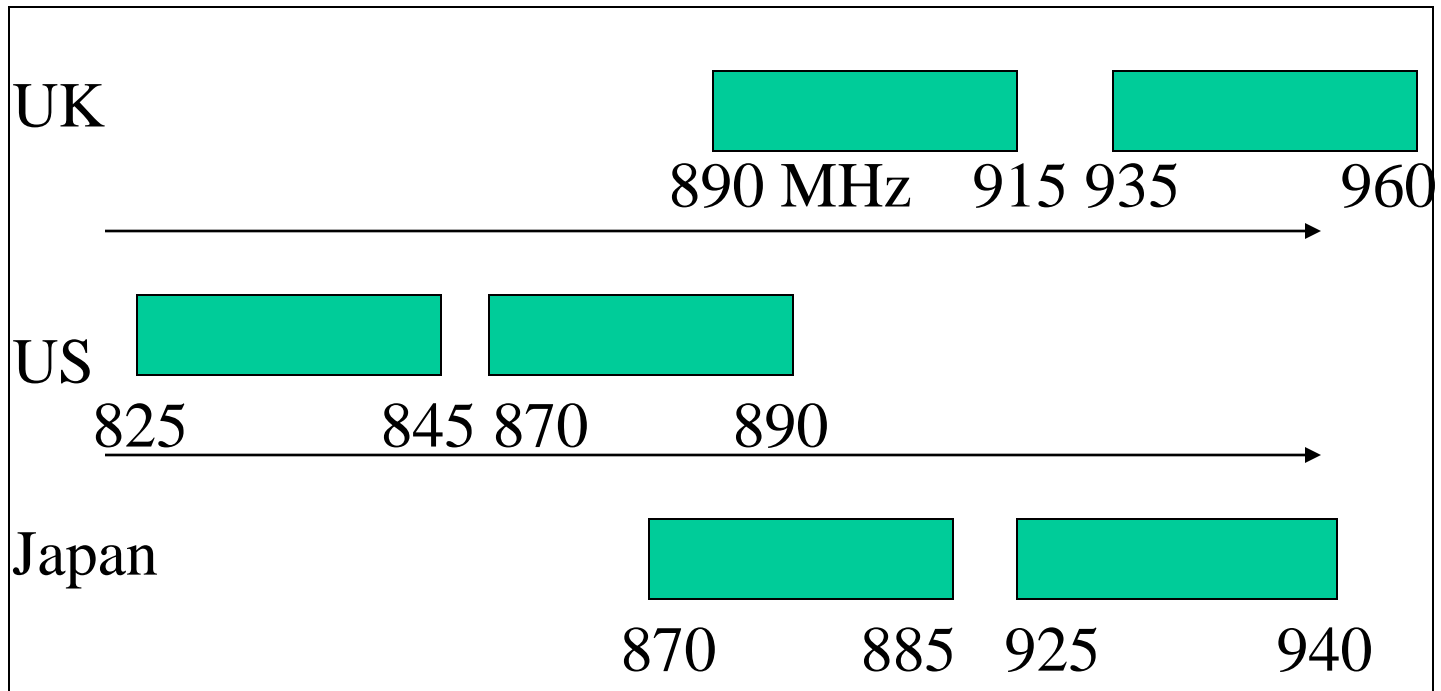
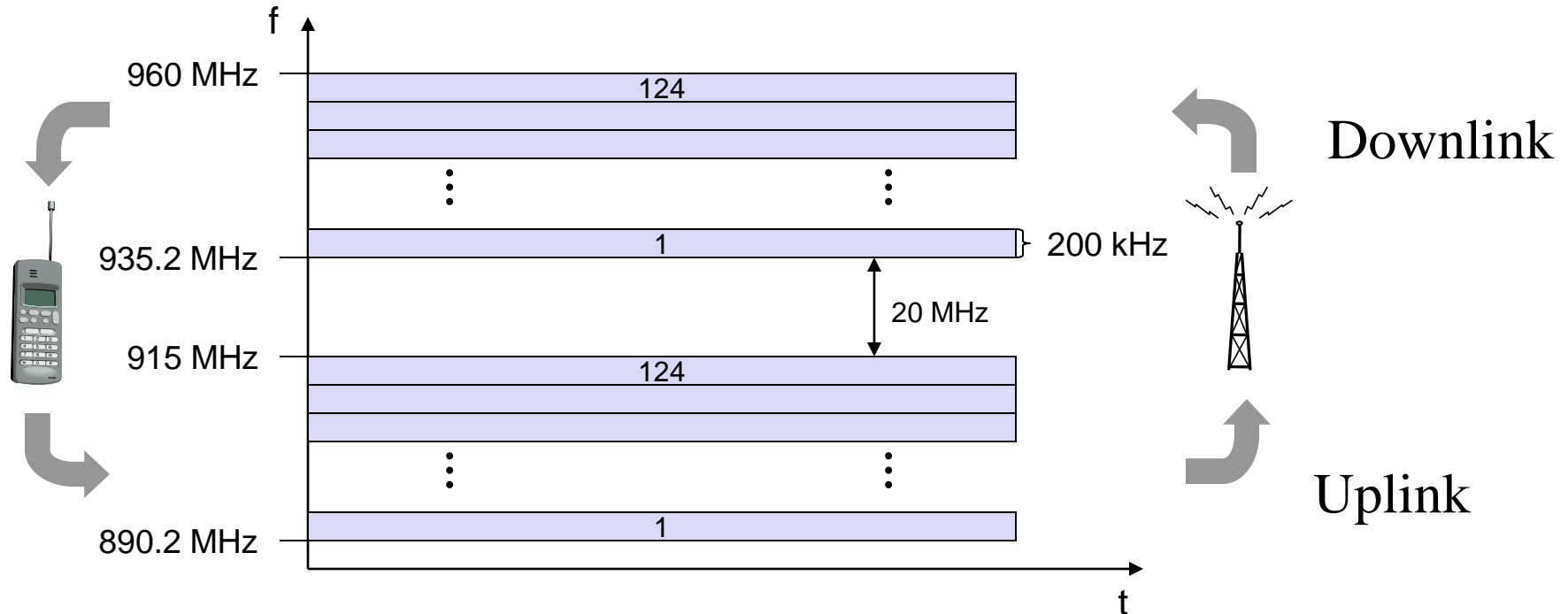


