Guide to Wireless Communications, Third Edition

Chapter 10
Wireless Wide Area Networks

Objectives

- Describe wireless wide area networks (WWANs) and how they are used
- List the types of applications that can be used on a digital cellular phone
- Explain the basic concepts of how cellular telephony functions
- Describes the various generations of cellular telephony
- Discuss satellites and their applications in WWANs

Cellular Telephone Technology

- Digital cellular telephones can be used to:
  - Browse the Internet
  - Send and receive short messages and e-mails
  - Participate in videoconferencing
  - Receive various sorts of information
  - Run a variety of business applications
  - Connect to corporate networks
  - Watch television or on-demand movies
  - Take and transmit pictures and short movies
  - Locate family members and employees using GPS

Cellular Telephone Technology

- Short Message Services (SMS)
  - One of the most widely used applications
  - Allows for the delivery of short, text-based messages between cellular phones
    - Messages are limited to 160 characters
  - Applications
    - Person-to-person
    - Agent-to-person
    - Information broadcast services
    - Software configuration
    - Advertising

How Cellular Telephony Works

- Keys to cellular telephone networks
  - Cells
    - Typical cell ranges from a few thousand feet to approximately 10 square miles
    - At the center of each cell is a cell transmitter connected to a base station
    - Each base station is connected to a **mobile telecommunications switching office (MTSO)**
      - Link between the cellular network and the wired telephone world
      - Controls all transmitters and base stations

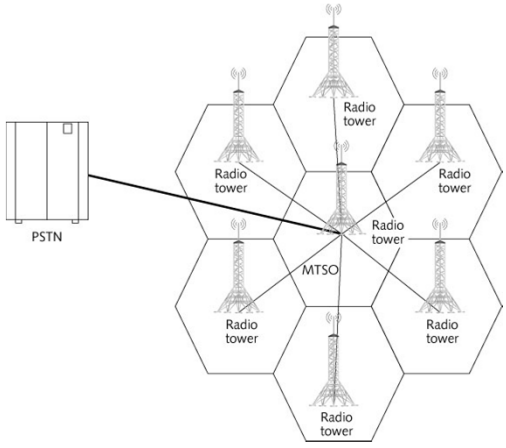

Figure 10-1 Cellular phone network

How Cellular Telephony Works

- Keys to cellular telephone networks (cont'd)
  - Transmitters and cell phones operate at low power
    - Enables the signal to stay confined to the cell
    - Signal at a specific frequency does not go far beyond the cell area
      - Same frequency can be used in other cells at the same time
      - Except in adjacent cells
- Cell phones have special codes
  - Codes are used to identify the phone, phone's owner, and carrier or service provider

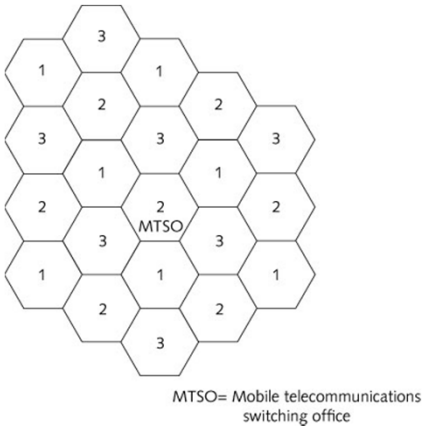

Figure 10-2 Frequency reuse with three frequencies

How Cellular Telephony Works

- Some cellular phones require a SIM card to be installed before they can be used
  - SIM (subscriber identity module) card – very small electronic card used to associate the phone with the user's account and with the carrier
  - SIM cards have between 64 KB and 512 KB of ROM, between 1 KB and 8 KB of RAM, and between 64 KB and 512 KB of EEPROM
  - Users can move the card between one phone and another and use different phones without reprogramming

Code Name	Size	Purpose
System Identification Code (SID)	5 digits	A unique number that identifies the carrier
Electronic serial number (ESN)	32 bits	The cellular phone's unique serial number; not used on phones with a SIM card
International Mobile Equipment Identity (IMEI)	15 decimal digits (14 plus a check digit)	A unique number that identifies mobile phones as well as some satellite phones; also acts as the serial number
Mobile identification number (MIN)	10 digits	A unique number generated from the phone's telephone number; not used on phones with a SIM card

