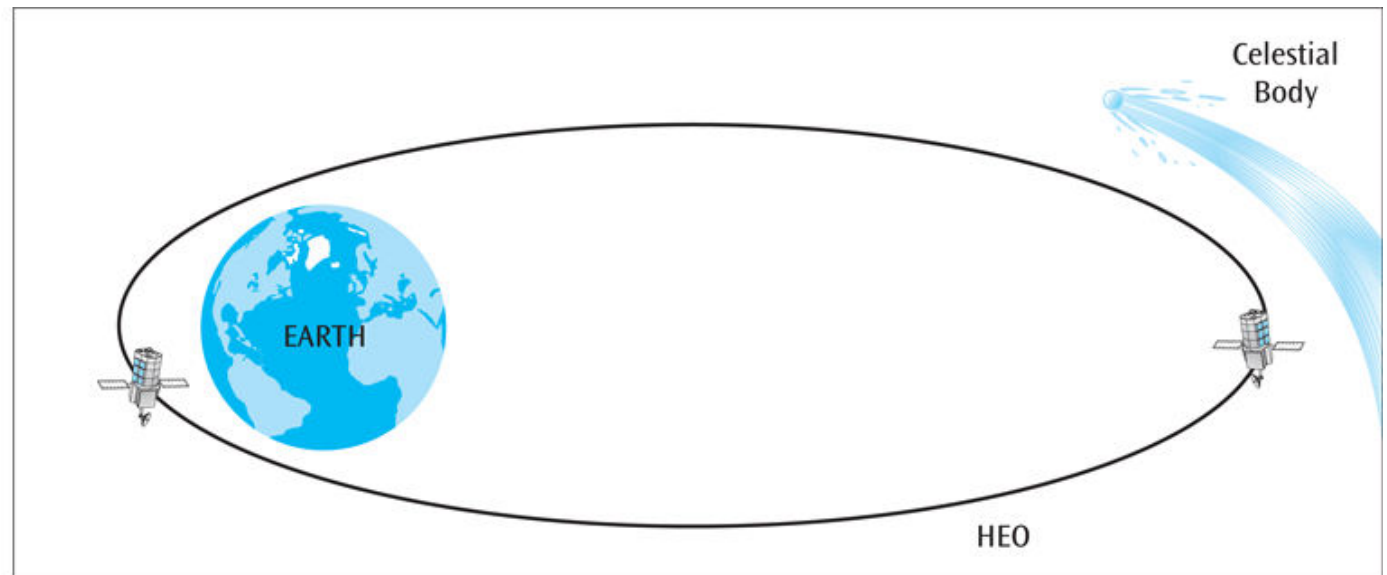


Figure 3-14 Bulk carrier facilities, multiplexed Earth station, and single-user Earth station configurations of satellite systems

Satellite Microwave Transmission (continued)

Figure 3-15

Diagram of a highly elliptical Earth orbit satellite



Satellite Microwave Transmission (continued)

Band Number	Symbol	Frequency	Common Use
4	VLF (very low frequency)	3–30 kHz	Radio navigations systems
5	LF (low frequency)	30–300 kHz	Radio beacons
6	MF (medium frequency)	300 kHz–3 MHz	AM radio
7	HF (high frequency)	3–30 MHz	CB radio
8	VHF (very high frequency)	30–300 MHz	VHF TV, FM radio
9	UHF (ultra high frequency)	300 MHz–3 GHz	UHF TV, cell phones, pagers
10	SHF (superhigh frequency)	3–30 GHz	Satellite
11	EHF (extremely high freq)	30–300 GHz	Satellite, radar systems

Satellite Microwave Transmission (continued)

Radar Band	Frequency	Common Use
L	~1–2 GHz	GPS, government use, GSM cell phones
S	2–4 GHz	Weather systems, digital satellite radio system
C	4–8 GHz	Commercial satellite systems
X	~7–12.5 GHz	Some communication satellites, weather
Ku	12–18 GHz	NASA, television station remotes to station
Ka	18–40 GHz	Communication satellites
V	50–75 GHz	Not heavily used
W	75–111 GHz	Misc (military, car radar systems)

