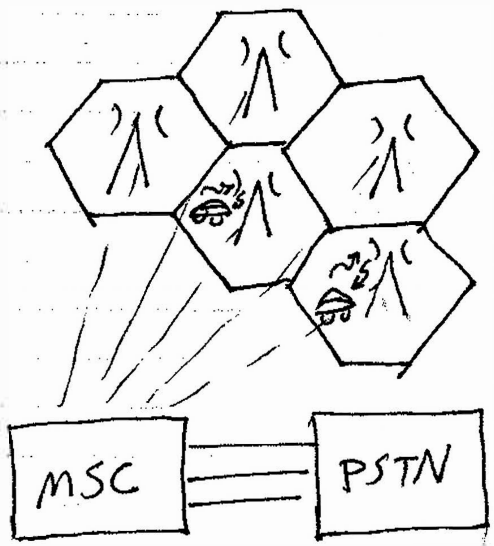
Lecture 2:

Elements of a Cellular System:

1) Mobile Terminal (MT) or Mobile Station (MS).

2) Base Station (BS): Consisting of several transceivers and antennas. There is one BS per cell.

3) Mobile Switching Center (MSC): MSC Coordinates the activities of the Base Stations. It also is responsible for connecting the cellular system to the Public Switched Telephone Network (PSTN).



The Communication between Base Stations and Mobile Terminals is defined by a Common Air Interface (CAI). The air interface varies from system to system and can be simpler or more sophisticated based on services provided. However, a basic CAI defines the following four types of channels:

FVC: Forward Voice (Traffic) Channel
This is the traffic channel from the BS to the Mobile Terminal. Forward channel is also called downlink or out-bound.

RVC: Return Voice (Traffic) Channel
from Mobile to BS, also called Uplink or in-bound.

FCC: Forward Control Channel

RCC: Return (Reverse) Control Channel.

While Traffice (Voice) Channels are used only when a call is in progress, Control Channels are used as long as the mobile unit is on.

On turning on the subscriber set, it scan FCCs to find the strongest signal (the closest BS) and starts tracking it until the power falls below certain level, then it rescan and switch to the strongest signal.

After locking onto a BS, MT sends its MIN (mobile identification number) and its ESN (Electronic Serial Number) to the BS.

- BS sends MT's MIN and ESN to the MSC. MSC checks its HLR (Home Location Register) and if the user is in HLR accepts it. If a mobile is roaming, then it send its own MSC's Station ID (SID) to the visited BS (who sends it to the visited MSC). Visited MSC, contacts the home MSC and if the ESN and MIN are authenticated by the home MSC Then the visted MSC ~~puts~~ includes the mobile in its VLR (Visitor Location Register). From then on each time user turns on its set. Its ESN and MIN are compared against entries in VLR.

~~(after not being found~~

Making a call from PSTN to mobile.

- MSC receives a call from PSTN for a given user (a given MIN).
- MSC sends a request to all BS's
- MIN is sent over all FCCs.
- Mobile sends an acknowledgement to the BS that it is tracking.
- BS sends ack. to MSC.
- MSC asks BS to give the MT a pair of VC's.
- BS asks mobile to move to a pair of FVC and RVC.

A call initiated by a mobile:

- Mobile sends its MIN, ESN and Tel. # of the called party plus SCM (Station Class Mark) which is its max. power level.
- BS sends these information to MSC.
- MSC validates the request.
- MSC makes dialing through PSTN.
- when MSC is connected to the called party, it instructs the BS to give mobile a pair of (FVC & RVC) to start communication.

Cellular Concept:

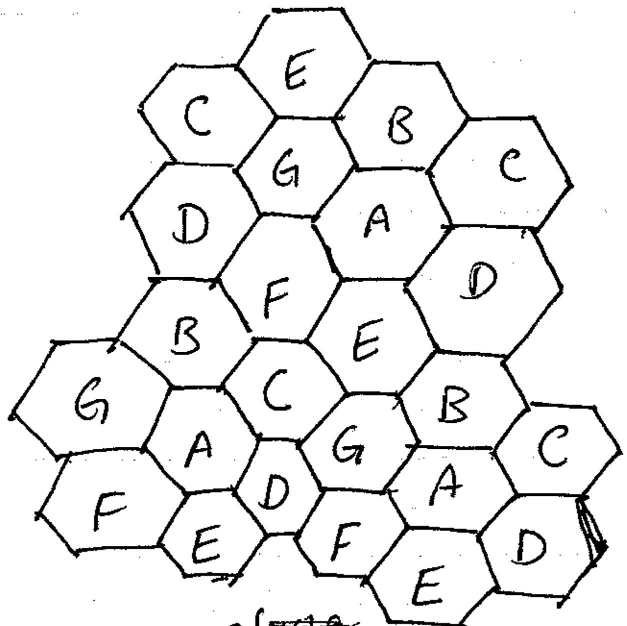
The main idea behind the cellular system is frequency reuse (or in general resource reuse):

- Each base station (assigned to one cell) is given a set of: frequencies (in FDMA) codes (in CDMA) and channels or time slots (in TDMA).
- As the band become congested, i.e., the number of users in a cell become larger than what the assigned resources (e.g., frequencies)

can support, one may reduce the size of the cells (to increase the number of cells) to increase frequency (resource) reuse.