Table 10-1 Cellular phone codes

How Cellular Telephony Works

- When user moves within the same cell
  - Transmitter and base station for that cell handle all of the transmissions
- As the user moves toward the next cell
  - A handoff process occurs
- Roaming
  - User moves from one cellular network to another

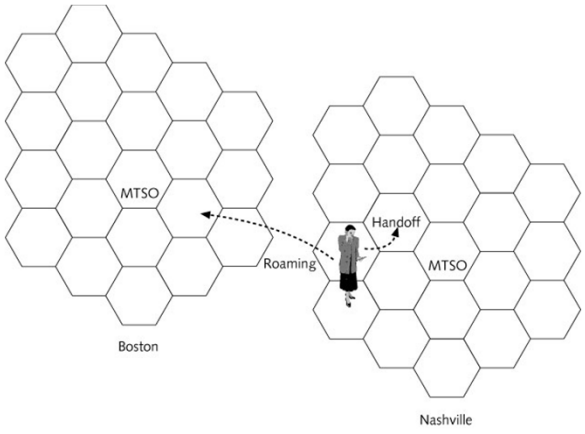

Figure 10-4 Handoff and roaming

How Cellular Telephony Works

- Steps to receive a call
  - Cell phone listens for the SID being transmitted by the base station on the control channel
  - Phone compares SID with its programmed SID
    - If they match, phone is in a network owned by carrier
  - If SIDs do not match, phone is roaming
  - When a call comes in, MTSO locates the phone through the registration request
  - User can move to another cell
  - Phone and transmitter can change frequencies as required

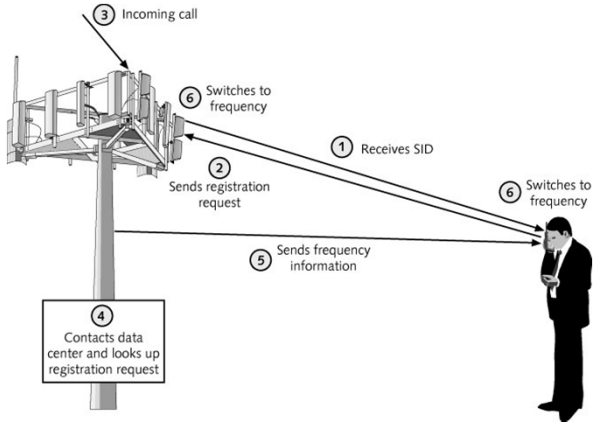

Figure 10-5 Receiving a call on a cellular phone

Evolution of Cellular Telephony

- Cellular phones have been available since the early 1980s in the United States
- Most industry experts outline several generations of cellular telephony

First Generation Cellular Telephony

- First Generation (1G)
  - Uses analog signals modulated using FM
  - Based on Advanced Mobile Phone Service (AMPS)
    - Operates in the 800-900 MHz frequency spectrum
    - Each channel is 30 KHz wide with a 45 KHz passband
    - There are 832 frequencies available
    - Uses Frequency Division Multiple Access (FDMA)
    - FDMA allocates a single cellular channel with two frequencies to one user at a time
- 1G networks use circuit-switching technology

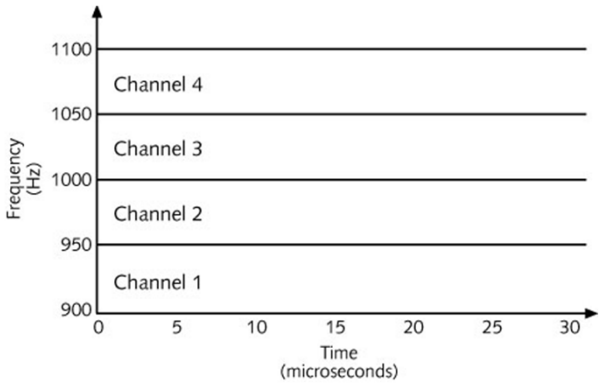

Figure 10-6 FDMA

First Generation Cellular Telephony

- Circuit-switching technology
  - Makes a dedicated and direct physical connection
    - Between the caller and the recipient
- Analog signals are prone to interference
  - Do not have the same quality as digital signals