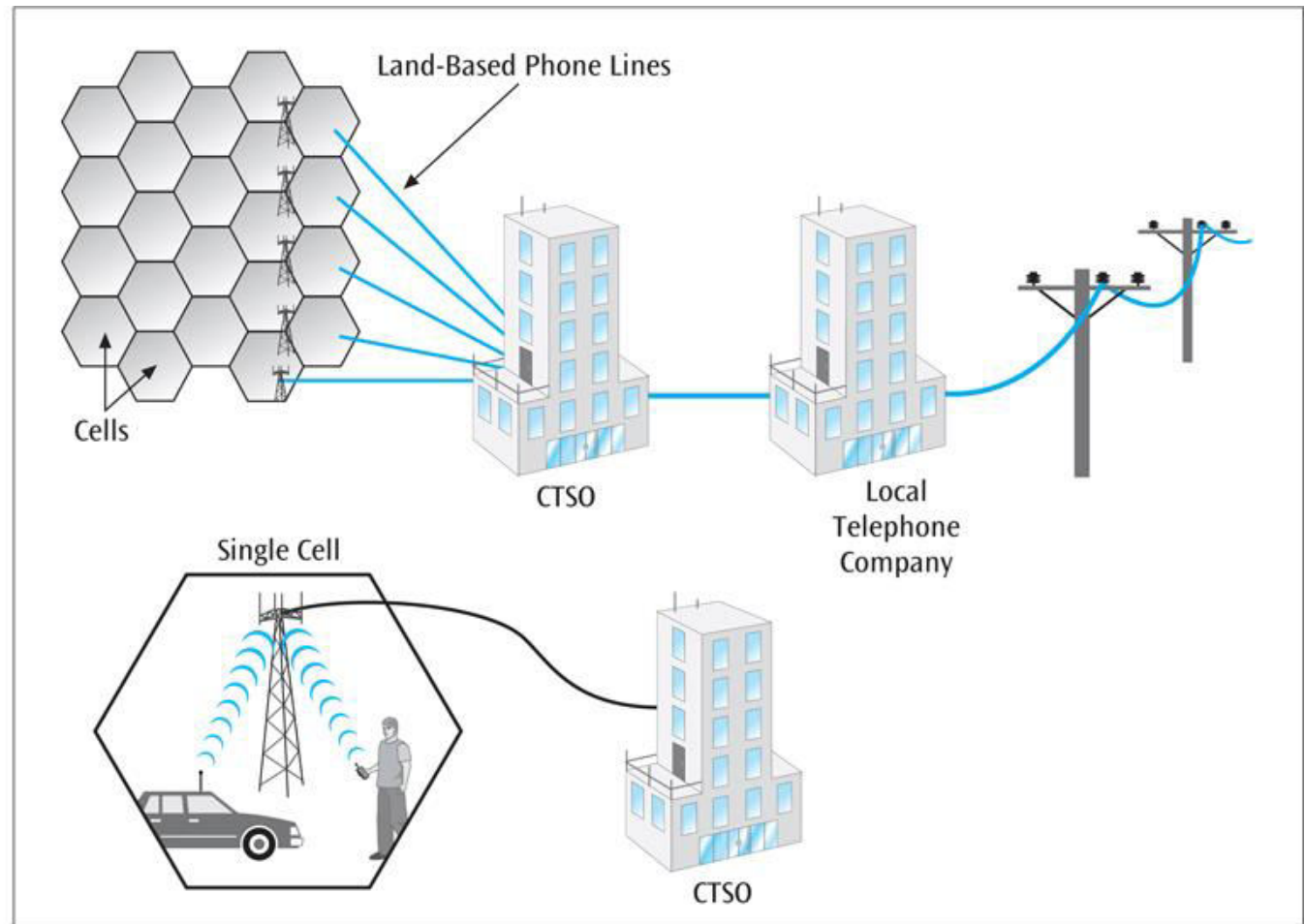
Cellular Telephones

- Wireless telephone service, also called mobile 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 Telephones (continued)

Figure 3-16

One cellular telephone market divided into cells



Cellular Telephones (continued)

Figure 3-17

A cellular telephone tower



Cellular Telephones (continued)



Figure 3-18

Cell phone towers disguised as trees

Cellular Telephones (continued)

- Placing a call on a cell phone
 - You enter a phone number on your cell phone and press Send. Your cell phone contacts the nearest cell tower and grabs a set-up channel. Your mobile identification information is exchanged to make sure you are a current subscriber.
 - If you are current, you are dynamically assigned two channels: one for talking, and one for listening. The telephone call is placed. You talk.

