Οικονομικό Πανεπιστήμιο Αθηνών
Τμήμα Πληροφορικής

Ευφυή Κινητά Δίκτυα: Κυτταρική Δομή Κινητών Επικοινωνιών Συστήματα Κινητής Τηλεφωνίας 1ης & 2ης Γενιάς

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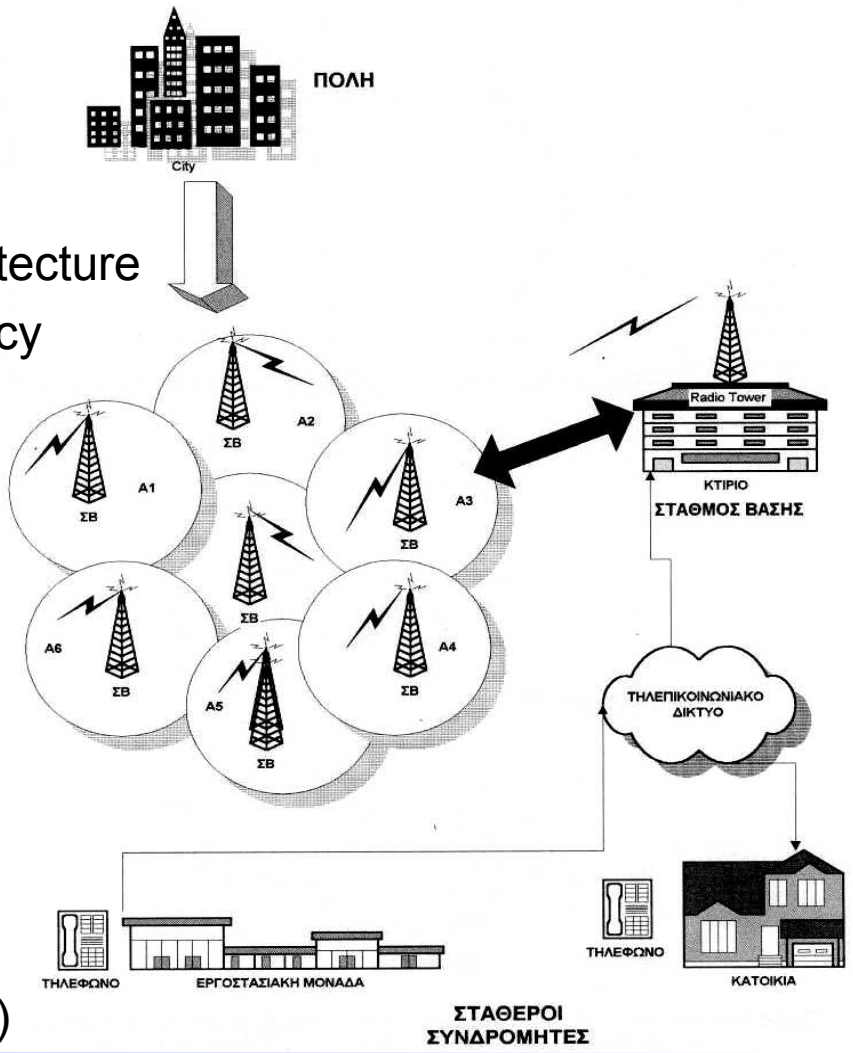
(βασισμένο σε διαφάνειες του Βασίλειου Σύρη)

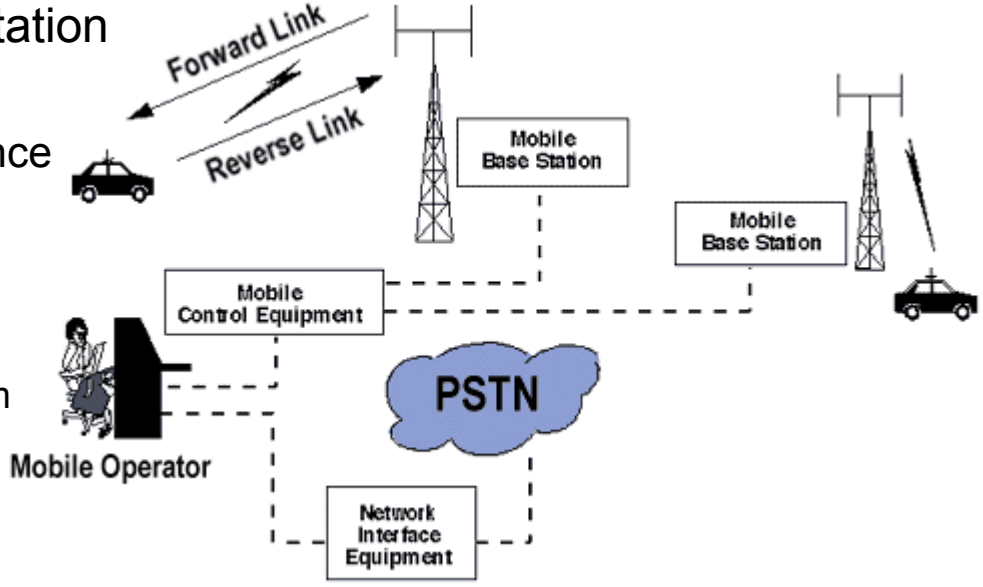
Κυτταρική Δομή Κινητών Επικοινωνιών

- Mobile Communications Principles
- Early Mobile Telephone System Architecture
- Co-channel Interference and Frequency Reuse
- The Cellular Concept
- Cellular System Architecture
- Frequency Reuse
- Cell Splitting
- Handoff
- Handoff Initiation
- Cellular System Components
- Digital Cellular
- Time Division Multiple Access (TDMA)