Cellular Concept

Frequency Assignments



Frequency usage in GSM at Europe



Bandwidth per channel is 200 kHz

Each user is assigned channel for an uplink and a downlink

So at most 124 simultaneous calls. Wow!

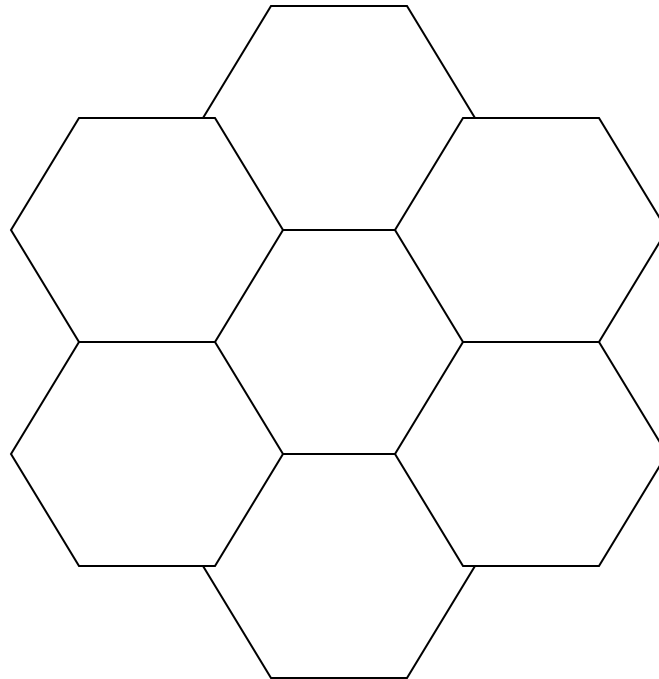
Goals

- Low power transmitter system
- Increase network capacity
- Frequency reuse
- Build robust scaleable system
- Architecture to deal with different user densities at different places

Idea!

- Partition the region into smaller regions called cells.
- Each cell gets at least one base station or tower
- Users within a cell talks to the tower
- How can we divide the region into cells?

