Wireless communication and Mobile Computing

Chapter One

Introduction to Wireless Communication

Shewakena G.

Outline

- Introduction to wireless communication
  - Overview of Current Wireless systems
  - Wireless channel and system Models
  - Cellular Communication
  - Multiple Access Schemes
    - FDMA, TDMA, CDMA
  - Wireless Communication System Standards (1G/2G/3G) systems
  - Topologies of cellular and ad-hoc networks

2

Introduction

- Wireless Communication System:
  - Wireless communications is a type of data communication that is performed and delivered wirelessly.
  - Any electrical communication system that uses a naturally occurring communication channel, such as air, water, earth.
  - Transmission of voice and data over *radio wave* and allows communication with *out requiring physical connection* to network.
- Examples:
  - Cell phone, Sonar(system for detecting underwater objects)
  - Broadcast: (one way)-Radio, TV, pagers, satellite TV, etc.
  - TwoWay: Walkie-talkie, cell phones, satellite phones, WLAN
- Wireless communications is the fastest growing segment of the communications industry.

Today: Wireless Everywhere

- Laptops
- Wireless LAN cards
- Netbooks
- Tablets
- PDAs
- Smart phones
- Sensor nodes
- Remote control
- Cordless telephone
- Headsets
- Garage openers
- Badges
- Cell phones/modems
- Radio!
- Pagers
- Satellite TV

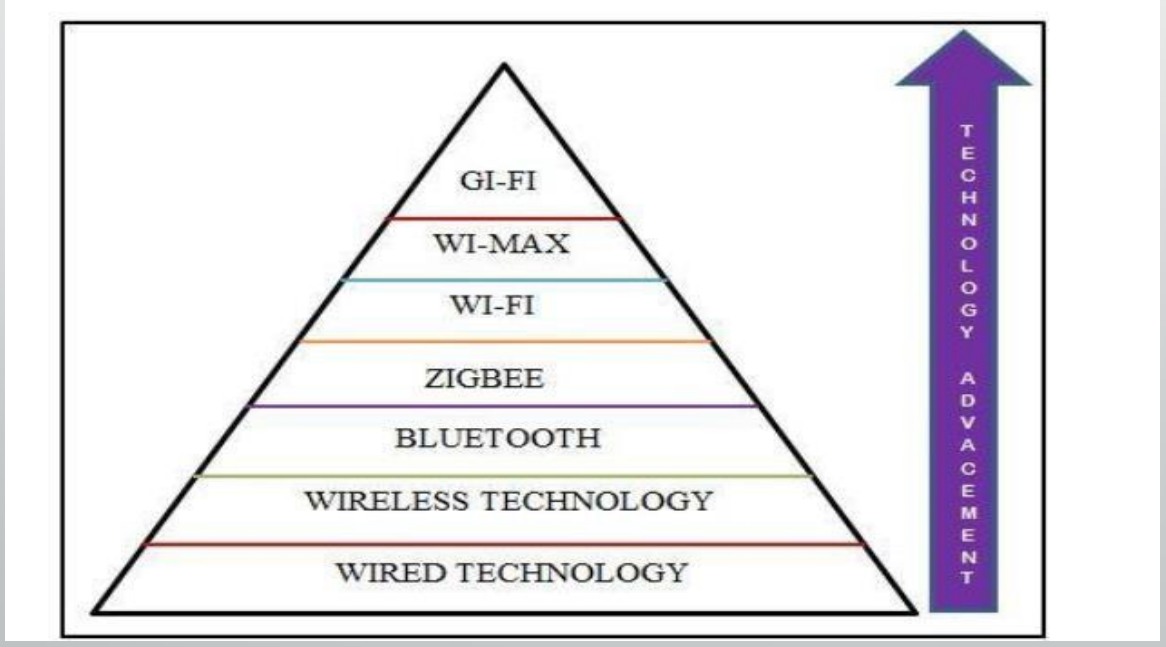
Introduction (cont'd)

- Why wireless communication
  - No cost of installing wires and rewiring
  - No bunches of wires running here and there.
  - Auth-magical instantaneous communications without physical connection setup.eg Bluetooth, wifi.
  - Communications can reach where wiring is infeasible or costly.
  - Wireless broadband provides Internet access to mobile devices in addition to allowing network operators to extend their networks beyond the range of their wired connections.

Introduction (cont'd)

Network Evolution

- *Communication or data transfer technology* is mainly classified into two groups which are
  - Wired technology and Wireless technology
- The diagram below will give you a brief idea to the network evolution.



Introduction (cont'd)

- Wireless systems consist of
  - wireless wide-area networks (WWAN)[i.e., cellular systems],
  - Wireless local area networks (WLAN),
  - Wireless personal area networks (WPAN)
  - Wireless metro area networks(WMAN)
- Applications: *WSNs, automated highways and factories, smart homes, remote telemedicine*, etc.
- The handsets used in all of these systems possess complex functionality, yet they have become *small*, *low-power consuming* devices that are mass produced at a *low cost*, which has in turn accelerated their widespread use.

Introduction (cont'd)