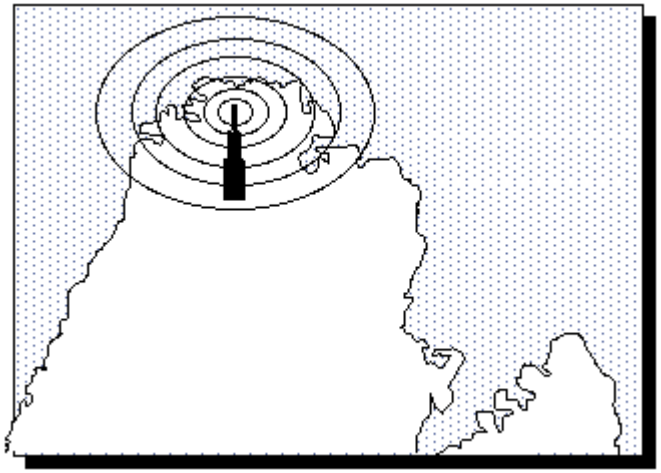
Mobile Communications Principles

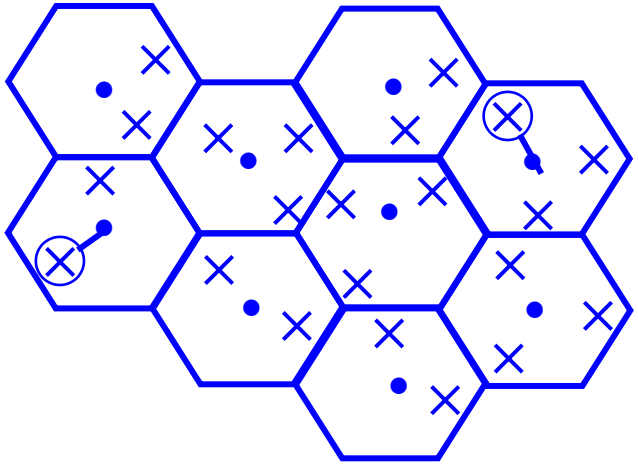
- each mobile (station)
  - uses a separate, temporary radio channel to talk to the cell site
- the cell site (base station)
  - talks to many mobiles at once, using one channel per mobile
- a pair of frequencies are used for communication
  - one (the forward link) for transmitting from the cell site
  - another frequency (the reverse link) for the cell site to receive calls from the users
- mobiles must stay near the base station
  - to maintain communications
  - radio energy dissipates over distance
- mobile (voice) networks include
  - mobile radio service
    - operates in a closed network
    - no access to the telephone system
  - mobile telephone service
    - interconnection to the telephone network



Early Mobile Telephone System Architecture

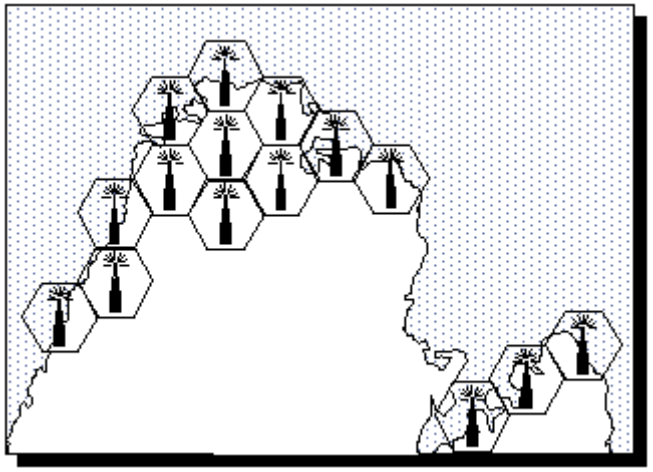
- Traditional mobile service
  - structured in a fashion similar to TV broadcasting
  - one powerful transmitter in a (e.g., metropolitan) area
    - could broadcast in a radius of up to 50 km
- The cellular concept
  - different!
  - many low-power transmitters placed throughout an area



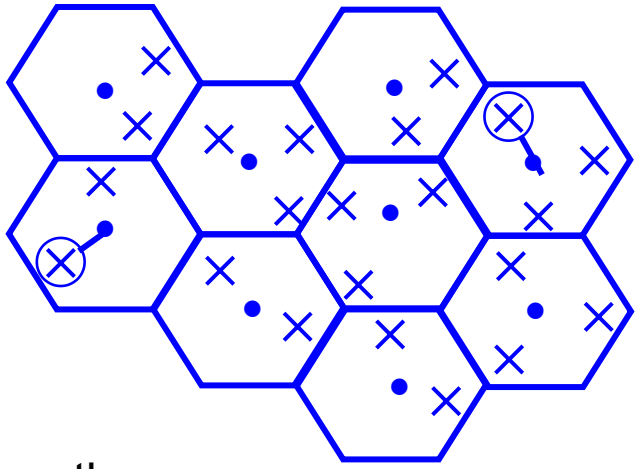


Co-channel Interference and Frequency Reuse

- co-channel interference
  - caused by mobile units using the same channel in adjacent areas
  - all channels cannot be (re-)used in every cell
  - areas have to be skipped before the same channel is reused
- frequency reuse is still a key technique for mobile communications systems
- interference
  - is *not* proportional to the distance between areas, but to the ratio of the distance between areas to the transmitter power (radius) of the areas
  - reducing the radius of an area by 50%, increases the number of potential customers in an area 4x
    - systems with a 1 Km radius can have 100 times more channels than systems with areas 10 Km in radius – Why?