“Cell”ular Structure



Properties of Cell structure

- Typical Cell sizes
 - some cities few hundred meters
 - country side few tens of kilometers
- Advantages of cell structures:
 - more capacity due to frequency reuse
 - less transmission power needed
 - more robust, tolerate failures
 - deals interference, transmission area locally
- Problems:
 - fixed network needed for the base stations
 - handover (changing from one cell to another) necessary
 - interference with other cells

Inside a cell

- Center-excited cell where the tower is placed somewhat near the center with a omni-directional antenna
- Edge-excited cell where the towers are placed on three of the six corners with sectored directional antennas.

Channels Reuse

- Cell structure can reuse frequency only when certain distance is maintained between cells that use the same channels.
- Fixed frequency assignment:
 - certain frequencies are assigned to a certain cell
 - problem: different traffic load in different cells
- Dynamic frequency assignment:
 - base station chooses frequencies depending on the frequencies already used in neighbor cells
 - more capacity in cells with more traffic
 - assignment can also be based on interference measurements

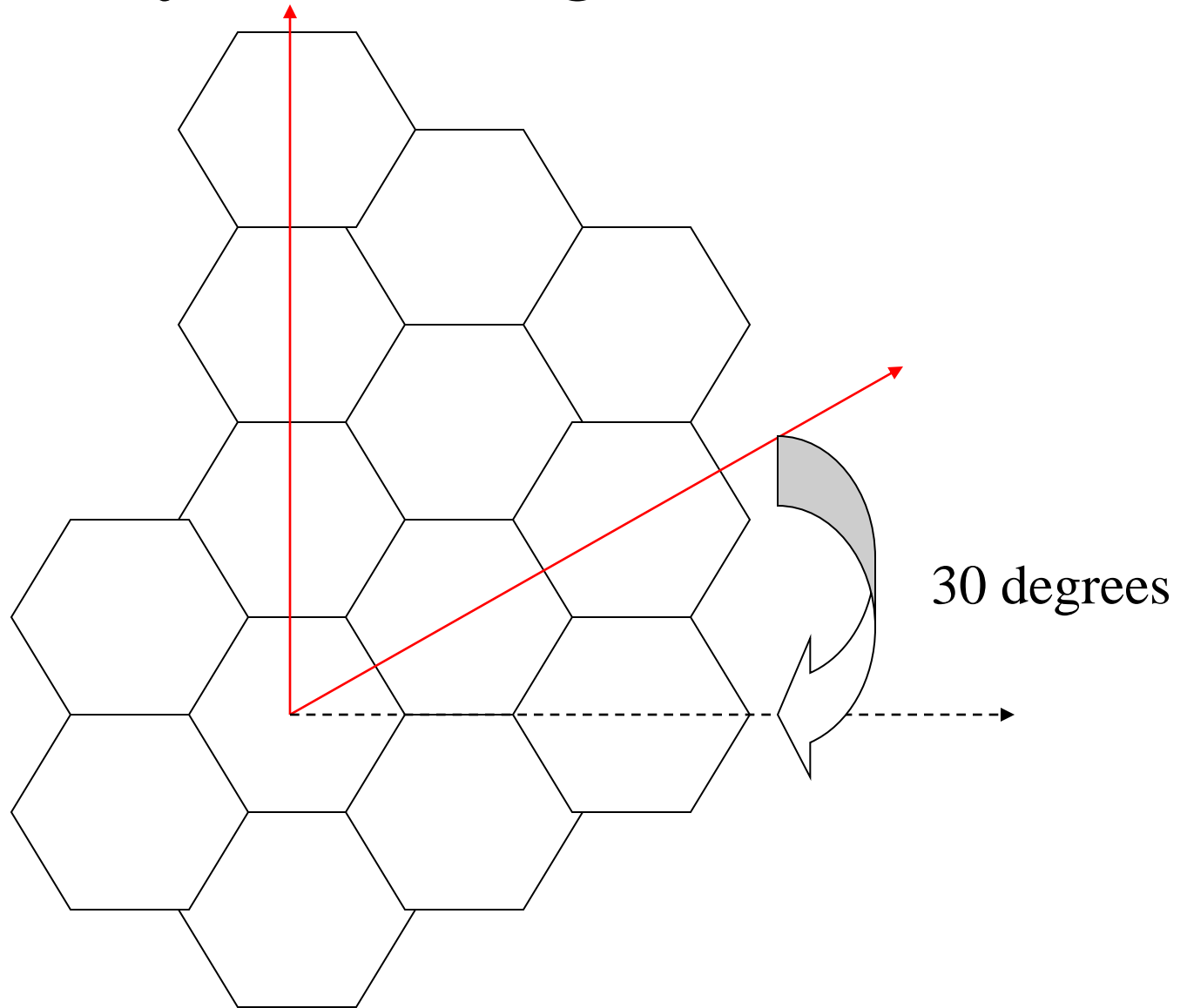
Interference

- Co-channel interference
 - Signals from cells that share a channel cause co-channel interference
 - Can't remove it by increasing power.
- Adjacent channel interference
 - Signals from adjacent cells cause this.
 - Use filter to reduce it
- But, available channels decrease for incoming calls.

Frequency reuse factor

- Total available channels = S
- N “adjacent” cells (called a cluster) share S channels
- System has M clusters
- Each cell gets k channels
 - $S = k N$
- Capacity of the system is $C = MkN$
- Frequency reuse factor is $1/ N$