Cellular Telephones (continued)

- Receiving a call on a cell phone
 - Whenever a cell phone is on, it “pings” the nearest cell tower every several seconds, exchanging mobile ID information. This way, the cell phone system knows where each cell phone is.
 - When someone calls your cell phone number, since the cell phone system knows what cell you are in, the tower “calls” your cell phone.

Cellular Telephones (continued)

- 1st Generation
 - AMPS (Advanced Mobile Phone Service) – first popular cell phone service; used analog signals and dynamically assigned channels
 - D-AMPS (Digital AMPS) – applied digital multiplexing techniques on top of AMPS analog channels

Cellular Telephones (continued)

- 2nd Generation
 - PCS (Personal Communication Systems) – essentially all-digital cell phone service
 - PCS phones came in three technologies:
 - TDMA – Time Division Multiple Access
 - CDMA – Code Division Multiple Access
 - GSM – Global System for Mobile Communications

Cellular Telephones (continued)

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

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
 - two forms:
 - 1xEV-DO for data only
 - 1xEV-DV for data and voice

Cellular Telephones (continued)

- 4th Generation
 - LTE (Long Term Evolution) – theoretical speeds of 100 Mbps or more, actual download speeds 10-15 Mbps
 - WiMax – introduced in a couple slides – theoretical speeds of 128 Mbps; actual download speeds 4 Mbps (didn't make it for cellular)
 - HSPA (High Speed Packet Access) – 14 Mbps downlink, 5.8 Mbps uplink; (didn't make it)
 - HSPA+ – theoretical downlink of 84 Mbps, 22 Mbps uplink (T-Mobile) (didn't make it)