Second Generation Cellular Telephony

- Second Generation (2G)
  - Transmits data between 9.6 Kbps and 14.4 Kbps
    - In the 800 MHz and 1.9 GHz frequencies
  - 2G networks are also circuit-switching
  - 2G systems use digital transmissions
- Digital transmissions
  - Use the frequency spectrum more efficiently
  - Over long distances, the quality of the voice transmission does not degrade
  - Difficult to decode and offer better security

Second Generation Cellular Telephony

- Digital transmissions (cont'd)
  - Use less transmitter power
  - Enable smaller and less expensive individual receivers and transmitters
- Multiple access technologies
  - Time Division Multiple Access (TDMA)
  - CDMA
  - Global System for Mobile communications (GSM)
    - Uses a combination of FDMA and TDMA technologies

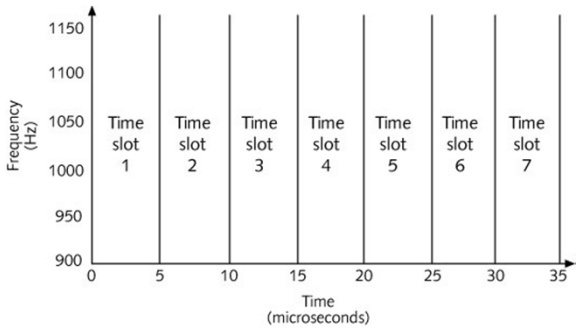

Figure 10-7 TDMA

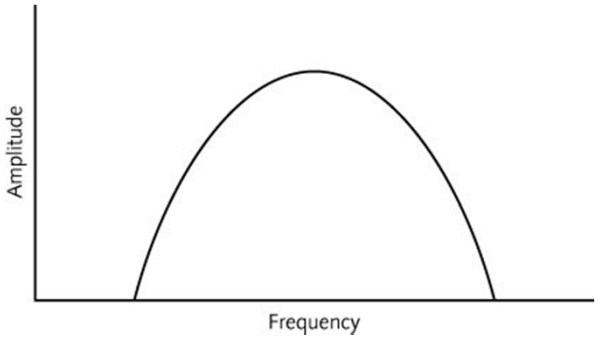

Figure 10-8 CDMA

2.5 Generation Cellular Telephony

- 2.5 Generation (2.5G)
  - Interim step between 2G and 3G
  - Operates at a maximum speed of 384 Kbps
  - Primary difference between 2G and 2.5G:
    - 2.5G networks are packet-switched
  - Advantages of packet switching
    - Much more efficient
      - Can handle more transmissions over a given channel
    - Permits an always-on connection

2.5 Generation Cellular Telephony

- Three 2.5G network technologies
  - General Packet Radio Service (GPRS)
    - For TDMA or GSM 2G networks
    - Uses eight time slots in a 200 KHz spectrum and four different coding techniques to transmit at 114 Kbps
  - Enhanced Data rates for GSM Evolution (EDGE)
    - Can transmit up to 384 Kbps
    - Based on a modulation technique called 8-PSK
  - CDMA2000 1xRTT (1-times Radio Transmission Technology)
    - Operates on two 1.25 MHz-wide frequency channels
    - Supports 144 Kbps packet data transmission

Third Generation Cellular Telephony

- Third Generation (3G)
  - Intended to be a uniform and global standard for cellular wireless communication
- Standard data rates
  - 144 Kbps for a mobile user
  - 386 Kbps for a slowly moving user
  - 2 Mbps for a stationary user
- 3G network technologies
  - CDMA2000 1xEVDO
    - For 2.5G CDMA2000 1xRTT networks