Geometry of Hexagonal Cell



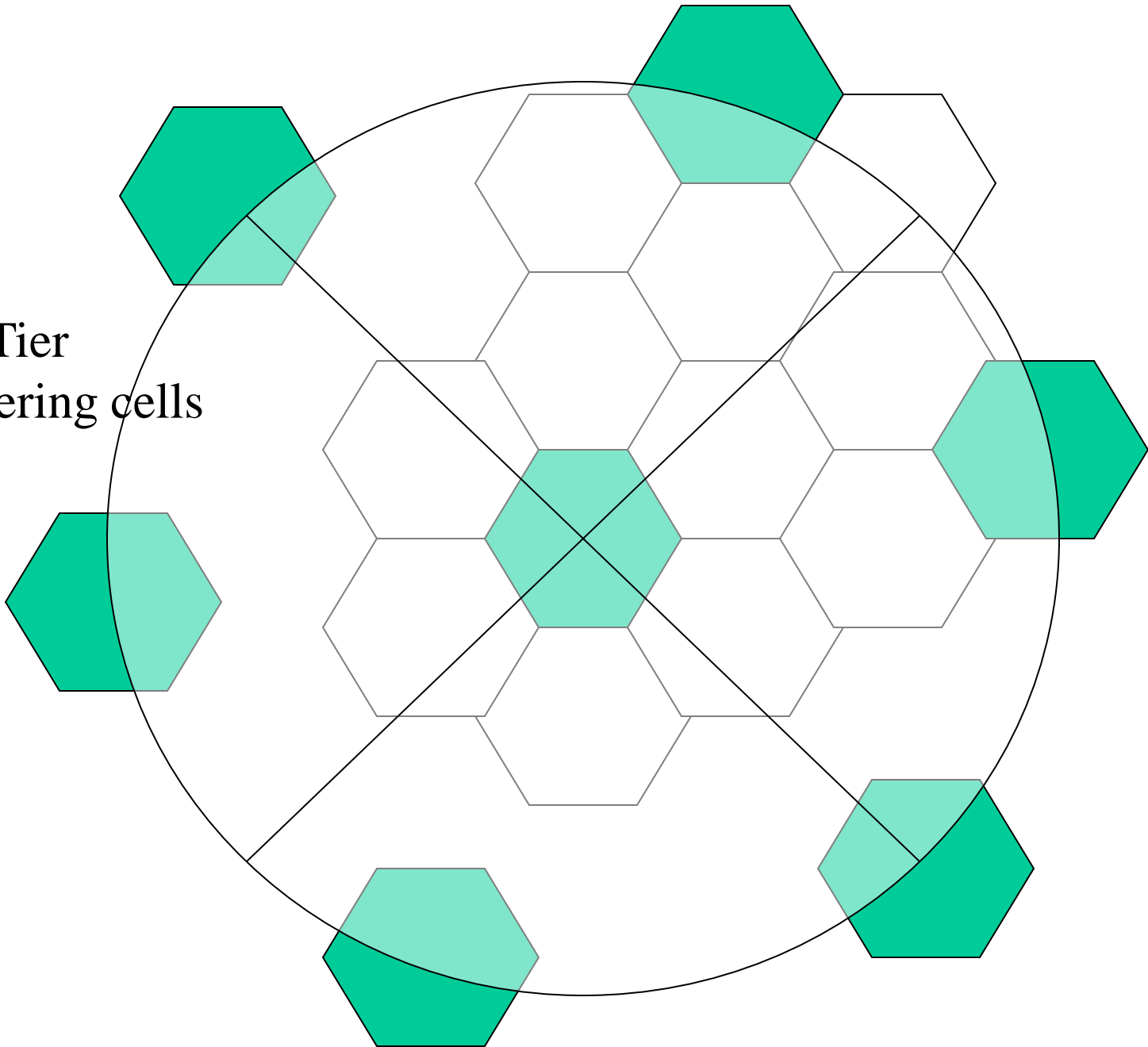
Distance calculation

- (u_1, v_1) and (u_2, v_2) are centers of two cells
- Distance D

$$\begin{aligned} D^2 &= [(u_2 - u_1)^2 (\cos 30)^2 + \\ &\quad \{ (v_2 - v_1) + (u_2 - u_1) \sin 30 \}^2] \\ &= [(u_2 - u_1)^2 + (v_2 - v_1)^2 + \\ &\quad (v_2 - v_1)(u_2 - u_1)] \\ &= [I^2 + J^2 + IJ] \text{ where} \\ &\quad (u_1, v_1) = (0, 0) \text{ and } (u_2, v_2) = (I, J) \end{aligned}$$

- Radius is R for a cell.
- Distance between adjacent cells is $1.732 R$

First Tier
Interfering cells



Co-channel interference

- It is a function of $q = D/R$ where R is the cell radius and D is the co-channel separation distance.
- Notice D is a function of n and S/I where n is the number of interfering channels in the first tier and S/I is signal to interference ratio.
- In a fully equipped hexagonal-shaped system n is always 6.

More Calculations

