Sri SAI RAM ENGINEERING COLLEGE
INSTITUTE OF TECHNOLOGY
West Tambaram, Chennai - 44

Sairam INSTITUTIONS

SAIRAM DIGITAL RESOURCES

YEAR II SEM III

EC8394

ANALOG AND DIGITAL COMMUNICATION

UNIT NO 5 MULTI-USER RADIO COMMUNICATION

TOPIC:CELLULAR CONCEPT AND FREQUENCY REUSE

ELECTRONICS & COMMUNICATION ENGINEERING

4 QUALITY EDUCATION

NBA NATIONAL BOARD OF ACCREDITATION | NAAC A+ | nirf NATIONAL INSTITUTIONAL RANKING FRAMEWORK | BUREAU VERITAS Certification


Cellular
Systems

Introduction

✔ Basic cellular system

- Consist of mobile stations, base stations, and a mobile switching center (MSC).
- Mobile switching center (MSC)
- Sometimes called a mobile telephone switching office (MTSO)
  - Coordinates the activities of all of the base stations
  - Connect the entire cellular system to the PSTN.
  - Accommodates all billing and system maintenance functions.
- Each mobile communicates via radio with one of the base stations and may be handedoff to any number of base stations throughout the duration of a call.
- Mobile station - Contains a transceiver, an antenna, and control circuitry.
- Base stations - Serve as a bridge between all mobile users in the cell and connects the simultaneous mobile calls via telephone lines or microwave links to the MSC

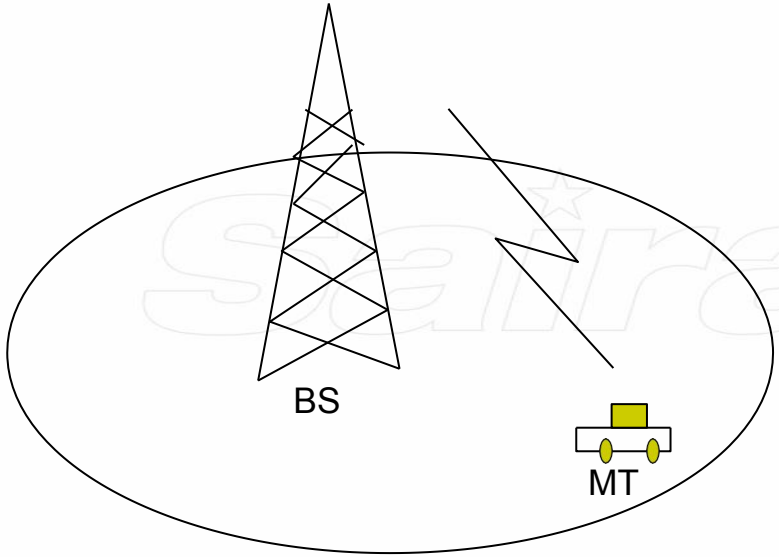
Introduction

- Goals of a Cellular System
  - High capacity
  - Large coverage area
  - Efficient use of limited spectrum

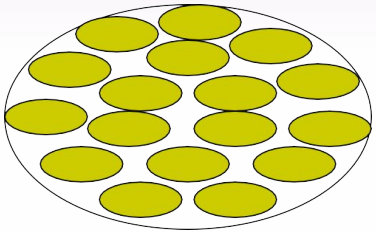
- Large coverage area - Bell system in New York City had early mobile radio
  - Single Tx, high power, and tall tower
  - Low cost
  - Large coverage area - Bell system in New York City had 12 simultaneous channels for 1000 square miles
  - Small number of users
  - Poor spectrum utilization

- What are possible ways we could increase the number of channels available in a cellular system?

Early mobile radio systems



Cellular concept



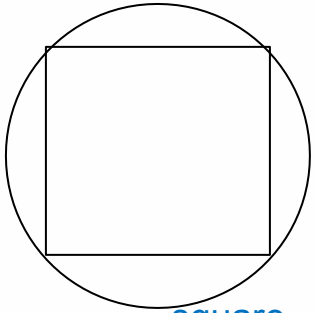
- ✔ A service area is split into small geographic areas, called cells.
- ✔ Each cellular base station is allocated a group of radio channels.
- ✔ Base stations in adjacent cells are assigned different channel groups.
- ✔ By limiting the coverage area of a base station, the same group of channels may be reused by different cells far away.

Cellular concept

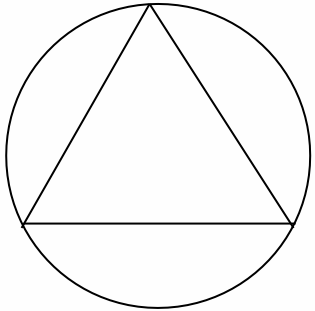
Cell Shapes

- Geometric shapes covering an entire region without overlap and with equal area.

