Cellular Wireless Networks and GSM Architecture

S.M. Riazul Islam, PhD

Desirable Features

- More Capacity
- Less Power
- Larger Coverage

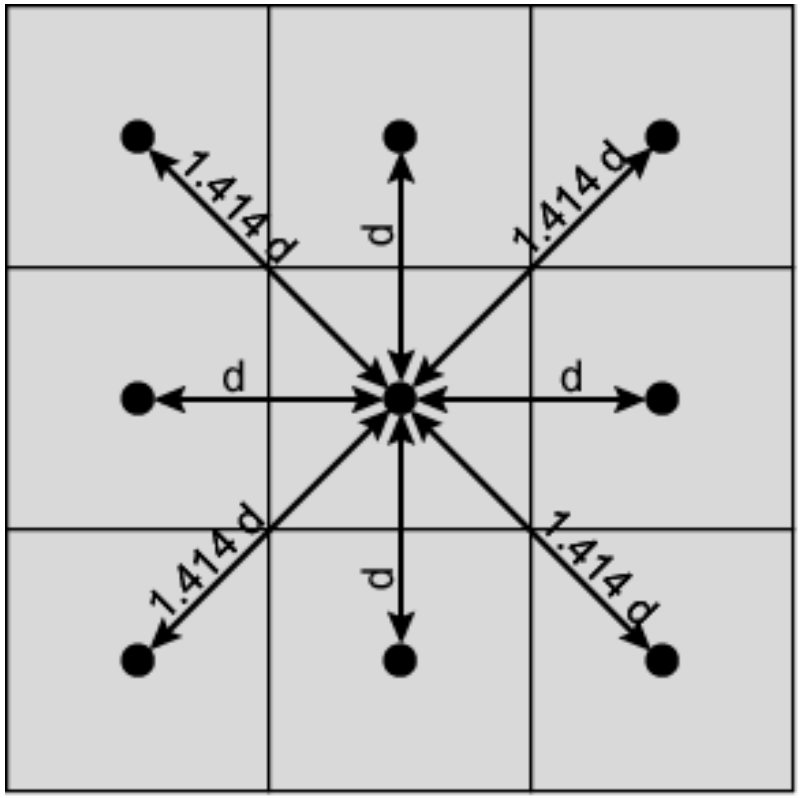
Cellular Network Organization

- 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

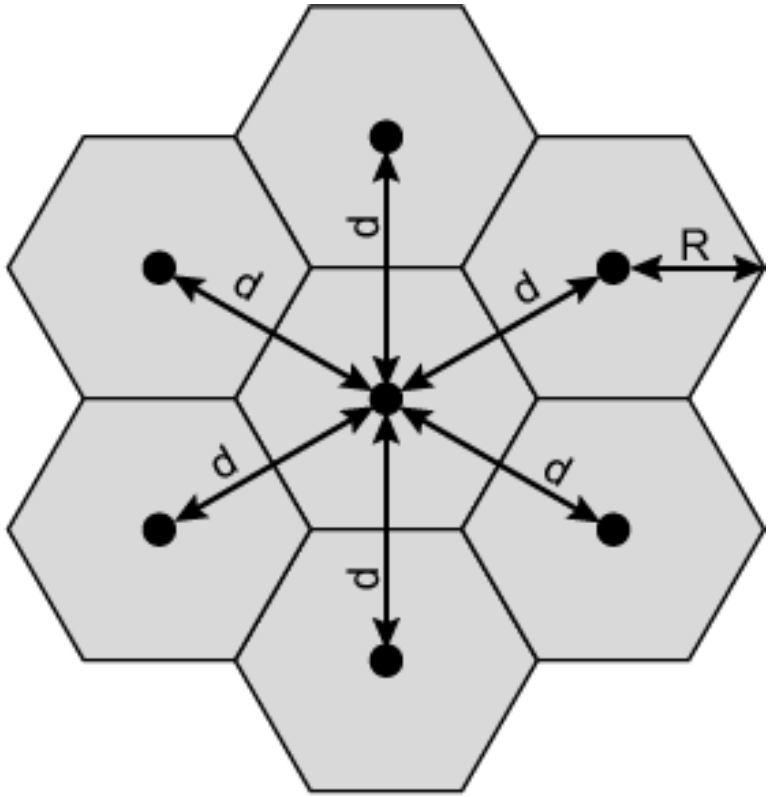
Shape of Cells

- 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 centre to vertex equals length of side
  - Distance between centres 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