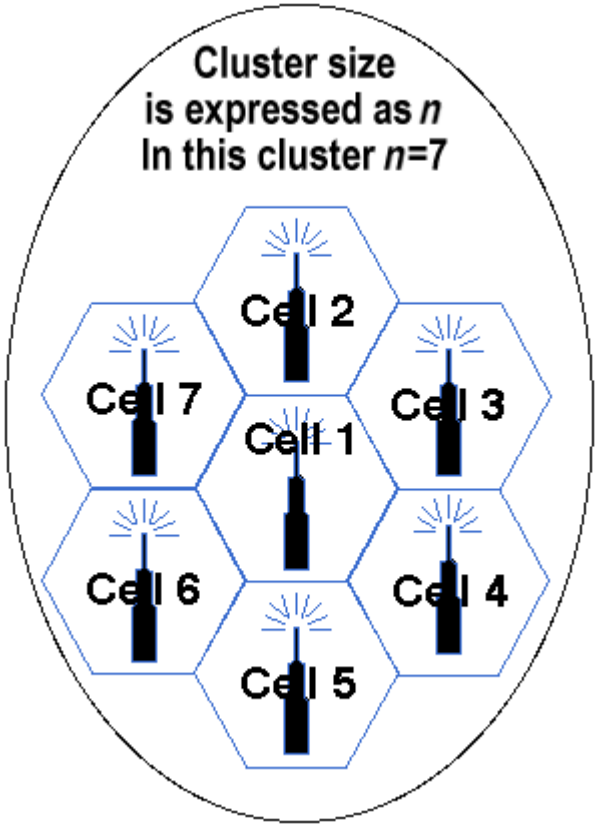
The Cellular Concept



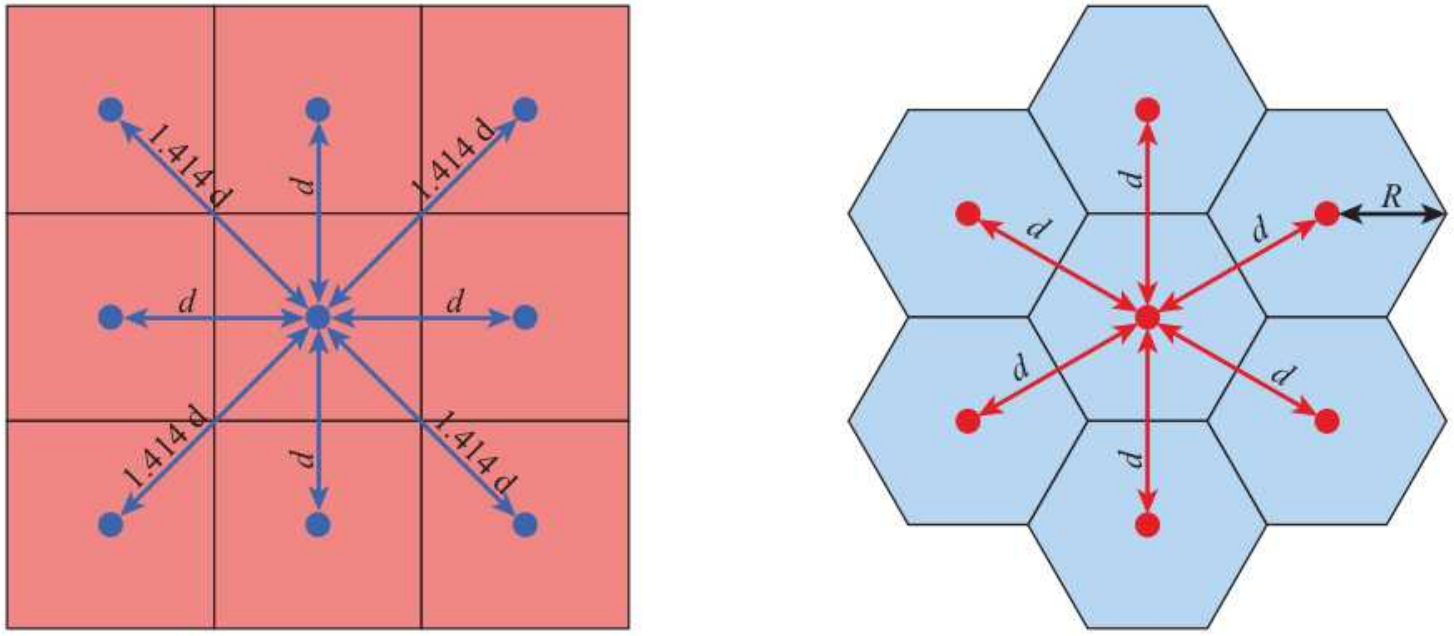
- variable low-power transmission levels
  - allow cells to be sized according to
    - subscriber density
    - traffic demands
- as the population or traffic grows
  - cells can be added to accommodate that growth
- frequencies used in one cell cluster can be re-used in other clusters
- conversations can be handed-off from cell to cell
  - to maintain continuous service as the user moves between cells
- the base station can communicate with mobiles as long as they are within range

Cellular System Architecture

- engineering plan
  - clusters
  - frequency reuse
  - handovers
- cells
  - basic geographic unit of a cellular system
  - base stations transmit over small geographic areas
  - often represented as hexagons
  - true shape of cells is not a perfect hexagon
    - because of constraints imposed by
      - natural terrain
      - man-made structures
  - cell size varies depending on the landscape
- clusters
  - a group of cells
  - no channels are reused within a cluster



Why cell?