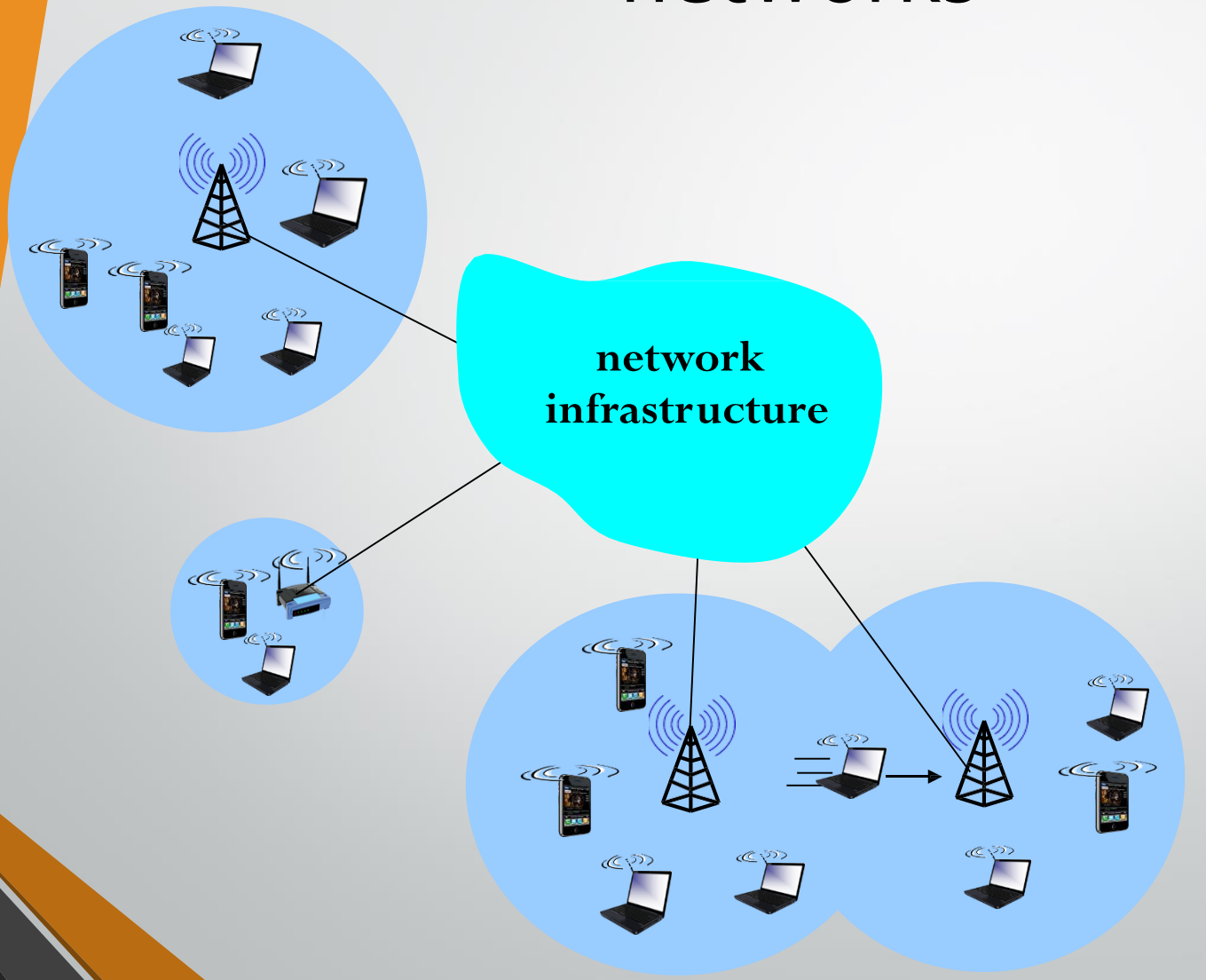
- Fundamentally different from wired networks
- Different wireless applications have different requirements
  - Voice systems
    - Have relatively low data rate requirements (around 20 Kbps)
    - Can tolerate a fairly high probability of bit error but the total delay must be less than around 30 msec.
  - Data systems
    - Require much higher data rates (1-100 Mbps) and very small bit error rates but do not have a fixed delay requirement.
  - Real-time video systems have high data rate requirements coupled with the same delay constraints as voice systems
  - Paging and short messaging have very low data rate
  - requirements and no delay constraints.

8

Introduction (cont'd)

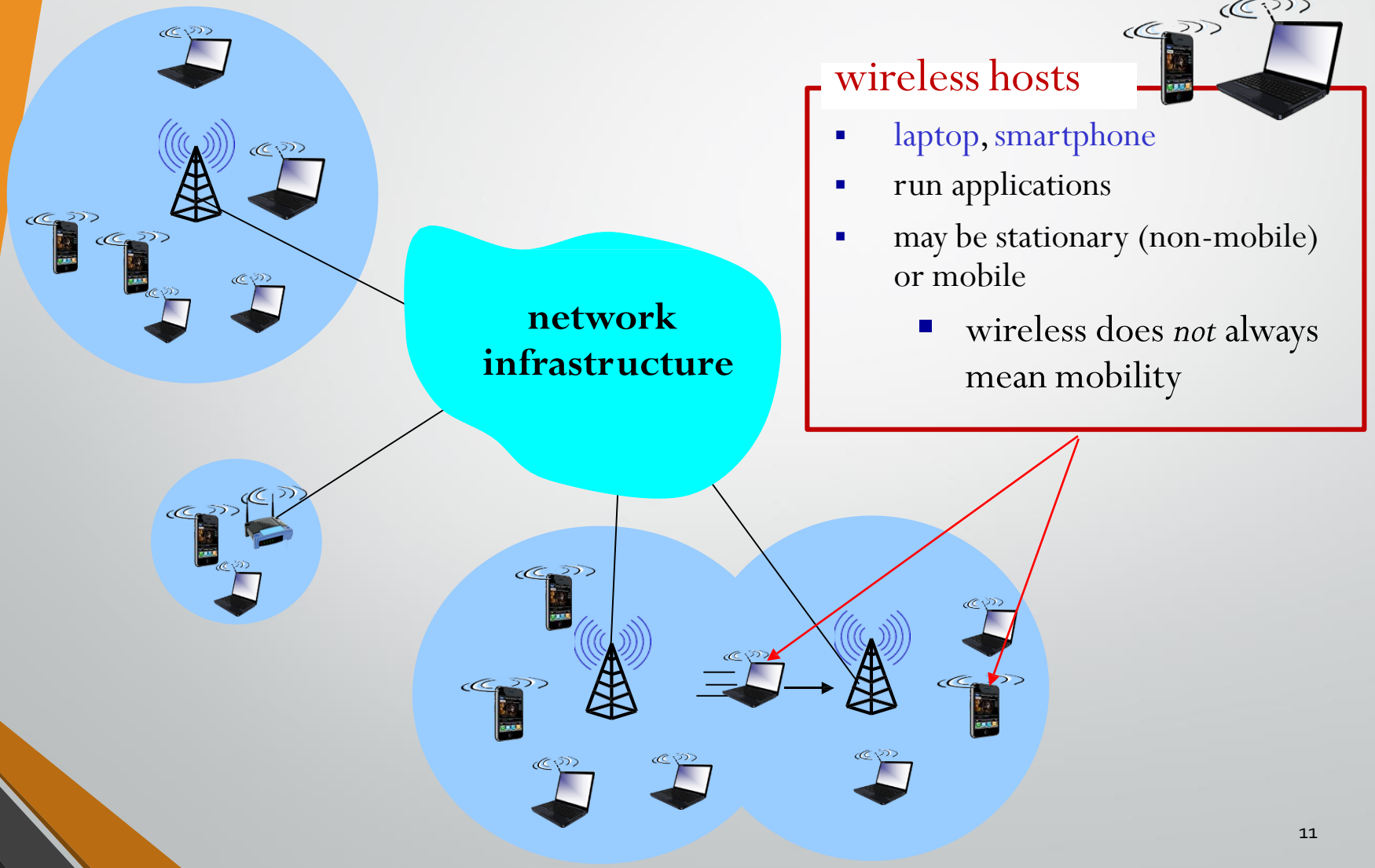
- These diverse requirements for different applications make it difficult to build one *wireless system* that can efficiently satisfy all these requirements simultaneously.
- For these reasons, at least in the near future, wireless systems will continue to be fragmented, with different protocols tailored to support the requirements of different applications.

