Week 1-2

Contents

1. Introduction
2. Dimensions of Mobile Computing
3. Condition of the Mobile User
4. Architecture of Mobile Software Applications

Introduction

Mobile computing systems are computing systems that may be easily moved physically and whose computing capabilities may be used while they are being moved

Examples :

laptops, personal digital assistants (PDAs), and mobile phones

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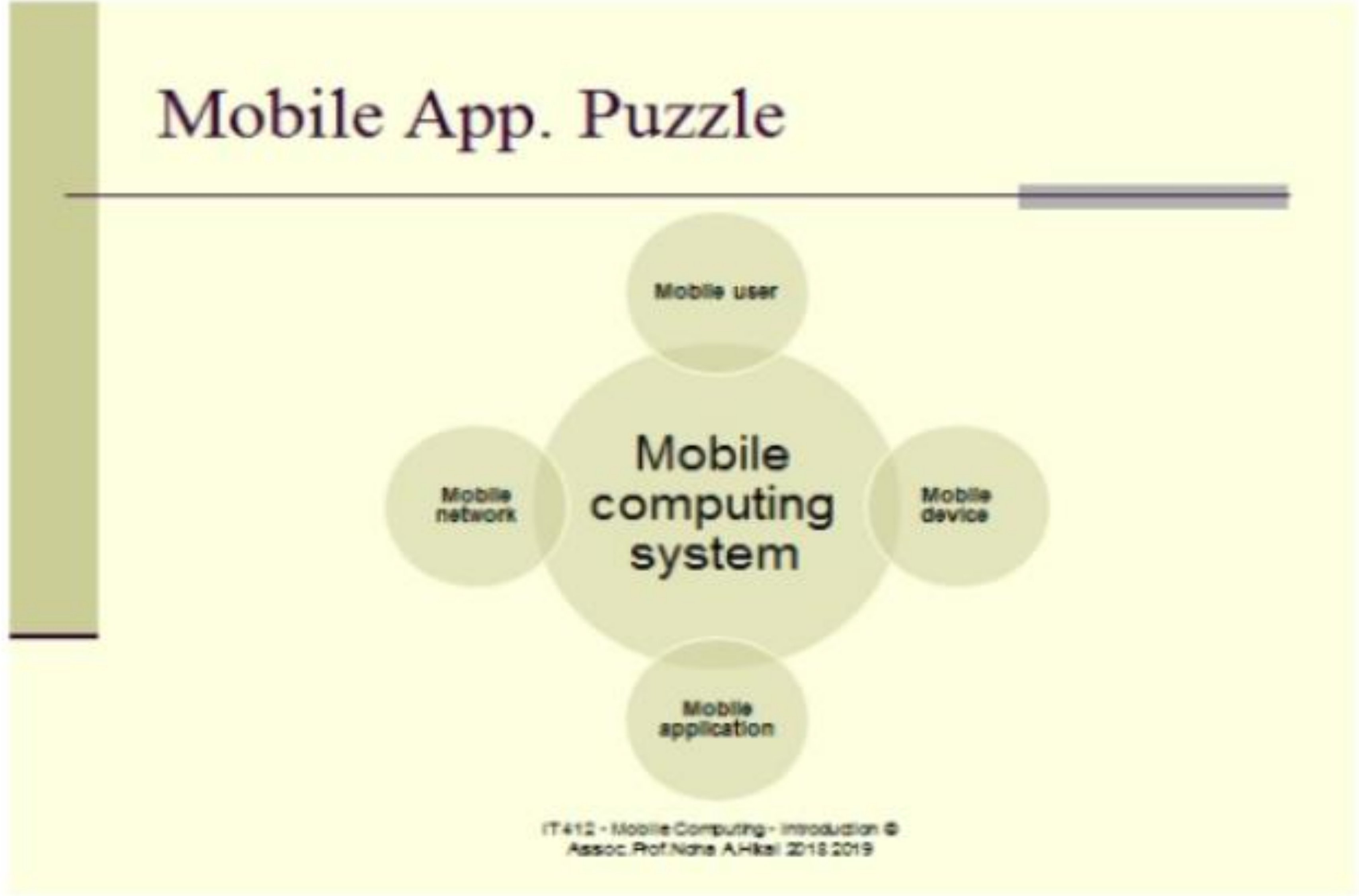
Mobile Computing is a two word terminology

Mobile (means Moving) and **Computing** (means using computer)

It is a terminology that describes technologies which enable people to access network services anytime, and anywhere

Recently, The ease of internet connection gave the distributed computers a great importance. Technological advances shaped a new computing environment that gives the user the freedom to work at any location, moreover it enabled him to work while on moving.

§ This new paradigm is often called **MOBILE COMPUTING**.

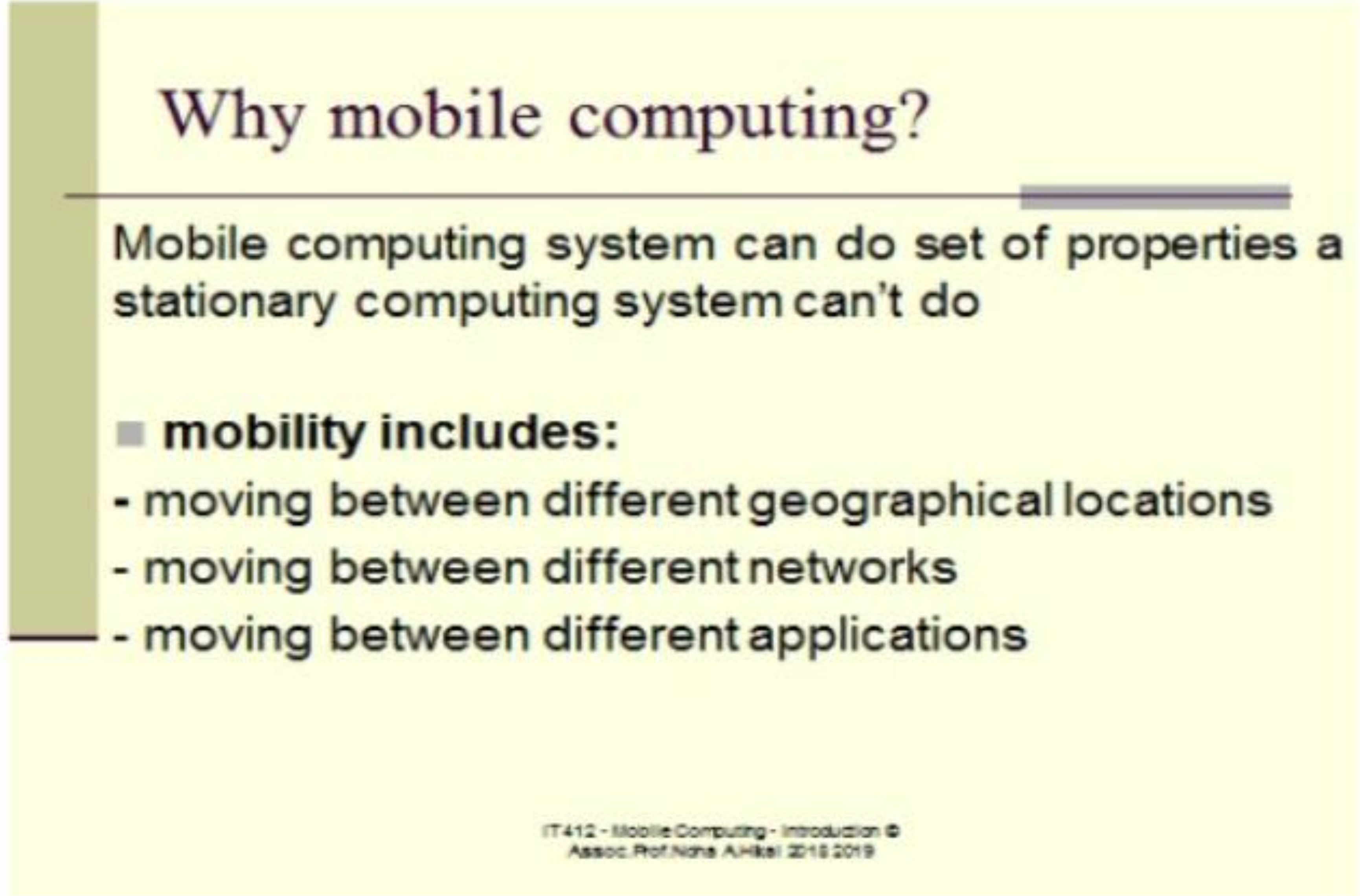


Mobile condition:

The set of properties that distinguishes the mobile user from the user of a typical, stationary computing system.

dimensions of mobility:

The set of properties that distinguishes the mobile computing system from the stationary computing system



Mobile computing system differs from other systems in the ***functionality requirements***, i.e, the tasks that they are designed to perform, the way that they are designed, and the way in which they are operated.

These functionality requirements forces the programmer to implement the required task through mobile computing environment

It doesn't mean that they don't have any commonalities; mobile computing systems are built on existing software technologies and techniques used for stationary systems.

Mobile computing systems can be considered a logical extension of a stationary technique or technology that can mobilize them.

Advantages of mobile computing systems:

- Prevalent wireless network connectivity
- Small size
- The mobility nature of their use
- Power sources
- Their functionalities that are particularly suited to the mobile user.

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Because of these features, mobile computing applications are inherently differ from the applications written for use on stationary computing systems

Brief History

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Connectivity to the network is **not a prerequisite** for being a mobile computing system

Brief History

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The great revolution of computing aspects lead to mobile computing systems, for example: storage, display communications...etc

There is a great confusion between ***wireless communications*** **and *mobile computing***

Mobile computing devices found a great way to connect with other devices on the network through wireless communications

BUT, Mobile computing devices don't need to be wireless. Laptop computers, calculators, electronic watches, and many

other devices are all mobile computing devices.

it should be clear that ***wireless communication systems are a type of communication system***. *What distinguishes a wireless communication system from others is that the communication channel is space itself*. There are a variety of physical waveguide channels such as fiber optics or metallic wires.

Wireless communication systems do not use a waveguide to guide along the electromagnetic signal from the sender to the receiver.

They rely on the fact that electromagnetic waves can travel through space if there aren't obstacles that block them.

Wireless communication systems are often used in mobile computing systems to facilitate network connectivity, but they are not mobile computing systems.

2- Dimensions of mobility

dimensions of mobility are the tools that allow us to qualify our problem of building mobile software applications and mobile computing systems.

- Dimensions of mobility are not completely orthogonal with respect to each other.
- Some of these dimensions are limitations

Mobile computing systems can be considered a stationary computing systems if we stop moving it. Therefore, mobile computing systems are a superset of stationary computing systems.

This brings us to a main question ***" What are the elements that must be added to the stationary computing system that give the dimensionality of mobile computing system?"***

Dimension of mobility are separate enough in nature that we can distinguish them and approximate them as orthogonal variables

continued

2.1 Location awareness

acquiring position infomation requires connectivity to some network-based infrastructure.

- *localization*
- *location sensitivity*

challenges and opportunities

challenges and opportunities:
changing the location of the mobile device (the mobile application) brings the designers of software applications to great difficulties. However, it can be exploited as an opportunity of using the location and the change in location to enhance the application.
Localization is often required in stationary applications where users at different geographical locations access a centralized system
Localization in mobile computing is the ability of the architecture of the mobile application to accommodate logic that allows the selection of different business logic, level of work flow, and interfaces based on a given set of location information commonly referred to as locales.
Location sensitivity is the ability of the device and the software application to obtain location information while being used and then to take advantage of this location information in offering features and functionality

continued

Methods for collecting and using the location of the user and the device

- user may simply be prompted for his or her location (user unfriendly)
- Location-sensing technology
  - ✓ *Triangulation*
  - ✓ *proximity*
  - ✓ *scene analysis*

continued

- *Triangulation*

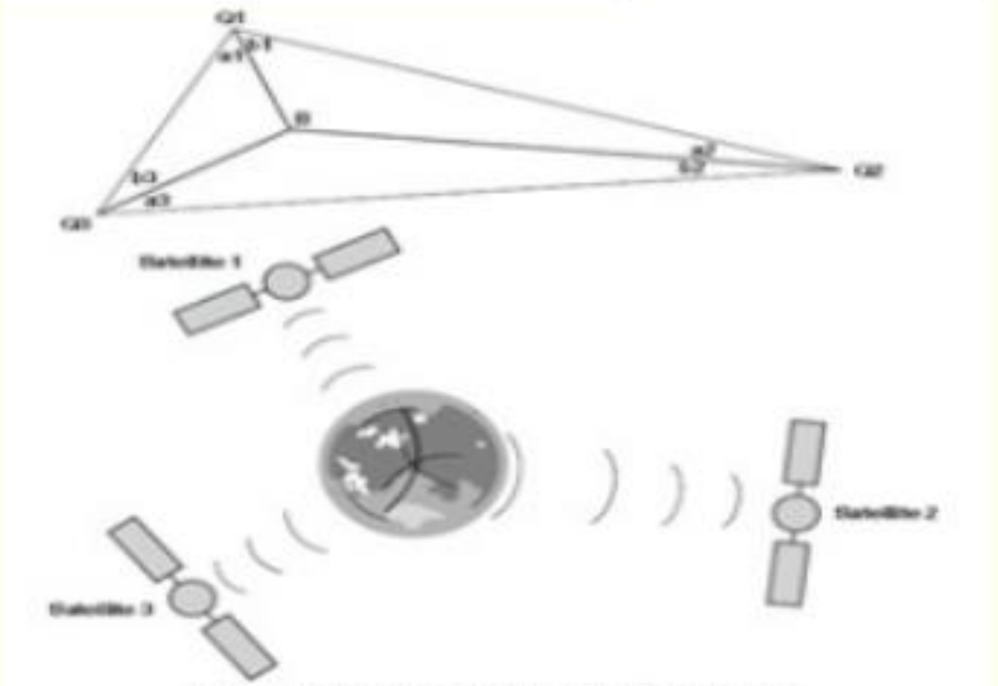
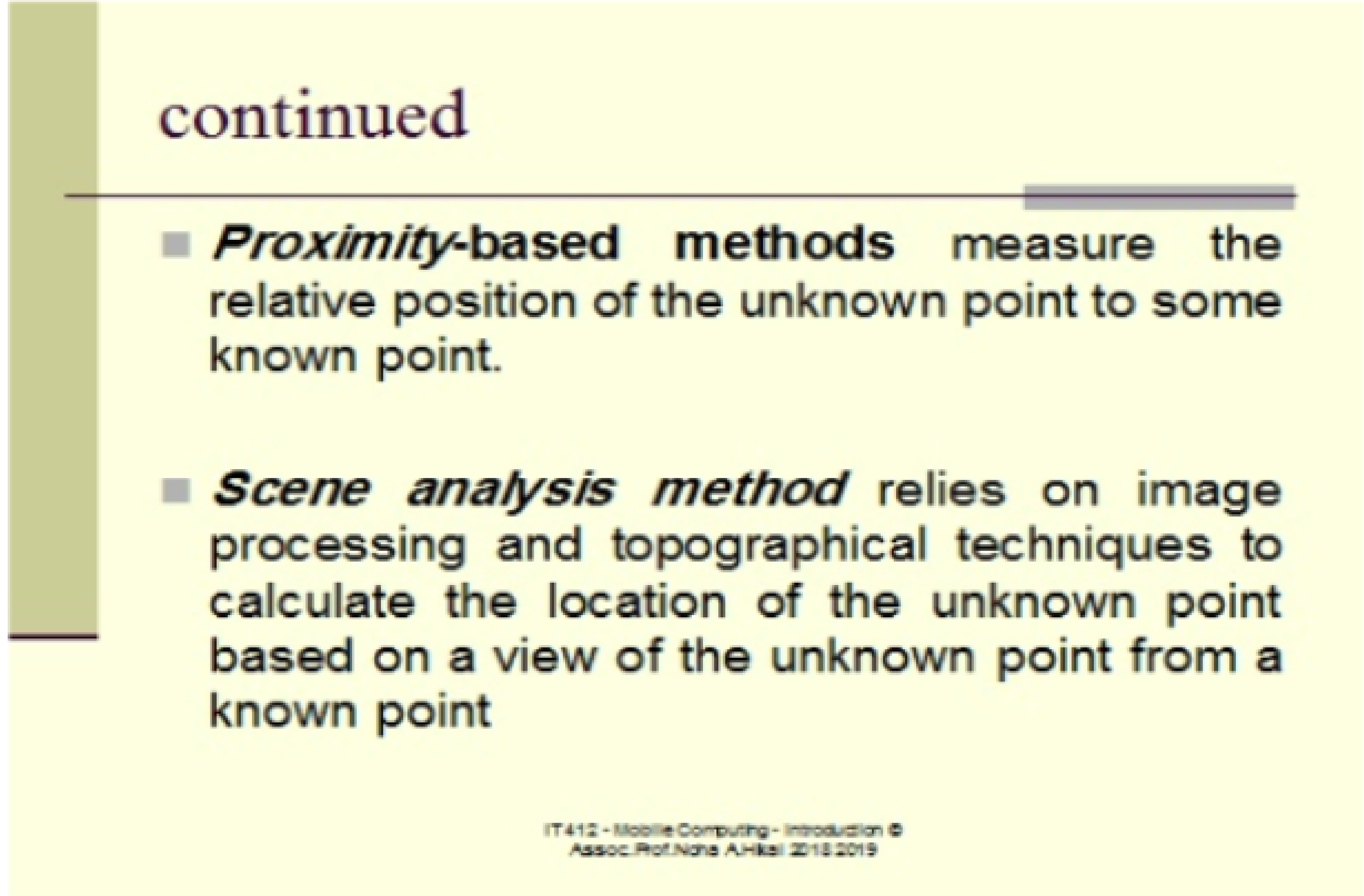


Figure 1.4. Determining Position Based on Triangulation.