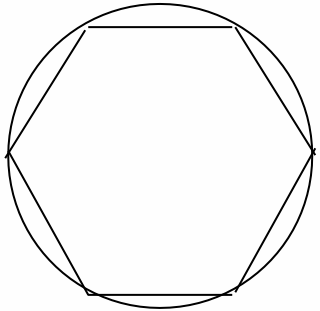
- By using the hexagon, the fewest number of cells can cover a geographic region, and the hexagon closely approximates a circular radiation pattern which would occur for an omni-directional antenna



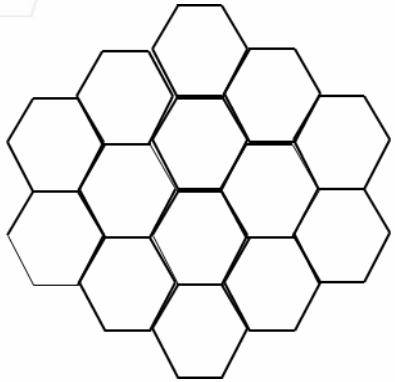
square



equilateral triangle



hexagon



- ✔ hexagonal cell shape assumed for planning
  - simple model for easy analysis → circles leave gaps
  - actual cell "footprint" is amorphous (no specific shape)
    - where Tx successfully serves mobile unit

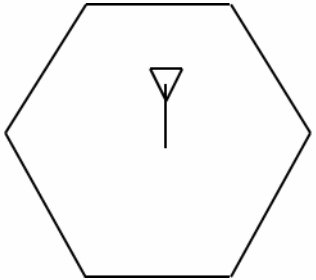
- ✔ Based on base station location: 2 types

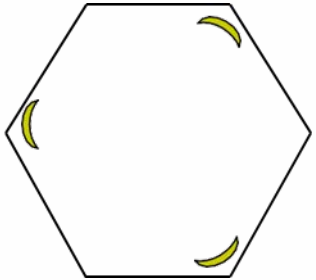
1. Center-excited cell

- Base station transmitter is in the center of the cell.
- Omni-directional antennas are used
- cell center → omni-directional antenna (360° coverage) not necessarily in the exact center (can be up to *R/4* from the ideal location)

2. Edge-excited cell

- Base station transmitters are on three of the six cell vertices.
- Sectored directional antennas are used.
  - cell corners → sectored or directional antennas on 3 corners with 120° coverage.
    - Note that what is defined as a “corner” is somewhat flexible → a sectored antenna covers 120° of a hexagonal cell.
    - So one can define a cell as having three antennas in the center or antennas at 3 corners.





Frequency Reuse/Planning

- The design process of selecting and allocating channel groups for all base stations within a system.
- Two competing/conflicting objectives:
  - maximize frequency reuse in specified area
  - minimize interference between cells

Frequency reuse Concept

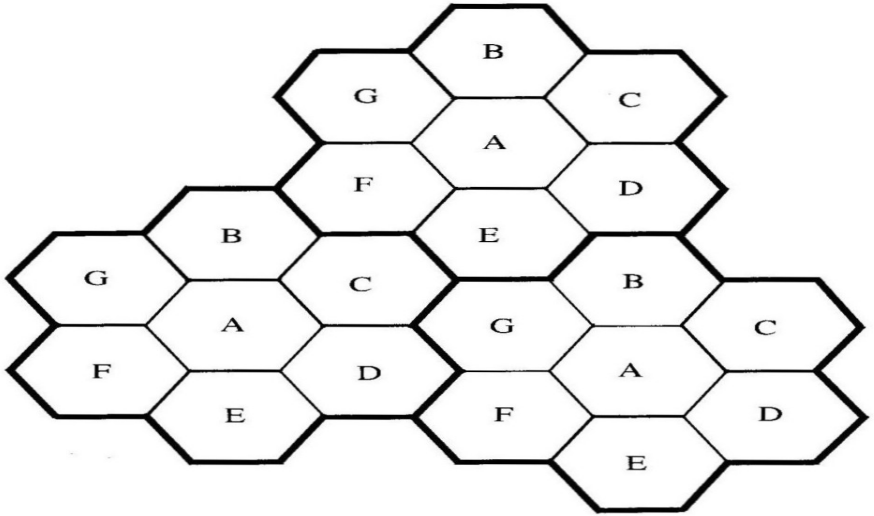


Figure 3.1 Illustration of the cellular frequency reuse concept. Cells with the same letter use the same set of frequencies. A cell cluster is outlined in bold and replicated over the coverage area. In this example, the cluster size, *N*, is equal to seven, and the frequency reuse factor is 1/7 since each cell contains one-seventh of the total number of available channels.