(a) Square pattern

(b) Hexagonal pattern

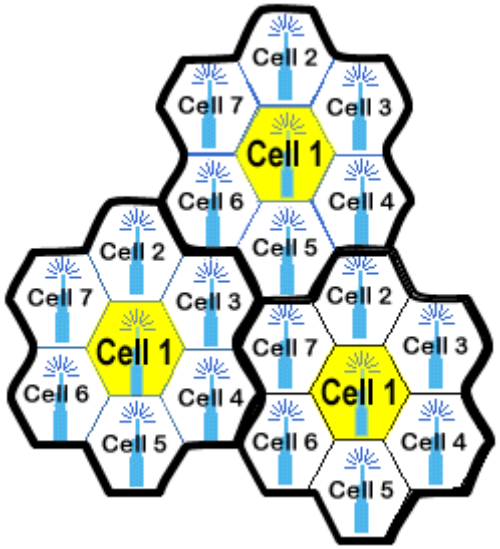
Figure 13.1 Cellular Geometries

Common *d* simplifies user mobility.

Frequency Reuse

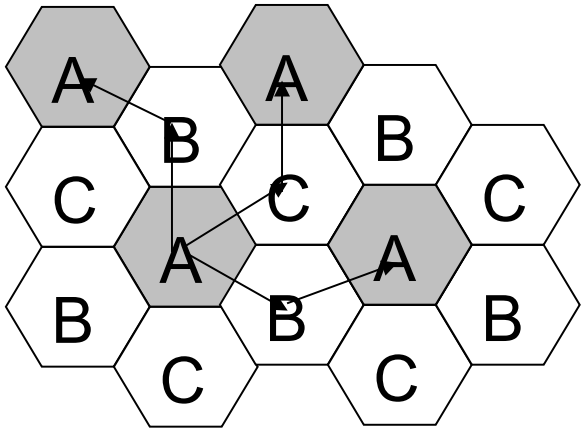
- no channels are reused within a cluster
- cells with same number have same group of frequencies
  - they are far enough so that there is no interference
- number of available frequency groups is 7
  - frequency reuse factor=7
  - each cell is using 1/7 of available channels
- Hexagon cell pattern, values of number of cells
  - N=1,3,4,7,9,12,13,16,19,21

- Each cell is allotted multiple freqs (10ths+). We only show one for simplicity.