It applies common geometric methods that calculate the location of a point that lies in the middle of three other points whose exact locations are known. the distance to each one of the three points is known, so the exact location of the unknown point can be calculated.



- GPS-enabled devices can obtain latitude and longitude with accuracy of about 1–5 m

- GPS devices use triangulation techniques by triangulating data points from the satellite constellation that covers the entire surface of the earth

- If a device does not have GPS capabilities but uses a cellular network for wireless connectivity, signal strength and triangulation or other methods can be used to come up with some. approximate location information, depending on the cellular network.

2.2 Quality of Service (QoS)

- Moving from one physical location to another may cause some disconnected time from the network
- The quality and type of the available network connectivity can significantly affect QoS
- network connectivity and QOS need to be taken into account while designing a mobile application

- Bad weather, solar flares, and a variety of other climate-related conditions can negatively affect the (QOS).

- QOS tools and products are typically used to quantify and qualify the reliability, or unreliability, of the connectivity to the network and are mostly used by network operators.

  - Network operators control the physical layer of the network and provide the facilities, such as Internet Protocol (IP), for software application connectivity.
  - (available bandwidth, risk of connectivity loss, and statistical measurements that allow software applications to make smart computing decisions) are the QoS measurements

continued

QoS:

- Available bandwidth
- Probability of connectivity
- Statistical traffic measurements

continued

- All mobile applications should know how to stop working when the application suddenly disconnects from the network and then resume working when it connects again
- QOS is provided by the network operator.
- Designing applications should dynamically adapt their features and functionality to the available bandwidth

2.3 Limited Device Storage and CPU

Size and Portability

&

Size and performance

Storage and processing issues are largely addressed by the various operating systems and platforms on the mobile devices.

continued

- Smaller physical size limitation imposes boundaries on volatile storage, nonvolatile storage, and CPU on mobile devices
- when it comes to mobile systems and devices, *smaller is nearly always better.*

Limitations of storage and CPU of mobile devices put another constraint on how to develop mobile applications.

For example, a mobile calendaring application may store some of its data on another node on the network (a PC, server, etc.). The contacts stored on the device may be available at any time. However, the contact information that exists only on the network is not available while the device is disconnected from the network.

But, because the amount of data that can be stored on each type of device varies depending on the device type, it is not possible to allocate this storage space statically

2.4 Limited Power Supply

The power supply has a direct or an indirect effect on everything in a mobile device.

Challenges:

- Battery life
- Mobility effect on battery life
- Connectivity effect on battery life
- Battery management

  OS or App job?

This constraint must be balanced with the processing power, storage, and size constraints; the battery is typically the largest single source of weight in the mobile device

Most power management functionality is built into the operating system of the mobile device. Therefore, when it comes to device power management, the design focus is more on making the right choice in selecting the proper platform (device, operating system, etc.) and configuring the platform properly. In a typical stationary application, this would suffice. But, in mobile applications, we need to look everywhere we can to save power. Because the operating systems of mobile devices are typically very lean and have as little functionality as possible, many times the application must carry some burden of awareness of the power supply

continued

Platforms should provide.

- monitoring of the remaining power and other related power information.
- allow multiprocessing and multithreading

which have an effect on the control over the variation of the CPU activity, which in turn has an effect on the control over the power consumed by the device.

Generally , operating systems and platforms are largely responsible for handling the power consumption issues. However, the effects

on choice of platform and other architectural and implementation effects that the power supply has on mobile computing systems

2.5 Varying User Interfaces

- Stationary application users have more efficient user interface capabilities than mobile application users
- Multichannel systems
- This is not true for all application

The challenge is how to choose the best UI for the context

continued

User interfaces are difficult to design and implement for the following reasons:

1. Designers have difficulties learning the user's tasks.
2. The tasks and domains are complex.
3. A balance must be achieved among the many different design aspects.
4. The existing theories and guidelines are not sufficient.
5. Iterative design is difficult.
6. There are real-time requirements for handling input events.
7. It is difficult to test user interface software.
8. Today's languages do not provide support for user interfaces.
9. Programmers report an added difficulty of modularization of user interface software.

2.6 Platform Proliferation

- Due to commercial competence in the world of mobile devices, every manufacture has his own platform proliferation (android vs ios)
- It affects the device supported-applications
- Platform proliferation heighten the importance of designing and developing mobile devices independent of the platforms
- UML based design

2.7 Active Transactions

- Passive transaction
- Active transaction
  - ✓ synchronous
  - ✓ asynchronous

Passive transaction: the user must initiate all the transactions (stationary system)

Synchronous active transactions can be summarized by a set of properties:

1-The transaction is initiated by the system, and during the same transaction, the user is given an opportunity, for a finite period of time, to respond to the action initiated by the system.

2. Synchronous active transactions require a timely response from the user.

3. The interactions between the system and the user work in a sequential and serial manner during a synchronous transaction.

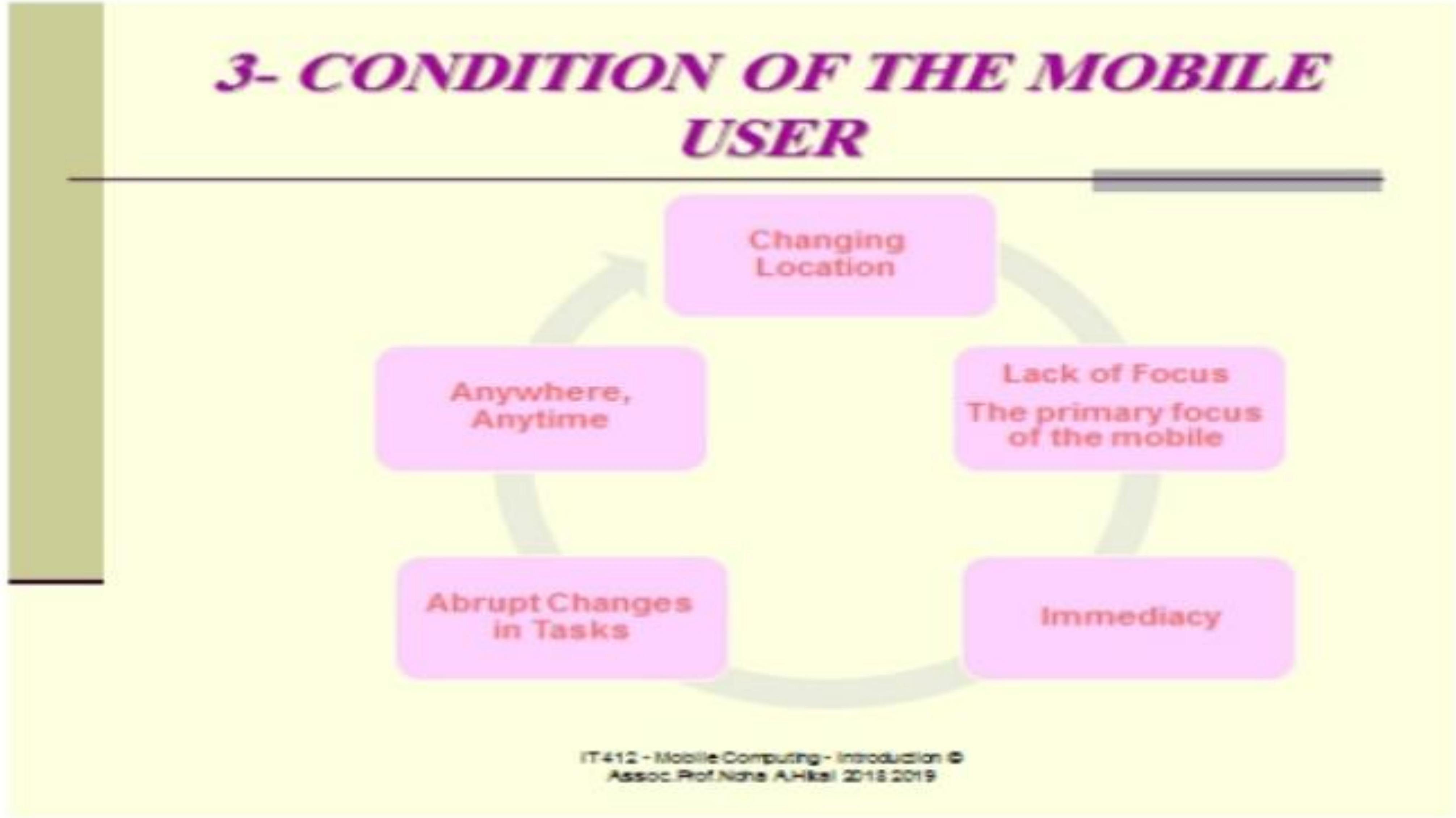
4. Synchronous active transactions are established between the system and a single user. This may be replicated for many users, but at the most elemental level, there is only one user in each active transaction

Asynchronous active transactions can be summarized by a set of properties:

1- Asynchronous active transactions work just like messaging systems. They can be established with either 1–n receivers or 1–n topics to which 1–m receivers are subscribed.

2. Asynchronous active transactions may be a composition of 1–n messages sent by the system and may require 1–m messages back from the users. If 1–m messages required as responses from the users are not received within some time frame specified by the system, the transactions may be deemed as failed. Note that we are not defining the semantics of messaging systems

we are defining the semantics of asynchronous active transactions to be such that they encapsulate a number of messages being sent from the system to the user and from the user to the system and that some messages from the user, marked as responses to the messages from the system, can be required for the successful completion of the transaction.



Mobile conditions is a set of conditions that make difference between the mobile user and the stationary user.

Means that how mobile application differ from stationary application.

Mobile condition is not just about the physical condition but also about the mental state of the user expectation.

Mobile computing differ from stationary computing in the following

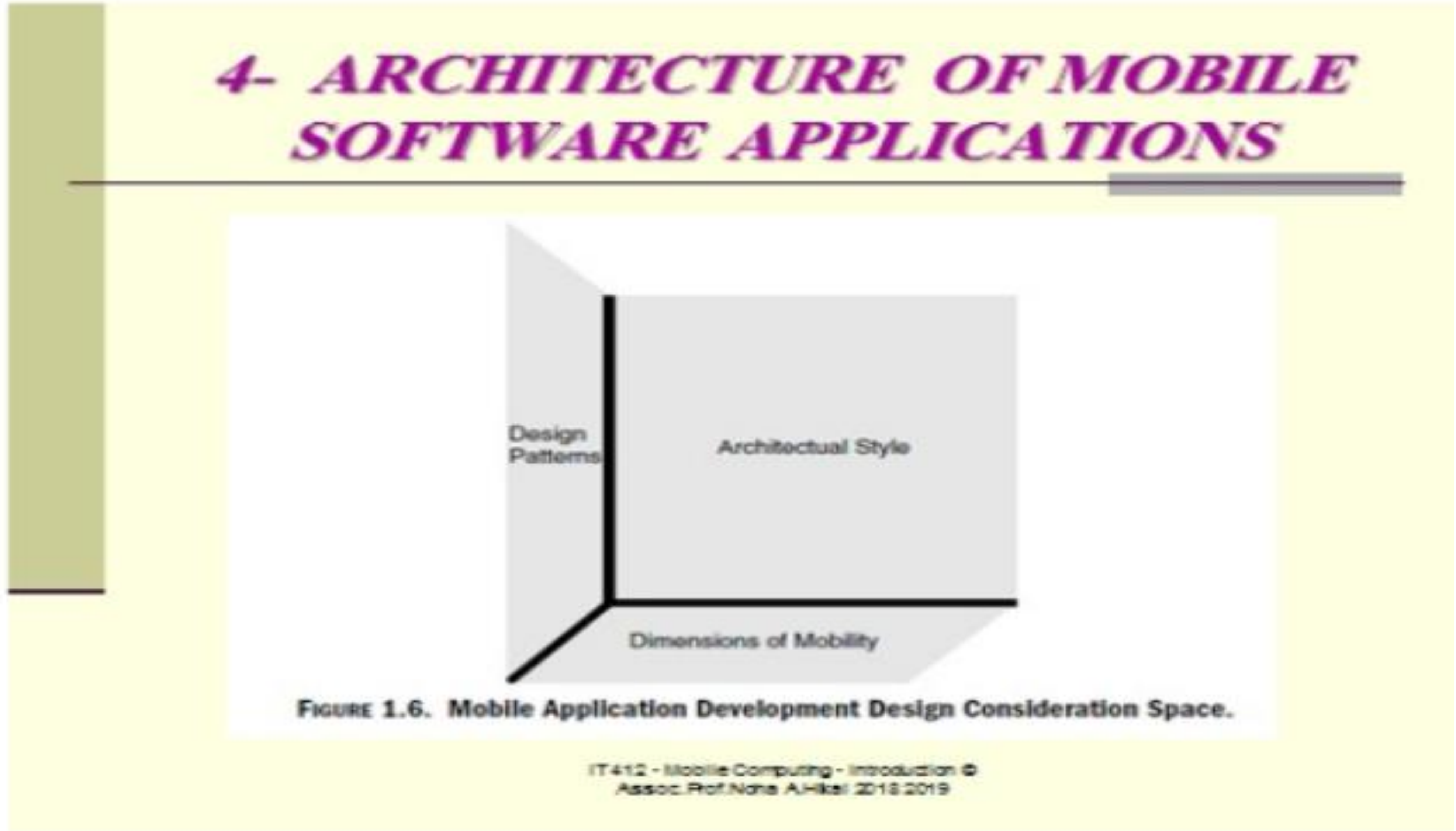
1-Moving, at least occasionally, between known or unknown locations.

2-Not focused on the computing task.

3-Seeks high degrees of immediacy and responsiveness from the system.

4-The mobile user is changing tasks frequently and/or abruptly.

5- Require access to the system anywhere and at any time.



-The high-level plan of what the application will be like when it is finished is called architecture of Mobile software applications

-There are a variety of design patterns with each addressing some specific problem with mobile applications (more in chapter 16)

-Architecture style is how to keep a particular high-level abstraction of the system and how its components collaborate

- Architectural patterns; these are patterns that are recognizable once they are used prevalently in some architectures. Although there are no fully established design patterns, architectural patterns, or even architectures in the field of mobile computing because of its infancy.

Thanks- Questions !

