

# Computer Networks and Internets, 5e

## Chapters 12 and 16 Access and Interconnection Technologies

(slidesets abridged/combined)

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Modified from the lecture slides of Lami Kaya  
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## Narrowband and Broadband Access Technologies

- Two broad categories of technologies are used for Internet access
  - Narrowband
  - Broadband

### Narrowband Technologies

refers to technologies that deliver data at up to 128 Kbps

For example, the maximum data rate for dialup noisy phone lines is 56 Kbps and classified as a narrowband technology

Narrowband
Dialup telephone connections
Leased circuit using modems
Fractional T1 data circuits
ISDN and other telco data services

# Narrowband and Broadband Access Technologies

- **Broadband Technologies**
  - generally refers to technologies that offer high data rates, but the exact boundary between broadband and narrowband is blurry
    - many suggest that broadband technologies deliver more than 1 Mbps
    - but this is not always the case, and may mean any speed higher than dialup

Broadband
DSL technologies
Cable modem technologies
Wireless access technologies
Data circuits at T1 speed or higher

# The Local Loop

- **Local loop** describes the physical connection between a telephone company **Central Office** (CO) and a subscriber
  - consists of twisted pair and dialup call with 4 KHz of bandwidth
    - It often has much higher bandwidth; a subscriber close to a CO may be able to handle frequencies above 1 MHz

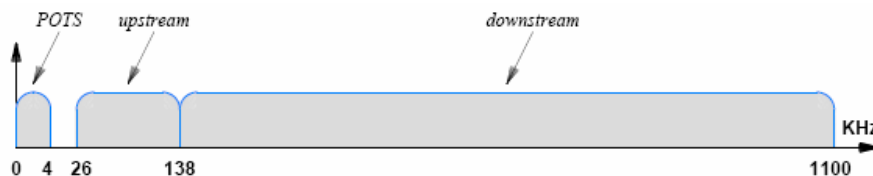
## Digital Subscriber Line (DSL) Technologies

- **DSL** is one of the main technologies used to provide high-speed data communication services over a local loop
- A number of DSL **variants** exist

Name	Expansion	General Use
ADSL	Asymmetric DSL	Residential customers
ADSL2	Asymmetric DSL version 2	Approximately three times faster
SDSL	Symmetric DSL	Businesses that export data
HDSL	High bit rate DSL	Businesses up to 3 miles away
VDSL	Very-high bit rate DSL	Proposed version for 52-Mbps

## Digital Subscriber Line (DSL) Technologies

- ADSL is the most widely deployed variant
  - and the one that most residential customers use
- ADSL uses FDM to divide the bandwidth of the local loop into three regions
  - one of the regions corresponds to traditional analog phone service, which is known as Plain Old Telephone Service (**POTS**)
  - and two regions provide data communication



## Cable Modem Technologies

- A variety of wireless and wired technologies have been developed for use in the local loop
- An alternative access technology that uses the wiring already in place for **cable television**
- It is also known as Community Antenna TeleVision (**CATV**)
- It uses FDM to deliver TV signals over coaxial cable
  - CATV is not available in all countries
- Coaxial cable has high bandwidth and is less susceptible to electromagnetic interference than twisted pair
- CATV systems use FDM to deliver many channels
  - In CATV the bandwidth is insufficient to handle a FDM scheme that extends a channel to each user
  - Using a separate channel per subscriber does not scale

## Hybrid Fiber Coax (HFC)

- HFC can provide high-speed data communications
  - a HFC system uses a combination of optical fibers and coaxial cables
  - fiber used for the central facilities and coax used for connections to individual subscribers
- An HFC system is hierarchical
  - It uses fiber optics for the portions that require the highest bandwidth
  - and it uses coax for parts that can tolerate lower data rates
- **Trunk** to refer to the high-capacity connections between the cable office and each neighborhood area
- **Feeder circuit** to refer to the connection to an individual subscriber
  - Trunk connections can be up to **15** miles long
  - Feeder circuits are usually less than a mile

## Hybrid Fiber Coax

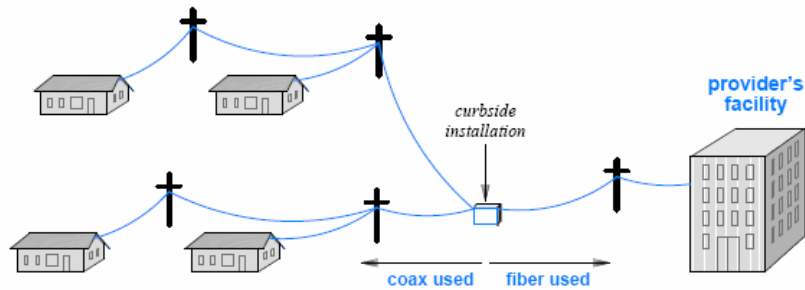


Figure 12.7 Illustration of a Hybrid Fiber Coax access system.