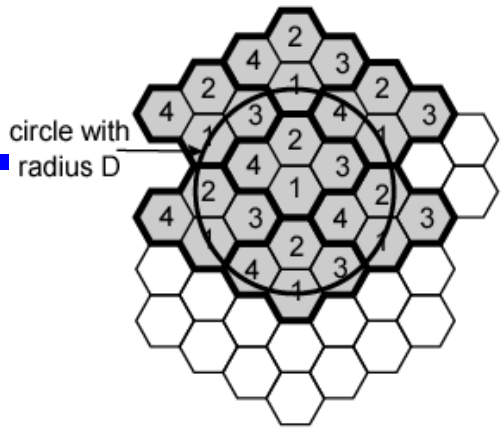
Frequency Reuse

- 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

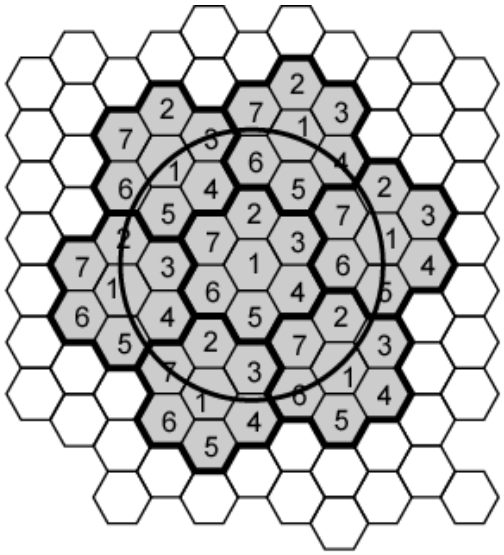
Characterizing Frequency Reuse

- D = minimum distance between centers of cells that use the same band of frequencies (called cochannels)
- 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, …
- $D/R = \sqrt{3N}$
- $D/d = \sqrt{N}$