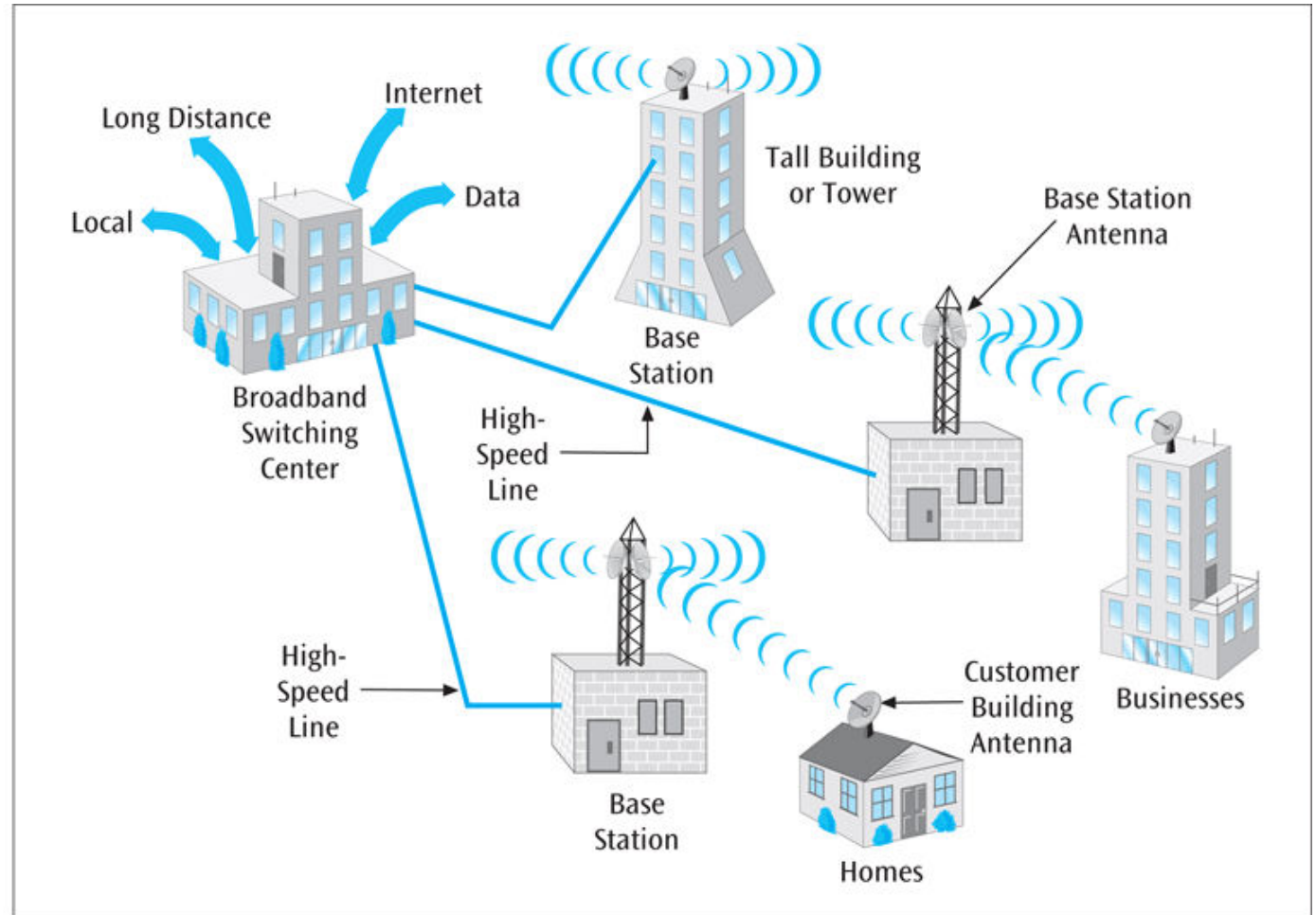
WiMax - Broadband Wireless Systems

- Delivers Internet services into homes, businesses and mobile devices
- Designed to bypass the local loop telephone line
- Transmits voice, data, and video over high frequency radio signals
- Maximum range of 20-30 miles and transmission speeds in Mbps
- IEEE 802.16 set of standards

WiMax (continued)

Figure 3-19

Broadband wireless configuration in a metropolitan area



Bluetooth

- Bluetooth is a specification for short-range, point-to-point or 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, but can be extended to 100 m by increasing the power

Bluetooth (continued)

- 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, pagers, modems, LAN access devices, headsets, notebooks, desktop computers, and PDAs

Wireless Local Area Networks (IEEE 802.11)

- This technology transmits data between workstations and local area networks using high-speed radio frequencies
- Current technologies allow up to 100 Mbps (theoretical) data transfer at distances up to hundreds of feet
- Three popular standards: IEEE 802.11b, a, g, n
- More on this in Chapter Seven (LANs)

Free Space Optics

- Free space optics
 - Uses lasers, or more economically, 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)

- Free space optics (continued)
 - Current speeds go from T-3 (45 Mbps) to OC-48 (2.5 Gbps) with faster systems in development
 - Major weakness is transmission thru fog
 - A typical FSO has a link margin of about 20 dB
 - Under perfect conditions, air reduces a system's power by approximately 1 dB/km
 - Scintillation is also a problem (especially in hot weather)

Ultra-Wideband

- Ultra-wideband
 - UWB not limited to a fixed bandwidth but broadcasts over a wide range of frequencies simultaneously
 - Many of these frequencies are used by other sources, but UWB uses such low power that it “should not” interfere with these other sources
 - Can achieve speeds up to 100 Mbps but for small distances such as wireless LANs

Ultra-Wideband (continued)

- Ultra-wideband (continued)
 - Proponents for UWB say it gets something for nothing, since it shares frequencies with other sources. Opponents disagree
 - Cell phone industry against UWB because CDMA most susceptible to interference of UWB
 - GPS may also be affected
 - One solution may be to have two types of systems – one for indoors (stronger) and one for outdoors (1/10 the power)