Components of a wireless networks



10

Components of a wireless network

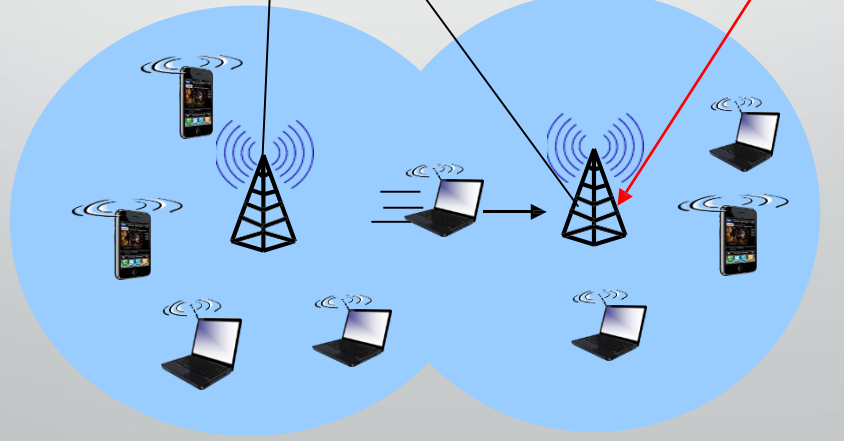


wireless hosts

- laptop, smartphone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

11

Components of a wireless network



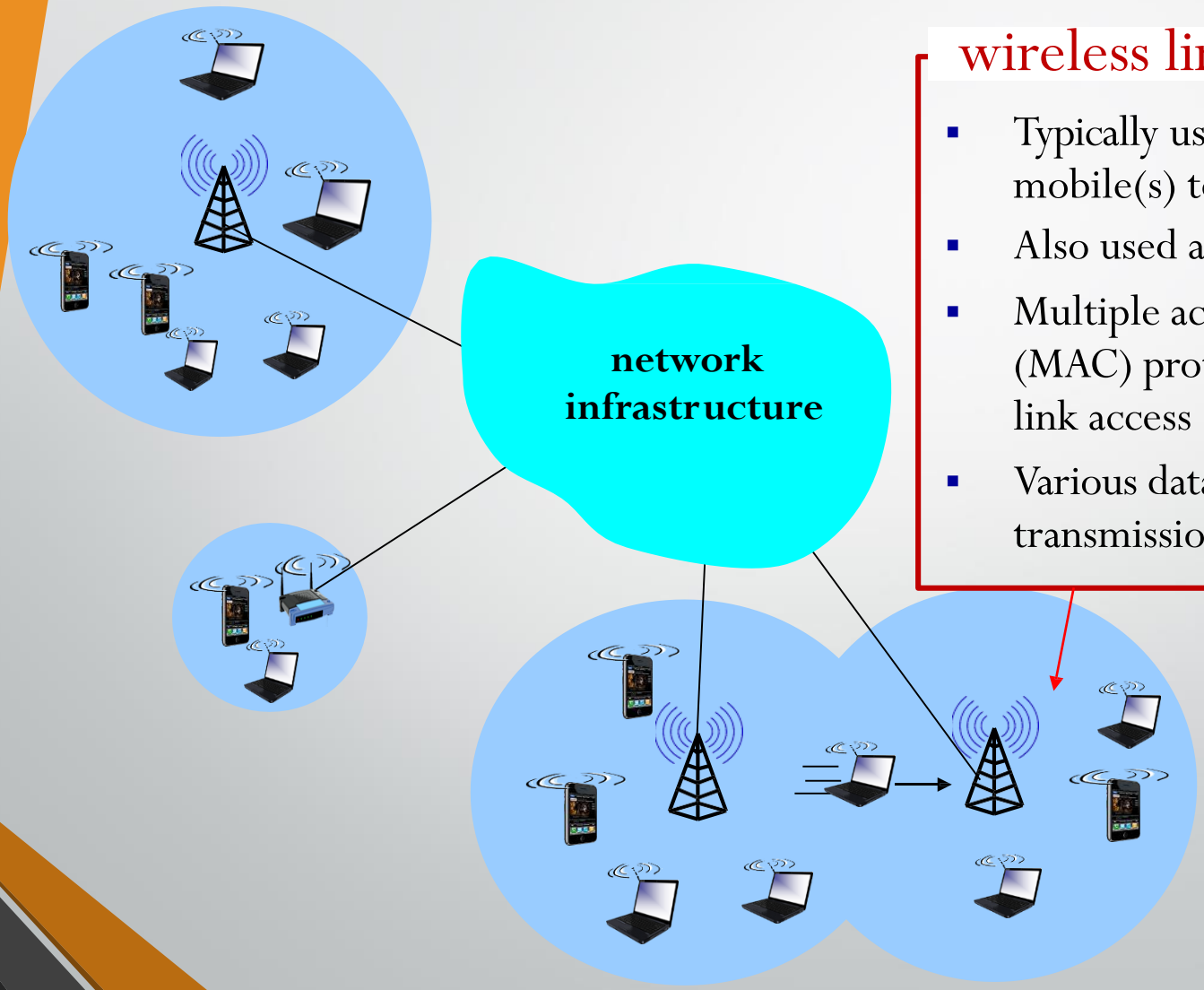
network infrastructure

base station

- Typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

12

Components of a wireless network

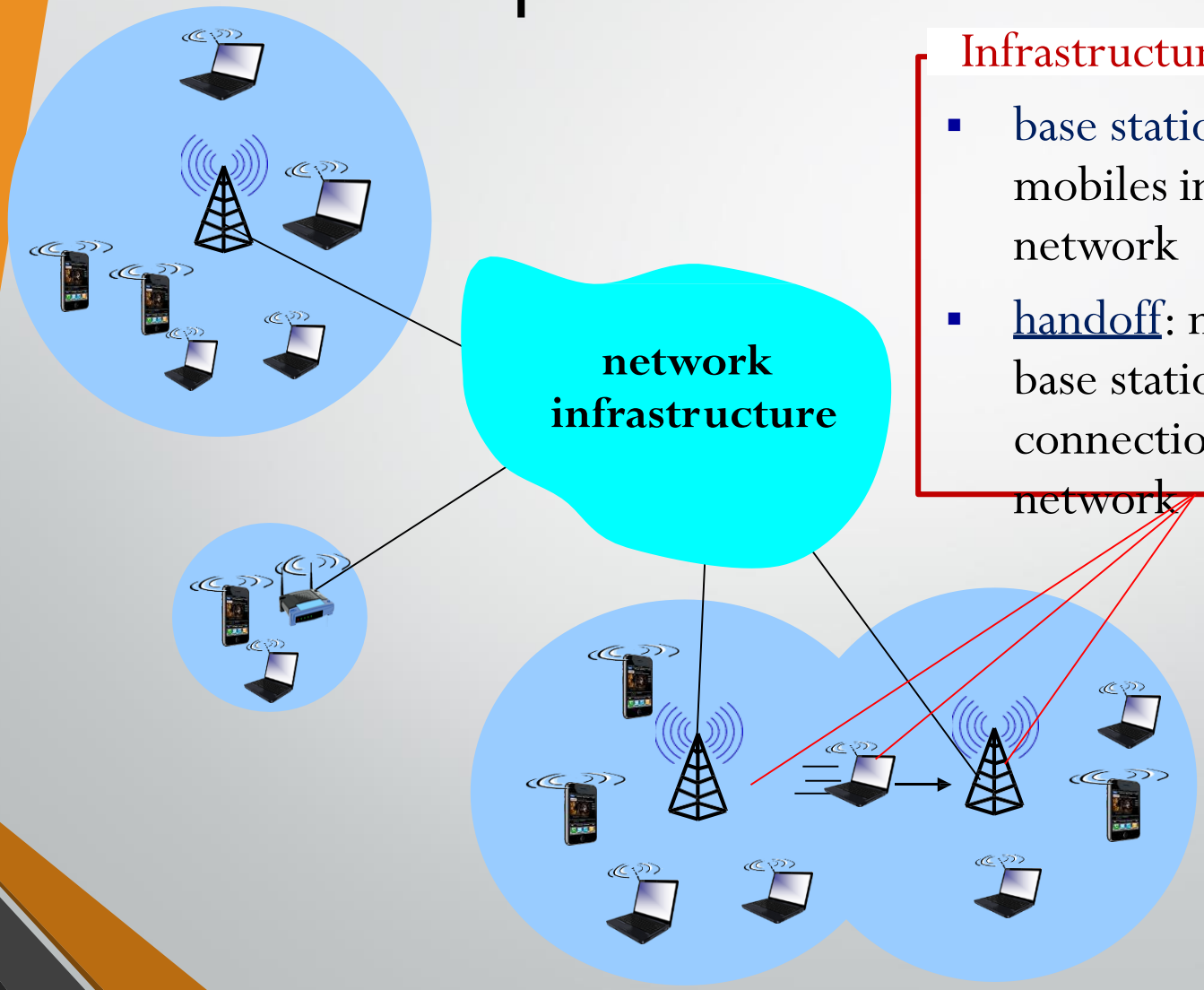


wireless link

- Typically used to connect mobile(s) to base station
- Also used as backbone link
- Multiple access control (MAC) protocol coordinates link access
- Various data rates, transmission distance

