Cellular Mobile Communication-1

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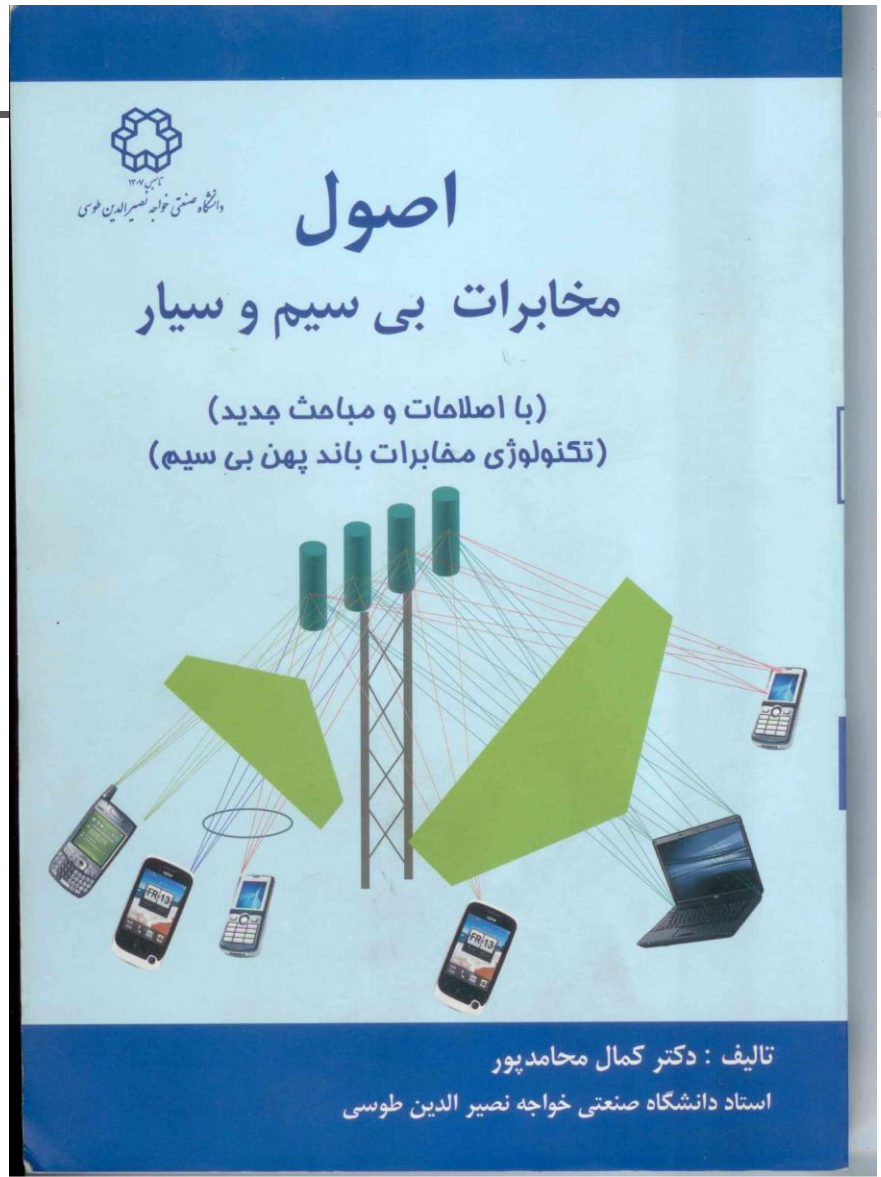
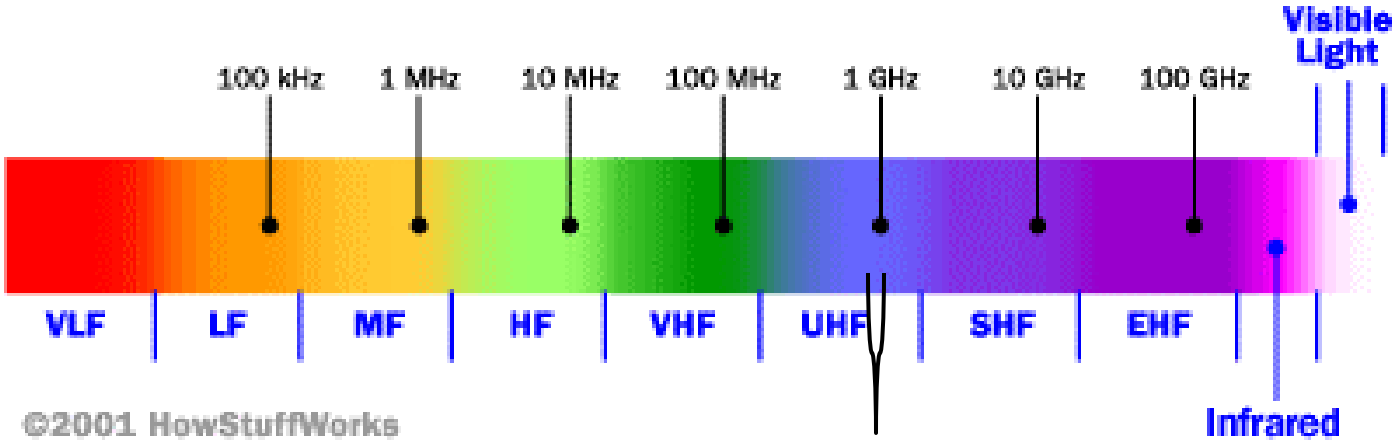
معرفی کتاب درس