Lecture 3-4
SATELLITE SYSTEMS

Reference
"INTRODUCTION TO WIRELESS AND MOBILE SYSTEMS ", *DHARMA ARAWAL*

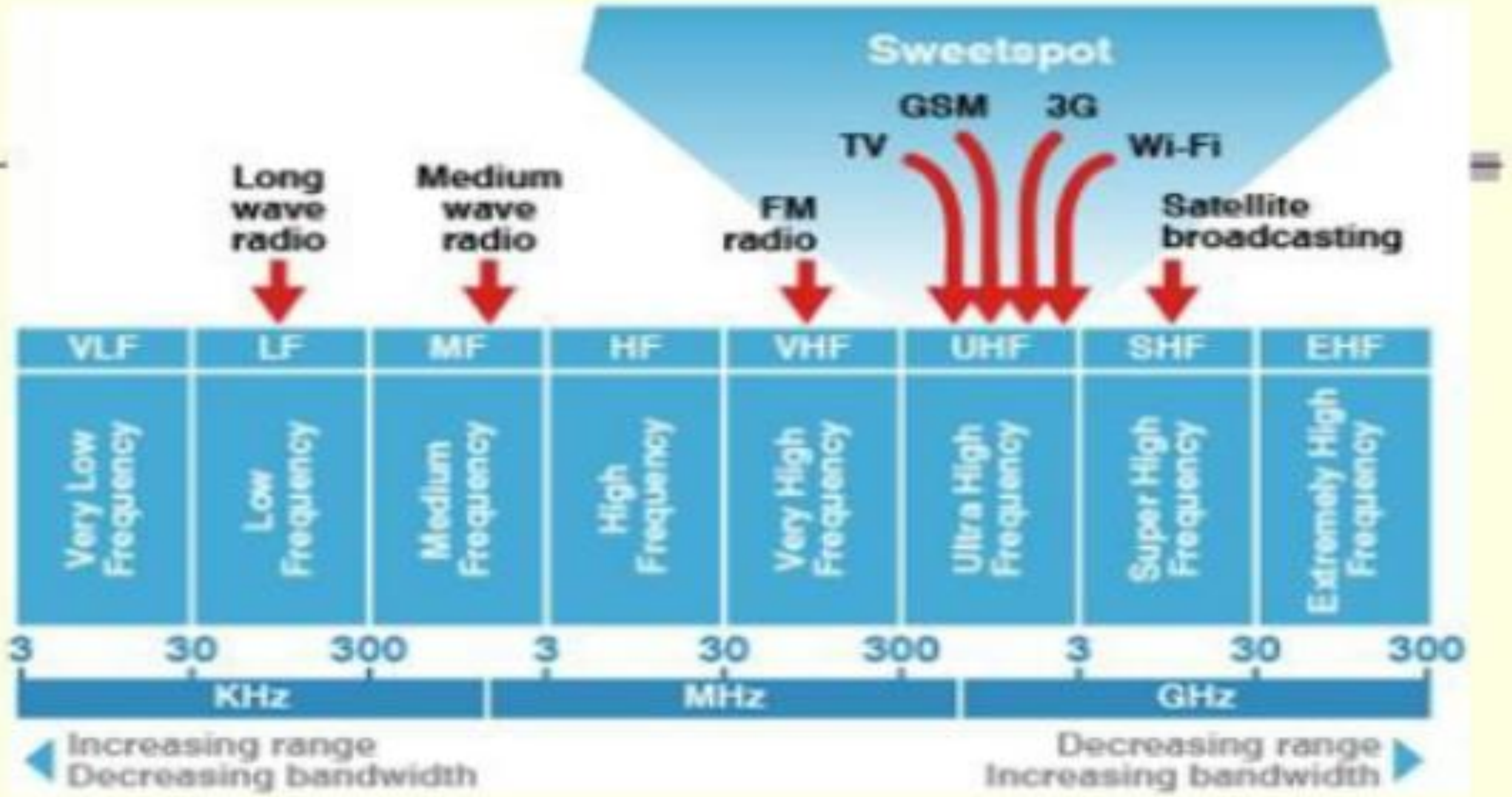
Contents

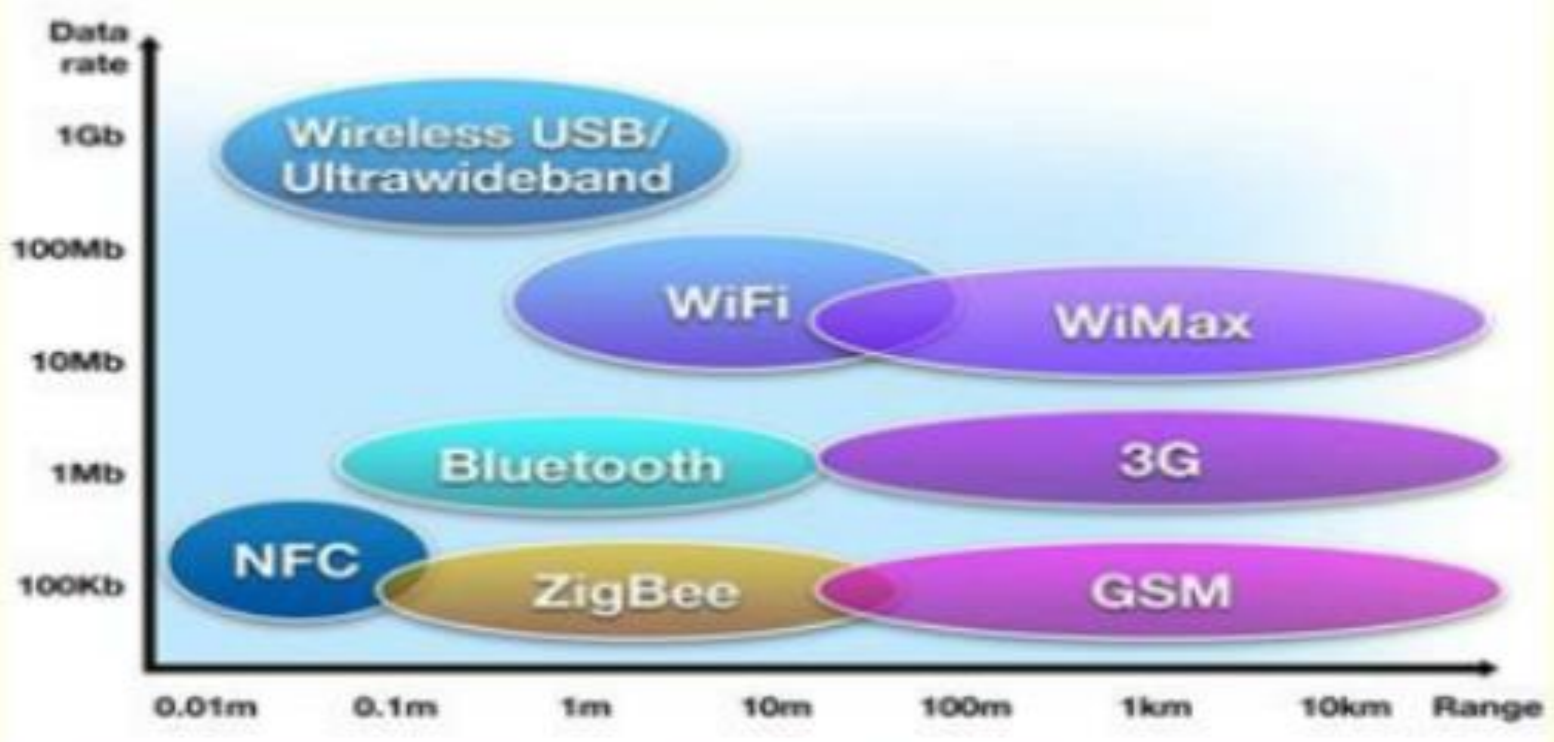
1. Introduction to satellite systems
2. Characteristics of satellite systems
3. Elements of wireless systems
4. Cellular network
5. Wireless mesh networks

Introduction to satellite systems

- **History of mobile communication**

  Please refer to Tables 1.1 - 1.6, pp. 2-10
- **Challenges were faced:**
  - Growing number of users
  - Covered area (cell size)
  - Mobility
  - QoS
  - Cost





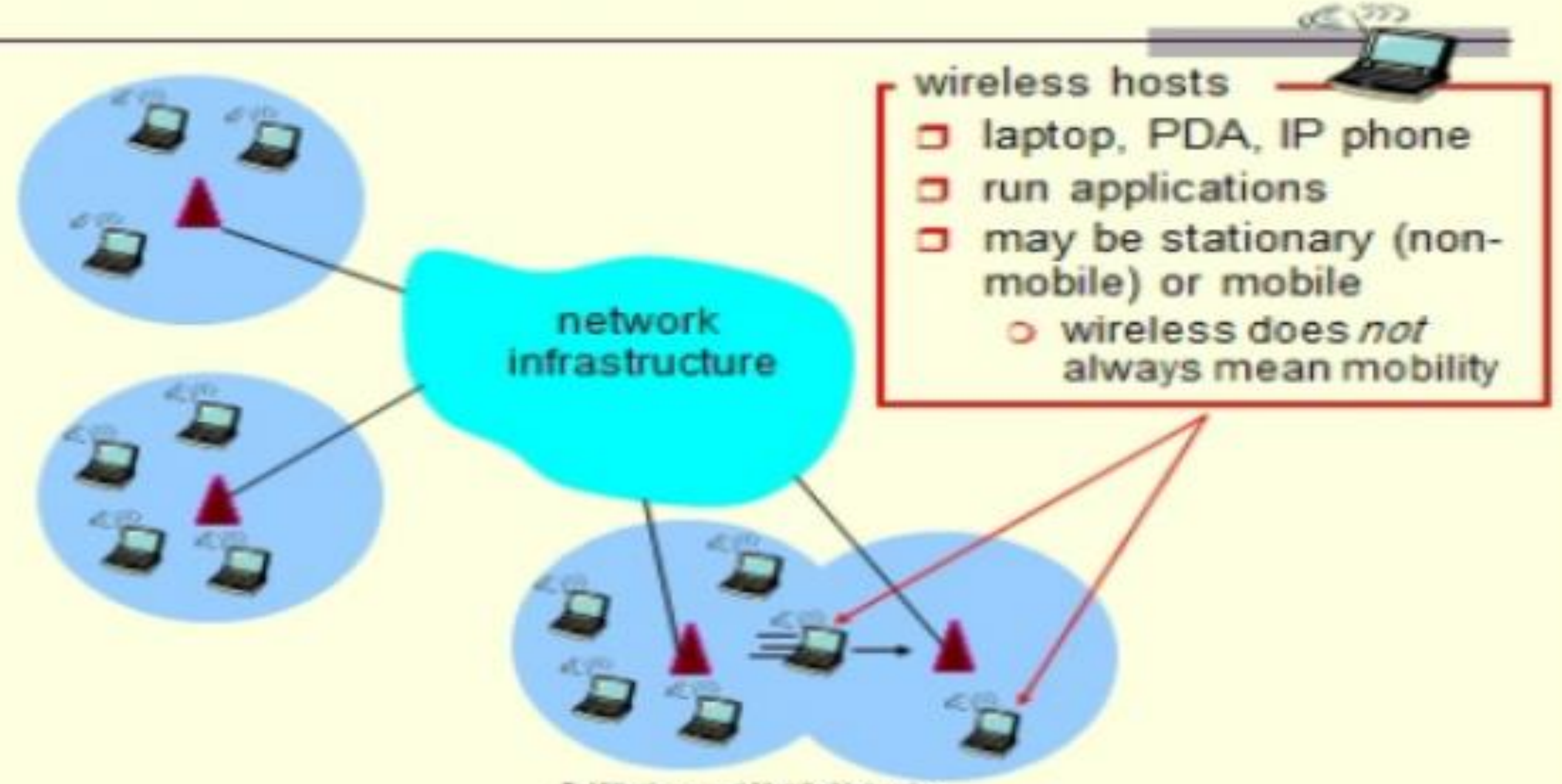
Technology	Services or Features	Coverage Area	Limitations	Examples
Cellular	Voice and data through handheld phones	Continuous coverage limited to metropolitan regions	Available bandwidth is very low for most data intensive applications	Cellular phones, personal digital assistant
Wireless local area network (LAN)	Traditional LAN extended with wireless interface	Used only in local environments	Limited range	NCR's Wavelan, Motorola's ALTAIR, Proxim's range LAN, Telesystem's ARLAN
GPS	Helps to determine the three-dimensional position, velocity, and time	Any place on the surface of earth	It is still not affordable by everyone	GNSS, NAVSTAR, GLONASS
Satellite-based PCS	Applications mainly for voice paging and messaging	Almost any place on earth	It is costly	Iridium, Teledesic

Ricochet	High-speed, secure mobile access to the desktop (data) from outside the office	Some major cities, airports, and some university areas	Has a transmission limitation. Environmental conditions affect quality of service	MicroCellular Data Network (MCDN)
Home networking	To connect different PCs in the house to share files and devices such as printers	Anywhere in the house	Limited to a home	Netgear Phoneline 10X, Intel AnyPoint Phoneline Home Network, 3Com Home Connect Home Network Phoneline
Ad hoc networks	Group of people come together for a short time to share data	Equal to that of local area network, but without fixed infrastructure	Limited range	Defense applications
WPAN (Bluetooth)	All digital devices can be connected without any cable	Private ad hoc groupings away from fixed network infrastructures	Range is limited due to the short-range radio link used	Home devices
Sensor networks	A large number of tiny sensors with wireless capabilities	Relatively small terrain	Very limited range	Defense and civilian applications

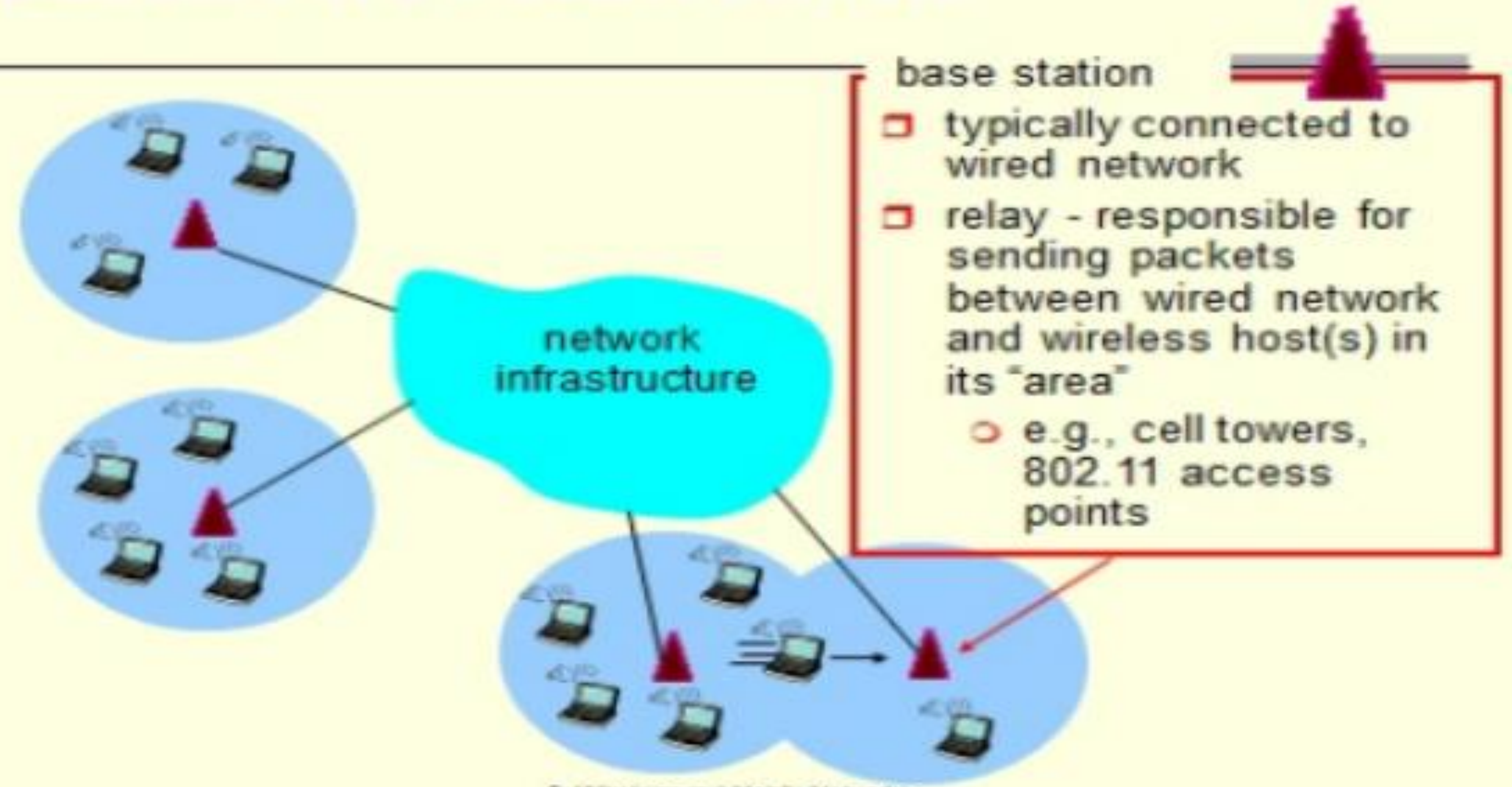
2-Characteristics of satellite systems

- Wireless systems had a high-power transmitter covering the entire service area.
- Different wireless devices need to be supported for different types of services; telephone, PDA, laptop (mobile subscriber)
- It has to maintain connectivity with the world while moving.