13

Wireless network: Mode of operation

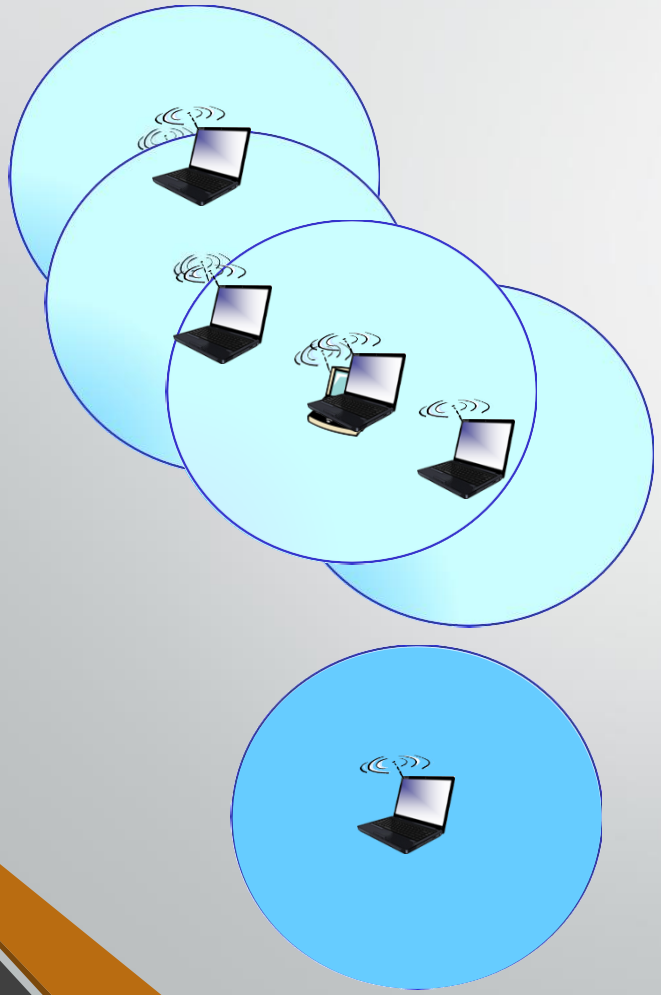


Infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

14

Wireless network: Mode of operation



ad-hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network

15

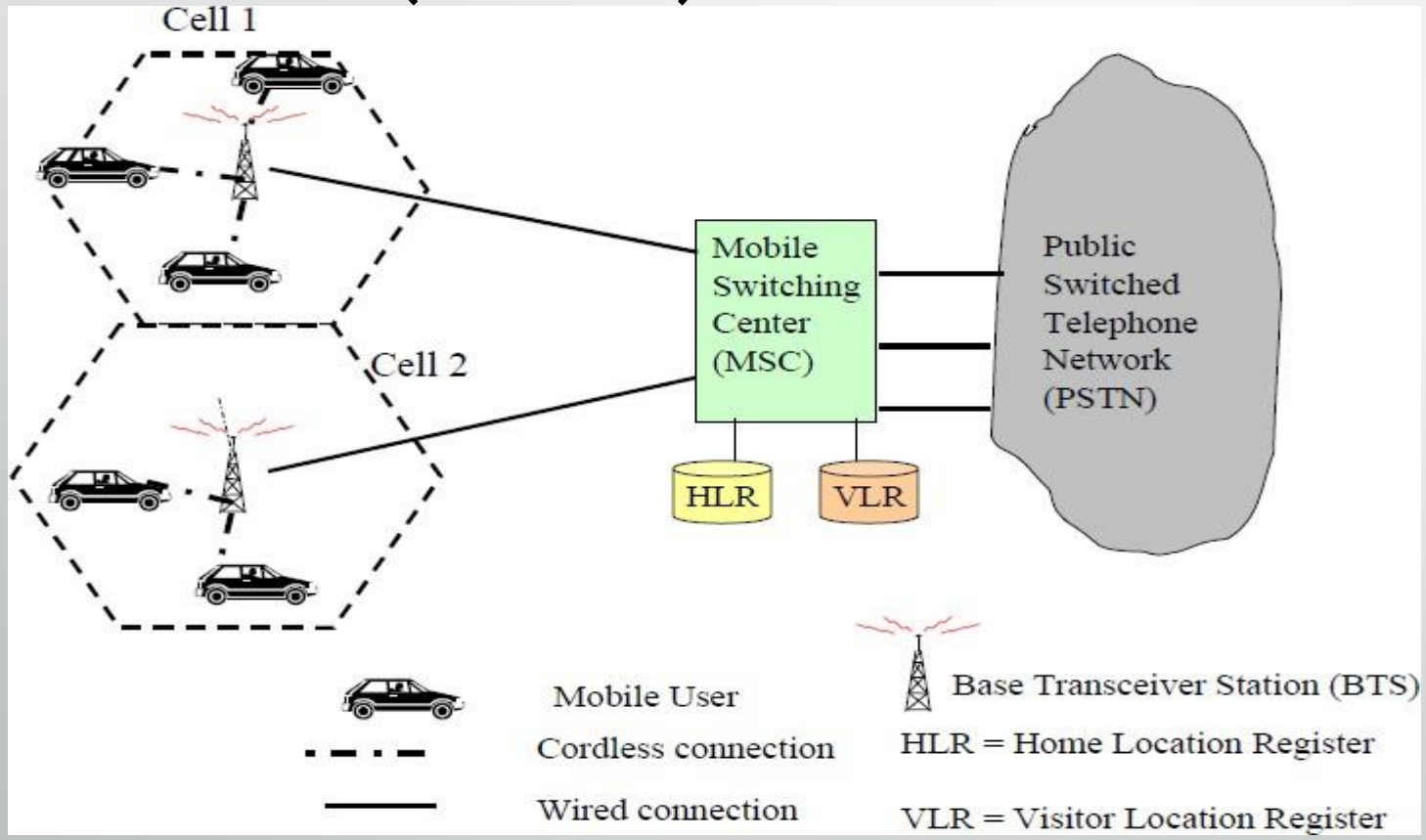
Cellular Networks

- Extremely popular. There are billions of cellular system users worldwide. Indeed cellular phones have become a critical business tool and part of everyday life
- Ignited the wireless revolution
- Provide two-way voice and data communication
- Initially designed for mobile terminals inside vehicles with antennas mounted on the vehicle roof
- Today these systems have evolved to support lightweight handheld mobile terminals

Cellular Networks (cont'd)

- Cellular Network Organization
  - Multiple low power transmitters(100W or less)
  - The service area is divided into cells
    - Each with own antenna
    - Each with own range of frequencies
    - Served by base station, consisting of transmitter, receiver, control unit
    - Adjacent cells on different frequencies to avoid interference
  - A combination of multiple cells is called a cellular structure
- Cell radii can vary from 1om in buildings up to tens of kilometers in the countryside
- Operate in licensed frequency bands roughly between 900 MHz and 2 GHz

Cellular Networks (cont'd)



- **A Cellular Communication Network**

Cellular Networks (cont'd)

- ***Cellular telephony*** is designed to provide *communications between two moving units*, called mobile stations (ms), or between one mobile unit and one stationary unit, often called a land unit.
- A service provider must be able to *locate and track a caller*, *assign a channel to the call*, and *transfer the channel from base station to base station* as the caller moves out of range.
- To make this tracking possible, each *cellular service area* is divided into small regions called *cells*.
- Each cell contains an *antenna* and is controlled by a solar or AC powered network station, called the *base station (BS)*. Each *base station*, in turn, is controlled by a *switching office*, called a *mobile switching center (MSC)*.

Cellular Networks (cont'd)

- *Cell size is not fixed* and can be increased or decreased depending on the population of the area. High-density areas require more, geographically smaller cells to meet traffic demands than do low-density areas.