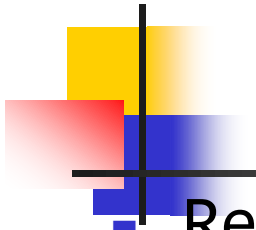
Frequency Bands

- There are many types of cellular services; before delving into details, focus on basics (helps navigate the "acronym soup")
- Cellular network/telephony is a *radio*-based technology; radio waves are electromagnetic waves that *antennas* propagate
- Most signals are in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands



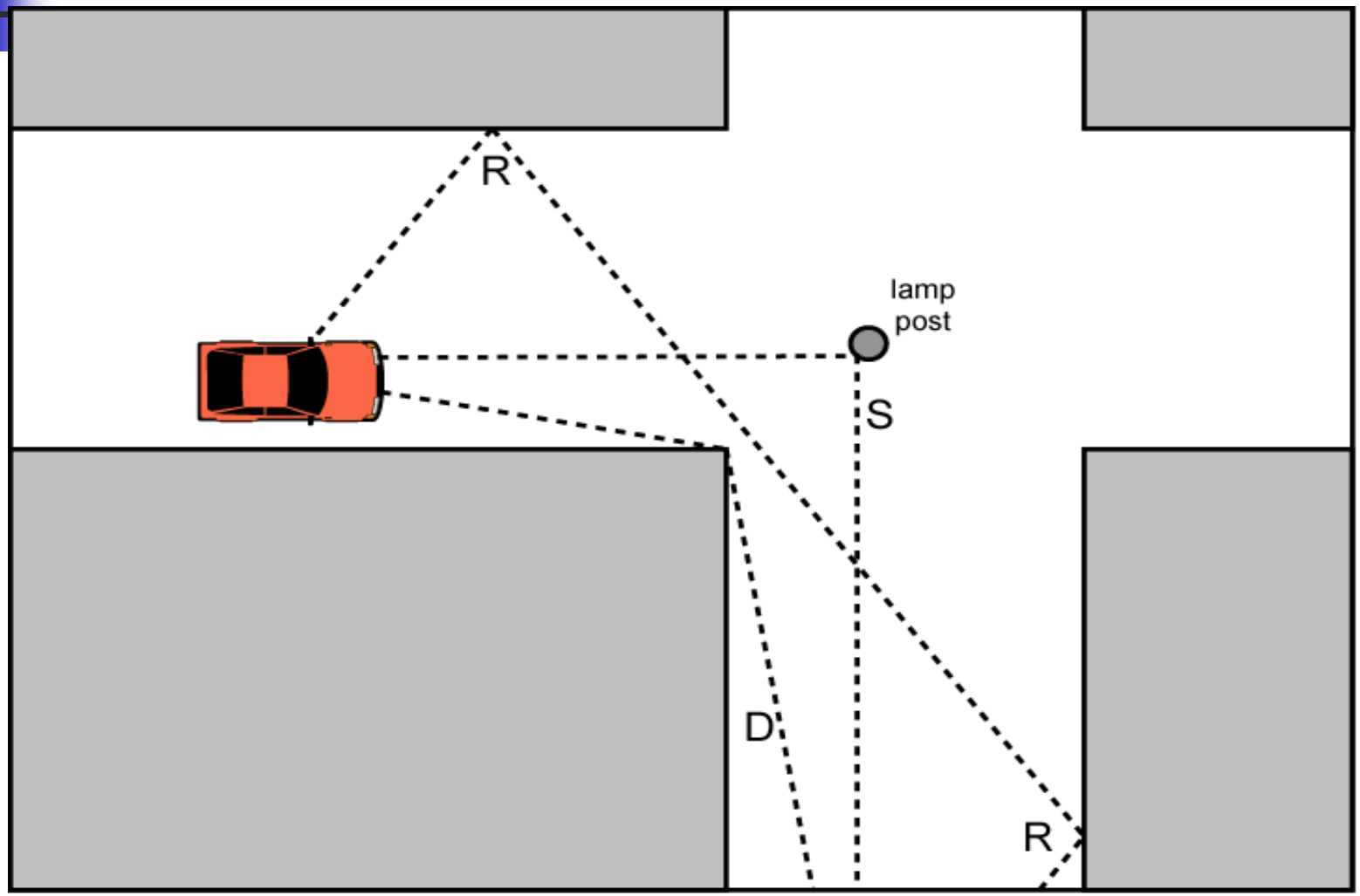
Cell phones operate in this frequency range (note the *logarithmic* scale)

Multipath Propagation



- Reflection
  - Surface large relative to wavelength of signal
  - May have phase shift from original
  - May cancel out original or increase it
- Diffraction
  - Edge of impenetrable body that is large relative to wavelength
  - May receive signal even if no line of sight (LOS) to transmitter
- Scattering
  - Obstacle size on order of wavelength
    - Lamp posts etc.
- If LOS, diffracted and scattered signals not significant
  - Reflected signals may be
- If no LOS, diffraction and scattering are primary means of reception