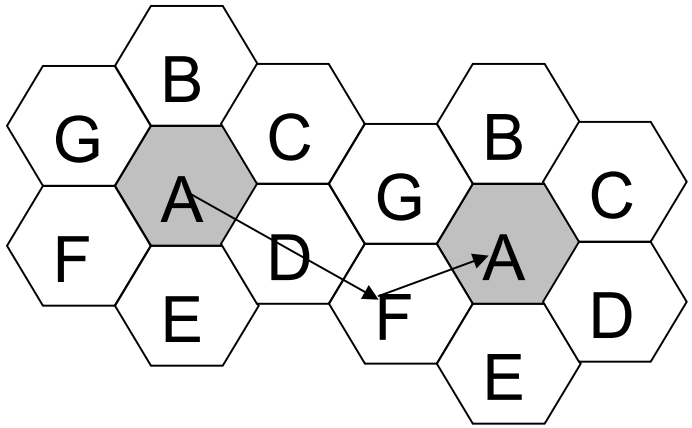


Reuse patterns

N = 3

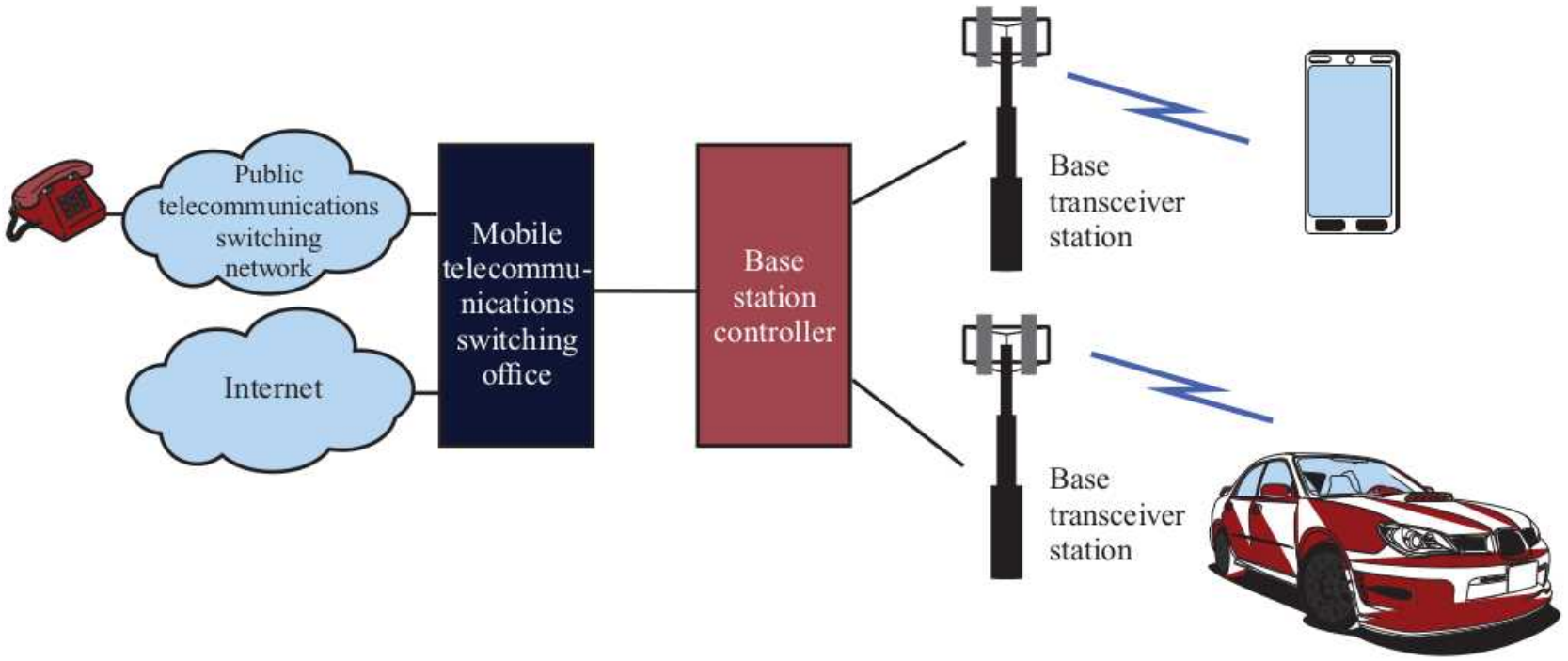


N = 7



Cellular architecture

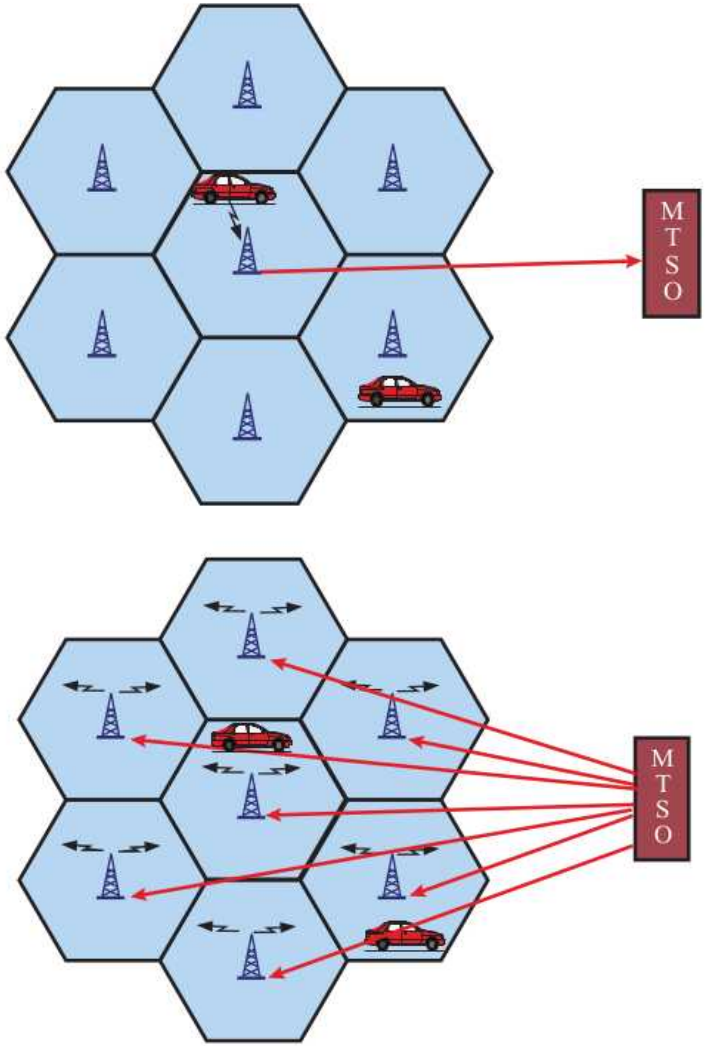
- Cellular backhaul or Radio Access Network: interconnect base stations to backbone
- Can be wired or wireless (point-to-point)
- 2 channels: Control & Traffic



A typical call – steps

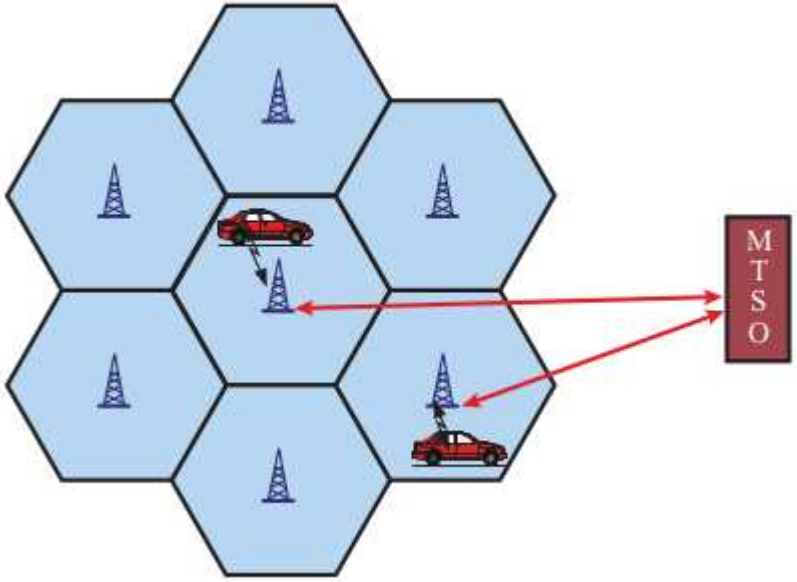
Two mobile users within an area controlled by a single MTSO.