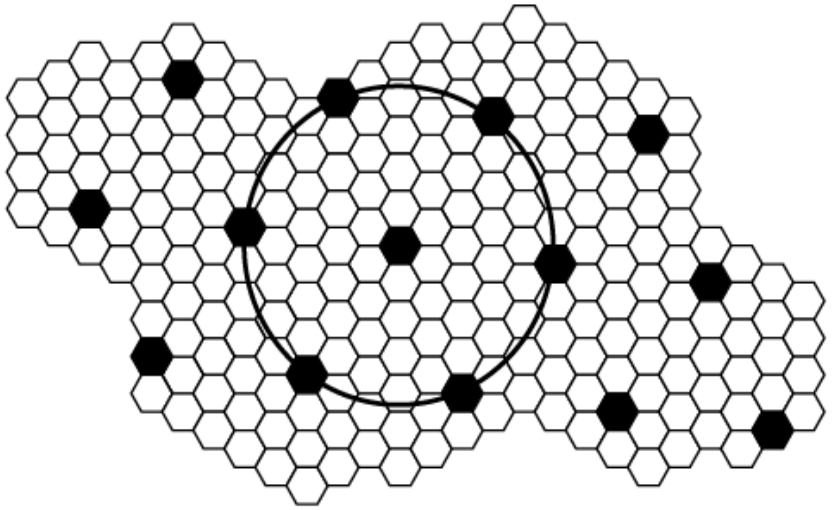
Frequency Reuse Patterns



(a) Frequency reuse pattern for N = 4



(b) Frequency reuse pattern for N = 7

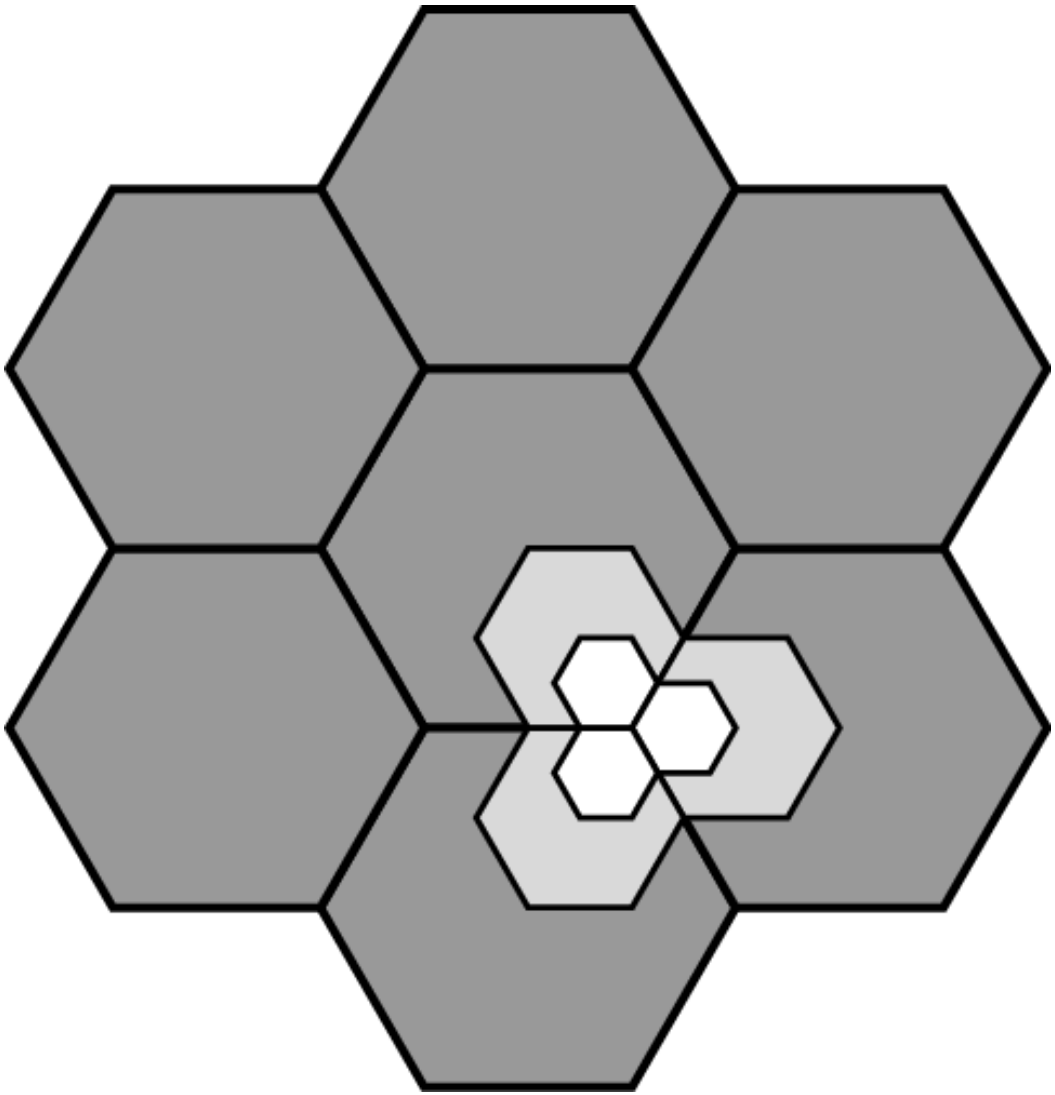


(c) Black cells indicate a frequency reuse for N = 19