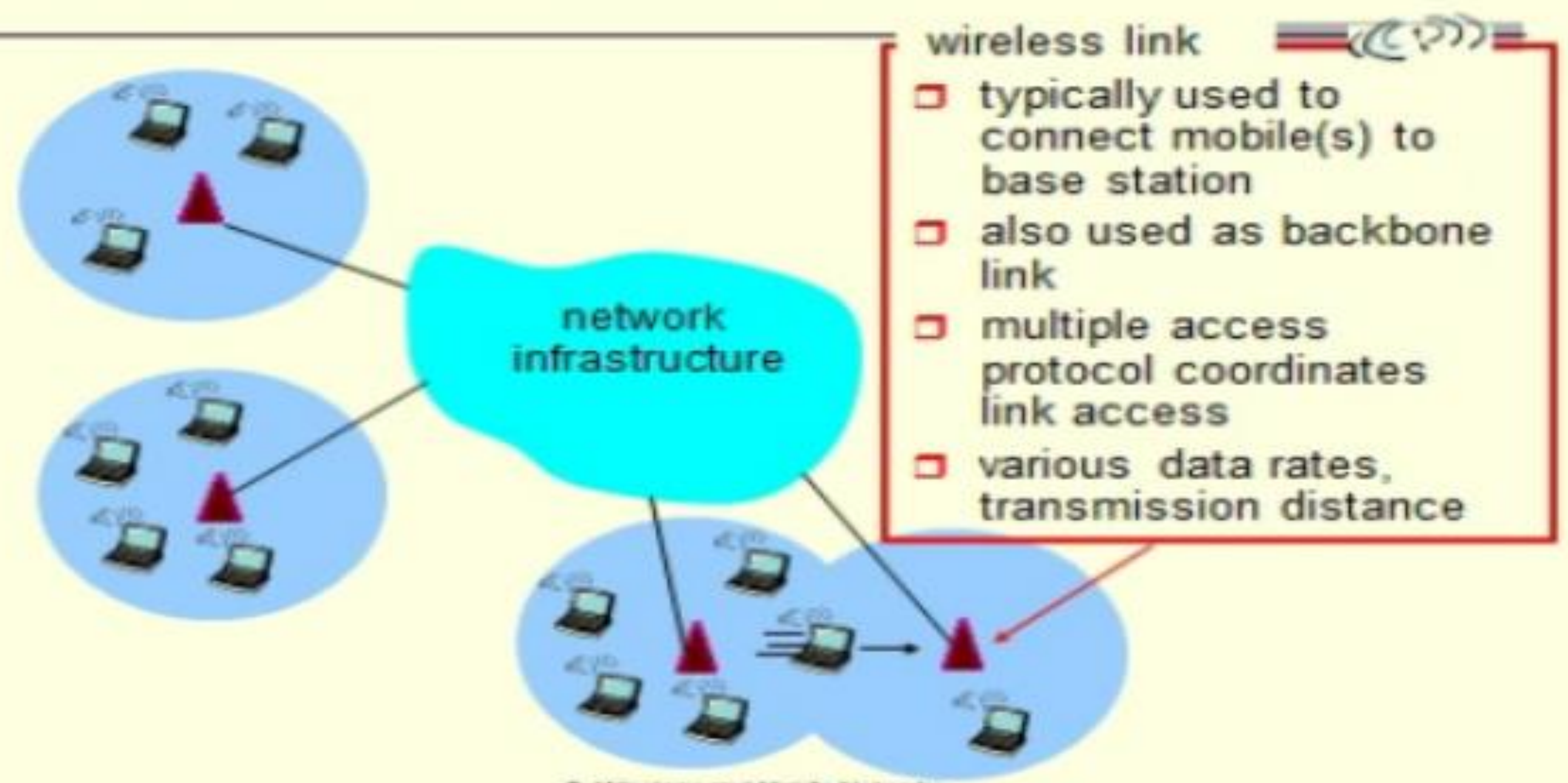
Elements of a wireless network



Elements of a wireless network

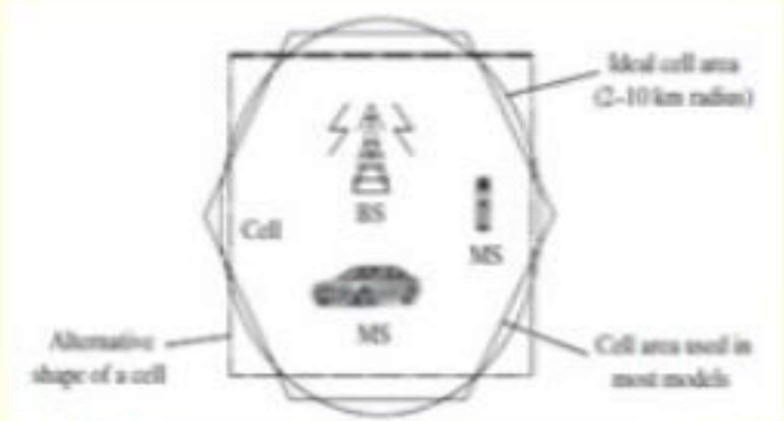


Elements of a wireless network



continued

- *Cell* basically represents the area that can be covered by a transmitting station, usually called a base station **(BS).**
- radius of the cell is equal to the reachable range of the transmitted signal.
- Each cell serves multiple Mobile Subscribers **(MS)** by connecting them to single BS



The hexagon is a good approximation of a circular region. Moreover, it allows a larger region to be divided into nonoverlapping hexagonal subregions of equal size, with each one representing a cell area. The square is another alternative shape that can be used to represent the cell area. The triangle is another less frequently used coverage area. Octagons and decagons do represent shapes closer to a circular area as compared to a hexagon

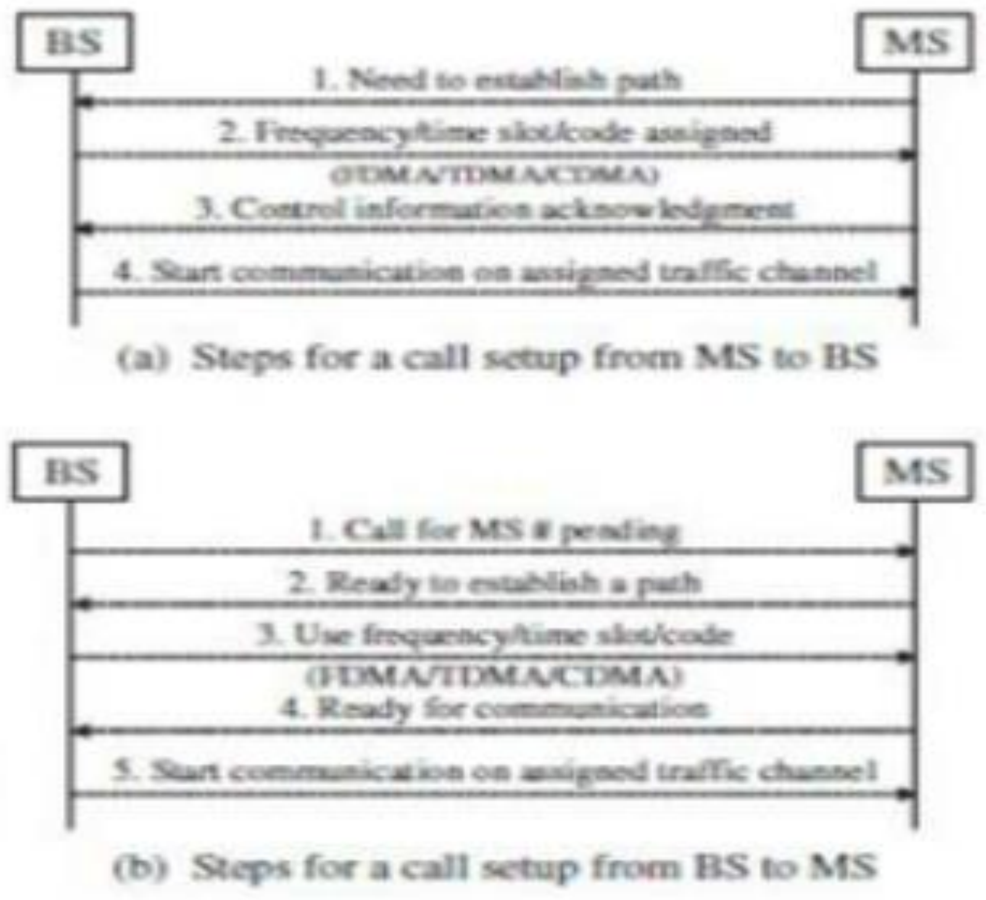


Figure 1.21
Handshake steps for a call setup between MS and BS using control channels.

continued

- ***Base station controllers (BSCs)*** which connect BS's via wire
- ***Mobile switching center (MSC)*** are connected to a MSCs are connected to the ***telephone network***

continued

- ***mobile switching center (MSC) :***

Is responsible for routing calls, SMS, and data

- Contains three components:
  - Home Location Register (HLR)
    - Initial home location of MS where billing and access information are maintained
  - Visitor Location Register (VLR)
    - Information about visiting MSs
  - Authentication Center (AuC)
    - Authentication information of MS SIM card
- Each MS subscribes to only one MSC

continued

- the MS needs to be in the area of one of the cells (and hence a BS) so that mobility of the MS can be supported.
- BSs are connected through hard-wires and are controlled by a BS controller (BSC).
- which in turn is connected to a mobile switching center (MSC).
- Several MSCs are interconnected to a PSTN (public switched telephone network) and the

ATM (asynchronous transfer mode) backbone.

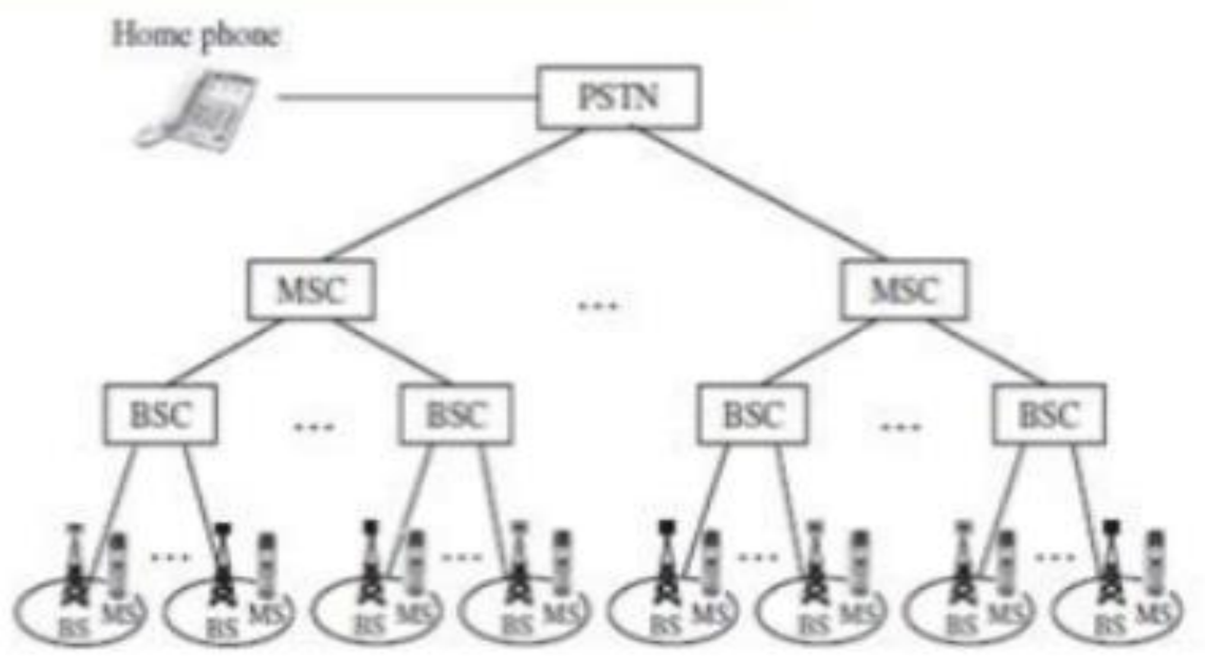


Figure 1.19
Cellular system infrastructure.

Cell Capacity

- **The offered traffic load or traffic intensity (a)** of a cell is characterized by:
  - Average number of MSs requesting the service (average call arrival rate λ)
  - Average length of time the MSs requiring the service (average holding time T)
- $a = \lambda T$
- A servicing channel that is kept busy for an hour is quantitatively defined as one **Erlang**
- If 30 requests are generated by users per hour, and T = 360 *sec*, then:
- $\lambda = \frac{30}{3600}$ and $a = \frac{30}{3600} \times 360 = 3\ Erlang$

Cell Capacity

- **Erlang B (B_c)** is the blocking probability, probability of loss, or probability of rejection for an arriving call
  - A call is blocked if all n channels are occupied when the call arrives

$$B_c = \mathrm{Erl}(n, a) := \frac{\frac{a^n}{n!}}{\sum_{i=0}^{n} \frac{a^i}{i!}}$$

  - $QoS = 1 - B_c$
- **Erlang C** is the probability of an arriving call being delayed

Cell Capacity

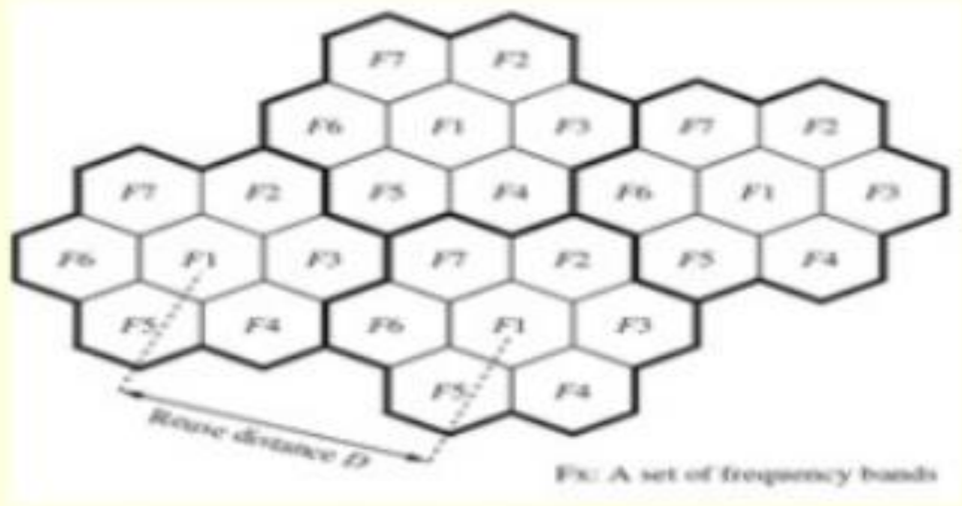
- **Capacity (n)** is the number of channels required for the cell based on its traffic load and a given blocking probability
- $n(a) = \min\{i = 1, 2, \mid Erl(i, a) < B_{c_{max}}\}$
- Assume that the the offered traffic is $a = 2.0\ Erlang$, and the blocking probability is 1%
- $n(2.0) = \min\{i = 1, 2, \mid Erl(i, 2.0) < 0.01\}$

$$B_c = \mathrm{Erl}(4, 2) = \frac{\frac{2^4}{4!}}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!} + \frac{2^4}{4!}} = \frac{\frac{16}{24}}{1 + 2 + \frac{4}{2} + \frac{8}{6} + \frac{16}{24}} = \frac{2}{21} \approx 9.5\%$$

$$B_c = \mathrm{Erl}(6, 2) = \frac{\frac{2^6}{6!}}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!} + \frac{2^4}{4!} + \frac{2^5}{5!} + \frac{2^6}{6!}} \approx 1.2\%$$