- $A(\text{large})/A(\text{small}) = D^2 / R^2$
- Because of the hexagonal shape the total number of cells included in first tier is

$$N + 6 (N/3) = 3N$$

- Therefore
 - $D^2/R^2 = 3N = 3(I^2+J^2+IJ)$

S/I ratio

- There are 6 interfering co-channels each gives $i = (D/R)^{-\gamma}$ where $2 \leq \gamma \leq 5$ and it is called propagation path-loss slope and depends upon the terrain. (choose 4!)
- $S/I = S/(6i)$
 - Experiment with actual users show that we need S/I to be at least 18 dB (or 63.1)

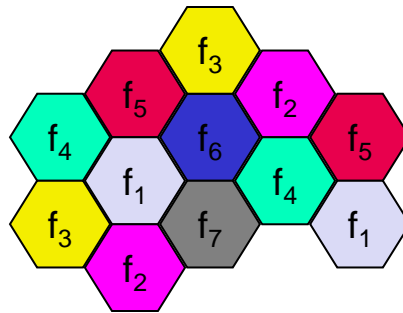
Substituting, we get $q = (6*63.1)^{0.25} = 4.41$

We then get $N = q^{2/3} = 6.49$ approximates to 7.

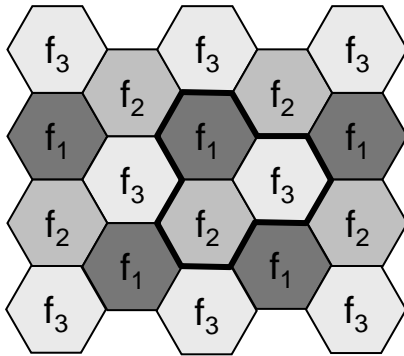
Cell reuse factor vs Mean S/I

Cell reuse factor N	$q = D/R$	Voice Channels per cell	Calls per Cell per Hour	Mean S/I dB
4	3.5	99	2610	14.0
7	4.6	56	1376	18.7
12	6.0	33	739	23.3

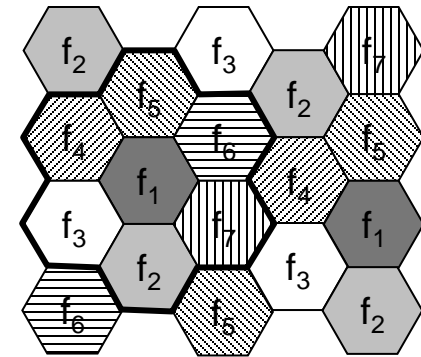
- Standard 7 cells sharing system ($N = 7$)