<u>Hexagonal</u> <u>Tesselation</u>

An example $N=7$ or 7 cell reuse:



If the total number of channels ~~assigned to a cell~~ ~~cluster~~ is S and the frequency re-use is N-cell, then the number of channels/cell is $k = \frac{S}{N}$ or $S = kN$ and total capacity of the system (Network) is

$$C = MkN = MS$$

where M is the number of times a cluster is repeated. The smaller the size of a cell the larger $M \Rightarrow$ the larger would be the capacity.

Frequency re-use factor $\eta = \frac{1}{N}$

~~Also~~ making N smaller also results in higher capacity, but increases interference.

With hexagonal cells:

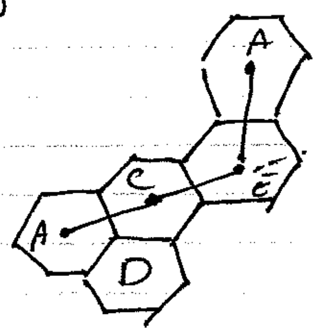
$$N = i^2 + ij + j^2$$

e.g., $i = 2$, $j = 1$ $\Rightarrow N = 7$.

to go from one cell to its co-channel cell:

1) Move i cells along any chain of hexagons.

2) turn 60° counter clockwise and move j cells.



example of $i=2, j=1, N=7$.

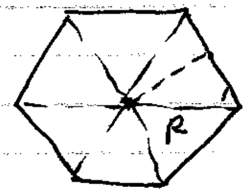
Example: A total of 33 MHz. is allocated to a particular FDD cellular system that uses 25 kHz. simplex channels to provide full-duplex voice. Find the number of channels per cell if N = 7. Assume that the coverage area is 10,000 km^2 and the cell radius is 5 km. Find the capacity of the system. Find the capacity if the cell radiuse is reduced to 2 km.

Solution:

a) Total number of channels $S = \frac{33000}{2 \times 25} = 660$

$$k = \frac{S}{N} = \frac{660}{7} \cong 95 \text{ Channels/cell}$$

b)



~~$A = 6(R\cos 60)(R\sin 60)/2 = 2\frac{\sqrt{3}}{2} \times \frac{1}{2} \times R^2 \times \frac{6}{2}$~~

$$A = 6\,R(R\sin 60)/2 = 6\,\frac{R^2\sqrt{3}/2}{2} = 3/2\sqrt{3}\,R^2$$

$$A = 2.5981\,R^2$$

$R = 5 \Rightarrow A = 64.95 \Rightarrow$ # of Cells $= \frac{10{,}000}{A} = 154$

$C = 154 * 95 = 14{,}630$ ch

c) $R = 2 \Rightarrow A = 10.39 \Rightarrow$ # of cells $= \frac{10000}{10.39} = 962$

$C = 962 \times 95 = 91{,}390$

Channel Assignment:

Fixed each cell has a fixed set of channels. If a mobile in a cell need a channel, when all channels are assigned then the call is blocked.

Borrowing: Under the supervision of the MSC a cell may borrow a channel from a neighboring cell when it has used all its channels.

Dynamic: Channels are not assigned permentently to cells, but are under the control of the MSC. MSC uses an algorithm to assign channels. This algorithm tries to reduce blocking probability and ensures that the given channel (frequency) is not used in a nearby cell.

Dynamic channel allocation reduces blocking capacity and increases the trunking capacity.

tL..1 ≈ 10 sec.

Handoff:

When a mobile moves from one cell to another cell, it should switch to the new BS. This process is called handoff. It is done based one the power received at base station.