Frequency Reuse

- A frequency band or channel in a cell can be ***reused*** in another cell if those cells are apart and there would be no **interference**

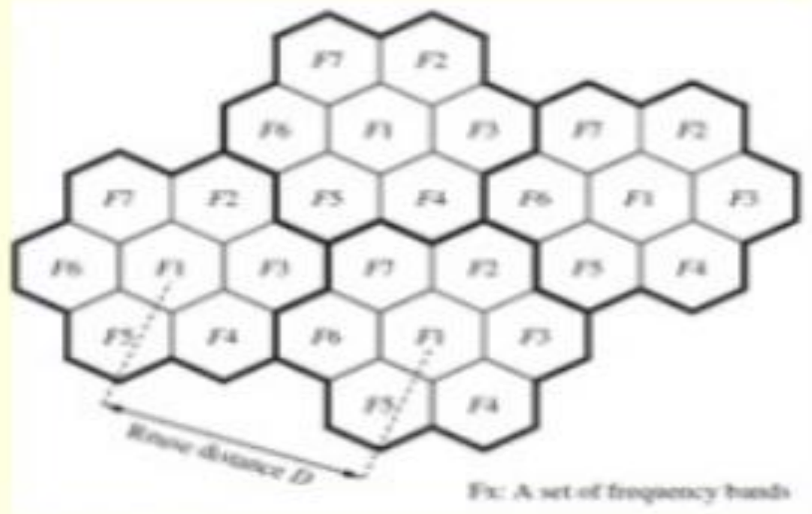


Frequency Reuse

- In the real world, **path loss** and **link budgets** are computed from the terrain features and antenna data
- This determines to coverage of each base station and interference to other cells
- **Path loss** is a model that describes signal attenuation between Tx and Rx antennas as a function of the **propagation** distance
- $L(dB) = 10n \log_{10}(d) + C$
  - n → path loss exponent (2 to 4 in free space and 4 to 6 in indoor environments)
  - d → distance between Tx and Rx
  - C → constant for system loss

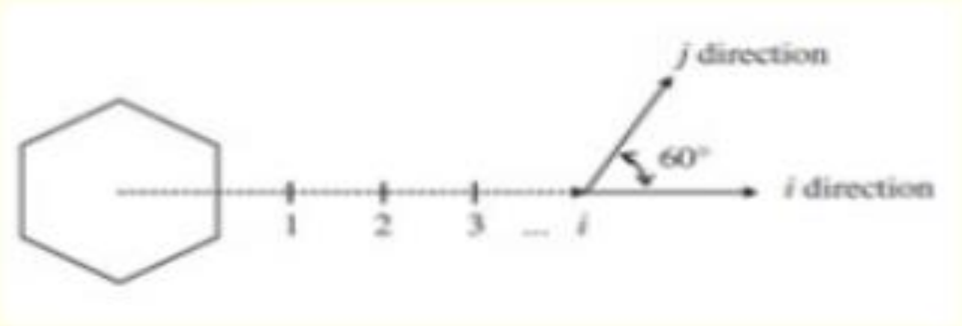
Reuse Distance

- **Reuse Distance** is the closest distance between the centers of two cells using the same frequency
- Determined by cluster size (a group of cells using different frequency bands)
- If we have:
  - N (number of cells in a cluster)
  - R (cell radius)
- Then we have **Reuse Distance**:
  - $D = \sqrt{3N}R$

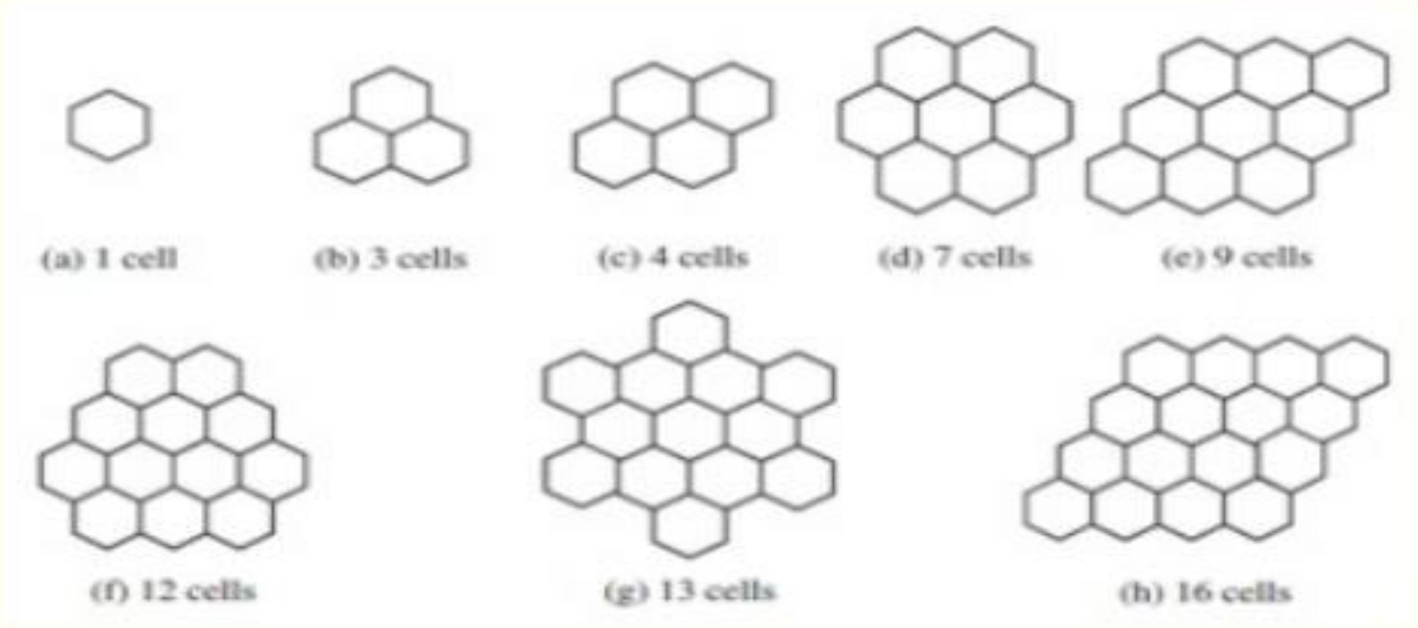


Reuse Distance

- Cluster size N is usually set to 1, 3, 4, 7, 9, ...
- $N = i^2 + ij + j^2$
  - i is number of cells in along direction
  - j is number of cells in direction 60^o to direction of i



Reuse Distance



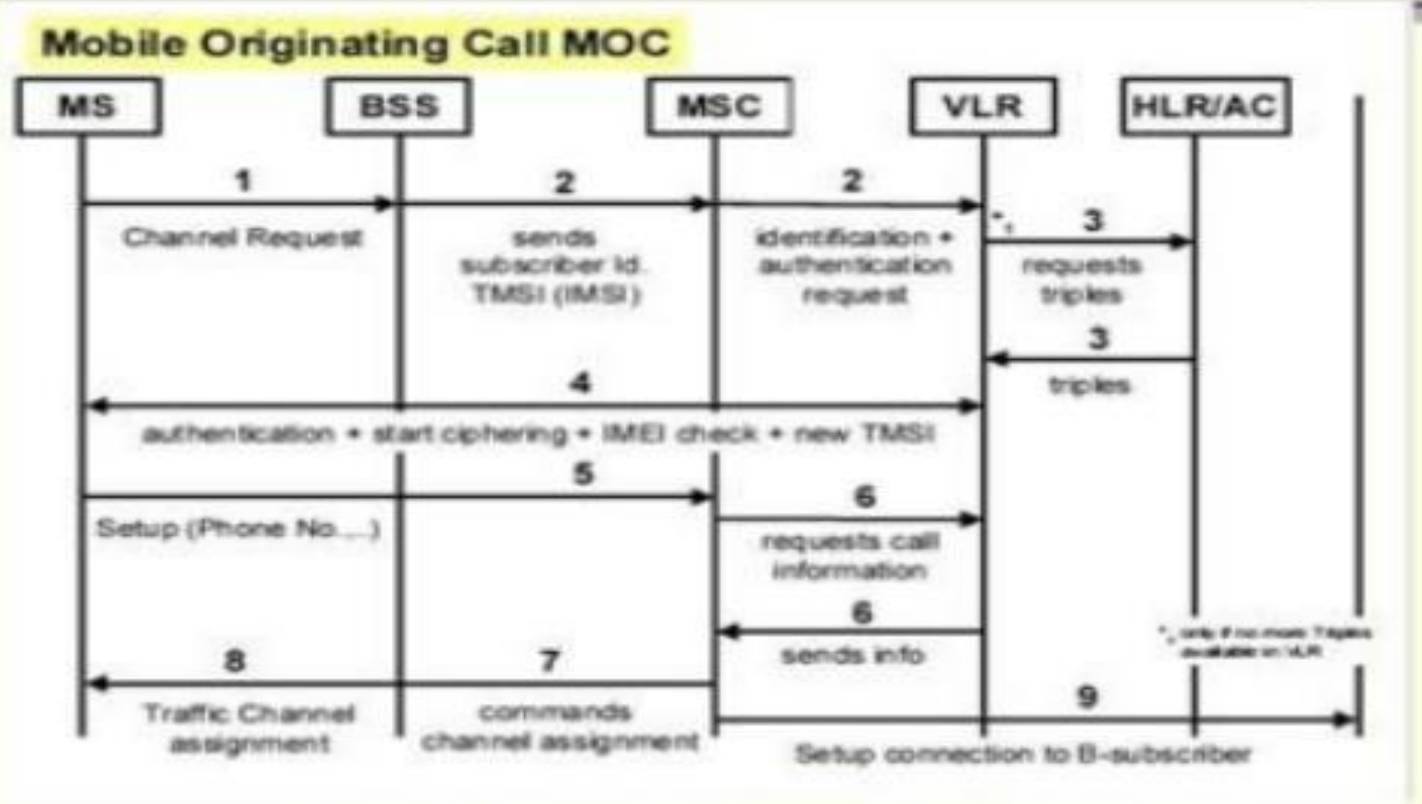
Frequency Reuse Example

- In the figure below, find the reuse distance if the radius of each cell is 2 km
- If each channel is multiplexed among 8 users, how many calls can be simultaneously processed by each cell if only 10 channels per cell are reserved for control, assuming a total bandwidth of 30MHz is available and each **simplex channel** consists of 25 kHz?

A Note on Signaling

- Control Plane
  - Used to control bearer traffic (authentication, subscriber info, call parameter negotiations)
- Data (User) Plane
  - Used for subscriber traffic (voice & data)

A Typical Call Setup

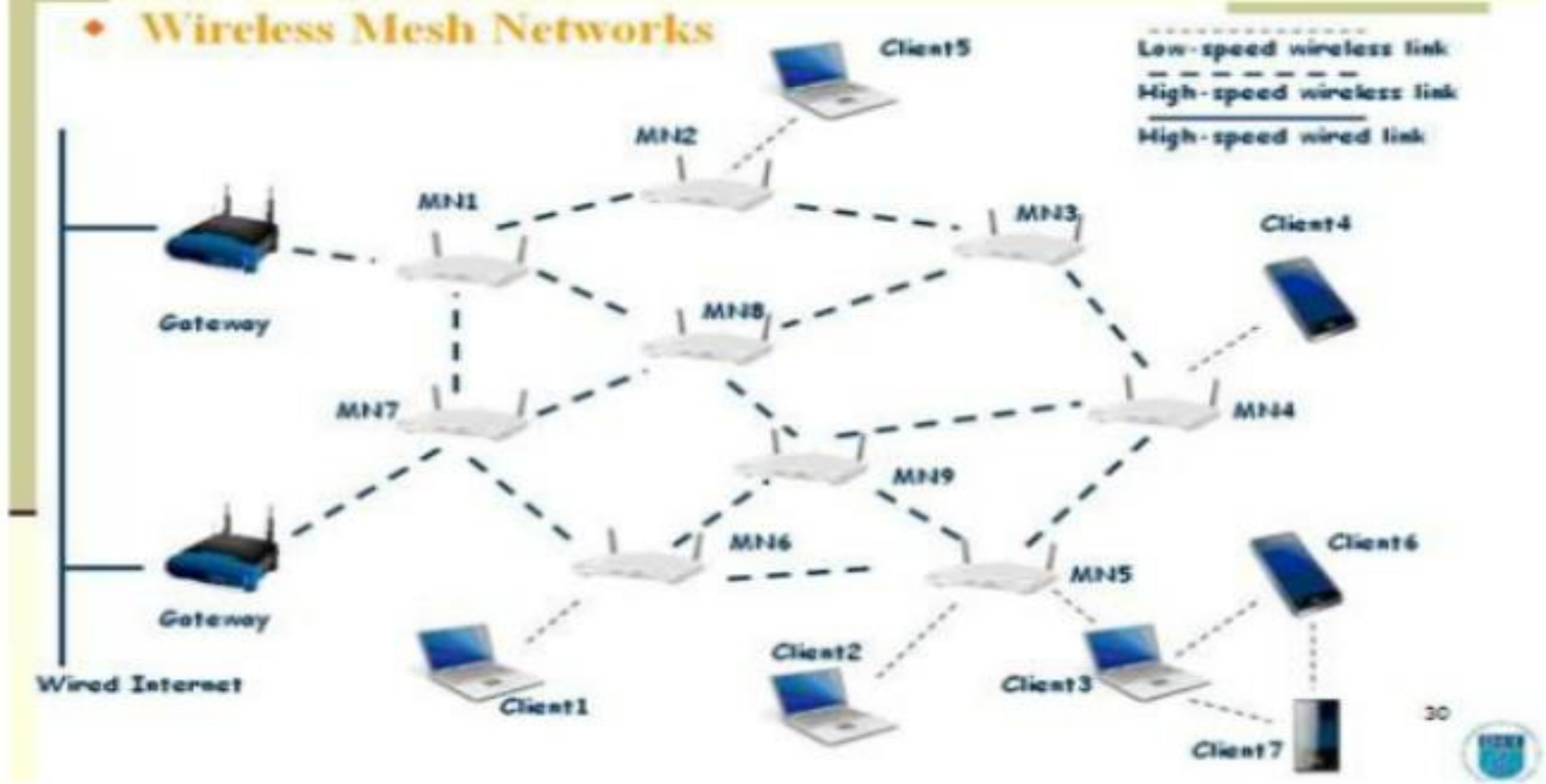


A Typical Call Setup

1. Validate information of subscriber originating the call (**authentication**)
2. Find the cell where the receiver is currently located (**location management**)
3. Allocate downlink and uplink channels (**resource management**)
4. Maintain the call if receiver moves while call is active (**handoff/admission control**)

- Channels used are either *control* or *data*, and either *uplink* (MS → BS) or *downlink* (BS → MS)

5. Wireless mesh networks



Thanks- Questions !