Third Generation Cellular Telephony

- 3G network technologies (cont'd)
  - CDMA2000 1xEVDV is the successor of CDMA2000 1xEVDO
  - Wideband CDMA (W-CDMA)
    - For 2.5G EDGE networks
  - High-Speed Downlink Packet Access (HSDPA)
    - Beyond W-CDMA
    - Uses a 5 MHz W-CDMA channel, variety of adaptive modulation, multiple in multiple out (MIMO) antennas, and hybrid automatic repeat request (HARQ)

Third Generation Cellular Telephony

- 3G network technologies (cont'd)
  - HSPA+ (also called Evolved HSPA) – successor to HSDPA
    - Provides theoretical data rates up to 168 Mbps on the downlink and 22 Mbps on the uplink
    - Provides an upgrade path to latest-generation technology: LTE (Long Term Evolution)
  - LTE (also known as 4G)
    - LTE Advanced: expands on LTE by allowing carriers to combine up to five 20-MHz-wide frequency channels
    - Maximum downlink data rate: up to 1 Gbps

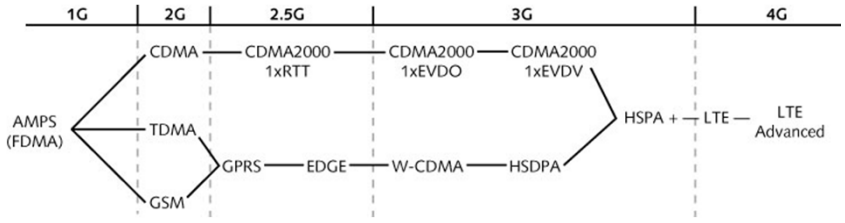

Figure 10-9 Cellular technology migration paths

Name	Generation	Technology	Maximum Peak Data Rate (Downlink)
AMPS	1G	Analog, circuit switched	9.6 Kbps
GSM	2G	Digital, circuit switched	9.6 Kbps
TDMA	2G	Digital, circuit switched	14.4 Kbps
CDMA	2G	Digital, circuit switched	14.4 Kbps
GPRS	2.5G	Digital, packet switched for data only; circuit switched for voice calls	114 Kbps
CDMA2000 1xRTT	2.5G	Same as GPRS	144 Kbps
EDGE	2.5G	Same as GPRS	384 Kbps
CDMA2000 1xEVDO	3G	Digital, packet switched for both voice and data	2 Mbps
W-CDMA	3G	Digital, packet switched for data; optionally circuit switched or packet switched for voice calls	2 Mbps
CDMA 1xEVDV	3G	Digital, packet switched for data, circuit switched for voice	3.09 Mbps
HSDPA	3G	Same as CDMA2000 1xEVDV	21 Mbps
HSPA+	3G	Digital, packet switched for both voice and data (IP-based)	42 Mbps
LTE	4G	Same as HSPA+	300 Mbps
LTE Advanced	4G	Same as LTE	1 Gbps

Table 10-2 Digital cellular technologies

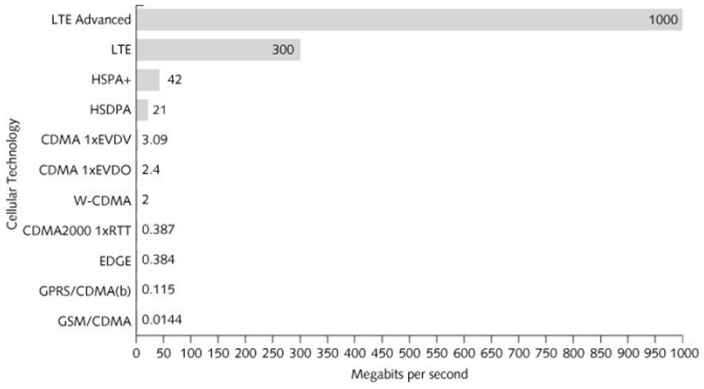

Figure 10-10 Comparison of data-rate speeds for various cellular technologies

Client Software

- Internet surfing or videoconferencing require client software to operate on a wireless digital cellular device
- In the near future, most mobile browsers will support HTML 5 and will be able to run a variety of software applications
- Four technologies used to display Web content:
  - Wireless Application Protocol (WAP)
  - Wireless Application Protocol version 2 (WAP2)
  - Binary Run-Time Environment for Wireless (BREW)
  - i-mode