Reflection, Diffraction, Scattering



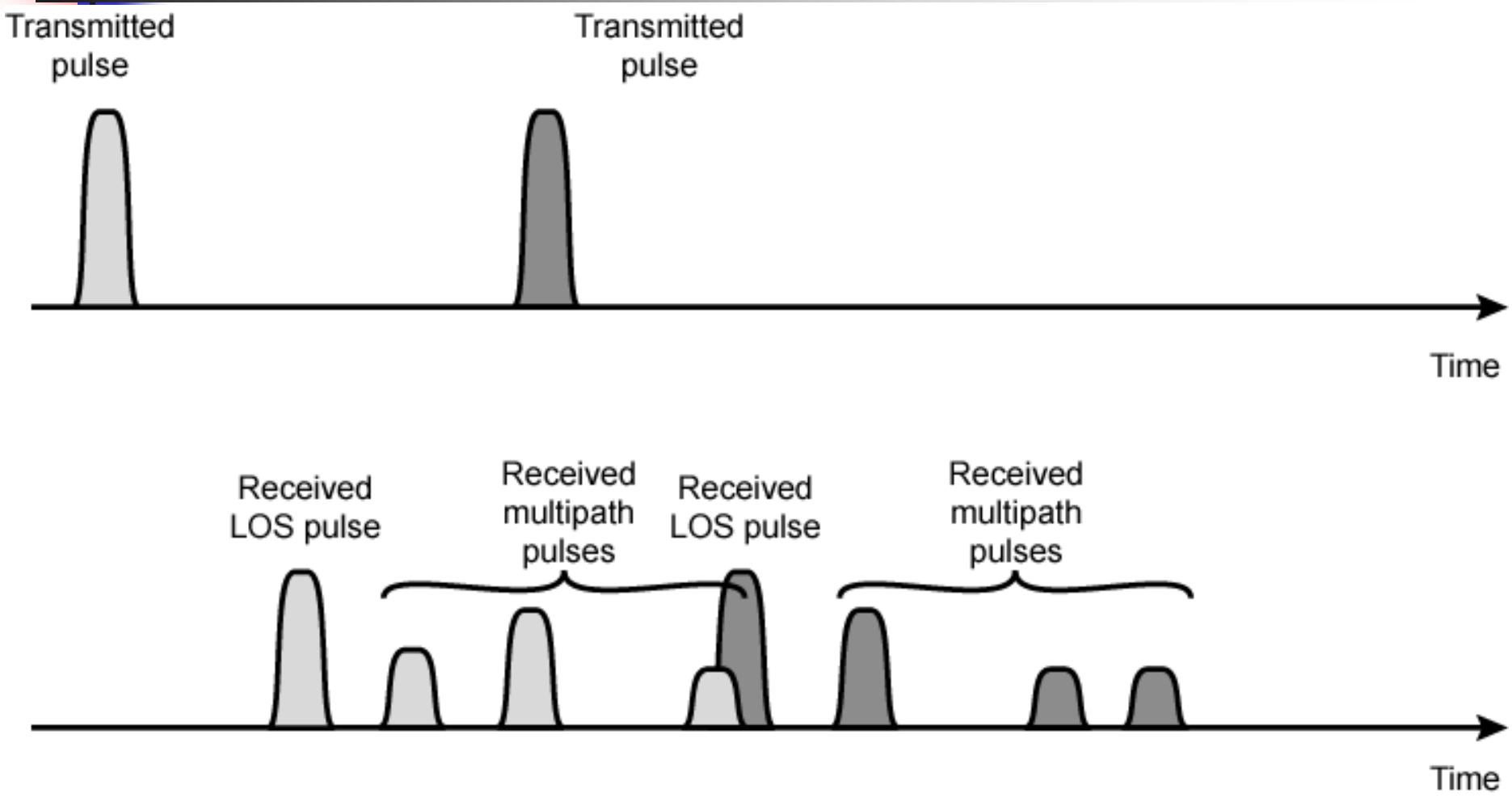
Mobile Radio Propagation Effects

- Signal strength
  - Strength of signal between BS and mobile unit strong enough to maintain signal quality at the receiver
  - Not strong enough to create too much cochannel interference
  - Noise varies
    - Automobile ignition noise greater in city than in suburbs
    - Other signal sources vary
    - Signal strength varies as function of distance from BS
    - Signal strength varies dynamically as mobile unit moves
- Fading
  - Even if signal strength in effective range, signal propagation effects may disrupt the signal

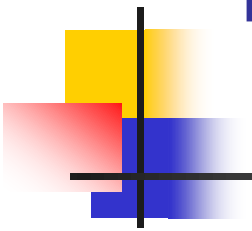
Effects of Multipath Propagation

- Signals may cancel out due to phase differences
- Inter-symbol Interference (ISI)
- Sending narrow pulse at given frequency between fixed antenna and mobile unit
- Channel may deliver multiple copies at different times
- Delayed pulses act as noise making recovery of bit information difficult
- Timing changes as mobile unit moves
  - Harder to design signal processing to filter out multipath effects

Two Pulses in Time-Variant Multipath

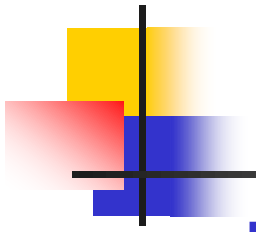


Fading



- Time variation of received signal
- Caused by changes in transmission path(s)
- E.g. atmospheric conditions (rain)
- Movement of (mobile unit) antenna