Lecture 5-6
WIRELESS NETWORKS

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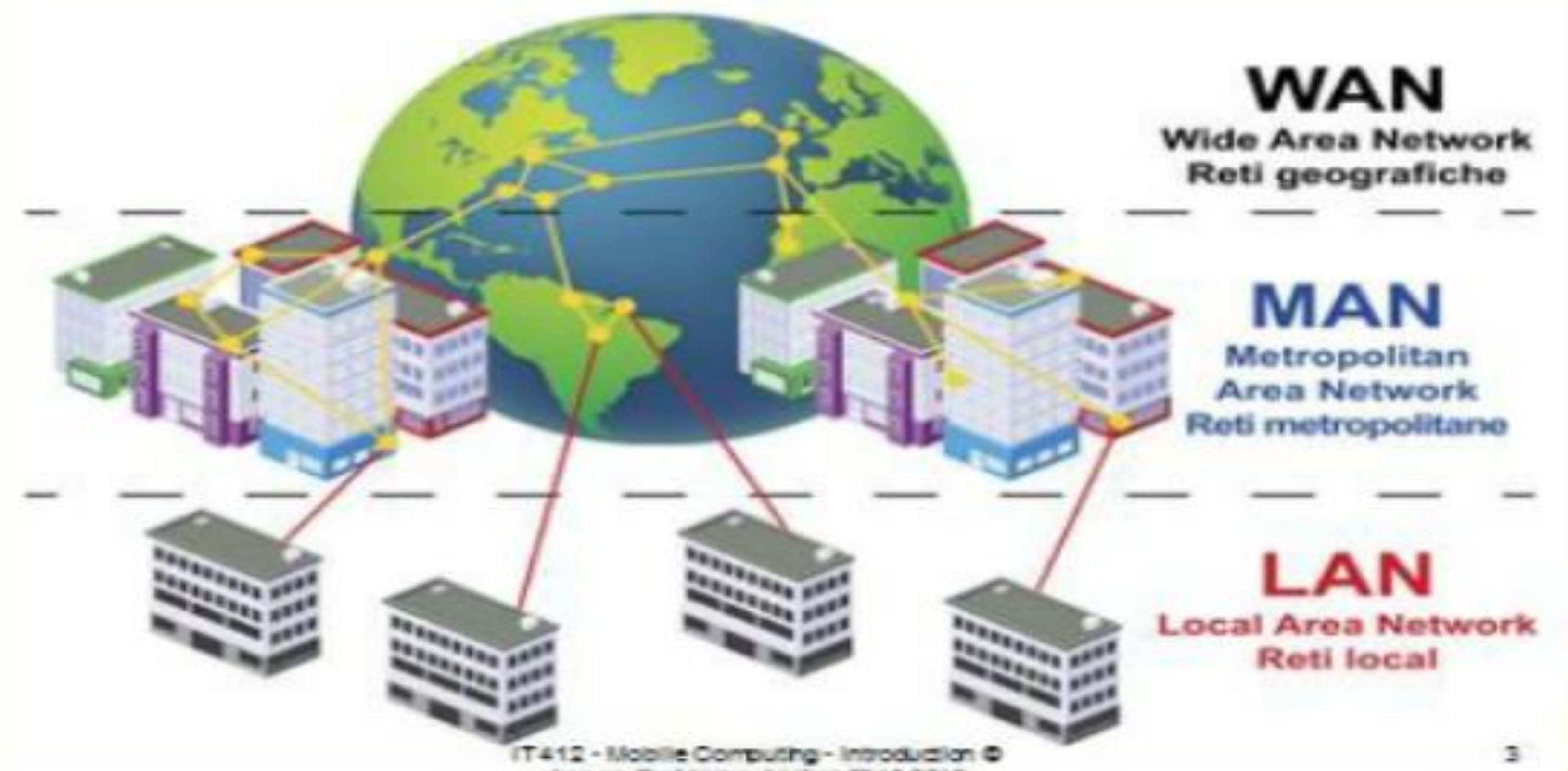
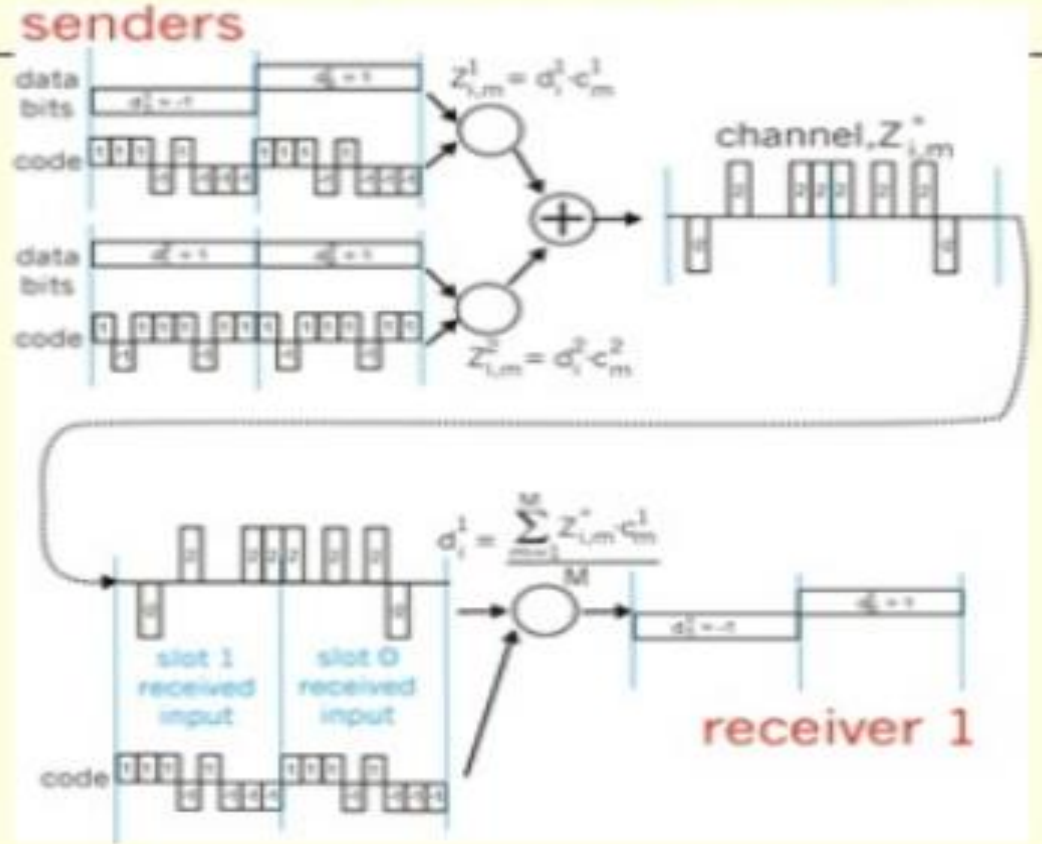
Contents

1. Introduction to satellite systems
2. Characteristics of satellite systems
3. GPS, Wireless LAN
4. Overview of IEEE802.11
5. Location managment

3. Overview of Wireless Networks



CDMA: two-sender interference



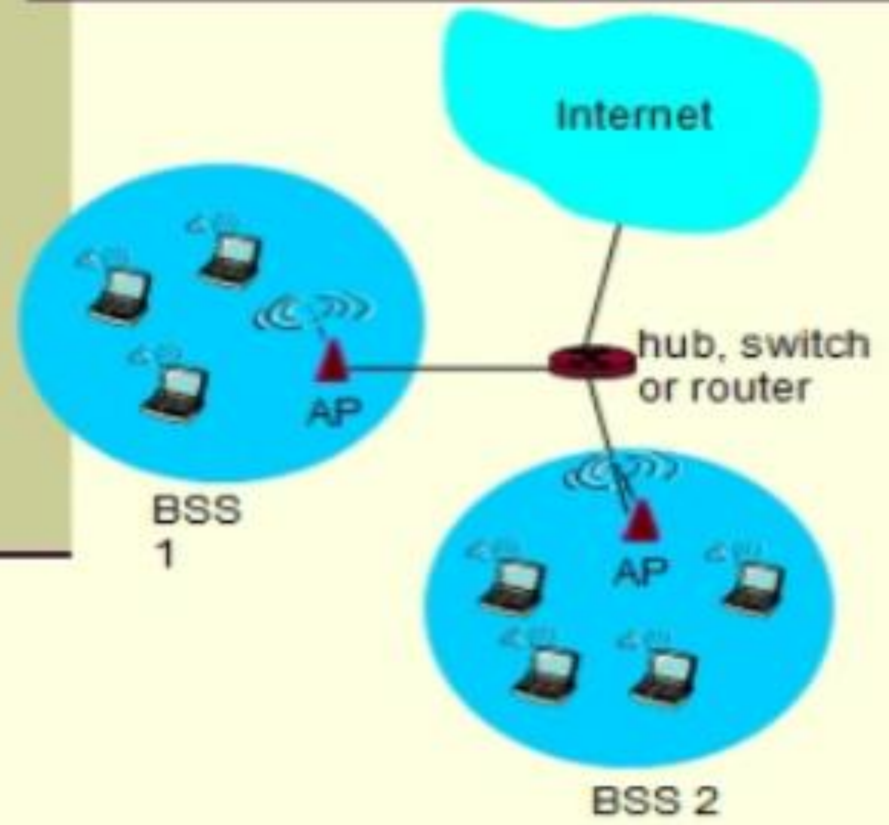
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- 802.11n: multiple antennae
  - 2.4-5 GHz range
  - up to 200 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

continued

802.11 LAN architecture



- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

802.11: Channels, association

- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - may perform authentication will typically run DHCP to get IP address in AP's subnet

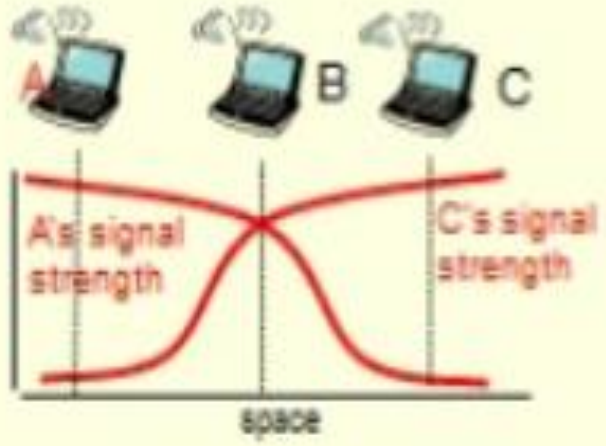
802.11: passive/active scanning

Passive Scanning:
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent: H1 to selected AP

Active Scanning:
(1) Probe Request frame broadcast from H1
(2) Probes response frame sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent: H1 to selected AP

IEEE 802.11: multiple access

- avoid collisions: 2+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions*: CSMA/C(ollision)A(voidance)



IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then

transmit entire frame (no CD)

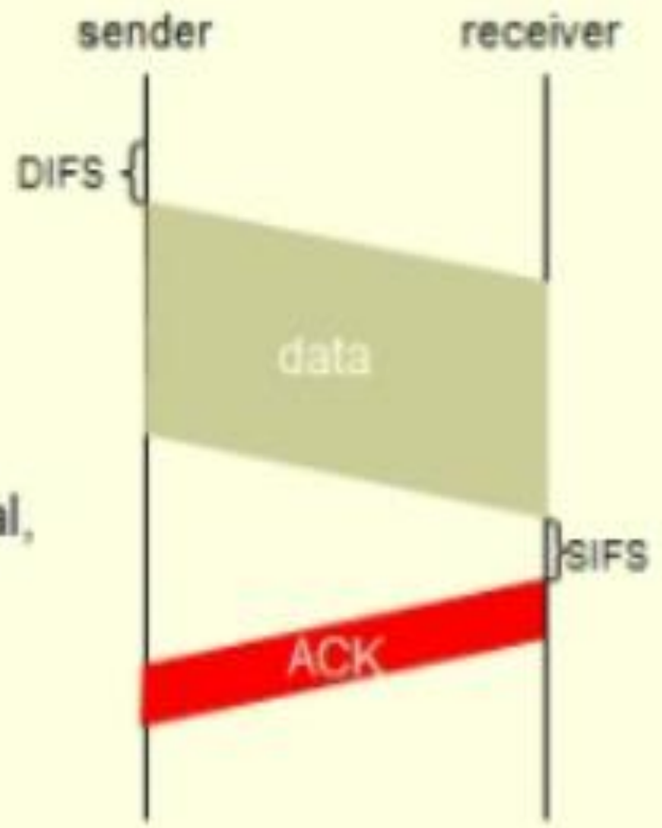
2 if sense channel busy then

start random backoff time

timer counts down while channel idle

transmit when timer expires

if no ACK, increase random backoff interval, repeat 2



802.11 receiver

- if frame received OK

return ACK after **SIFS** (ACK needed due to hidden terminal problem)

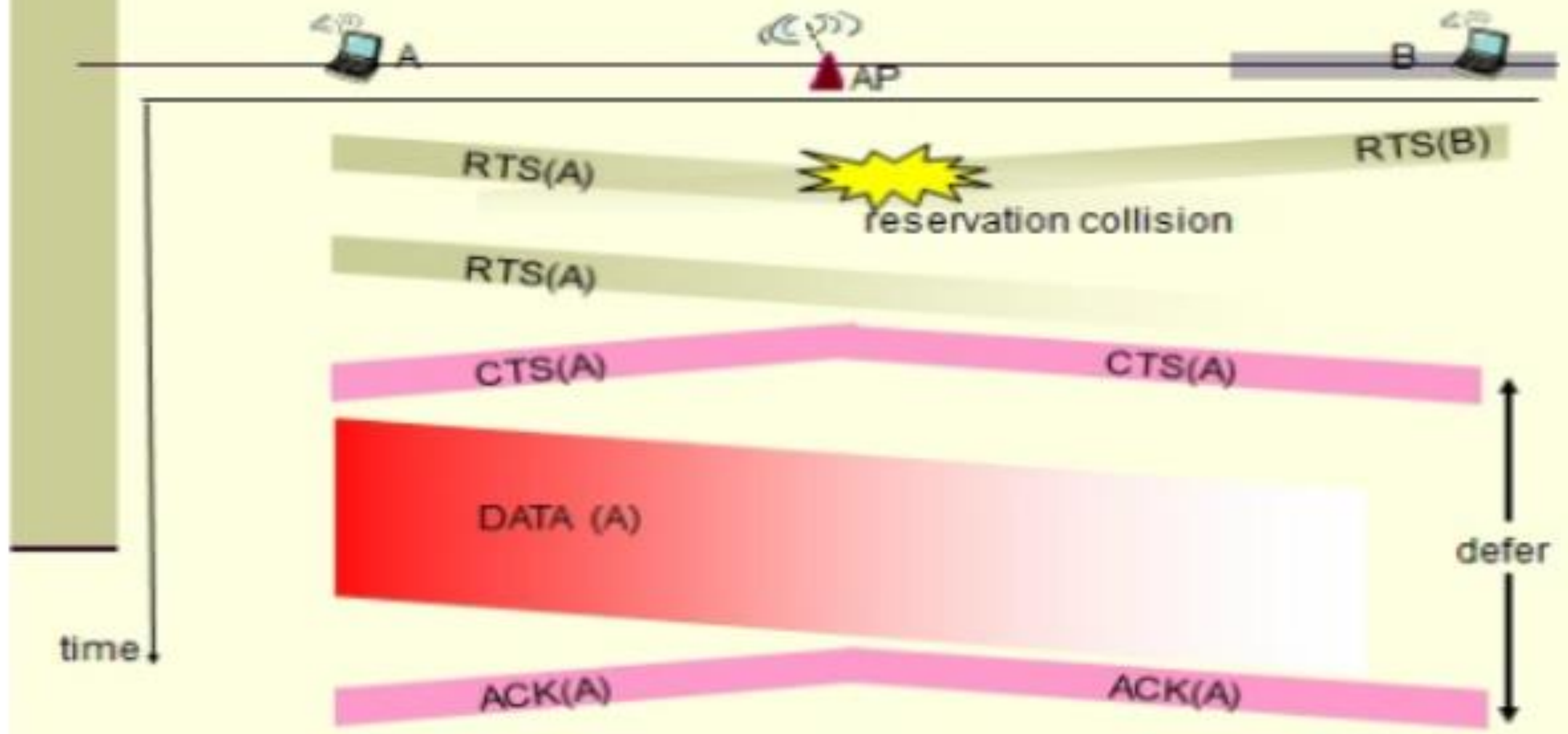
Avoiding collisions (more)