## Wireless Access Technologies

- How to provide access in rural areas?
  - Imagine a farm or remote village many miles from the nearest city
  - The twisted pair wiring used to deliver telephone service to such locations exceeds the maximum distance for technologies like ADSL
  - Rural areas are least likely to have cable television service
- Even in suburban areas, technologies like ADSL may have technical restrictions on the type of line they can use
  - it may be impossible to use high frequencies on telephone lines that contain loading coils, bridge taps, or repeaters
- Local loop technology may not work on all lines
  - To handle special cases, a variety of wireless access technologies have been explored

## Wireless Access Technologies

Technology	Description
3G services	Third generation cellular telephone services for data (e.g., EVDO)
WIMAX	Wireless access technology up to 155 Mbps using radio frequencies
Satellite	Various commercial vendors offer data services over satellite

Figure 12.9 Examples of wireless access technologies.

## A Taxonomy of Wireless Networks

- Wireless communication applies across a wide range of network types and sizes
- Part of the motivation for variety
  - government **regulations** that make specific ranges of the electromagnetic spectrum available for communication
- A **license** is required to operate transmission equipment in some parts of the spectrum
  - and other parts of the spectrum are **unlicensed**
- Many wireless technologies have been created
  - and new variants appear continually
- Wireless technologies can be classified broadly according to network type

# A Taxonomy of Wireless Networks

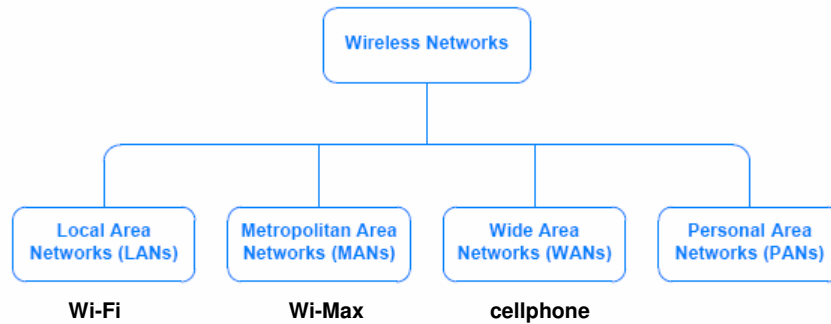
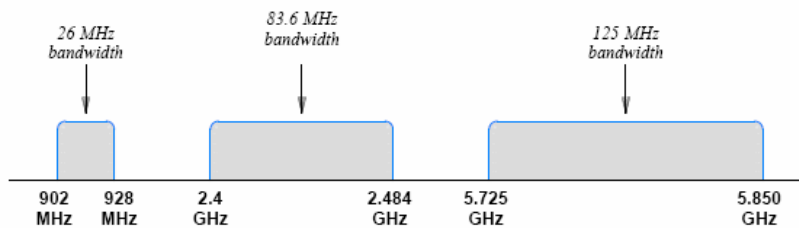


Figure 16.1 A taxonomy of wireless networking technologies.

## ISM Wireless Bands Used by LANs and PANs

- A region of electromagnetic spectrum is reserved for use by **Industrial, Scientific, and Medical** (ISM) groups
  - Known as ISM wireless
- The frequencies are not licensed to specific carriers
  - are broadly available for products, and are used for LANs and PANs



## Wireless LAN Technologies and Wi-Fi

IEEE Standard	Frequency Band	Data Rate	Modulation Technique	Multiplexing Technique
original 802.11	2.4 GHz	1 or 2 Mbps	FSK	DSSS
	2.4 GHz	1 or 2 Mbps	FSK	FHSS
	InfraRed	1 or 2 Mbps	PPM	– none –
802.11a	5.725 GHz	6 to 54 Mbps	PSK or QAM	OFDM
802.11b	2.4 GHz	5.5 and 11 Mbps	PSK	DSSS
802.11g	2.4 GHz	22 and 54 Mbps	various	OFDM

Figure 16.4 Key wireless standards certified by the Wi-Fi Alliance.

## Wireless LAN Architecture

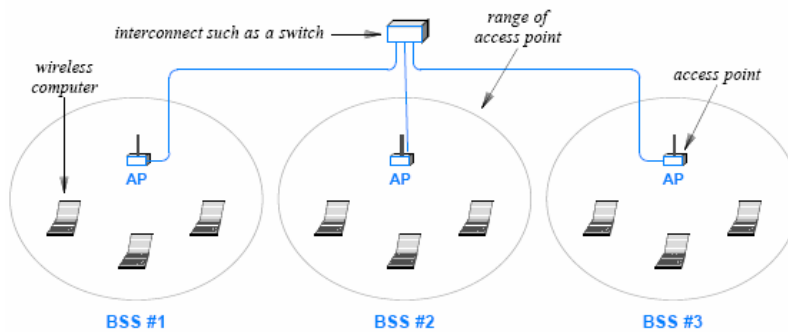


Figure 16.7 Illustration of an infrastructure architecture for a wireless LAN.