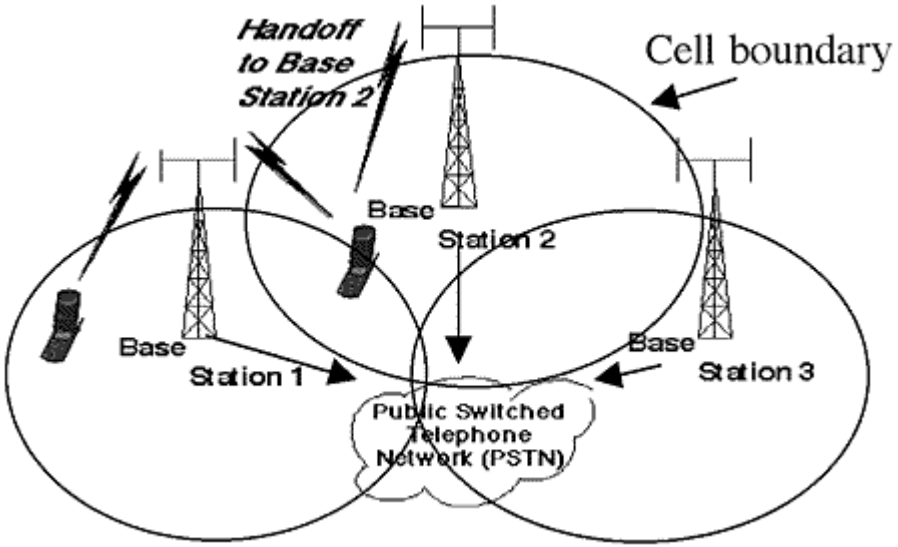
Types of Fading



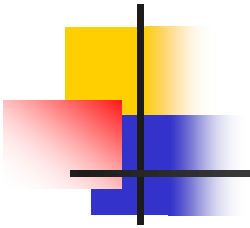
- Fast fading
  - Rapid changes in strength over distances about half wavelength
    - 900MHz wavelength is 0.33m
    - 20-30dB
- Slow fading
  - Slower changes due to user passing different height buildings, gaps in buildings etc.
  - Over longer distances than fast fading
- Flat fading
  - Nonselective
  - Affects all frequencies in same proportion
- Selective fading
  - Different frequency components affected differently

Cellular Network

- Base stations transmit to and receive from mobiles at the assigned spectrum
  - Multiple base stations use the same spectrum (spectral reuse)
- The service area of each base station is called a cell
- Each mobile terminal is typically served by the 'closest' base statio
  - Handoff v

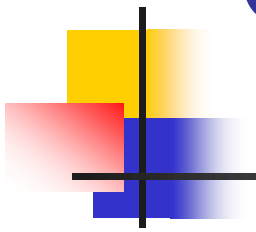


Principles of Cellular Networks



- Underlying technology for mobile phones, personal communication systems, wireless networking etc.
- Developed for mobile radio telephone
  - Replace high power transmitter/receiver systems
    - Typical support for 25 channels over 80km
  - Use lower power, shorter range, more transmitters

Cellular Network Organization



- Multiple low power transmitters
  - 100w or less
- Area divided into cells
  - Each with own antenna
  - Each with own range of frequencies
  - Served by base station
    - Transmitter, receiver, control unit
  - Adjacent cells on different frequencies to avoid crosstalk

Operation of Cellular Systems

- Base station (BS) at center of each cell
  - Antenna, controller, transceivers
- Controller handles call process
  - Number of mobile units may in use at a time
- BS connected to mobile telecommunications switching office (MTSO)
  - One MTSO serves multiple BS
  - MTSO to BS link by wire or wireless
- MTSO:
  - Connects calls between mobile units and from mobile to fixed telecommunications network
  - Assigns voice channel
  - Performs handoffs
  - Monitors calls (billing)

Frequency Reuse

- Power of base transceiver controlled
  - Allow communications within cell on given frequency
  - Limit escaping power to adjacent cells
  - Allow re-use of frequencies in nearby cells
  - Use same frequency for multiple conversations
  - 10 – 50 frequencies per cell
- *E.g.*
  - *N* cells all using same number of frequencies
  - *K* total number of frequencies used in systems
  - Each cell has *K/N* frequencies
  - Advanced Mobile Phone Service (AMPS) *K*=395, *N*=7 giving 57 frequencies per cell on average