Infrared Transmissions

- Transmissions that use a focused ray of light in the infrared frequency range
- Very common with remote control devices, but can also be used for device-to-device transfers, such as PDA to computer

Near-Field Communications

- Very close distances or devices touching
- Magnetic induction (such as radio frequency ID) used for transmission of data
- Commonly used for data transmission between cellphones (non-Apple devices)

ZigBee

- Based upon IEEE 802.15.4 standard
- Used for low data transfer rates (20-250 Kbps)
- Also uses low power consumption
- Ideal for heating, cooling, security, lighting, and smoke and CO detector systems
- ZigBee can use a mesh design – a ZigBee-enabled device can both accept and then pass on ZigBee signals

Wireless Media (continued)

Table 3-4 Summary of wireless media

Type of Wireless Medium	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
Terrestrial Microwave	Long-haul telecommunications, building to building	100s-Mbps	20–30 miles	Reliable, high speed, high volume	Long haul, expensive to implement, line-of-sight
Satellite LEO	Communications such as e-mail, paging, worldwide mobile phone network, spying, remote sensing, video conferencing	100s-Mbps	Depends on number of satellites	High-speed transfers, very wide distance, some applications inexpensive	Some applications expensive, interference
Satellite MEO	GPS-style surface navigation systems	100s-Mbps	Depends on number of satellites	High-speed transfers, wide distance	Expensive to lease, some interference
Satellite GEO	Signal relays for cable and direct television	100s-Mbps	One-third the Earth's circumference (8000 miles)	Very long distance, high speed, and high volume	Expensive to lease, some interference
Satellite HEO	Global surveillance, scientific applications	100s-Mbps	Variable	Variability of distance	Expensive
Cellular (AMPS and D-AMPS)	Cellular telephones	19.2 kbps	Each cell: 0.5–50 mile radius, but nationwide coverage	Widespread, inexpensive applications	Noise
PCS	Cellular telephones	9.6 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	Slow data rates
GPRS, 1xRTT	Cellular telephones	30–75 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	Slow data rates

Wireless Media (continued)

Type of Wireless Medium	Typical Use	Maximum Data Transfer Rate	Maximum Transmission Range	Advantages	Disadvantages
UMTS	Cellular telephones	320 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	
EV-DO	Cellular telephones	500 kbps	Each cell: 0.5–25 mile radius	Digital, low noise	
Infrared	Short-distance data transfer	16 Mbps	1.5 miles	Fast, inexpensive, secure	Short distances, line-of-sight
WiMAX	Wireless Internet access	30 Mbps	30 miles	High speed	
Bluetooth	Short-distance transfer	722 kbps	30 feet (10 meters)	Universal protocol	Limited Distances
Wireless LANs	Local area networks	100 Mbps	<328 feet (<100 meters)	Relative ease of use	Several standards
Free Space Optics	Short-distance, high-speed transfers	45 Mbps	1000s feet (100s meters)	High speed	Line-of-sight, affected by fog
Ultra-wideband	Short-distance, high-speed transfers	100 Mbps	<328 feet (100 meters)	High speed, not restricted to fixed frequencies	May interfere with other sources
Near-field communications	Very short distances, high-speed transfers	Depends upon underlying technology	Inches	High speeds	Only for short distances
ZigBee	Short-to-medium distance, low-speed transfers	250 Kbps	Unlimited distance (mesh)	Low power	Low transfer speeds

Media Selection Criteria

- Cost
- Speed
- Distance and expandability
- Environment
- Security

Cost

- Different types of costs
 - Initial cost – what does a particular type of medium cost to purchase? To install?
 - Maintenance / support cost
- ROI (return on investment) – if one medium is cheaper to purchase and install but is not cost effective, where are the savings?