Note: The set of computers within range of a given access point is known as a *Basic Service Set (BSS)*

## Handling computer mobility

- access points could coordinate a hand-off
- computer could handle its own re-association from weakening to strengthening access point as it moves

## Wi-Fi's Contention-based Access

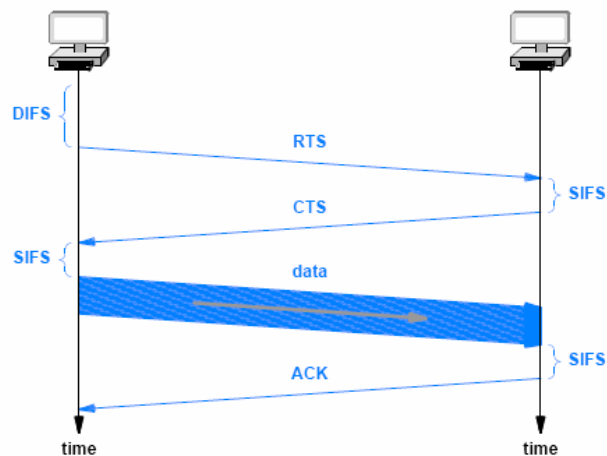


Figure 16.10 Illustration of CSMA/CA with SIFS and DIFS timing.

## Wireless MAN Technology and WiMax

- Standardized by IEEE under the category 802.16
- Two main versions of WiMAX are being developed that differ in their overall approach
  - Fixed WiMAX
    - no handoff among APs
  - Mobile WiMAX
    - offers handoff

## Wireless MAN Technology and WiMax

- Mobile WiMAX
  - built according to standard 802.16e-2005, known also as **802.16e**
  - the technology offers handoff among APs
    - which means a mobile WiMAX system can be used with portable devices such as laptop computers or cell phones
- WiMAX offers broadband communication that can be used in a variety of ways:
  - WiMAX can be used as an Internet **access technology**
  - WiMAX can provide a general-purpose interconnection among physical sites
    - especially in a city
  - To be used as **backhaul** connection between a service provider's central network facility and remote locations
    - such as cell towers

# Wireless MAN Technology and WiMax

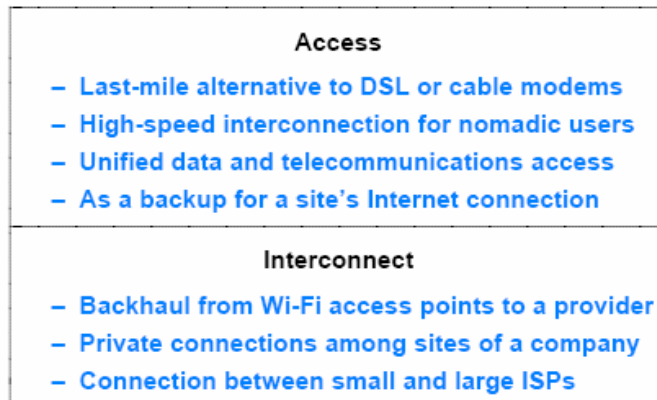


Figure 16.11 Potential uses of WiMAX technology.

# Wireless MAN Technology and WiMax

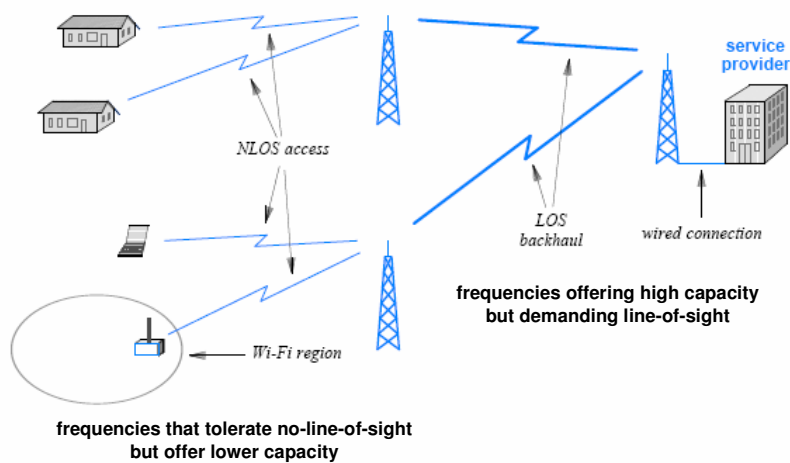


Figure 16.12 Illustration of WiMAX used for access and backhaul.