- **Mobile unit initialization**: mobile unit scans and selects the strongest setup control channel used for this system
  - handshake between the mobile unit and the MTSO
  - Scanning is periodic
- **Mobile-originated call:** mobile unit sends the number of the called unit on the preselected setup channel
  - first, checks that the setup channel is idle (based on information in the forward, from the BS, channel). When idle, it transmits to BS.
  - Second, the BS sends the request to the MTSO.
- **Paging:** MTSO completes the connection.
  - Locates the called unit. BS forward the paging messages



A typical call – steps (cont.)

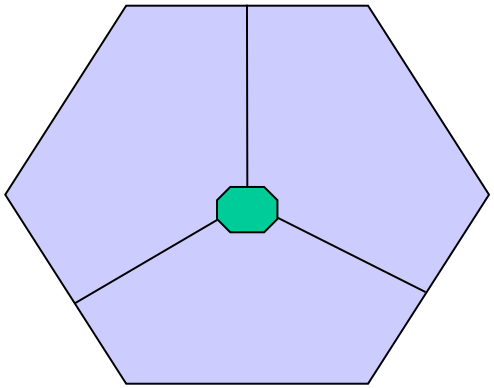
- **Call accepted:** called mobile unit rec
  setup channel being monitored and r
  - BS notifies MTSO, that builds a circu
  - MTSO selects an available traffic cha
  - BS notify units that tune to channel
- **Ongoing call**: mobile units exchange
  BSs and MTSO.
- **Handoff**: unit moves to diff cell, the *t*
  one assigned to the BS in the new ce
  - The system makes this change without either interrupting the call or alerting the user.



Increasing cellular capacity

- Frequency borrowing
  - congested cells borrow frequencies from less congested cells
  - dynamic allocation of frequencies
- Cell breathing
  - Increase/decrease cell coverage based on demand
  - Cell coverage control by base station power
- Cell splitting
  - smaller cells in high demand areas (original cell size 6.5-13km)
  - smaller cells => more base stations & more frequent handoffs
  - smaller cells (micro cells) => reduced transmission power
- Cell sectoring
  - cell divided into wedge-shaped sectors (typically 3)
  - use directional (sector) antennas

3-sector cell



Increasing cellular capacity (cont.)

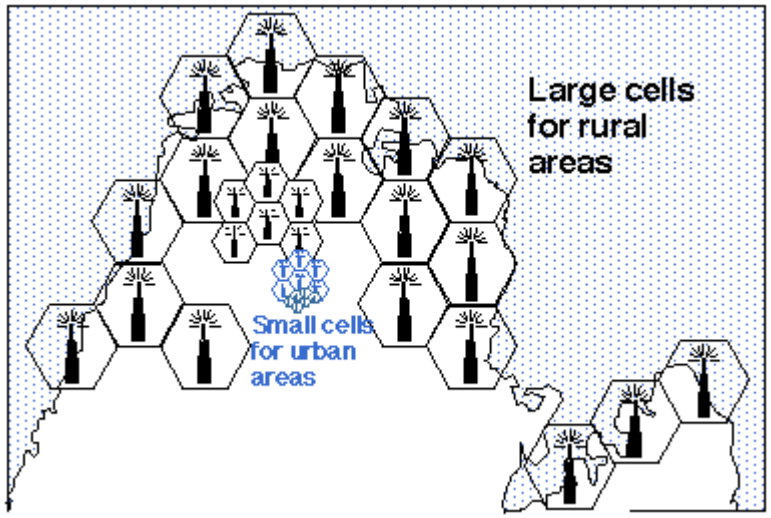
- Small cells
  - From antennas on top of hills to Picocells at lampposts
  - useful on city streets in congested areas, along highways, and inside large public buildings.
    - Indoors called *femtocells*, Outdoors called *macrocells*.
  - **This process of increasing capacity by using small cells is called network densification.**
  - Variety of frequency planning strategies to
    - share frequencies
    - avoid interference problems between small cells
    - **Dynamic channel assignment:** self-organizing networks of base stations make cooperative decisions as needs require.

Ultimatelly, capacity depends on how often frequencies can be reused!

- Limited by interference, not distance!