Client Software

- In addition, manufacturers began including support for the **Java** programming language
  - Java – object-oriented programming language used for general-purpose business programs as well as for interactive Web sites
  - Java 2 Micro Edition (J2ME) – specifically developed for programming software applications for wireless devices

Digital Cellular Challenges and Outlook

- Cellular telephony has significantly changed the way people work and communicate
- Users will benefit the most from digital cellular telephony once the industry settles on a single cellular standard
  - Having one worldwide standard will lower costs for carriers (more competitive pricing) and will enable consumers to use phone regardless of where they are in the world

Limited Spectrum

- Spectrum
  - Single largest factor limiting the development of 3G
- Although 3Gand 4G can operate at almost any spectrum
  - Industry tries to use the same part of the spectrum for communications around the world
    - 1.710 to 1.855 GHz and 2.520 to 2.670 GHz
- In North America, the 700 MHz band (formerly used for analog television), is also being used for cellular networks

Costs

- Monthly service fees for data transmission can be expensive
- User cost for cellular phone service pales in comparison to costs for the carriers to build and constantly upgrade cellular networks
  - In 2001, Germany paid over $46 billion for licenses to use the spectrum

Satellite Broadband Wireless

- Use of satellites for personal wireless communication is fairly recent
- Satellite use falls into three broad categories
  - Satellites are used to acquire scientific data and perform research in space
  - Satellites look at Earth from space
  - Satellites are used as reflectors that bounce or relay signals from one point on Earth to another
    - Wireless communications falls under this use of satellites

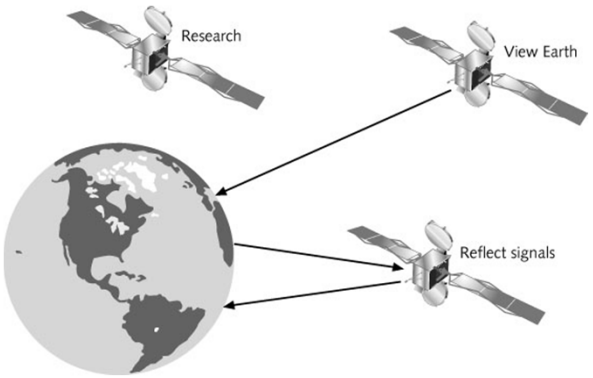

Figure 10-11 Three types of satellites

Satellite Transmissions

- Satellites generally send and receive on one of four frequency bands

Band	Frequency
L band	1.53–2.7 GHz
C band	3.6–7 GHz
Ku band	11.7–12.7 GHz for downlink; 14–17.8 GHz for uplink
Ka band	17.3–31 GHz

Table 10-3 Satellite frequencies

- Frequency band affects the size of the antenna

Figure 10-12 Satellite antenna sizes

Satellite Transmissions

- Class and Type of Service
  - Satellites can provide two classes of service
    - Consumer class service
      - Shares the available bandwidth between the users
    - Business class service
      - Offers dedicated channels with dedicated bandwidth
      - More expensive
  - Types of connectivity
    - Point-to-point, point-to-multipoint, and multipoint-to-multipoint