## Wireless MAN Technology and WiMax

- The key features of WiMAX can be summarized as follows:
  - Uses licensed spectrum (i.e., offered by carriers)
  - Each cell can cover a radius of 3 to 10 Km
  - Uses scalable **orthogonal** FDM
  - Guarantees quality of services (for voice or video)
  - Can transport 70 Mbps in each direction at short distances
  - Provides 10 Mbps over a long distance (10 Km)

## Wireless WAN Technologies Cellular Communication Systems

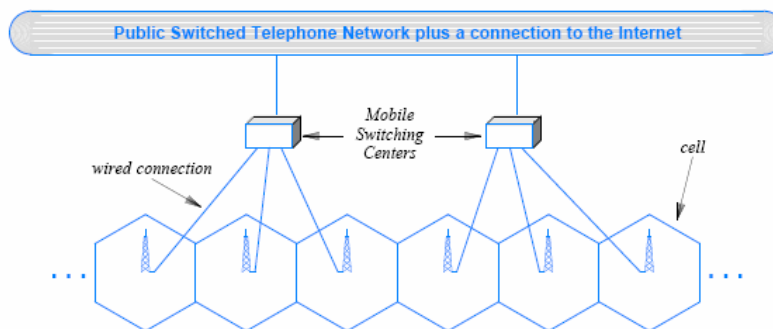


Figure 16.14 Illustration of the cellular architecture.

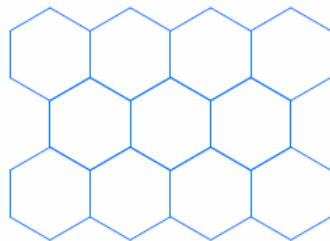
# Wireless WAN Technologies

## Cellular Communication Systems

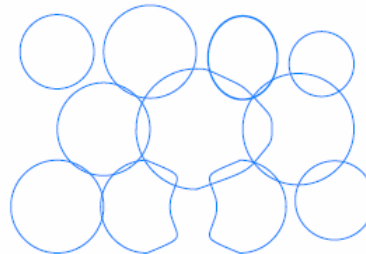
- When moving between two cells belonging to the same MSC
  - the switching center handles the change
- When a user passes from one geographic region to another
  - two MSCs are involved in the handoff
- Perfect cellular coverage occurs if each cell is a **hexagon**
  - because the cells can be arranged in a honeycomb
  - In practice, cellular coverage is imperfect
- Most cell towers use **omnidirectional** antennas
  - that transmit in a circular pattern
  - obstructions and electrical interference can attenuate a signal or cause an irregular pattern
    - in some cases, cells overlap and in others, gaps exist with no coverage

# Wireless WAN Technologies

## Cellular Communication Systems



(a)



(b)

**Figure 16.15** Illustration of (a) an idealized cellular coverage, and (b) a realistic version with overlaps and gaps.

## Generations of Cellular Technologies

- Telecommunications industry divides cellular technologies into four generations
  - that are labeled **1G**, **2G**, **3G**, and **4G**
  - with intermediate versions labeled **2.5G** and **3.5G**
- **1G**
  - Began in the late 1970s, and extended through the 1980s
  - Originally called cellular mobile radio telephones
    - used analog signals to carry voice
- **2G and 2.5G**
  - Began in the early 1990s and continues to be used
  - The main distinction between 1G and 2G arises
    - because 2G uses digital signals to carry voice
  - The label 2.5G is used for systems that extend a 2G system
    - to include some 3G features

## Generations of Cellular Technologies

- **3G and 3.5G**
  - Began in the 2000s
  - Focuses on the addition of higher-speed data services
  - A 3G system offers download rates of **400 Kbps** to **2 Mbps**, and is intended to support applications such as web browsing and photo sharing
  - 3G allows a single telephone to roam across the world
- **4G**
  - Began around 2008
  - Focuses on support for real-time multimedia
    - such as a television program or high-speed video
  - They include multiple connection technologies
    - such as Wi-Fi and satellite
    - at any time, the phone automatically chooses the best connection technology available

## 2G Cellular Technologies

Approach	Standard	Generation
GSM	GSM	2G
	GPRS	2.5G
	EDGE (EGPRS)	2.5G
	EDGE Evolution	2.5G
	HSCSD	2.5G
CDMA	IS-95A	2G
	IS-95B	2.5G
TDMA	iDEN	2G
	IS-136	2G
	PDC	2G

Figure 16.18 Major second-generation cellular technologies.

## 3G Cellular Technologies

Approach	Standard	Successor To
WCDMA	UMTS	IS-136, IS-95A, EDGE, PDC
	HSDPA	UMTS
CDMA 2000	1xRTT	IS-95B
	EVDO	1xRTT
	EVDV	1xRTT

Figure 16.19 Third-generation cellular technologies.