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

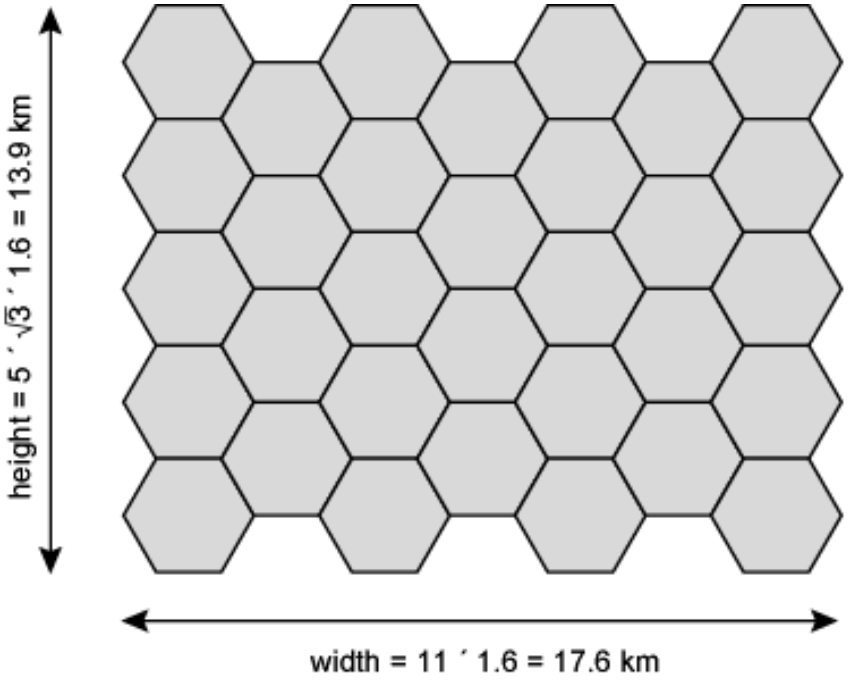
Cell Splitting



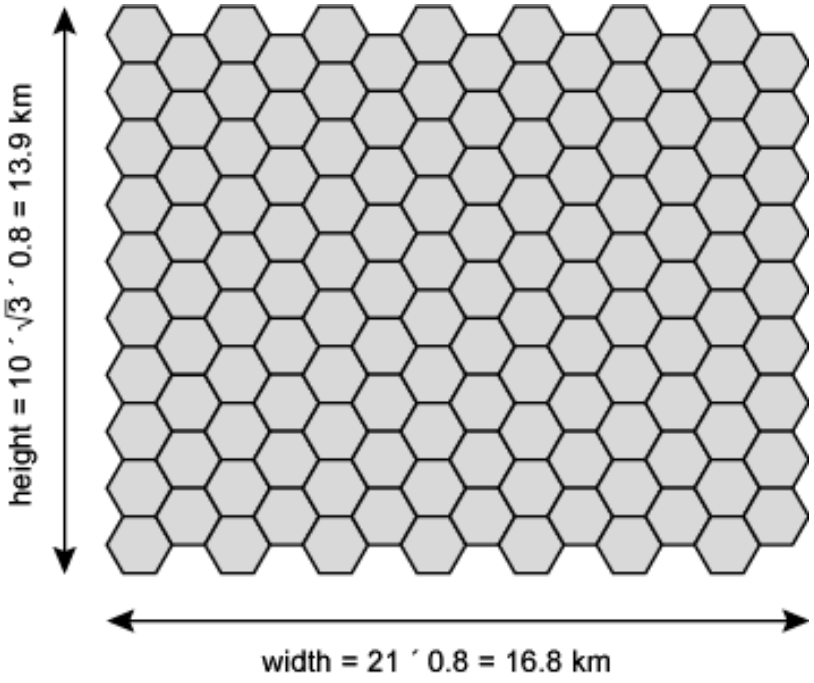
Increasing Capacity (2)

- 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 to 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