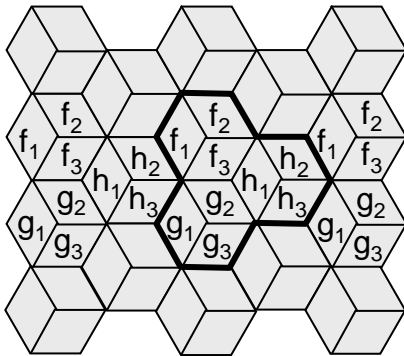
Other Common Channel Sharing



3 cell cluster



7 cell cluster



3 cell cluster
with 3 sector antennas

Handoff

- What happens when a user is mobile?
 - Especially when crossing a cell boundary while continuing the call.
- Handoff strategy is invoked.
 - Find a new base station
 - Process handoff
 - higher priority over new call invocation

Who and When

- Who initiates handoff
 - Network directed (tower determines)
 - Terminal assisted (user helps the tower)
 - Terminal directed (user determines)
- When to initiate handoff
 - When the mean signal (over some predetermined time) is below some threshold

Types of Handoff

- Hard handoff
 - Mobile user is passed between disjoint towers that assign different frequency or adapt different air-interface technology
- Soft handoff
 - Mobile user communicates to two towers simultaneously and the signal is treated as a multipath signal

High priority for Handoff

- Fraction of available channels is kept for handoff purpose. These channels are called guard channel.

Other problems with handoff

- High speed vehicles can cross many “small” cells in a short time.
 - Umbrella cell. Large cell with a powerful tower to handle high speed vehicles
- Another problem is called cell dragging.
 - Happens when the user moves slowly away from the cell and the tower didn't recognize it due to strong average signal.

Improving Capacity

- Sectoring
- Cell splitting
 - Process of subdividing a congested cell into smaller cells.
 - Each has its own base station
 - Smaller antenna and reduced transmission power
 - These smaller cells are called microcells

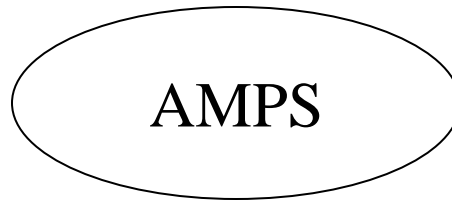
Generations

- 1G - First generation (Analog and FM)
- 2G - Second generation (Digital, TDMA, CDMA)
- 3G - Third generation (Multi-media)
- 4G - Fourth generation (?)