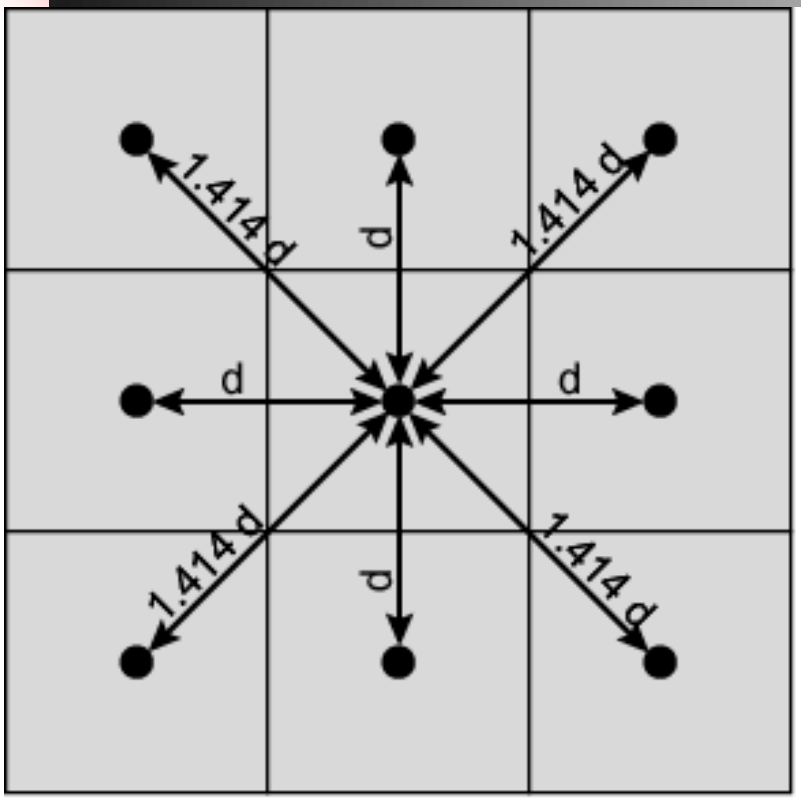
Characterizing Freq. Reuse

- D = minimum distance between centers of cells that use the same band of frequencies (called co-channels)
- R = radius of a cell
- d = distance between centers of adjacent cells (d = R)
- N = number of cells in repetitious pattern
  - Reuse factor
  - Each cell in pattern uses unique band of frequencies
- Hexagonal cell pattern, following values of N possible
  - $N = I^2 + J^2 + (I \times J)$, $I, J = 0, 1, 2, 3, \ldots$
- Possible values of N are 1, 3, 4, 7, 9, 12, 13, 16, 19, 21, …
- $D/R = \sqrt{3N}$
- $D/d = \sqrt{N}$

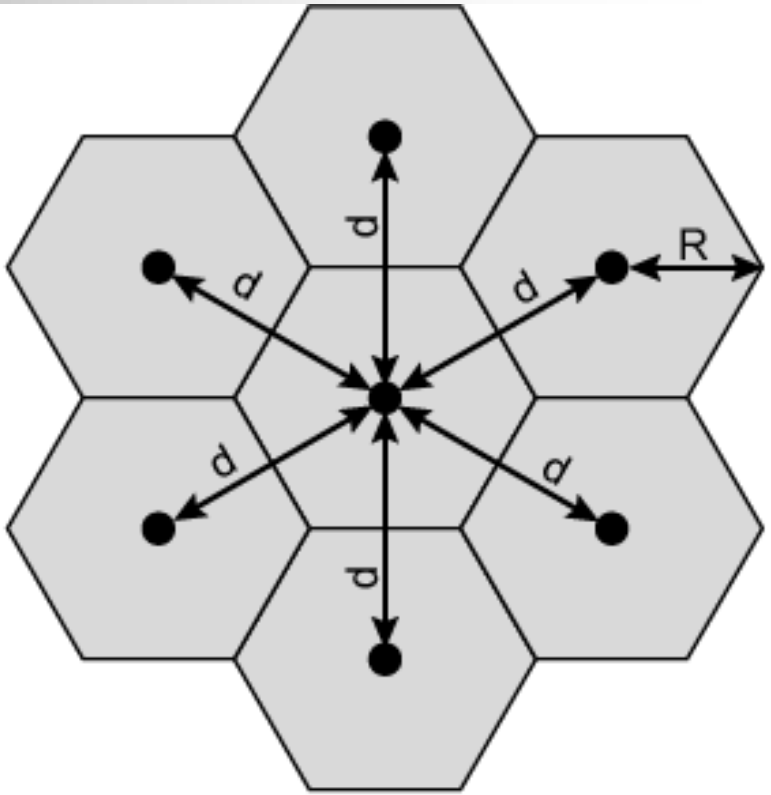
Shape of Cells

- Square
  - Width d cell has four neighbours at distance d and four at distance $\sqrt{2}\,d$
  - Better if all adjacent antennas equidistant
    - Simplifies choosing and switching to new antenna
- Hexagon
  - Provides equidistant antennas
  - Radius defined as radius of circum-circle
    - Distance from center to vertex equals length of side
  - Distance between centers of cells radius R is $\sqrt{3}\,R$
  - Not always precise hexagons
    - Topographical limitations
    - Local signal propagation conditions
    - Location of antennas