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

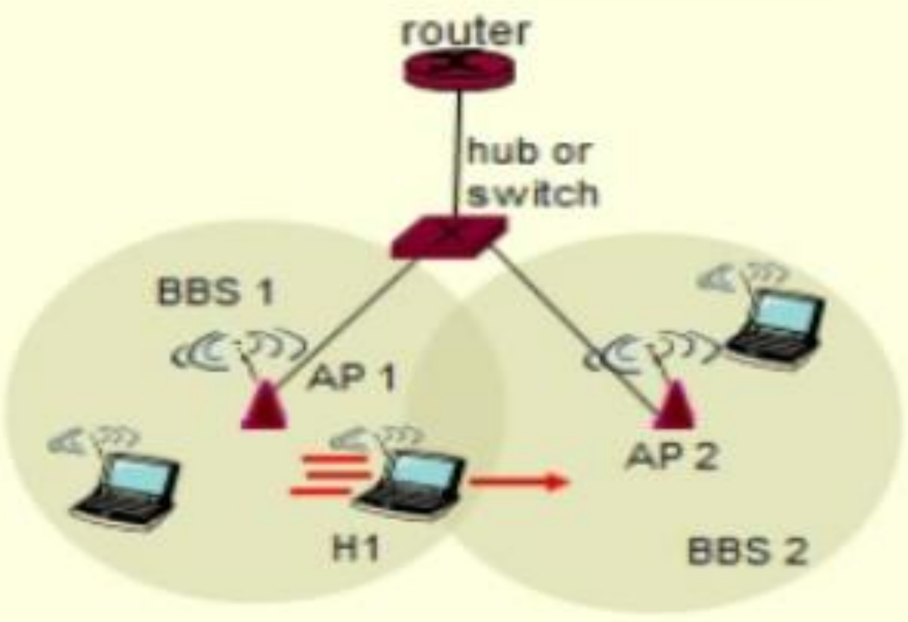
avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



802.11: mobility within same subnet

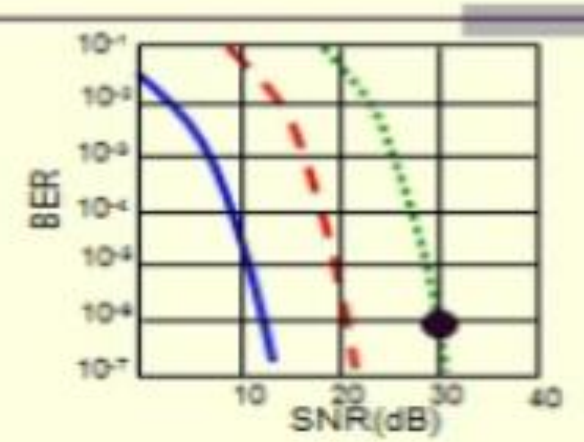
- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning (Ch. 5): switch will see frame from H1 and "remember" which switch port can be used to reach H1

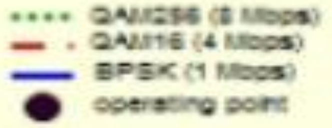


802.11: advanced capabilities

Rate Adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies





1. SNR decreases, BER increase as node moves away from base station
2. When BER becomes too high, switch to lower transmission rate but with lower BER

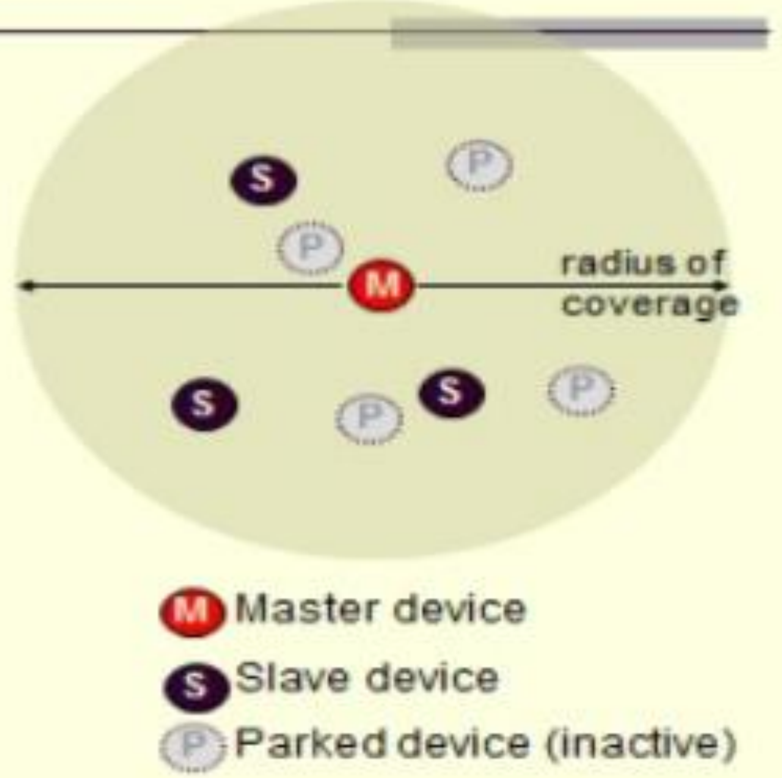
802.11: advanced capabilities

Power Management

- node-to-AP: "I am going to sleep until next beacon frame"
  - AP knows not to transmit frames to this node
  - node wakes up before next beacon frame
- beacon frame: contains list of mobiles with AP-to-mobile frames waiting to be sent
  - node will stay awake if AP-to-mobile frames to be sent; otherwise sleep again until next beacon frame

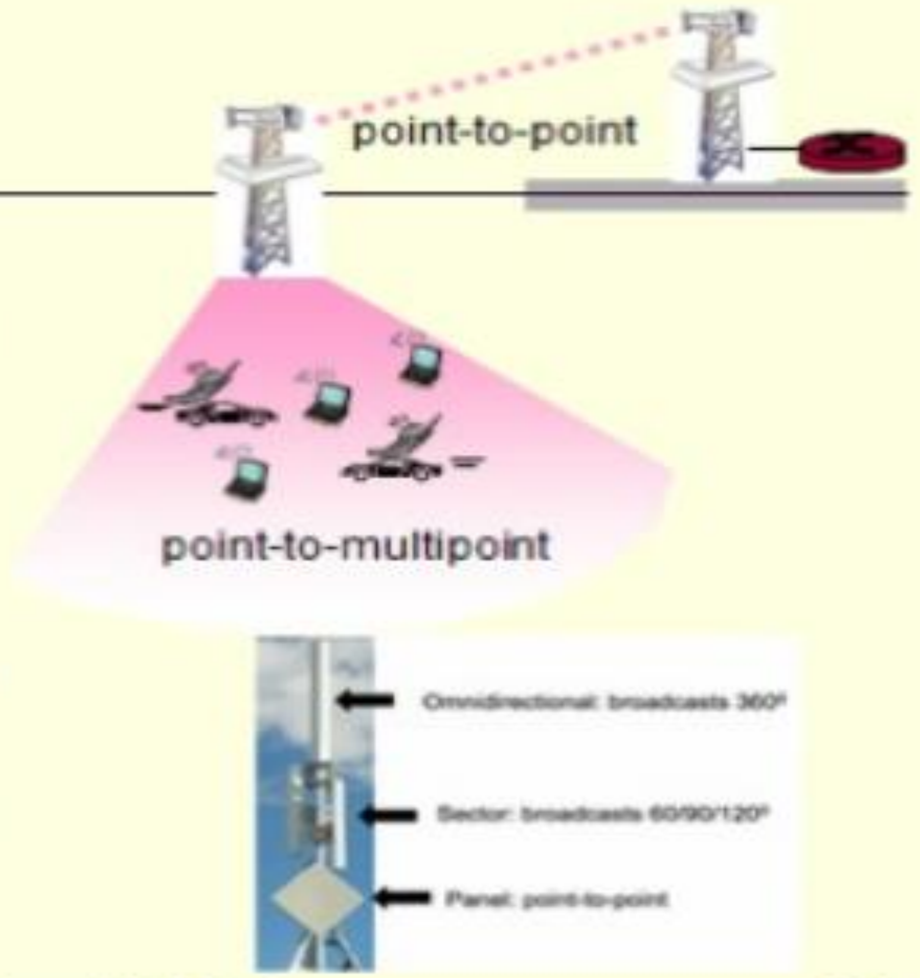
802.15: personal area network

- less than 10 m diameter
- replacement for cables (mouse, keyboard, headphones)
- ad hoc: no infrastructure
- master/slaves:
  - slaves request permission to send (to master)
  - master grants requests
- 802.15: evolved from Bluetooth specification
  - 2.4-2.5 GHz radio band
  - up to 721 kbps



802.16: WiMAX

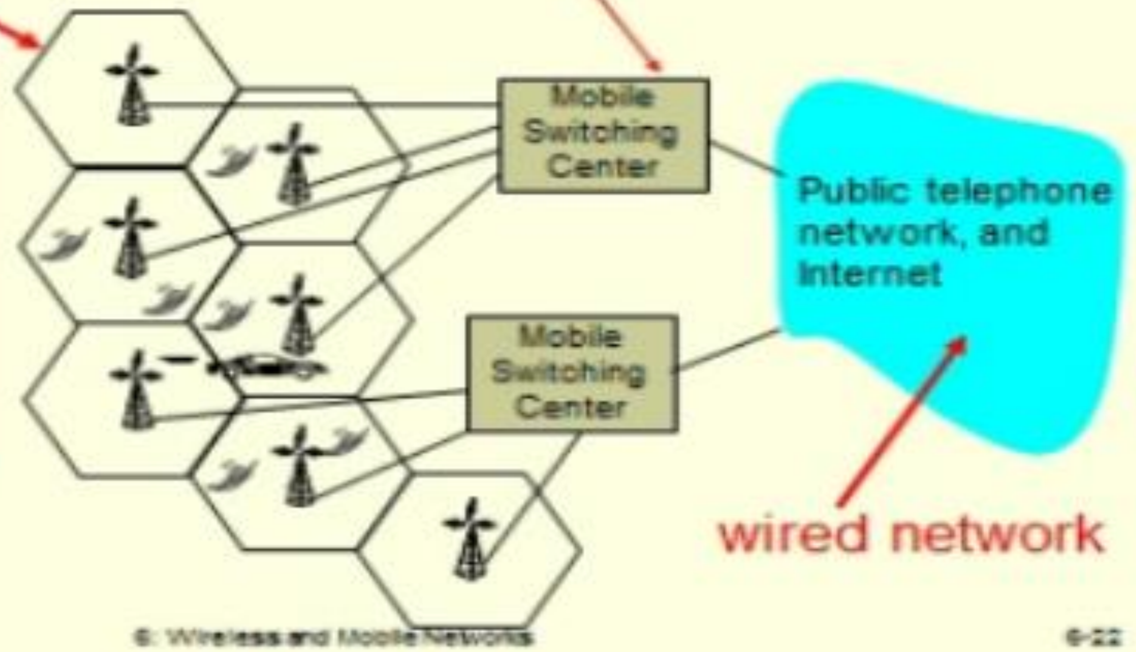
- like 802.11 & cellular: base station model
  - transmissions to/from base station by hosts with omnidirectional antenna
  - base station-to-base station backhaul with point-to-point antenna
- unlike 802.11:
  - range ~ 6 miles ("city rather than coffee shop")
  - ~14 Mbps



Components of cellular network architecture

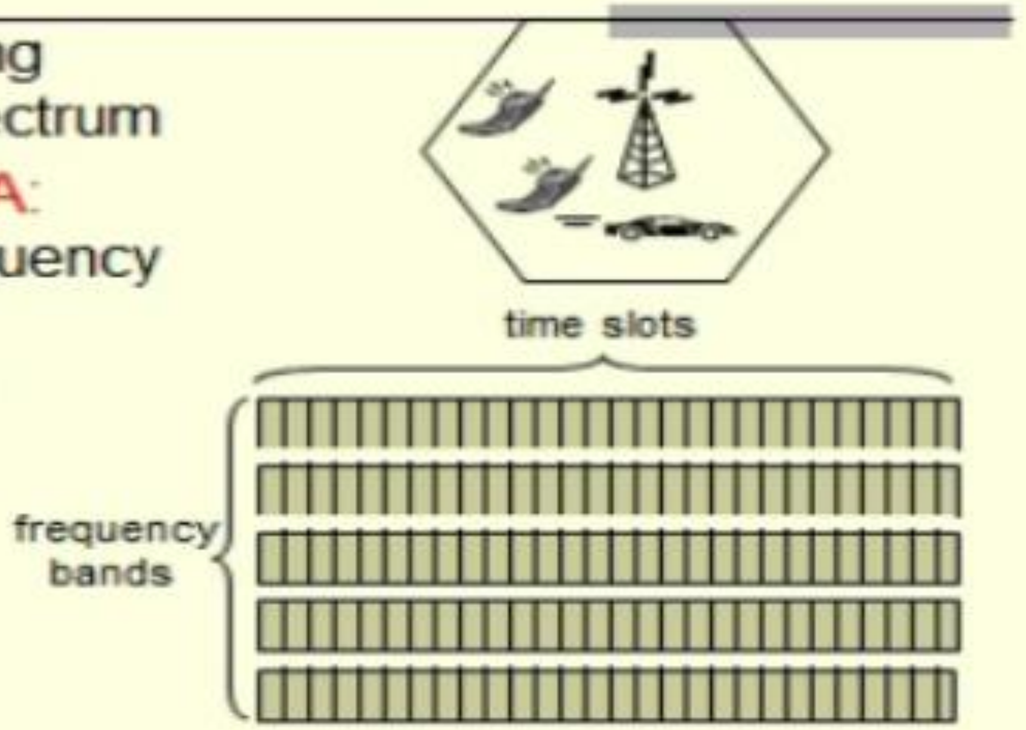
MSC
- connects cells to wide area net
- manages call setup (more later!)
- handles mobility (more later!)

cell
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS



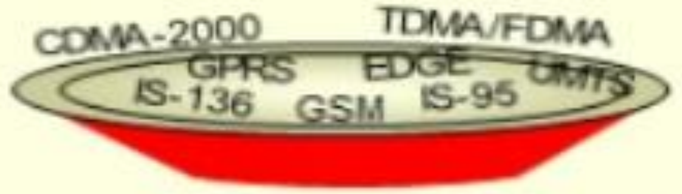
Cellular networks: the first hop

Two techniques for sharing mobile-to-BS radio spectrum
- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access



Cellular standards: brief survey

2G systems: voice channels
- IS-136 TDMA: combined FDMA/TDMA (north america)
- GSM (global system for mobile communications): combined FDMA/TDMA
  - most widely deployed
- IS-95 CDMA: code division multiple access



Don't drown in a bowl of alphabet soup: use this for reference only

Cellular standards: brief survey

2.5 G systems: voice and data channels
- for those who can't wait for 3G service: 2G extensions
- general packet radio service (GPRS)
  - evolved from GSM
  - data sent on multiple channels (if available)
- enhanced data rates for global evolution (EDGE)
  - also evolved from GSM, using enhanced modulation
  - data rates up to 384K
- CDMA-2000 (phase 1)
  - data rates up to 144K
  - evolved from IS-95

Cellular standards: brief survey

3G systems: voice/data

- Universal Mobile Telecommunications Service (UMTS)
  - data service: High Speed Uplink/Downlink packet Access (HSDPA/HSUPA): 3 Mbps
- CDMA-2000: CDMA in TDMA slots
  - data service: 1xEvlution Data Optimized (1xEVDO) up to 14 Mbps

..... more (and more interesting) cellular topics due to mobility (stay tuned for details)