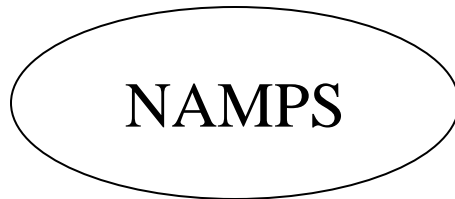
North American Systems

Generation

1st

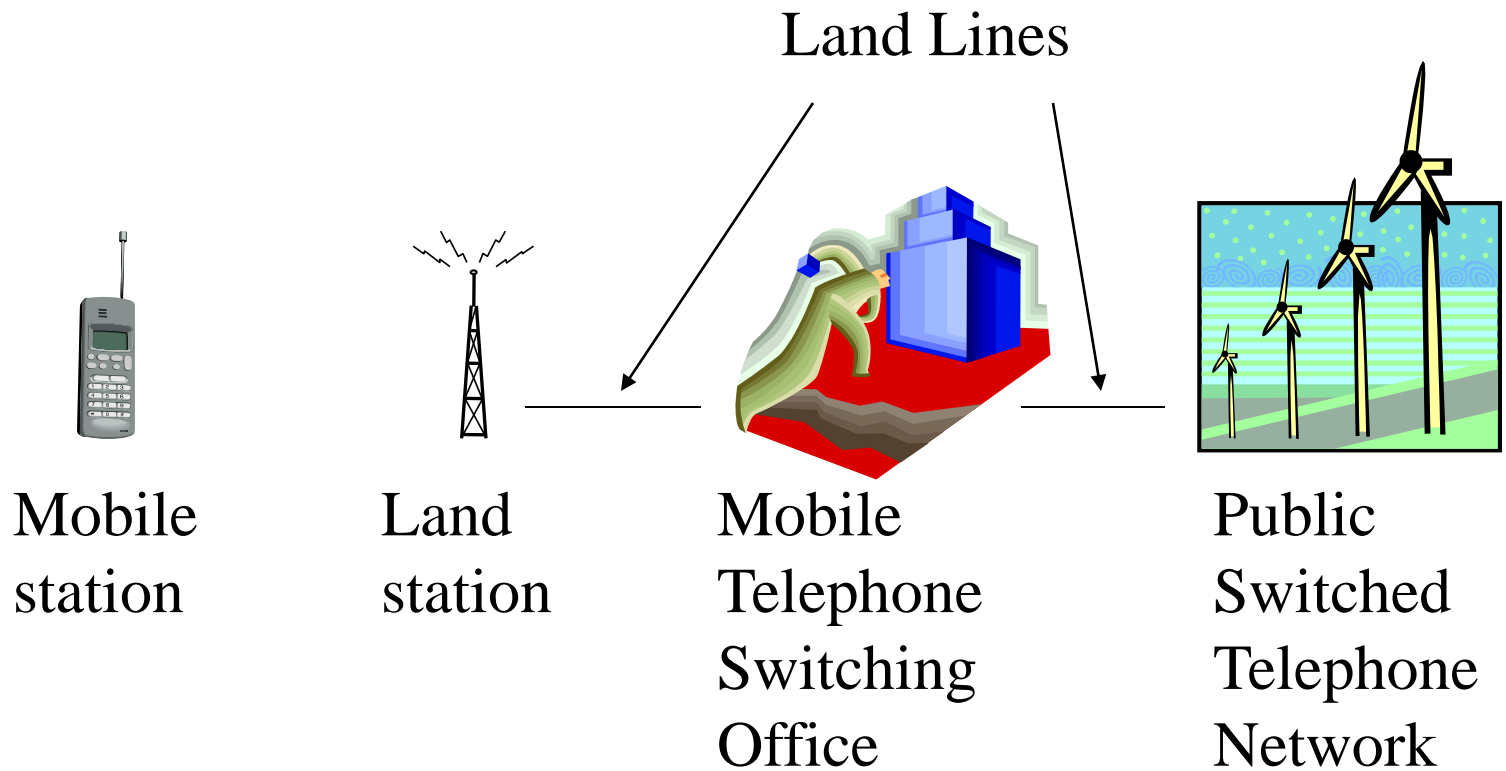


2nd



AMPS Architecture

- Advanced Mobile Phone System



Operation Frequency

- Original Spectrum (40 MHz)

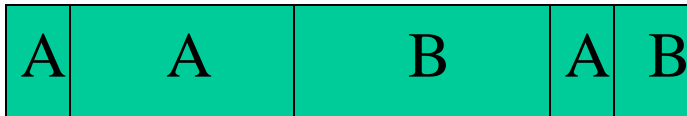


1

666



- Expanded Spectrum (additional 10 MHz)



832 Channels

Channel Allocation

- Each channel gets 30KHz.
- So a call takes two channels
 - Forward channel (tower to mobile)
 - Reverse channel (mobile to tower)
- Spectrum is divided into two bands
 - A and B bands
 - Two cellular operating licenses
 - Each authorized to use 416 channels (expanded)

Control Channels

- 42 channels (21 in each band) are called control channels
 - Carry only system information
 - Receiver tunes to the control channel
 - Use this channel to establish contact with tower and determine what channel to use for conversation.

Power Control

- AMPS terminal can transmit at 6 or 8 different power levels
 - Increase in steps of 4dB
 - Message from Base Station control the power level of active terminal
 - Typically power remains the same during a conversation
 - DTX (Discontinuous Transmission) where the power varies depending upon speech activity

AMPS Identifiers

Notation	Name	Size bits	Description
MIN	Mobile Identifier	34	Assigned by company to subscriber
ESN	Electronic serial no.	32	Assigned by manufacturer
SID	System identifier	15	Assigned by regulators to a geographical service area
SCM	Station class mark	4	Capability of a mobile station
SAT	Supervisory audio tone	*	Assigned by operating company to each BST
DCC	Digital color code	2	Same as above

Frequency Assignments