Speed

- Two different forms of speed:
 - Propagation speed – the time to send the first bit across the medium
 - This speed depends upon the medium
 - Airwaves and fiber are speed of light
 - Copper wire is two thirds the speed of light
 - Data transfer speed – the time to transmit the rest of the bits in the message
 - This speed is measured in bits per second

Expandability and Distance

- Certain media lend themselves more easily to expansion
- Don't forget right-of-way issue for conducted media and line-of-sight for certain wireless media

Environment

- Many types of environments are hazardous to certain media
 - Electromagnetic noise
 - Scintillation and movement
 - Extreme environmental conditions

Security

- If data must be secure during transmission, it is important that the medium not be easy to tap
 - Make the wire impervious to electromagnetic wiretapping
 - Encrypt the signal going over the medium

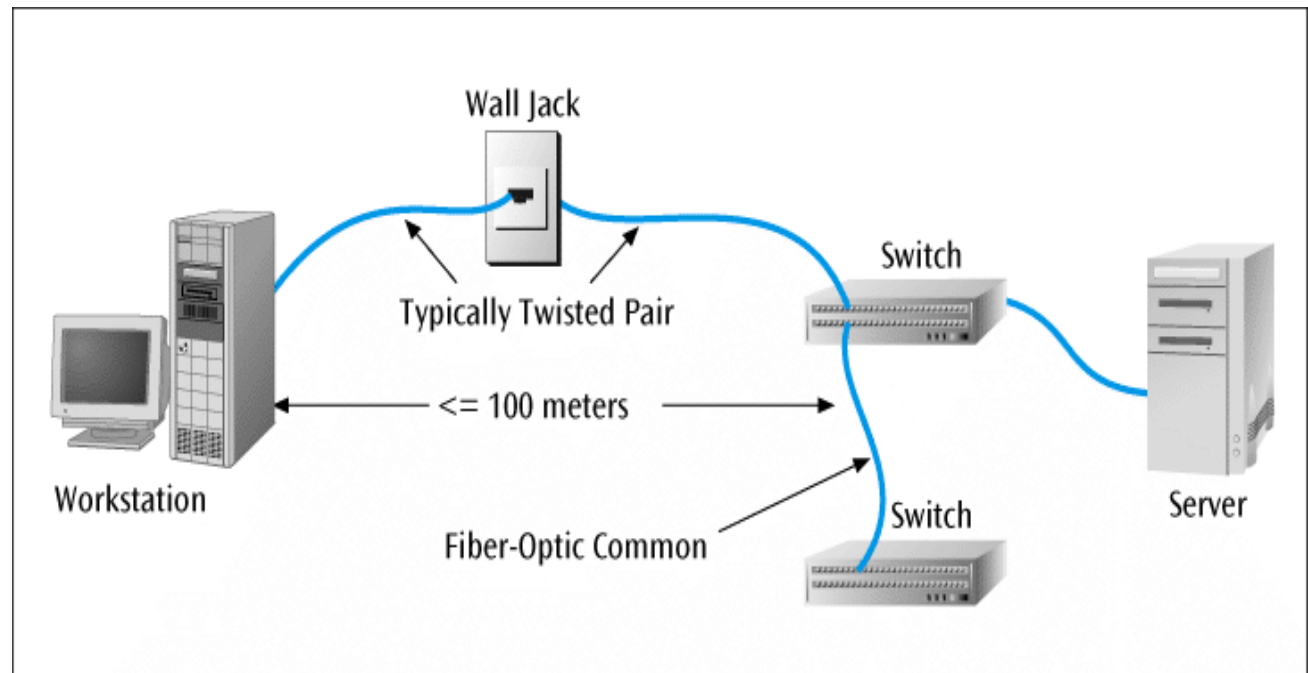
Conducted Media in Action: Two Examples

- First example – simple local area network
 - Hub typically used
 - To select proper medium, consider:
 - Cable distance
 - Data rate

Conducted Media in Action: Two Examples (continued)

Figure 3-20

Example of a wiring situation involving a workstation and a local area network



Conducted Media in Action: Two Examples (continued)

- Second example – company wishes to transmit data between buildings that are one mile apart
 - Is property between buildings owned by company?
 - If not consider using wireless
 - When making decision, need to consider:
 - Cost
 - Speed
 - Expandability and distance
 - Environment
 - Security