Frequency Reuse Example



(a) Cell radius = 1.6 km

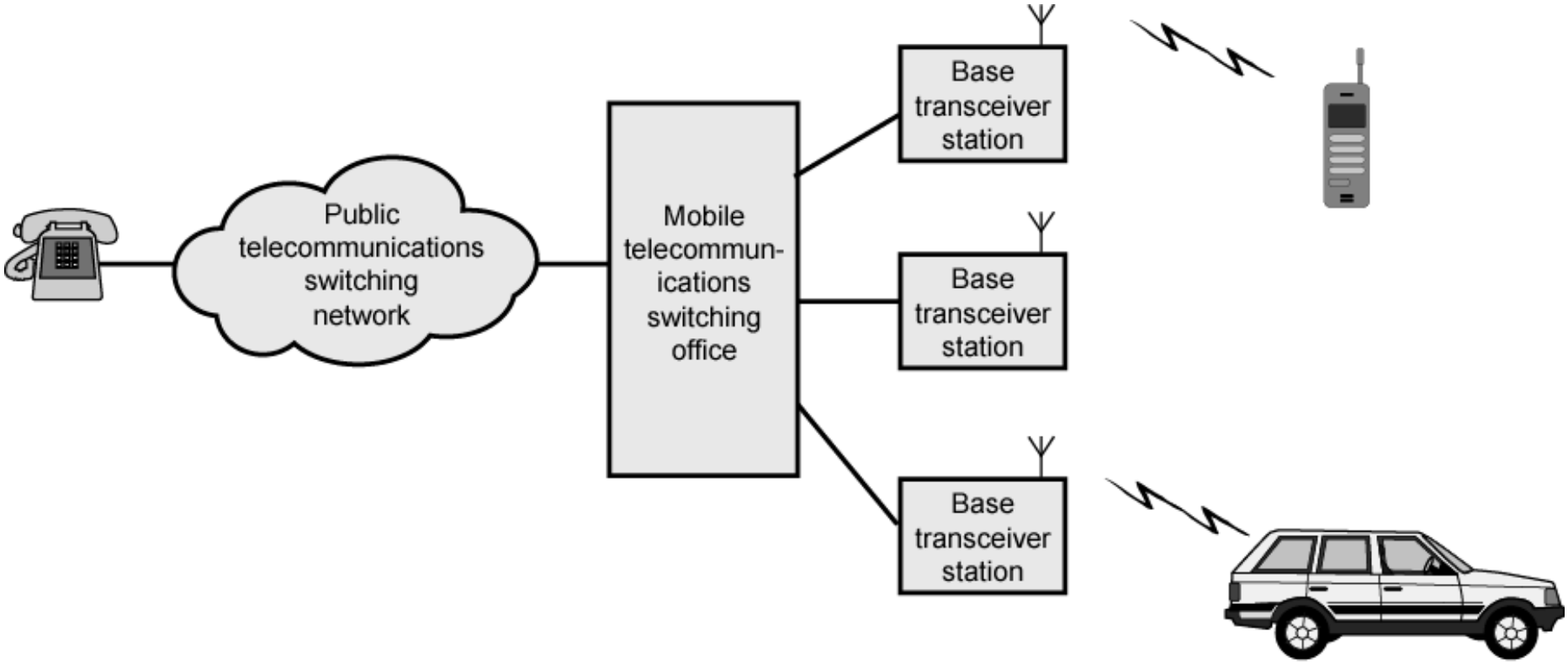


(b) Cell radius = 0.8 km

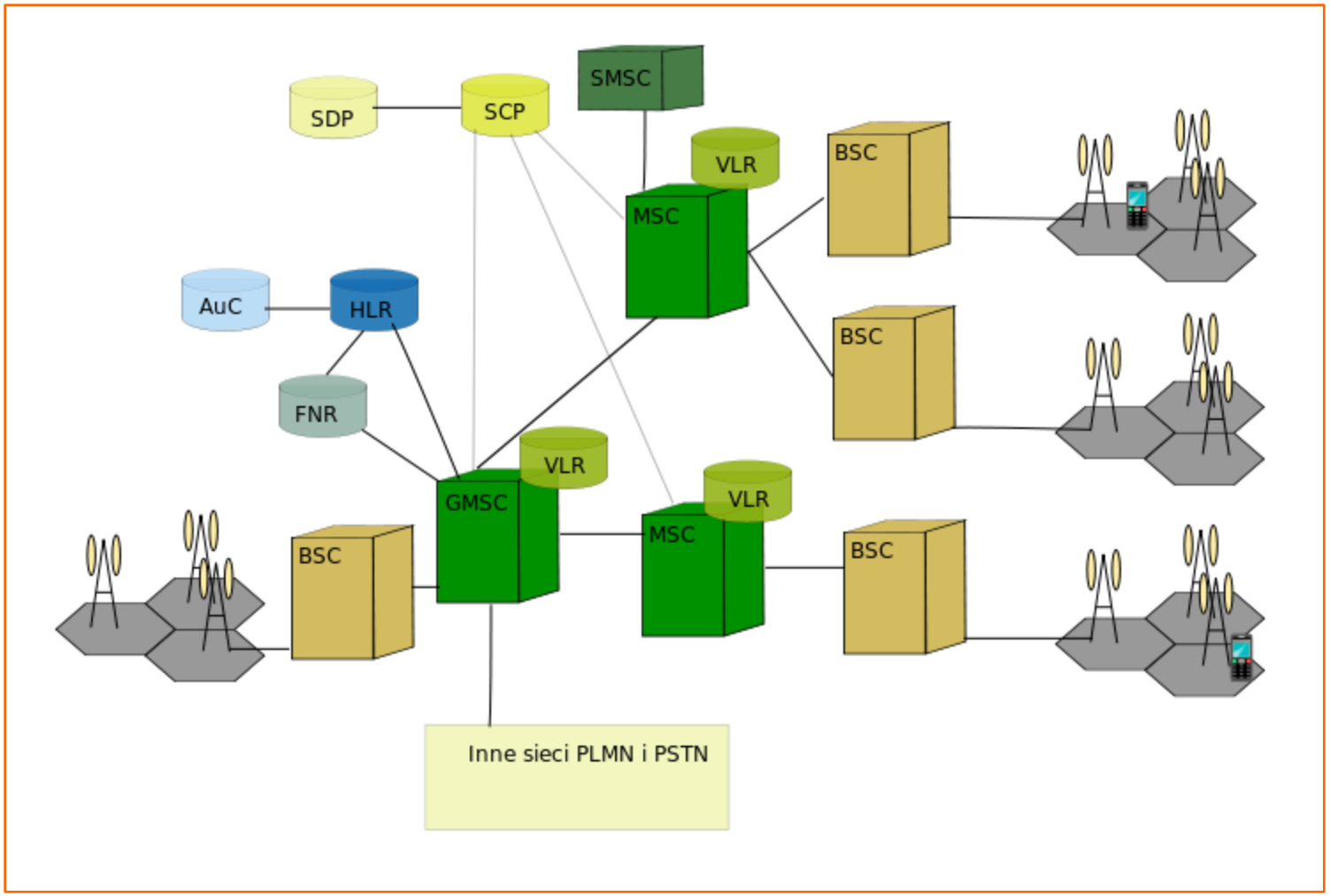
Operation of Cellular Systems

- 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)
- Fully automated

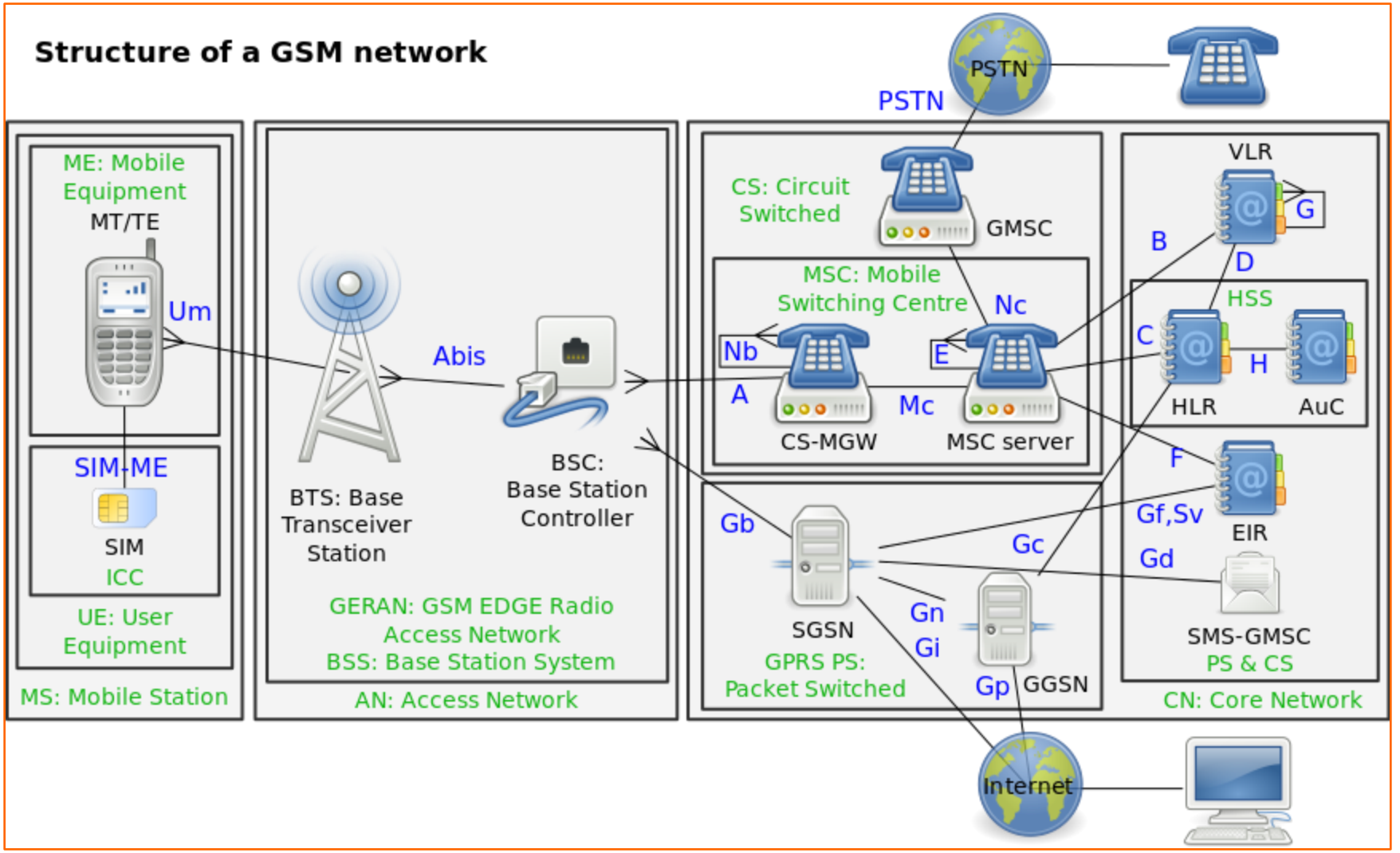
Overview of Cellular System



GSM Network Architecture



GSM Network Architecture



Channels and GSM Frequency Bands

- Control channels
  - Setting up and maintaining calls
  - Establish relationship between mobile unit and nearest BS
- Traffic channels
  - Carry voice and data

GSM-850	850	824.2–849.2	869.2–894.2	128–251	5
P-GSM-900	900	890.0–915.0	935.0–960.0	1–124	
E-GSM-900	900	880.0–915.0	925.0–960.0	975–1023, 0-124	8
R-GSM-900	900	876.0–915.0	921.0–960.0	955–1023, 0-124	
T-GSM-900	900	870.4–876.0	915.4–921.0	dynamic^	
DCS-1800	1800	1,710.2–1,784.8	1,805.2–1,879.8	512–885	3
PCS-1900	1900	1,850.2–1,909.8	1,930.2–1,989.8	512–810	2

- P-GSM, Standard or Primary GSM-900 Band
- E-GSM, Extended GSM-900 Band (includes Standard GSM-900 band)

Handoff Mechanism

Def: Process of transferring an ongoing call or data session from one channel connected to the core network to another channel

Hard Handoff: channel in the source cell is released and only then the channel in the target cell is engaged.

Soft Handoff: the channel in the source cell is retained and used for a while in parallel with the channel in the target cell