- Once determined, cell size is optimized to prevent the interference of adjacent cell signals. The transmission power of each cell is kept low to prevent its signal from interfering with those of other cells.
- The *MSC coordinates communication between* all the *base stations and the telephone central office*. It is a computerized center that is responsible for connecting calls, recording call information, and billing

Cellular Networks (cont'd)

Transmitting

- To place a call from a mobile station, the *caller enters a code* of 7 or 10 digits (a phone number) and *presses the send button*.
  - *The mobile station then scans the band*, *seeking a setup channel with a strong signal*, and *sends the data* (phone number) *to the closest base station* using that channel.
  - The *base station relays the data to the MSC*.
- The *MSC sends the data on to the telephone central office*.
  - If the called *party is available*, a *connection is made* and the result is *relayed back to the MSC*.
  - At this point, the *MSC assigns an unused voice channel to the call*, and a *connection is established*.
  - The mobile station automatically adjusts its tuning to the new channel, and communication can begin.

Cellular Networks (cont'd)

Receiving

- When a *mobile phone is called*, the *telephone central office sends the number to the MSC*.
- The MSC searches for the location of the mobile station by sending query signals to each cell in a process called *paging*.
- *Once the mobile station is found, the MSC* transmits a ringing signal and, when the mobile station answers, assigns a voice channel to the call, allowing voice communication to begin.

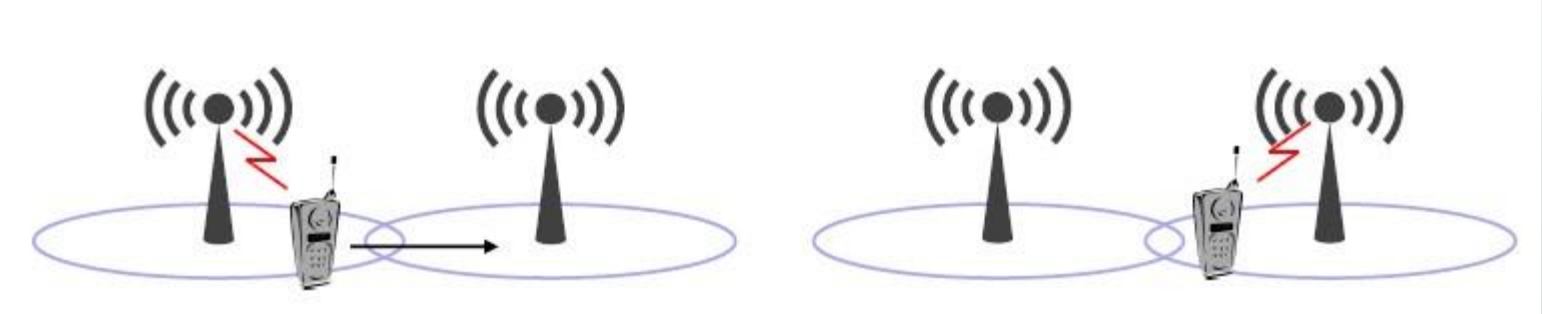
Cellular Networks (cont'd)

Handoff

- It may happen that, during a conversation, the mobile station moves from one cell to another.
  - When it does, the signal may become weak.
  - To solve this problem, the MSC monitors the level of the signal every few seconds.
  - If the strength of the signal diminishes, the MSC seeks a new cell that can better accommodate the communication.
- The MSC then changes the channel carrying the call (hands the signal off from the old channel to a new one).

Cellular Networks (cont'd)

- Handover/Handoff
  - *Is switch from one channel to another* as the mobile moves from one cell area to another.