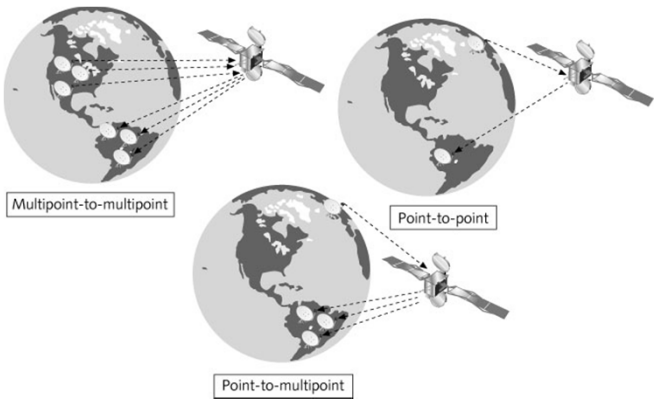

Figure 10-13 Types of satellite service

Satellite Transmissions

- Modulation techniques
  - Binary phase shift keying (BPSK) – Shifts the starting point of a carrier wave by 180 degrees
  - Quadrature phase shift keying (QPSK) – Shifts the starting point of the carrier wave by 90 degrees
  - Eight-phase shift keying (8-PSK) – Can transmit up to 3 bits per symbol
  - 16-level quadrature amplitude modulation (16-QAM) – Primarily used for sending data downstream; considered efficient but is susceptible to interference

Satellite Transmissions

- Multiplexing techniques – Satellite systems employ two multiplexing techniques, FDMA and TDMA, along with specialized techniques:
  - Permanently assigned multiple access (PAMA) – a frequency channel is permanently assigned to a user
  - Single channel per carrier (SCPC) – Assigns a frequency channel to a single source
  - Multi-channel per carrier (MCPC) – Uses TDM to consolidate traffic from different users on to each carrier frequency
  - Demand assigned multiple access (DAMA) – allocates bandwidth on a per-call session

Satellite Classification

- Satellite systems are classified according to the type of orbit they use
- Three orbits:
  - Low earth orbit (LEO)
  - Medium earth orbit (MEO)
  - High earth orbit (HEO)
    - Most HEO satellites fall into a subclass called geosynchronous earth orbit (GEO)

Low Earth Orbit (LEO)

- Low earth orbit (LEO) satellites
  - Circle the Earth at altitudes between 200 to 900 miles
  - Must travel at high speeds
    - So that the Earth's gravity will not pull them back into the atmosphere
  - Area of Earth coverage (called the footprint) is small
- LEO systems have a low latency
  - Use low-powered terrestrial devices (RF transmitters)
  - Round trip time: 20 to 40 milliseconds for a signal to bounce from an Earth-bound station to a LEO, then back to an Earth station

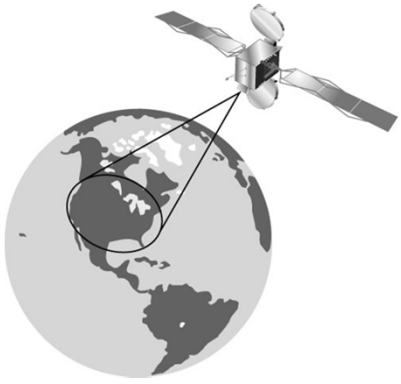

Figure 10-14 LEO footprint

Low Earth Orbit (LEO)

- LEO satellites groups
  - Little LEO
    - Provides pager, satellite telephone, and location services
  - Big LEO
    - Carries voice and data broadband services, such as wireless Internet access
- In the future, LEOs are expected to be in demand for three markets:
  - Rural conventional telephone, global mobile digital cellular, and international broadband services

Medium Earth Orbit (MEO)

- Medium earth orbit (MEO) satellites
  - Orbit the Earth at altitudes between 1,500 and 10,000 miles
  - Some MEO satellites orbit in near-perfect circles
    - Have a constant altitude and constant speed
  - Other MEO satellites revolve in elongated orbits called highly elliptical orbits (HEOs)
- Advantages
  - MEOs do not have to travel as fast; a MEO can circle the Earth in up to 12 hours
  - Have a bigger Earth footprint

Figure 10-15 MEO footprint

Medium Earth Orbit (MEO)

- Disadvantage
  - Higher orbit increases the latency
  - Round trip time: 50 to 150 milliseconds
- HEO satellites
  - Have a high apogee (maximum altitude) and a low perigee (minimum altitude)
  - Can provide good coverage in extreme latitudes
  - Orbits typically have a 24-hour period

Geosynchronous Earth Orbit (GEO) and High Earth Orbit (HEO)