Cell Splitting

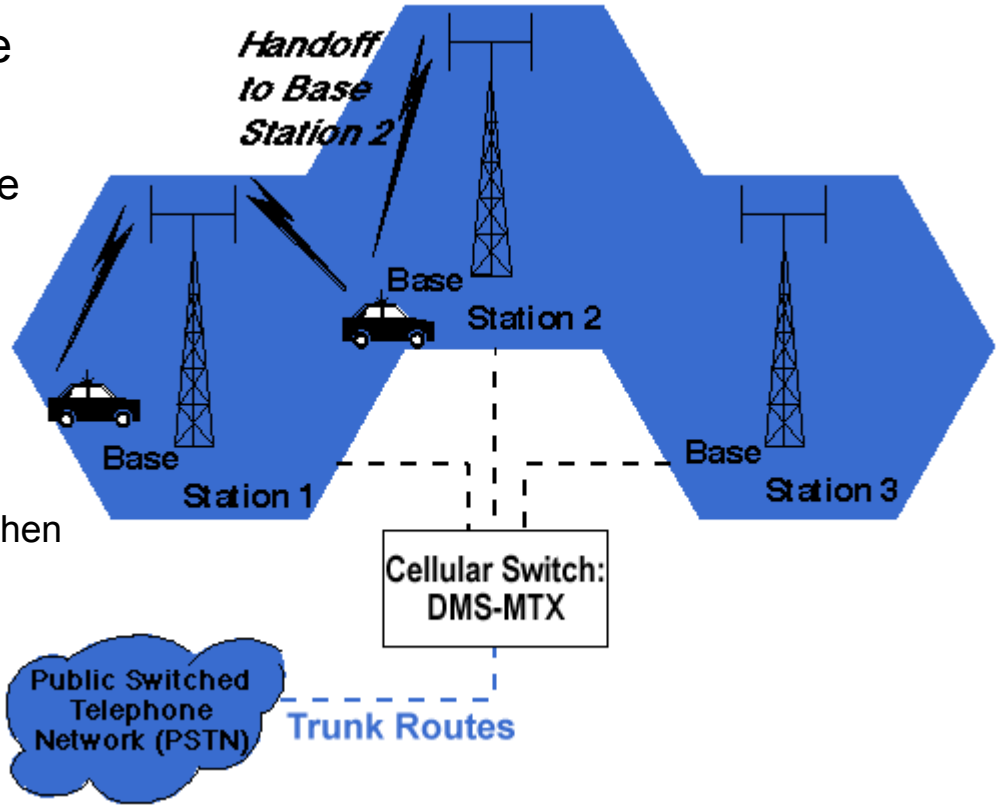
- creating full systems with many small areas impractical
- cell splitting
  - as a service area becomes full of users
  - split a single area into smaller ones
- urban centers
  - can be split into as many areas as necessary
  - to provide acceptable service levels in heavy-traffic regions
- rural regions
  - larger, less expensive cells



Handoff

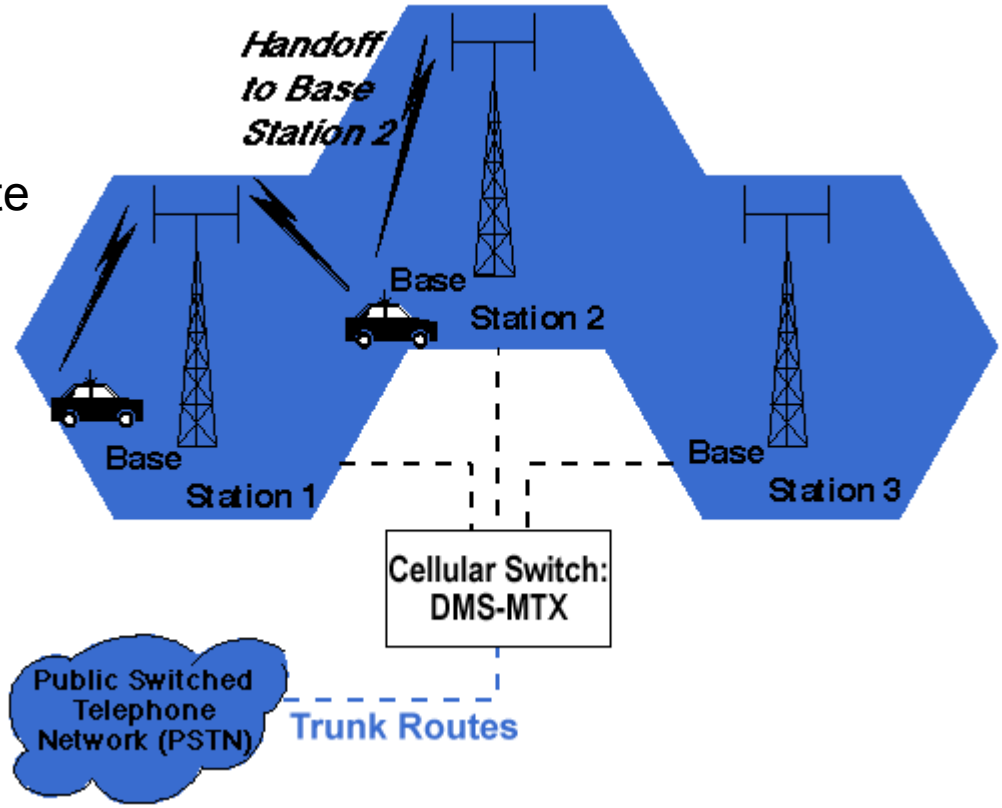
- mobile subscriber travels from one cell to another during a call
  - adjacent cells do not use the same radio channels
  - call must either
    - be dropped or
    - transferred

    from one radio channel to another when a user crosses cells
  - dropping the call is unacceptable
- hand-off (US, hand-over in UK)
  - mobile telephone network automatically transfers a call
  - from radio channel to radio channel, as a mobile crosses adjacent cells