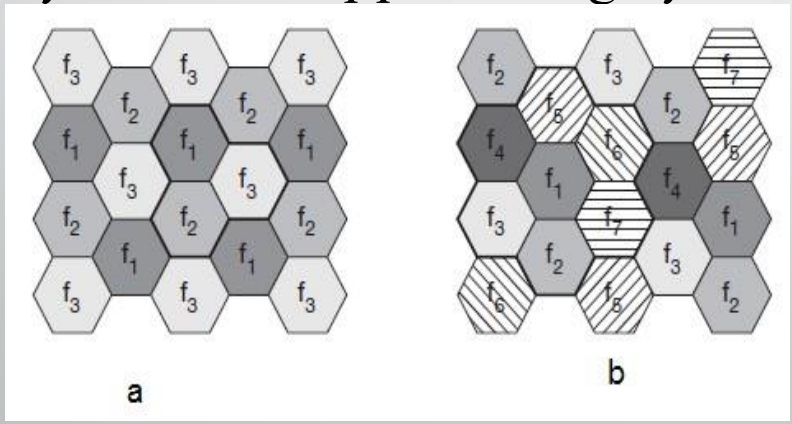
- Reasons for handovers are:
  - leaving the transmission range of a cell
  - overloading or breakdown of the used cell
  - loss of connection quality

Cellular Networks (cont'd)

- Hard Handoff Early systems used a hard handoff.
  - In a hard handoff, a mobile station only communicates with one base station.
  - When the MS moves from one cell to another communication must first be broken with the previous base station before communication can be established with the new one.
  - This may create a rough transition.
- Soft Handoff New systems use a soft handoff. In this case, a mobile station can communicate with two base stations at the same time.
  - This means that, during handoff, a mobile station may continue with the new base station before breaking off from the old one.

Cellular Networks (cont'd)

- The basic premise behind cellular system design is *frequency reuse*.
  - Transmission power controlled to limit power at that frequency escaping to adjacent cells. Objective is to *reuse frequency* in nearby cells
  - *10-50 channels* (TDM, FDM or CDMA) assigned per cell
- A cell of any size can support roughly the same number of users



a. Cellular system with three cell clusters

b. Cellular system with seven cell clusters

Cellular Networks (cont'd)

- The shape of cells are never perfect circles or hexagons. It depend on:
  - The environment (buildings, mountains, valleys etc.),
  - on weather conditions, and
  - Sometimes even on system load
- Well known from mobile networks (GSM, UMTS)
- A procedure inside a cellular network controls the switching process between the cells and end devices(more on the 2nd chapter)

Cellular Networks (cont'd)

- Advantages of cellular systems with small cells
  - *Higher capacity* - allows frequency reuse(higher number of users per unit area)
  - *Less transmission power*
    - Receiver far away from a base station would need much more transmit power and Power aspects are not a big problem for base stations.
    - Energy is a serious problem for mobile handheld devices
  - *Local interference only:* With small cells, mobile stations and base stations only have to deal with 'local' interference
  - *Robustness:* Cellular systems are decentralized and so, more robust against the failure of single components

Cellular Networks (cont'd)

- Disadvantages:
  - *Infrastructure needed*: Cellular systems need a complex infrastructure to connect all base stations.
  - *Handover needed*: The mobile station has to perform a handover when changing from one cell to another.
  - *Frequency planning:* To avoid interference between transmitters using the same frequencies, frequencies have to be distributed carefully.

Multiple Access Schemes

- Introduction
- Narrowband Channelized Systems
  - FDMA- frequency
  - CDMA- code
  - TDMA- Time Division
  - SDMA-spatial
  - FDD(Frequency Division Duplex) andTDD (Time Division Duplex)
- Random AccessTechniques
  - ALOHA, CSMA, CSMA/CD, CSMA/CA

30

Introduction Multiple Access Schemes

- Multiple Access Schemes-used to allow many *mobile users to share* simultaneously a finite amount of *radio spectrum(*frequencies from 3 Hz to 3 000 GHz).
- The goal of *cellular system design* is *to handle calls in a given bandwidth.*
- Multiplexing
  - Is the division of resources to create *multiple channels*.
  - Describes how several users can share a medium with minimum or no interference.
  - InWC, multiplexing can be carried out in four dimensions: space, time, frequency, and code.

31

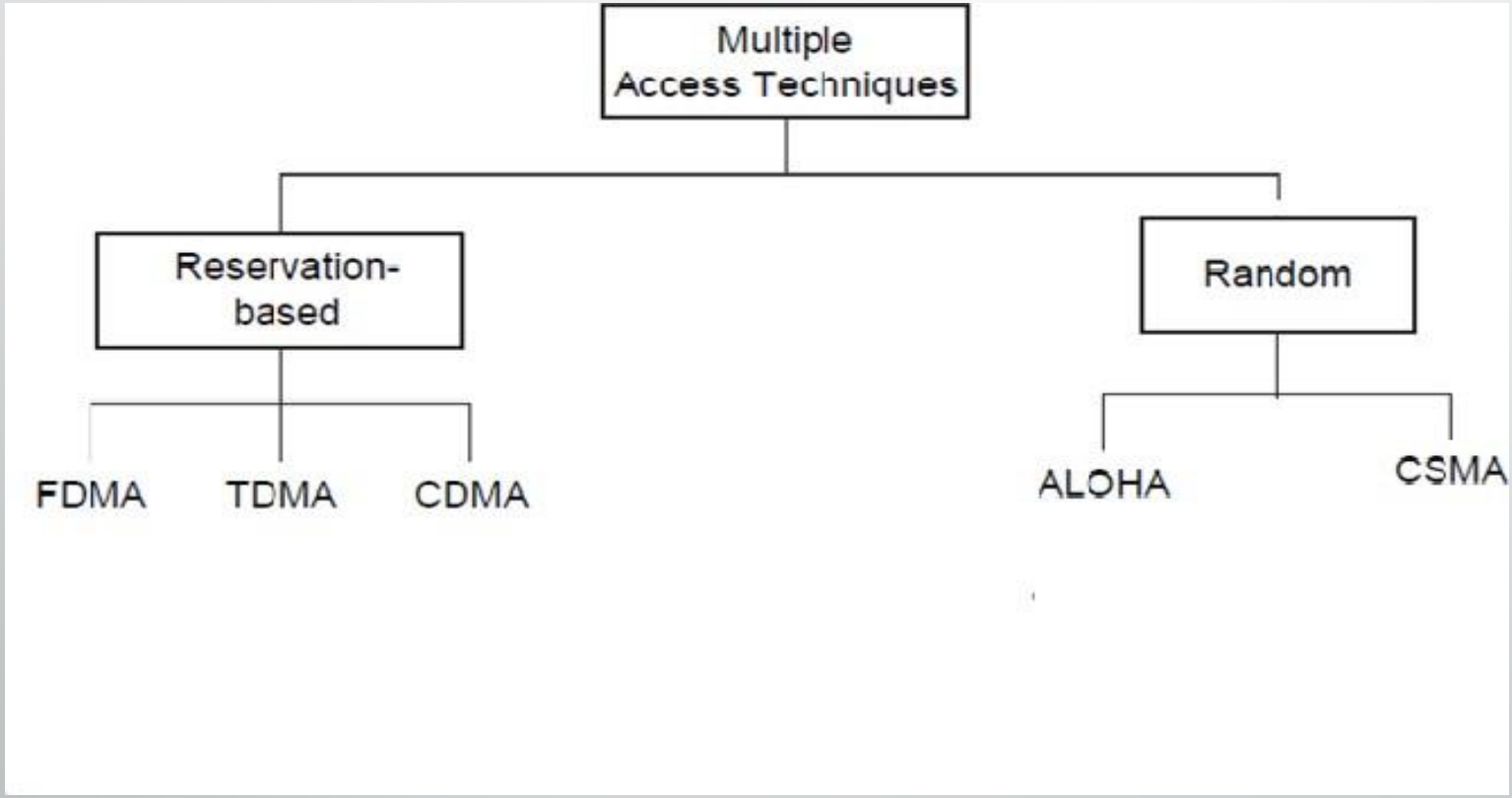
Introduction (cont'd)