Cellular standards: brief survey

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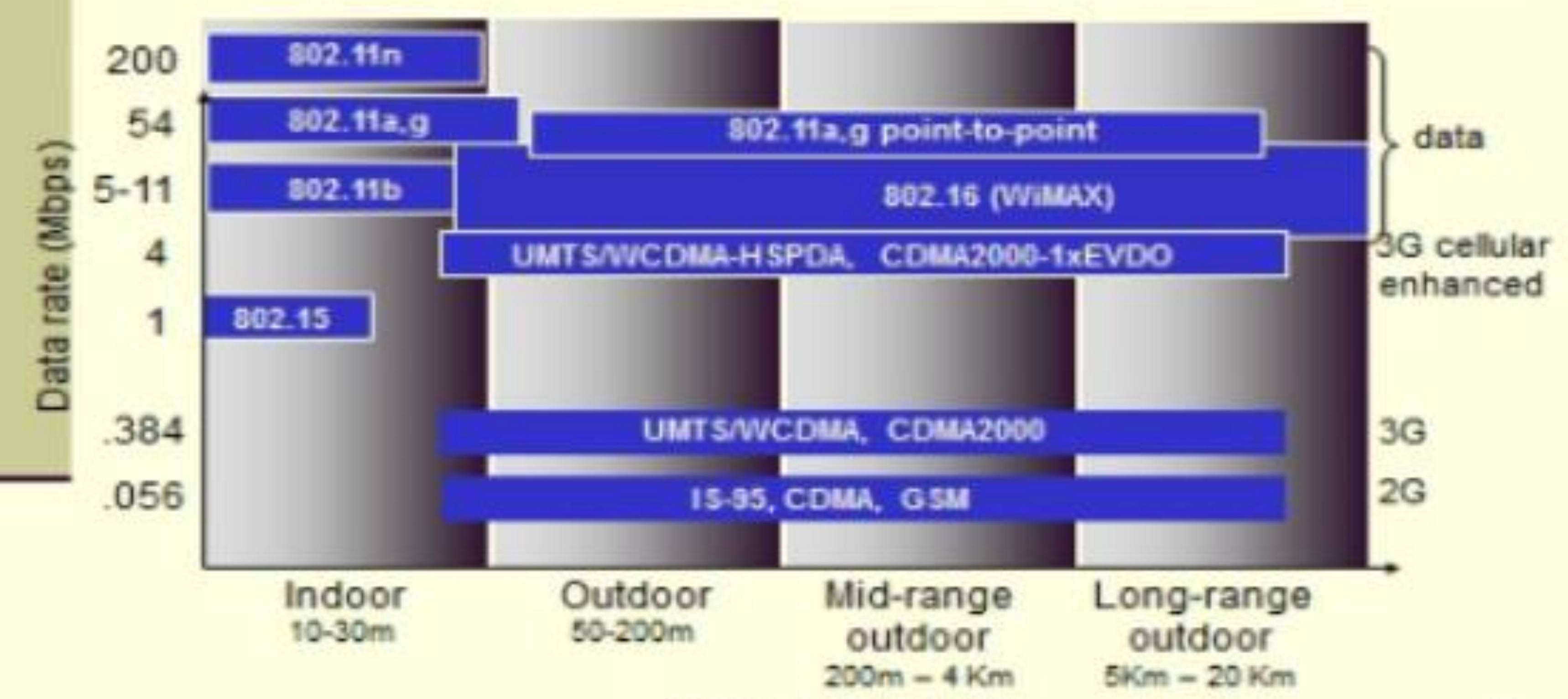
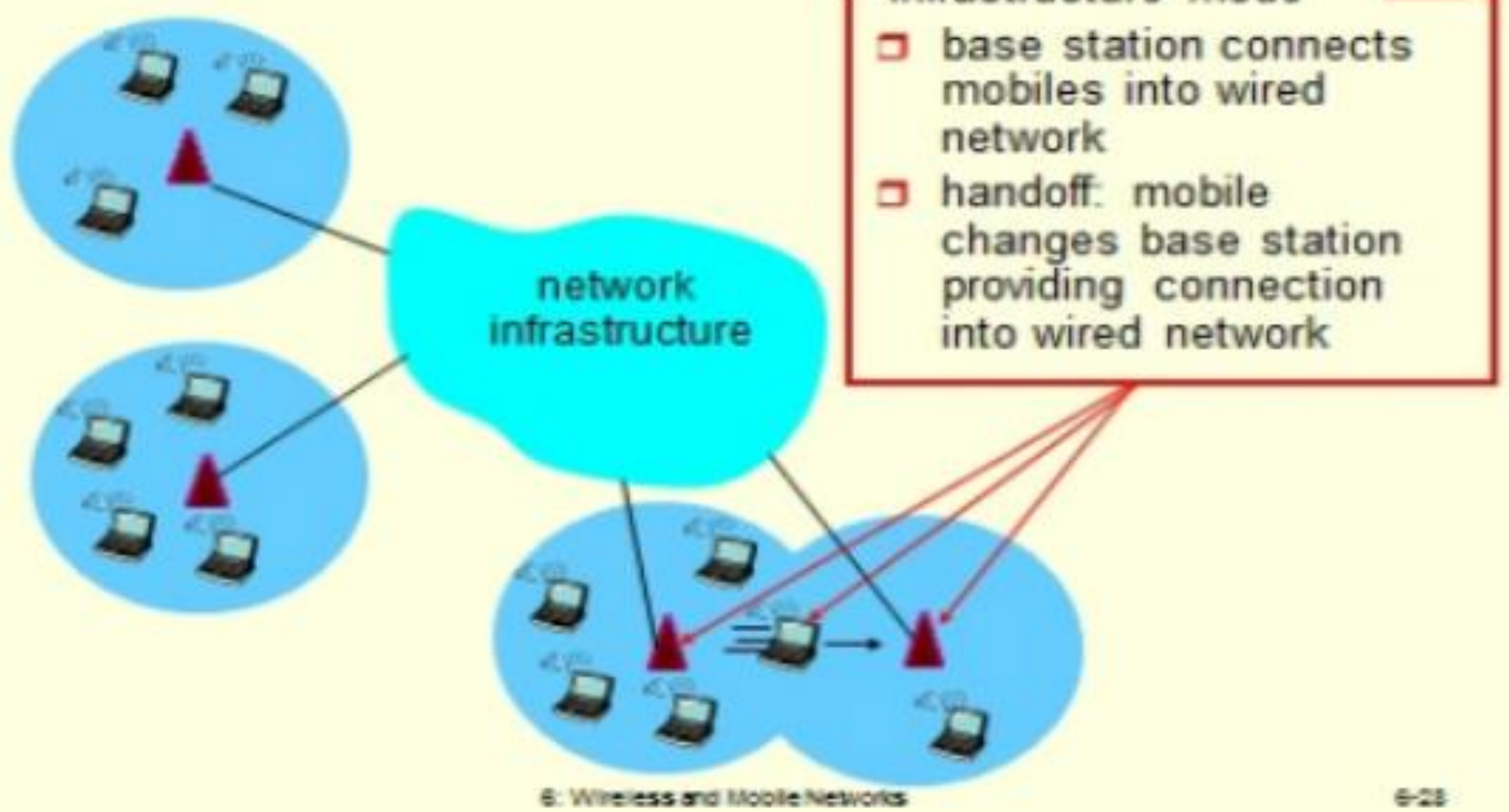
6: Wireless and Mobile Networks 6-26

Characteristics of selected wireless link standards



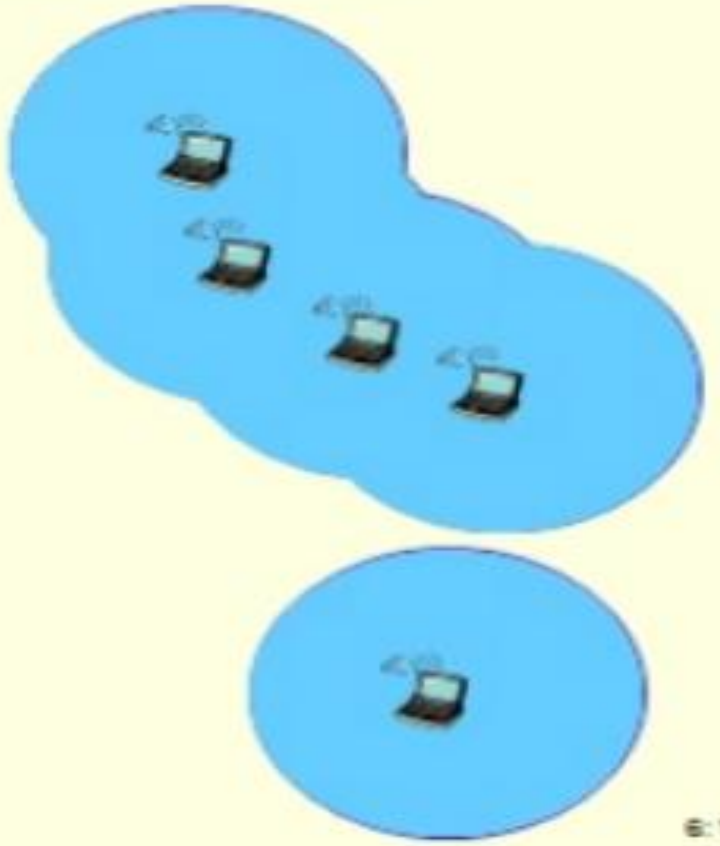
Elements of a wireless network



infrastructure mode

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

Elements of a wireless network



ad hoc mode
- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

Wireless network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless Link Characteristics (1)

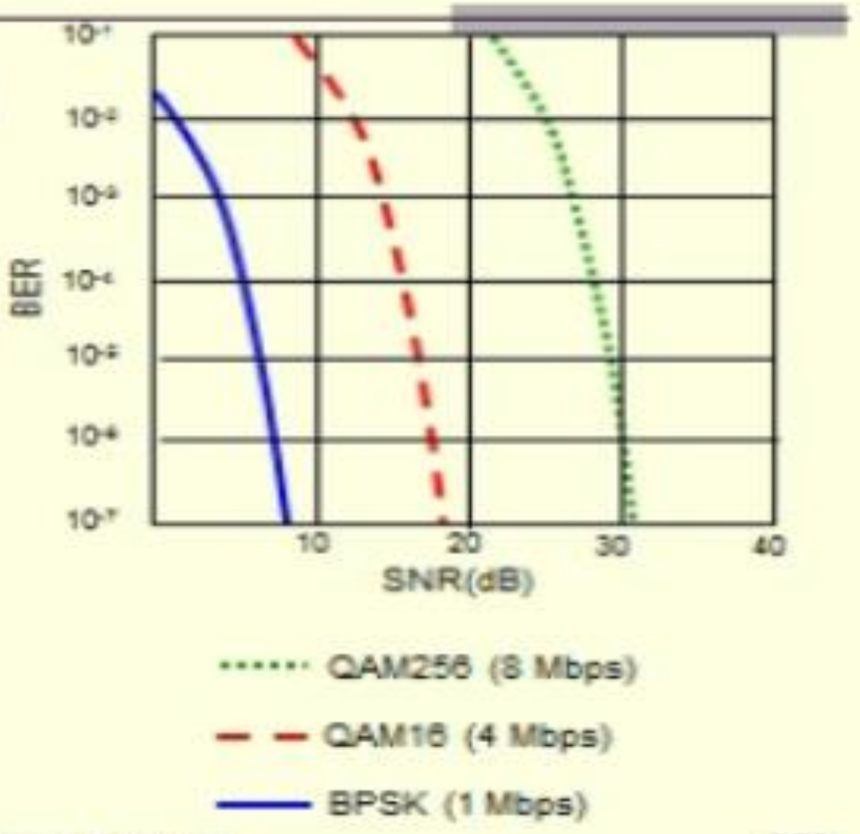
Differences from wired link ….

- decreased signal strength: radio signal attenuates as it propagates through matter (path loss)
- interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- multipath propagation: radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

Wireless Link Characteristics (2)

- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- *SNR versus BER tradeoffs*
  - *given physical layer:* increase power -> increase SNR->decrease BER
  - *given SNR:* choose physical layer that meets BER requirement, giving highest thruput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



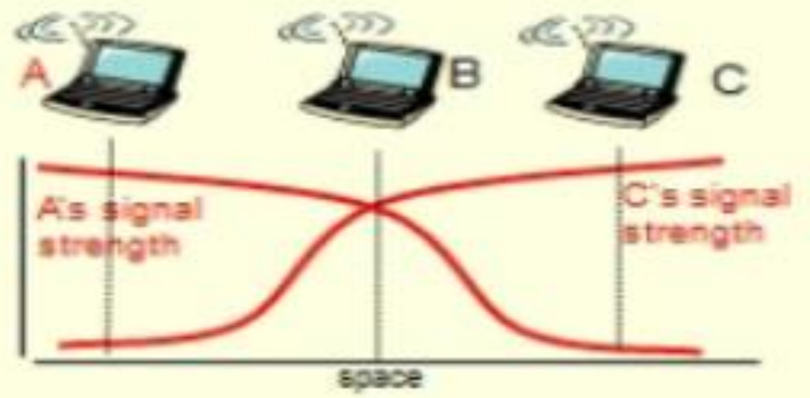
Wireless network characteristics

Multiple wireless senders and receivers create additional problems (beyond multiple access):

Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other

means A, C unaware of their interference at B



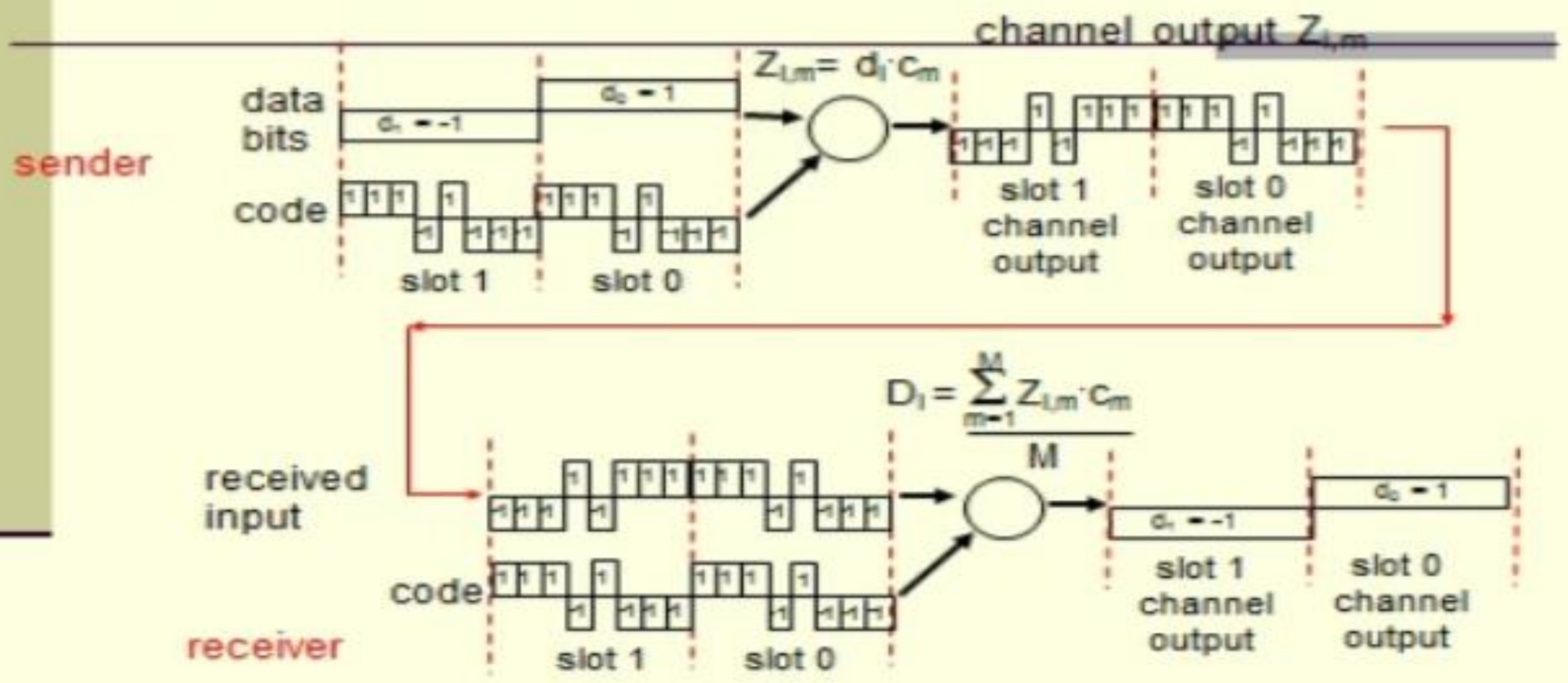
Signal attenuation:

- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

Code Division Multiple Access (CDMA)

- used in several wireless broadcast channels (cellular, satellite, etc) standards
- unique "code" assigned to each user; i.e., code set partitioning
- all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
- *encoded signal* = (original data) X (chipping sequence)
- *decoding*: inner-product of encoded signal and chipping sequence
- allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

CDMA Encode/Decode



Thanks- Questions !