Handoff Initiation

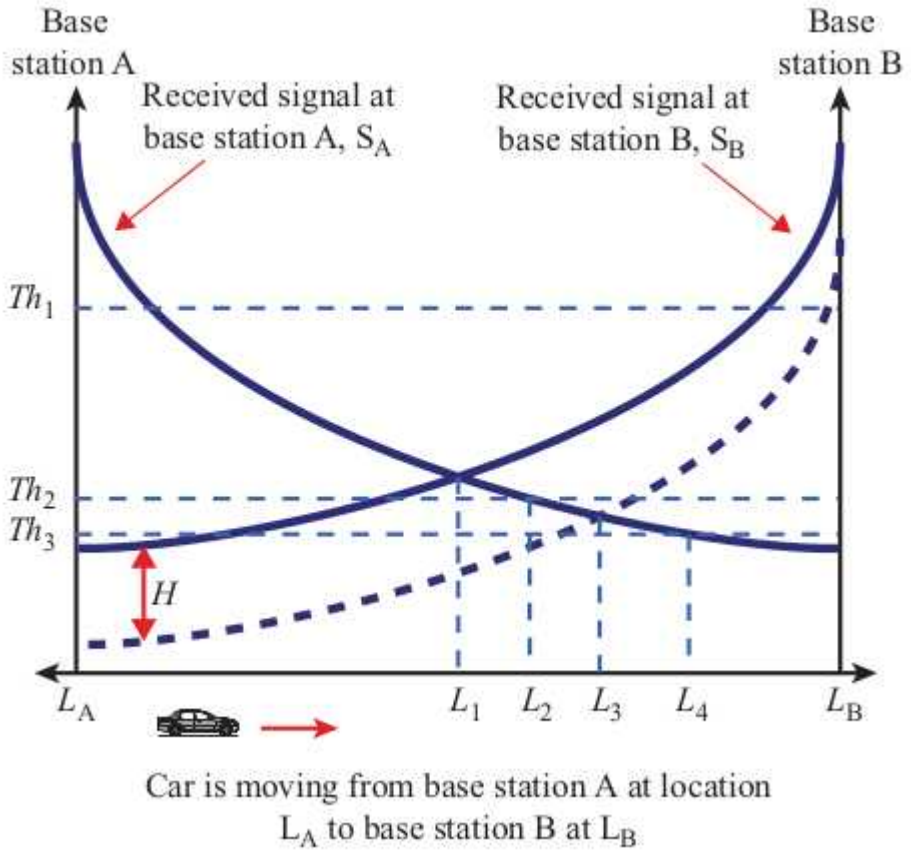
- when MS moves out of the coverage area of a given cell site
  - the reception becomes weak
  - the cell site (in use) or the MS requests a handoff
  - system switches the call to
    - a new site (and channel) with
    - a stronger signal
  - without interrupting the call or alerting the user
  - call continues as long as the user is talking, and the user does not notice the handoff at all



Handoff threshold

- Relative signal strength
  - What happens when car lives near the L1 area?
- W/ lower threshold
  - Avoid unnecessary handoffs
- W/ hysteresis
  - “Flapiness” / ping-pong

What about prediction?



Power control

- Sufficiently above noise, w/out interfering, wasting energy or frying birds..
  - Intra-user power equalization (at the BS) critical for CDMA. Why?
- Power changes based on distance or environment shifts (fading, m-path)
- **Open-loop PC**: solely at mobile unit, no feedback from the BS
  - BS continuously transmits an unmodulated signal, the *pilot*
  - Unit sets power inversely proportional to pilot's received power level
    - Introduces symmetrically correlated power control
    - Faster responsiveness
- **Closed-loop PC**: BS decides and communicates a power adjustment command to the mobile unit on a control channel.
  - Based on SNR, error rate of *reverse* channel
  - Unit can also send info to BS to update the power of the forward channel

Traffic engineering

- Why needed?
  - Not all subscribers are active at the same time
  - Not designed to have the capacity to handle any load at any time.
    - Akin to “physical” money
- Blocking system: user can be blocked due to BW scarcity
- Erlang unit: $A = \lambda H$ (in channels)
  - A = the mean rate of calls attempted per unit time
  - H = avg. service time
- Silver linning:
  - common practice is to size the system to meet the avg load of busy hours
    - Pick 10-30 most busy hours over a year
    - Mother’s day.. Other?

Handling blocked calls

- Opt 1: Reject call
- Opt 2: Delay call
  - Put it in a queue waiting for resources/free channel
- Various mixtures of the 2 options is orchestrated to deal with “annoying” users..
  - Delay in case a channel will be freed soon
  - Perhaps start with delaying and transition to rejecting after 3rd try in a row.

Συστήματα Κινητής Τηλεφωνίας 1ης Γενιάς

- 1st generation – Analog

Advanced Mobile Phone Service (AMPS) – 1983-2010

- Designed by Bell Labs and Motorolla
- two 25-MHz bands
  - 869–894 MHz: BS→unit / 824–849: unit→ BS
- Bands split into 2 for accommodating 2 operators (for competition)
- Each band has 416 full-duplex channels
  - 30kHz appart
  - 21 channels for control / 395 for traffic
  - ~10kbps
  - Traffic: FM modulation / Control: FSK modulation (DIGITAL)
  - Cell radius 2-20km

Επιστρέφουμε 2:10