Cellular Geometries

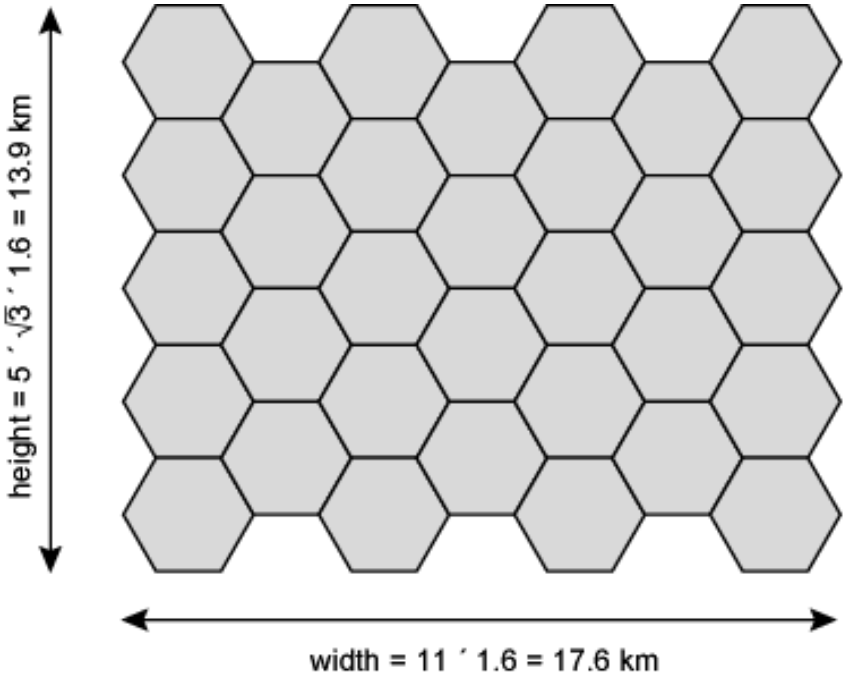


(a) Square pattern

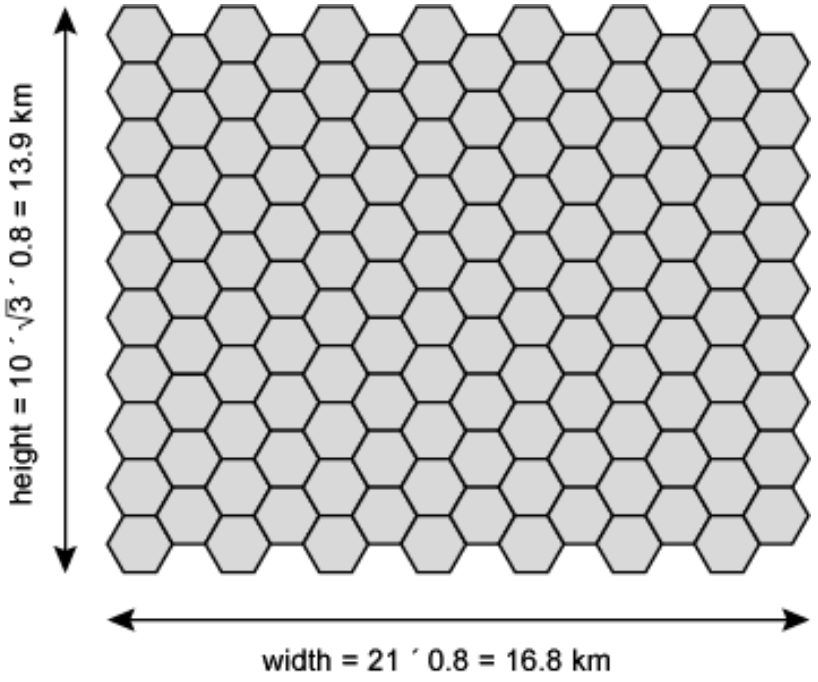


(b) Hexagonal pattern

Frequency Reuse Example

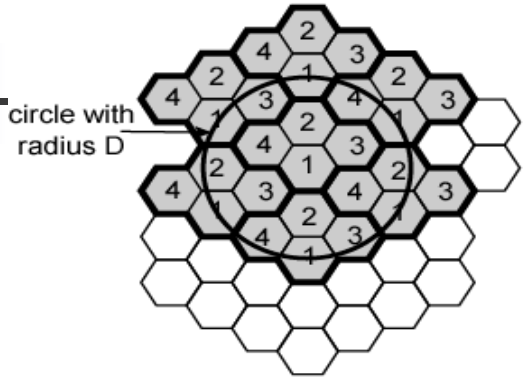


(a) Cell radius = 1.6 km

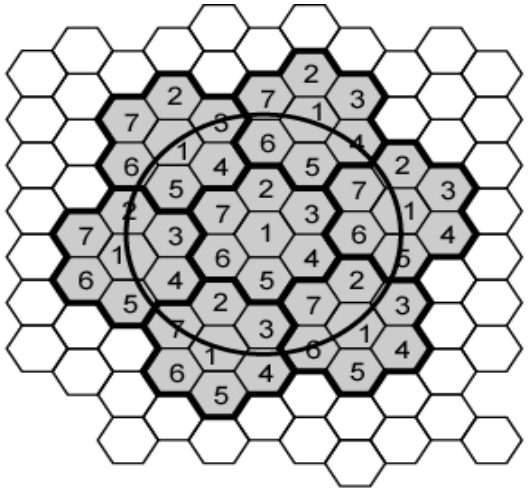


(b) Cell radius = 0.8 km

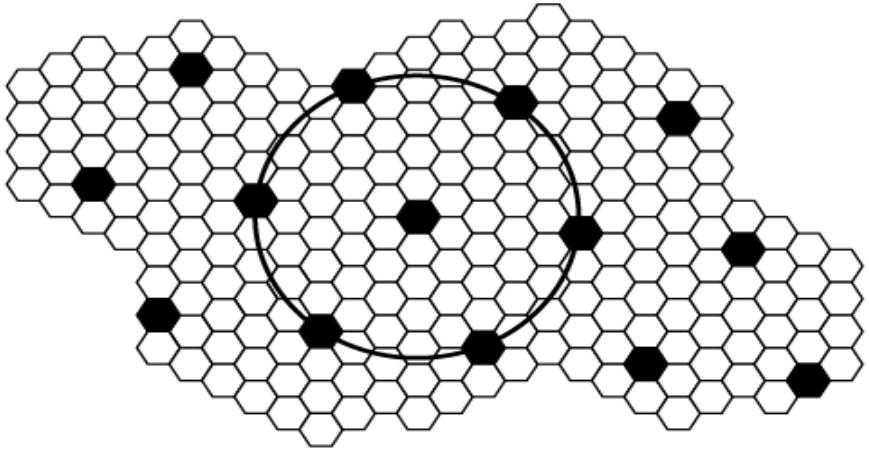
Frequency Reuse Patterns



(a) Frequency reuse pattern for N = 4

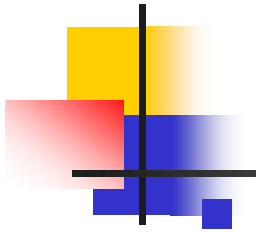


(b) Frequency reuse pattern for N = 7



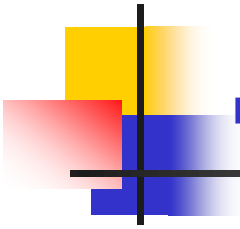
(c) Black cells indicate a frequency reuse for N = 19