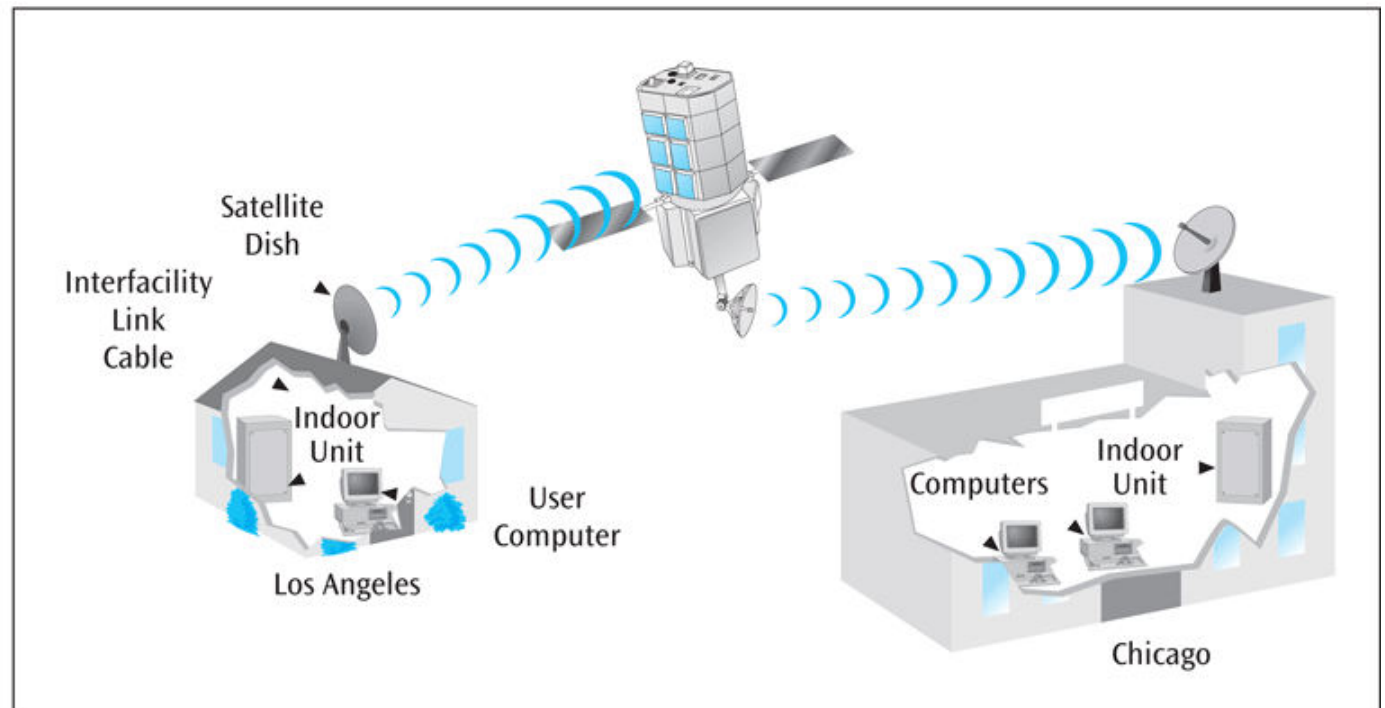
Wireless Media In Action: Three Examples

- First example – you wish to connect two computers in your home to Internet, and want both computers to share a printer
 - Can purchase wireless network interface cards
 - May consider using Bluetooth devices
- Second example – company wants to transmit data between two locations, Chicago and Los Angeles
 - Company considering two-way data communications service offered through VSAT satellite system

Wireless Media In Action: Three Examples (continued)