Multiple access schemes (ways to allow access a channel) can be classified as

- Reservation-based multiple access
  - used if data traffic is continuous and a small transmission delay is required, E.g. voice and video
    - Types:
      - Frequency Division Multiple Access(FDMA)
      - Time Division Multiple Access(TDMA)
      - Code Division Multiple Access(CDMA)
- Random multiple access
  - Communication channel is shared by many users and users transmit their data in a random or partially coordinated fashion.
  - Examples:ALOHA, CSMA

32

Introduction(cont'd)



Multiple access schemes

33

Cont'd

- Depending on how the available *bandwidth is allocated to users*, these techniques can be classified
  - *Narrowband* systems and
  - *Wideband* systems.

Narrowband Channelized Systems

- Total *spectrum* is divided into a large number of relatively *narrow radio channels*.
- Each *radio channel* consists of a pair of frequencies
  - ***Forward channel (downlink channel):*** the frequency used for transmission *from base station to mobile station*.
  - ***Reverse channel (uplink channel):*** the frequency used for transmission from *mobile station to base station*.

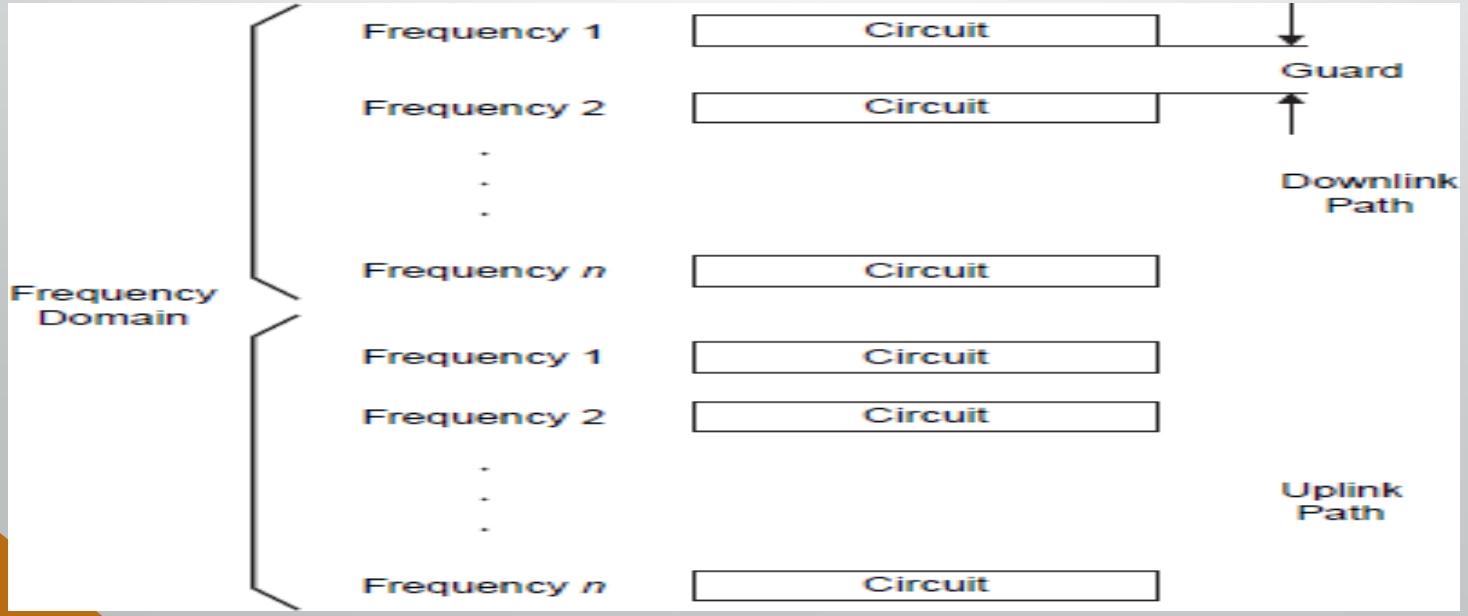
34

Cont'd

- A user is assigned *both frequencies* for the duration of call.
- The *forward* and *reverse* *channels* are assigned *widely* *separated*
- frequencies to *minimize interference*
- Most systems use a combination of FDMA andTDMA.

Frequency Division Multiple Access (FDMA)

- FDMA
  - Allots a different *sub-band of frequency* to each different user to access the network.
  - Divides *entire channel bandwidth into M equal sub channels* that are separated to prevent *channel interference*.
  - It is often used in *first generation of analog mobile phone*.



FDMA (cont'd)

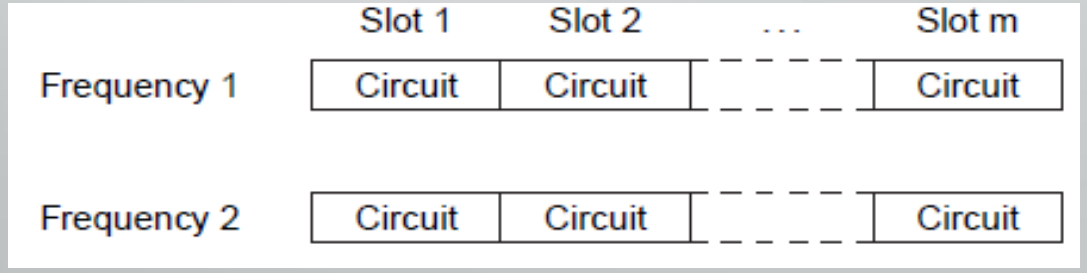
- Advantages:
  - Technological advances required for implementation are simple.
  - *Hardware simplicity*, because multiple users are isolated by employing simple bandpass filters.
    - A **bandpass filter** is an electronic device or circuit that allows signals between two specific frequencies to **pass**, but that discriminates against signals at other frequencies.
- Disadvantages:
  - *Inefficient use of spectrum*, in FDMA if a channel is not in use, it remains idle and cannot be used to enhance the system capacity.
  - *Inflexible* and *guard spaces*

Time Division Multiple Access (TDMA)

TDMA

- It allows several users to share the *same frequency channel* by dividing the signal into different time slots.
- Shares *single carrier frequency* with several users where each users makes use of non-overlapping time slots
- Users transmit in rapid succession, one after the other, each using its own time slot.
- The *entire bandwidth* is available to user but only for a *finite period of time*.
- Available bandwidth is divided into fewer channels compared to FDMA and users are allotted time slots during which they have the entire channel bandwidth at their disposal.