Increasing Capacity (1)



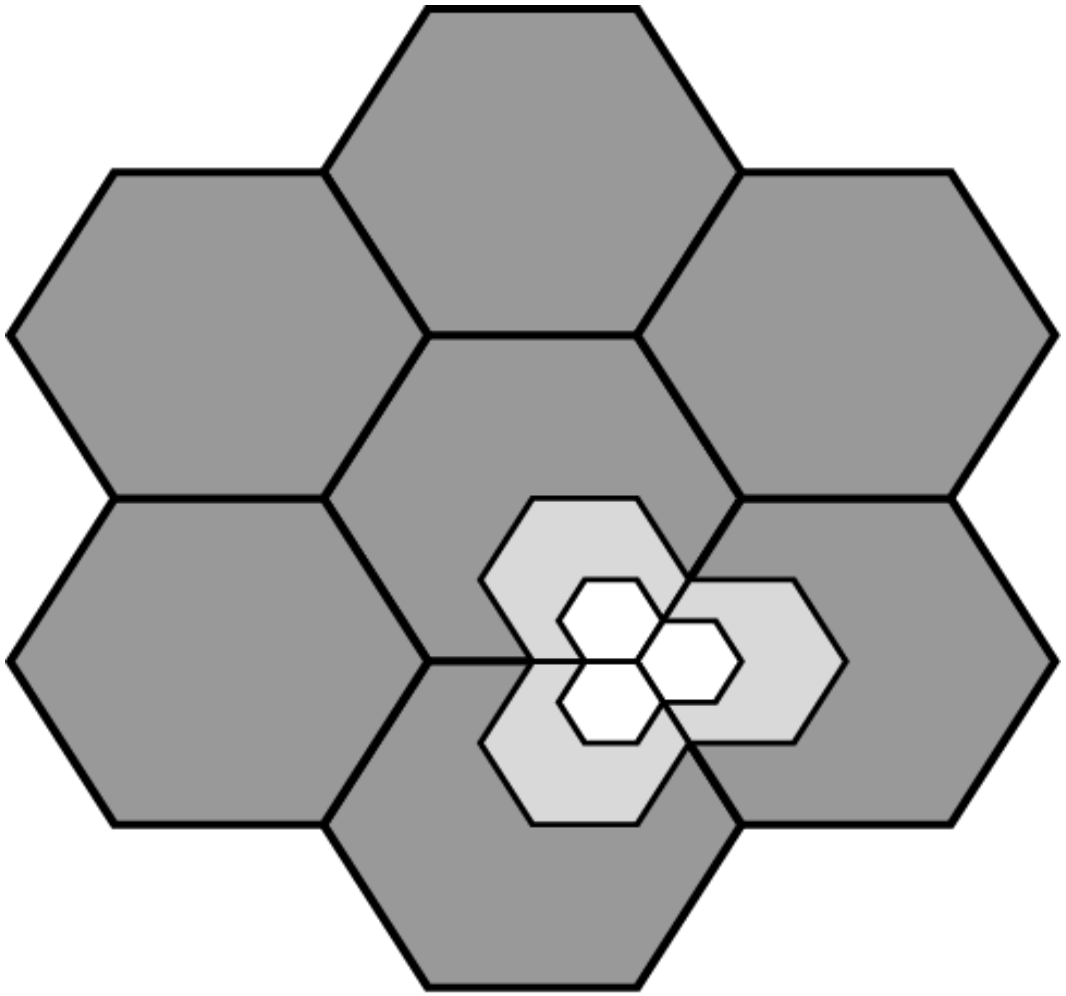
- Add new channels
  - Not all channels used to start with
- Frequency borrowing
  - Taken from adjacent cells by congested cells
  - Or assign frequencies dynamically
- Cell splitting
  - Non-uniform distribution of topography and traffic
  - Smaller cells in high use areas
    - Original cells 6.5 – 13 km
    - 1.5 km limit in general
    - More frequent handoff
    - More base stations

Increasing Capacity (2)

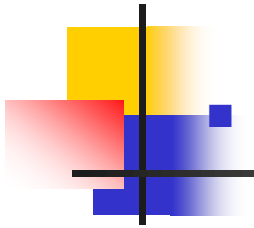


- Cell Sectoring
  - Cell divided into wedge shaped sectors
  - 3 – 6 sectors per cell
  - Each with own channel set
    - Subsets of cell's channels
  - Directional antennas
- Microcells
  - Move antennas from tops of hills and large buildings t tops of small buildings and sides of large buildings
    - Even lamp posts
  - Form microcells
  - Reduced power
  - Good for city streets, along roads and inside large buildings