Figure 3-21

*VSAT satellite solution
for DataMining
Corporation*



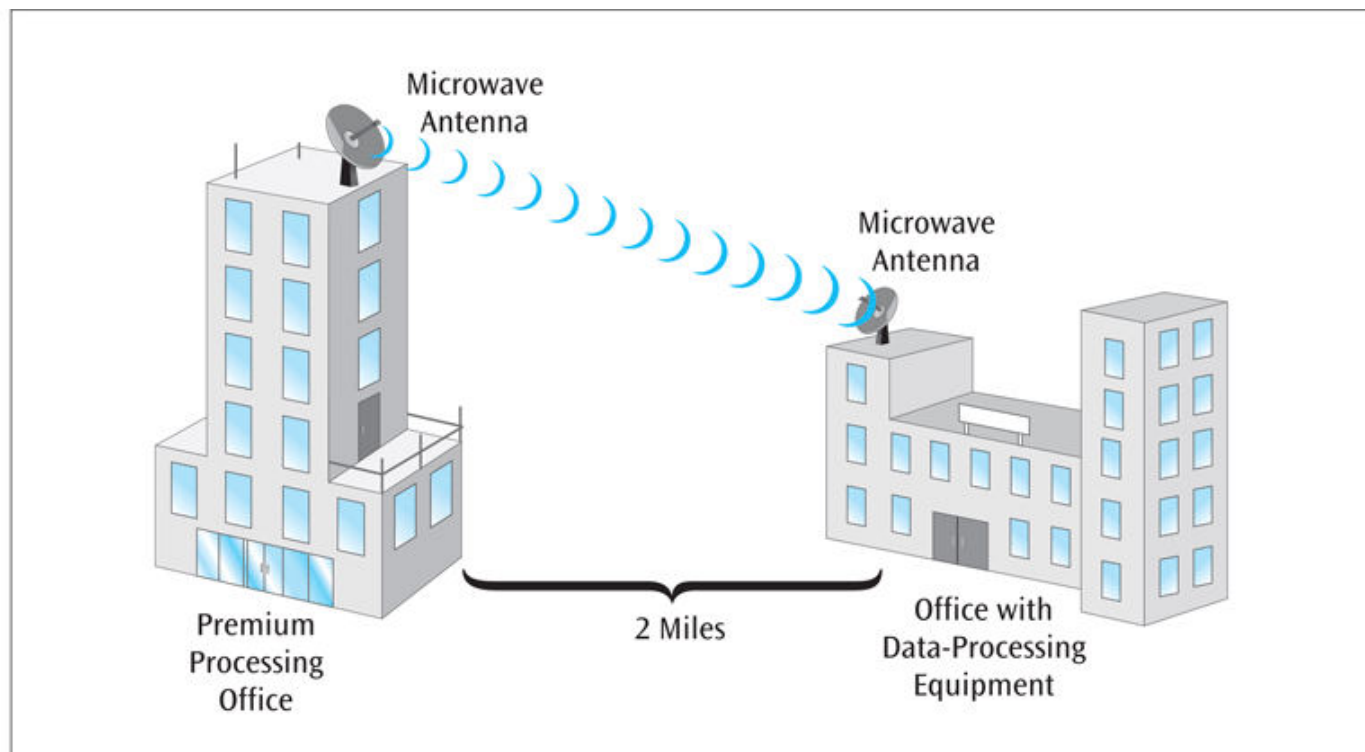
Wireless Media In Action: Three Examples (continued)

- Third example – second company wishes to transmit data between offices two miles apart
 - Considering terrestrial microwave system

Wireless Media In Action: Three Examples (continued)

Figure 3-22

Microwave communication between American Insurance's corporate buildings



Summary

- All data communication media can be divided into two basic categories: (1) physical or conducted media, and (2) radiated or wireless media, such as satellite systems
- The three types of conducted media are twisted pair, coaxial cable, and fiber-optic cable
- Twisted pair and coaxial cable are both metal wires and are subject to electromagnetic interference
- Fiber-optic cable is a glass wire and is impervious to electromagnetic interference
 - Experiences a lower noise level
 - Has best transmission speeds and long-distance performance of all conducted media

Summary (continued)

- Several basic groups of wireless media exist: terrestrial microwave transmissions, satellite transmissions, cellular telephone systems, infrared transmissions, WiMAX, Bluetooth, Wi-Fi, free space optics, ultra-wideband, near-field communications, and ZigBee
- Each of the wireless technologies is designed for specific applications
- When trying to select particular medium for an application, it helps to compare the different media using these six criteria: cost, speed, expandability and distance, right-of-way, environment, and security