- Geosynchronous earth orbit (GEO) satellites
  - Stationed at an altitude of 22,282 miles
  - Orbit matches the rotation of the Earth
    - And moves as the Earth moves
  - Can provide continuous service to a very large footprint
    - Three GEO satellites are needed to cover the Earth
  - Have high latencies of about 250 milliseconds
  - Require high-powered terrestrial transmitting devices

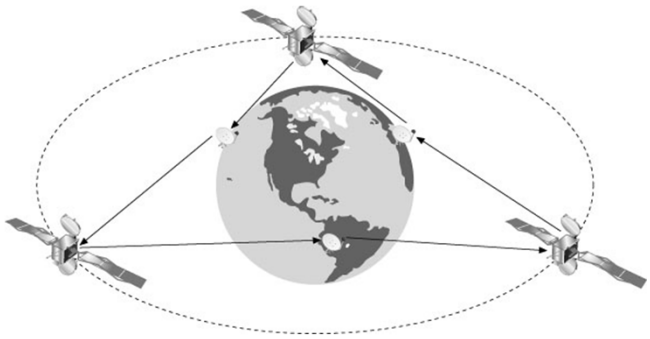

Figure 10-16 Three GEO satellites covering the entire planet

Satellite Orbit	Advantages	Disadvantages
LEO	Low-latency (20–40 milliseconds) Low-power High-speed communications (500 Kbps or higher, depending on application)	Very high orbital speed Average of 225 satellites to cover the entire Earth Small footprint Short life span (average 5 years)
MEO	Medium latency (50–150 milliseconds) Larger footprint than LEO; 24 satellites required to cover the Earth Slower orbital speed; dwells over an area longer; 12-hour orbit Longer life span than LEO (10+ years)	Higher latency than LEO More expensive to replace than LEO
HEO	Similar speed and latency characteristics to MEO; can dwell over an area longer Footprint similar to MEO Can provide good coverage at extreme latitudes (North and South Poles)	Fewer satellites required to cover the Earth than MEO At apogee (high point of orbit), latency increases Highly elliptical orbit, which requires great accuracy and increases cost
GEO	Very large footprint; only three satellites required to cover entire Earth Synchronized with Earth's rotation, allowing for permanent, fixed antennas Very high speeds used for broadcasting Long life span (15+ years)	Very high latency (250 milliseconds); not efficient for two-way IP comm Very expensive to replace Higher power required by greater distance from Earth; more subject to interference Does not provide good coverage at very high latitudes

Table 10-4 Satellite orbit advantages and disadvantages

Experimental Technologies

- NASA experimented with ultra-lightweight, solar-powered, high-flying aircraft in the 1990s
  - To be used in place of a satellite or ground-based antenna tower infrastructure
  - Would be less expensive to launch and operate than a LEO satellite

Satellite Technology Outlook

- Satellites can provide wireless communication
  - In areas not covered by cellular or WiMAX
- Satellites today are enabling carriers to offer
  - Internet access and voice calls to passengers and crews across large oceans
    - And in high latitudes and remote corners of the Earth
- Can also make these services available in many other unpopulated areas

Summary

- In cellular telephone networks, the coverage area is divided into sections called cells
- Some cellular phones use SIM cards to store user and carrier information
- First Generation (1G) cellular technology uses analog signals and a circuit-switching technology to transmit data at a maximum speed of 9.6 Kbps
- Second Generation (2G) can transmit data between 9.6-14.4 Kbps using digital signals instead of analog signals

Summary

- 2.5G networks transmit data at a maximum speed of 384 Kbps and uses a packet-switched technique
- 3G networks provide new and expanded capabilities and data applications features to mobile users
- 4G networks achieve data rates comparable to wired networks
  - Long Term Evolution (LTE) technology
- One of the most widely used applications in the world today is Short Message Services (SMS)
  - Allows for delivery of short, text-based messages

Summary

- Java 2 Micro Edition (J2ME)
  - Subset of Java specifically developed for programming wireless devices
- Satellites used for wireless data connectivity
  - Employ common modulation and multiplexing techniques
- Satellite orbit types
  - LEO satellites
  - MEO satellites
  - GEO satellites