Cell Splitting

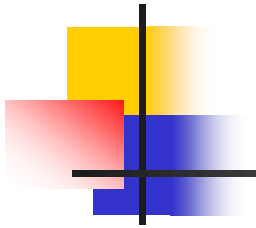


Design Factors

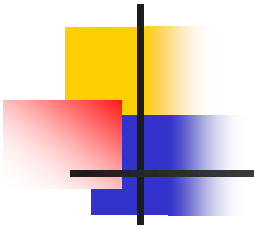


- Propagation effects
  - Dynamic
  - Hard to predict
- Maximum transmit power level at BS and mobile units
- Typical height of mobile unit antenna
- Available height of the BS antenna
- These factors determine size of individual cell
- Model based on empirical data
- Apply model to given environment to develop guidelines for cell size
- E.g. model by Okumura et al refined by Hata
  - Detailed analysis of Tokyo area
  - Produced path loss information for an urban environment
  - Hata's model is an empirical formulation
    - Takes into account variety of environments and conditions

Other Functions



- Call blocking
  - During mobile-initiated call stage, if all traffic channels busy, mobile tries again
  - After number of fails, busy tone returned
- Call termination
  - User hangs up
  - MTSO informed
  - Traffic channels at two BSs released
- Call drop
  - BS cannot maintain required signal strength
  - Traffic channel dropped and MTSO informed
- Calls to/from fixed and remote mobile subscriber
  - MTSO connects to PSTN
  - MTSO can connect mobile user and fixed subscriber via PSTN
  - MTSO can connect to remote MTSO via PSTN or via dedicated lines
  - Can connect mobile user in its area and remote mobile user



Network Generations

Cellular Network Generations

- It is useful to think of cellular Network/telephony in terms of *generations*:
  - 0G: Briefcase-size mobile radio telephones
  - 1G: *Analog* cellular telephony
  - 2G: *Digital* cellular telephony
  - 3G: *High-speed* digital cellular telephony (including *video telephony*)
  - 4G: IP-based "anytime, anywhere" voice, data, and multimedia telephony at *faster* data rates than 3G
    (to be deployed in 2012–2015)

برخی استانداردهای نسل اول

- 1946: Mobile Tel. Service (MTS),US

  Unique TX, half-duplex, No handovers & Roaming, manually searches for an idle channel

- 1964: Improved MTS (IMTS), US

  full-duplex, automatic searching for an idle channel, direct dialing & number identification signaling

- 1978: National autotel.(Natel-A), Switzerland
- 1984: Natel-B, Switzerland

استانداردهای نسل اول...

First Generation(1G), Analoge Cellular

- Analogue Transmission, Cellular concepts
- Narrowband channel for voice
- Frequency reuse & handover, FDMA

  1979: Nippon Telephone & Telegraph (NTT), Japan

  1981: Nordic Mobile Telephone (NMT), Sweden

  1983: Advance Mobile Phone Service (AMPS), US
- Mobile sends MIN/ESN to network for automated billing, etc.

  1986: Natel-C (NMT), switzerland

  1986: C-Netz, Germany
- Introduces authentication card (magnetic) stripe, memory chip, smart card processor

خلاصه تکنولوژي هاي نسل اول

	NTT (Japan)	NMT (Scandinavian)	AMPS (N. America)	TACS (UK)	C-450 (W. Germany)
Company	Nippon T&T	Ericsson Radio System	ATT		
Year of Introduction	1979	1981	1983	1985	1985
Multiple Access	FDMA	FDMA	FDMA	FDMA	FDMA
Transmit Frequency • Base Station • Mobile Station	870 - 885 925 - 940	463 - 467.5 453 - 457.5	870 - 890 825 - 845	935 - 960 890 - 915	461.3 - 465.74 451.3 - 455.74
Tx & Rx Spacing	55 (MHz)	10 (MHz)	45 (MHz)	45 (MHz)	10 (MHz)
Channel Bandwidth (kHz)	25/6.25	25 & 12.5	30	25	20
# of channels	600/2400	1999	666/832	1000	222
Coverage Area (km)	1.8-40.0	5 - 10	2-25	2-20	5-30
Audio Signal • Modulation • F. Deviation	FM 5 (kHz)	FM 5 (kHz)	FM 12 (kHz)	FM 9.5 (kHz)	FM 4 (kHz)
Control Signal • Modulation • FM (kHz)	FSK 4.5	FSK 3.5	FSK 8	FSK 6.5	FSK 2.5
Data Rate kbps	0.3	1.28	10	8	5.28
Error control on control channels	Check on signals sent back	Predetermined from message content	Majority Decision	Majority Decision	Retransmit if error occur

1G , Summery

- Circuit-switched technology.
- FDMA (Frequency Division Multiple Access).
- Analog system.
- Basic mobility.
- Poor voice quality.
- Poor security.

AMPS
American Mobile Phone System

- Two 25-MHz bands are allocated to AMPS
  - One from BS to mobile unit (869–894 MHz)
  - Other from mobile to base station (824–849 MHz)
- Bands is split in two to encourage competition
  - In each market two operators can be accommodated
- Operator is allocated only 12.5 MHz in each direction
- Channels spaced 30 kHz apart
  - Total of 416 channels per operator
- Twenty-one channels allocated for control
- 395 to carry calls
- Control channels are 10 kbps data channels
- Conversation channels carry analog using frequency modulation
- Control information also sent on conversation channels in bursts as data
- Number of channels inadequate for most major markets
- For AMPS, frequency reuse is exploited

AMPS Control Channels

- 21 full-duplex 30-kHz control channels
  - Transmit digital data using FSK
  - Data are transmitted in frames
- Control information can be transmitted over voice channel during conversation
  - Mobile/base station inserts burst of data
    - Turn off voice FM transmission for about 100 ms
    - Replacing it with an FSK-encoded message
  - Used to exchange urgent messages
    - Change power level
    - Handoff