- Digital data could be split up in time and sent as bursts when required



TDMA (cont'd)

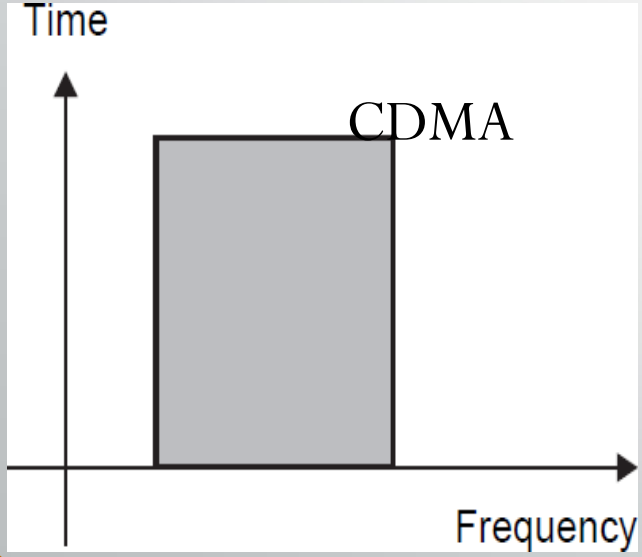
- Advantages:
  - *Only one carrier in medium at any time*
  - *Throughput high even for many users*
- Disadvantages:
  - precise *synchronization necessary*. If time slot synchronization
    is lost, the channels may collide with each other.
    - **Synchronization**:-Process of precisely coordinating or matching two or more activities, devices, or processes in time.

Code Division Multiple Access

- CDMA
  - Several *transmitters use single channel to send information simultaneously*.
  - Allow transmissions to occupy the channel at the same time without interference.
  - Every user uses the full available spectrum instead of getting allotted by separate frequency.
  - Recommended for *voice and data* communications.
  - While multiple codes occupy the same channel in CDMA, the users having same code can communicate with each other.
  - CDMA offers more *air-space capacity* thanTDMA

CDMA (cont'd)

- **Analogy**
  - In a large room with many peoples
  - two people can talk in English if nobody else understand English
  - two people can talk in Chinese if they are the only ones who understand Chinese and so on



- **Advantages**:
  - bandwidth efficient; all terminals can use the same frequency
  - *no coordination and synchronization necessary*
  - *good protection against interference* and tapping
- Disadvantages:
  - *more complex signal regeneration*

41

Wireless Communication System Standards

1. 1G - FDMA - 2.4kbps - Circuit - Voice
2. 2G - GSM (TDMA)/CDMA - 10kbps - Circuit - Voice+Data
3. 2.5G - GPRS/EDGE - 50/200kbps - C/P - Voice+Data
4. 3G - WCDMA/UMTS/CDMA 2000 - 384kbps - Circuit/Packet - Voice+Data+Video Calling
5. 3.5G - HSUPA/HSDPA/EVDO - 5-30Mbps - Packet - Voice+Data+Video Calling
6. 3.75G - LTE (OFDMA)/WIMAX (SOFDMA) - 100-200Mbps - Packet - Online Gaming+HDTV
7. 4G - LTE-A/WIMAX - 3Gbps/100-200Mbps - Packet - Online Gaming+HDTV
8. 5G - BDMA - 10-50Gbps - Packet - Ultra HD Video+Virtual Reality Apps

Topologies of Cellular and ad-hoc networks

- There are basically three ways to set up a wireless network

Point-to-point bridge

- *bridge* is used to connect two networks.
- *point-to-point bridge* interconnects two buildings having different networks.
- For example, a wireless LAN bridge can interface with an Ethernet network directly to a particular access point

Point-to-multipoint bridge

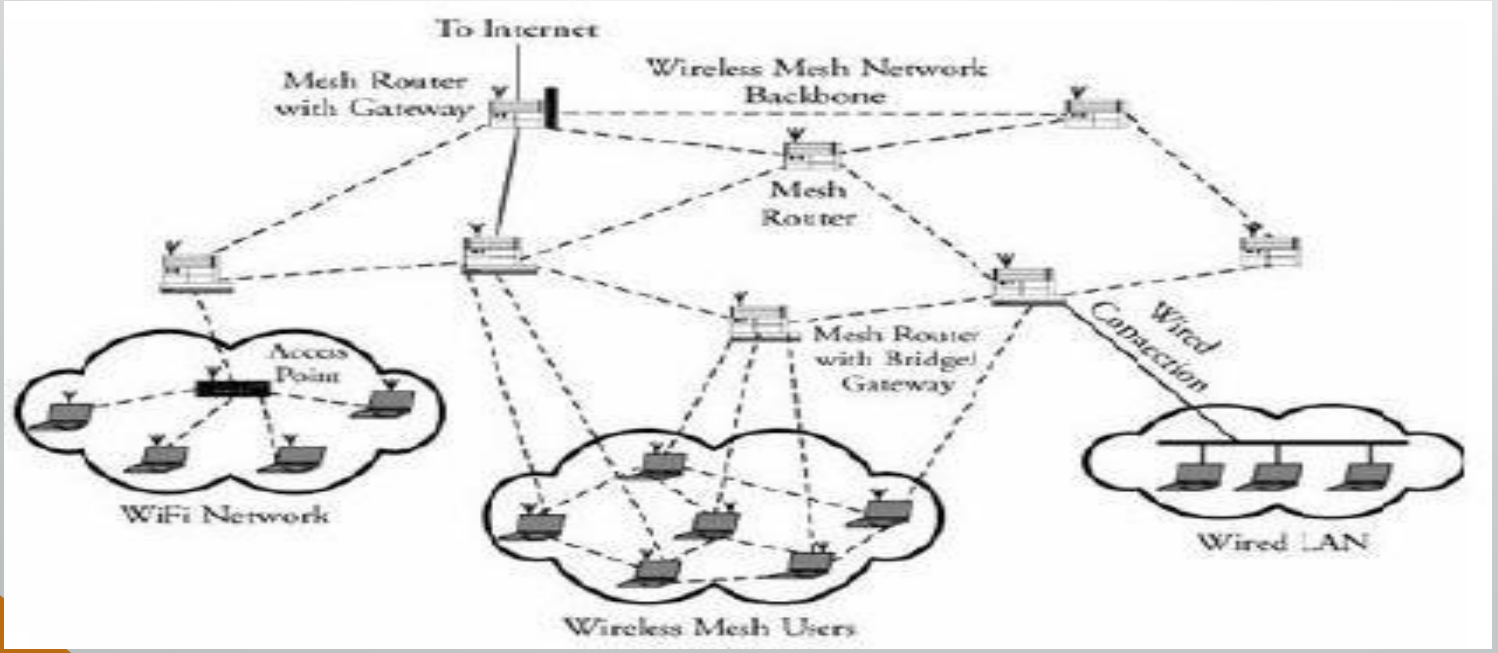
- This topology is used to connect three or more LANs that may be located on different floors in a building or across buildings

43

Cont'd

Mesh or ad hoc network

- This network is an independent local area network that is *not connected to a wired infrastructure* and in which *all stations are connected directly to one another*



END

45