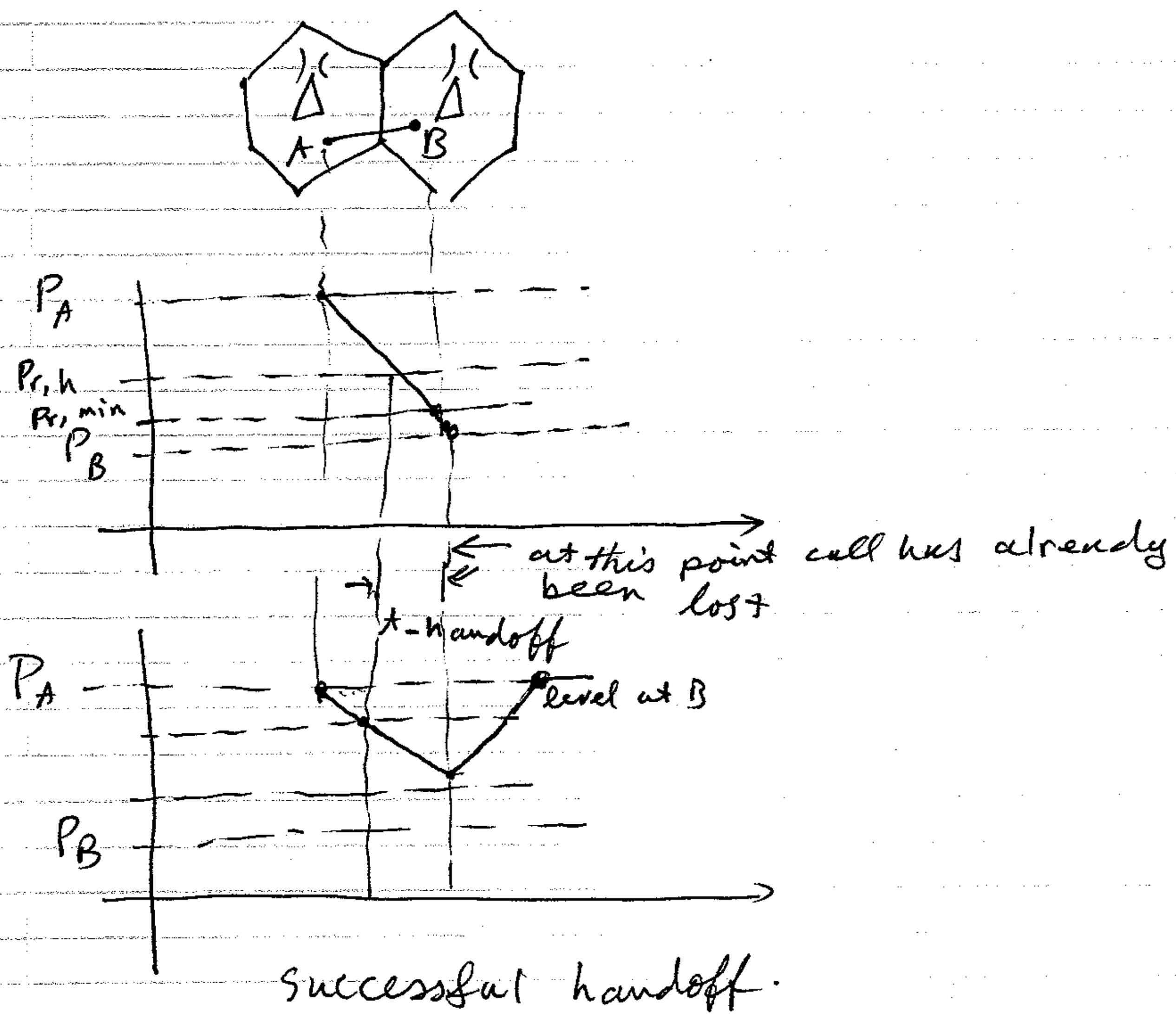
When the power falls below a certain level, current BS informs the MSC and MSC instructs the new BS to accep the mobile (to assign to it two new channels: FVC and RVC) and move the call to these new frequencies (channels).

This takes time depending on the way the handoff is implemented. So, the process of handoff should start when the signal power is still above the outage power. There should be a margin $\Delta = P_{r,handoff} - P_{r,min}$ between the $P_{r,handoff}$ (power at which handoff is initiated) and min useable power $P_{r,min}$.

~~If~~ in analog systems Δ is 6 to 12 dB and $P_{r,min}$ is -90 dBm to -100 dBm.

In digital systems handoff is made much faster Δ is very small ≃ 0

- If Δ is too large, there are two many unnecessary handoffs
- If Δ is too large : calls get lost



Successful handoff.

Mobile Assisted Handoff (MAHO) in TDMA systems:

Mobile keep track of Power received from Base Stations and report it to current BS. Handoff is initiated When power from a neighboring BS exceeds that of current BS.

in this case $\Delta t_{h-o} \simeq 1$ to 2 sec.

and Δ is between 0 and 6 dB.

- <u>Prioritizing handoffs</u>
- Guard channels.
- Queuing of handoffs.

} are use to avoid losing a call in progress as it is more annoying to lose a call than not being admitted.