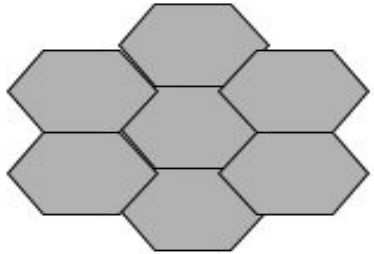
- Cells labeled with the same letter use the same group of channels.
- Cell Cluster: group of *N* cells using complete set of available channels
- Many base stations, lower power, and shorter tower
- Small coverage areas called “cells”
- Each cell allocated a percentage of the total number of available channels
- Nearby (adjacent) cells assigned different channel groups
  - to prevent interference between neighboring base stations and mobile users

- Same frequency channels may be reused by cells a “reasonable” distance away
  - reused many times as long as interference between same channel (co-channel) cells is < acceptable level
- As frequency reuse↑ → no. of possible simultaneous users↑→ no. of subscribers ↑→ but system cost ↑ (more towers)
- To increase number of users without increasing radio frequency allocation, reduce cell sizes (more base stations) ↑ → no. of possible simultaneous users ↑
- The cellular concept allows all mobiles to be manufactured to use the same set of freqencies

- A fixed number of channels serves a large no. of users by reusing channels in a coverage area

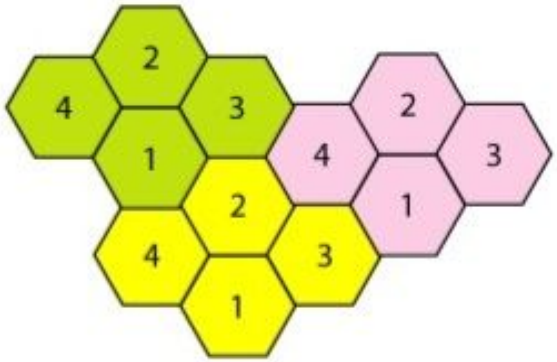
Frequency Reuse

- each cell allocated a group k channels
  - a cluster has N cells with unique and disjoint channel
- groups, N typically 4, 7, 12
- total number of duplex channels S = kN
- Cluster repeated M times in a system
- Total number of channels that can be used (capacity)
  - C = MkN = MS
- Smaller cells ➔ higher M ➔ higher C
  - + Channel reuse ➔ higher capacity
  - + Lower power requirements for mobiles
  - – Additional base stations required
  - – More frequent handoffs
  - – Greater chance of 'hot spots'

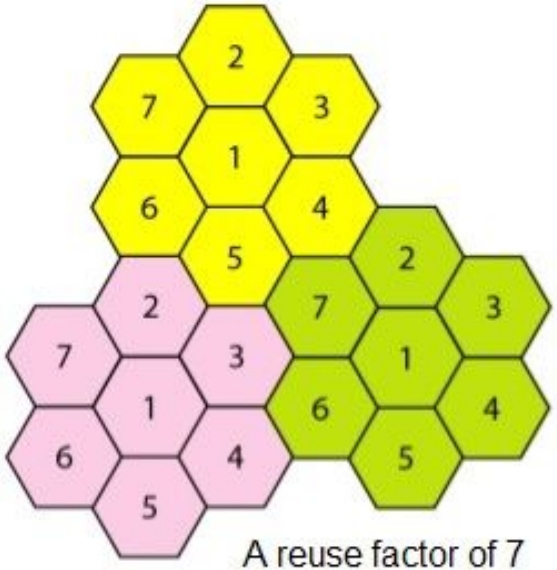


Frequency Reuse/Planning

Frequency Reuse Concept



A reuse factor of 4

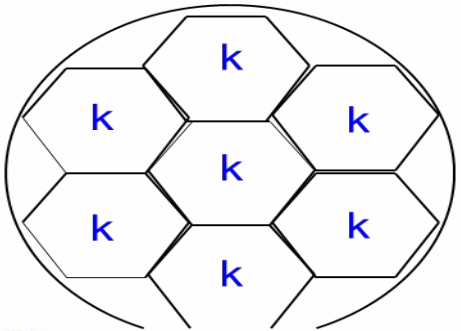


A reuse factor of 7

Frequency Reuse Concept

The concept of Cluster:

- Consider a cellular system which has a total of S duplex channels available for use.
- The S channels are divided among N cells (cluster).
- Each cell is allocated a group of k channels.
- The total number of available radio channels can be expressed as S=kN.



Cluster: N=7

The N cells which collectively use the complete set of available frequencies is called a cluster.

Cluster size: N=4,7,12

Frequency reuse Factor: 1/N

Totally S=kN duplex channels

Frequency Reuse factor

- Frequency reuse factor = 1 / N
  - each frequency is reused every N cells
  - each cell assigned

$$k = S / N$$

- *N* cells/cluster
  - connect without gaps

- specific values are required for hexagonal geometry
  - $N = i^2 + ij + j^2$ where $i, j \geqq 1$
  - Typical *N* values → 3, 4, 7, 12; (*i, j*) = (1,1), (2,0), (2,1), (2,2)

System Capacity

- S : total number of duplex channels available for use in a given area which is determined by:
  - amount of allocated spectrum
  - channel BW → modulation format and/or standard specs. (e.g. AMPS)
- k : number of channels for each cell (k < S)
- N : cluster size → No. of cells forming cluster
- S = k N

System Capacity

- *M* : Number of times a cluster is replicated over a geographic coverage area
- System Capacity = Total no.of Duplex Channels = *C*

$$C = M S = M k N$$

(assuming exactly *MN* cells will cover the area)

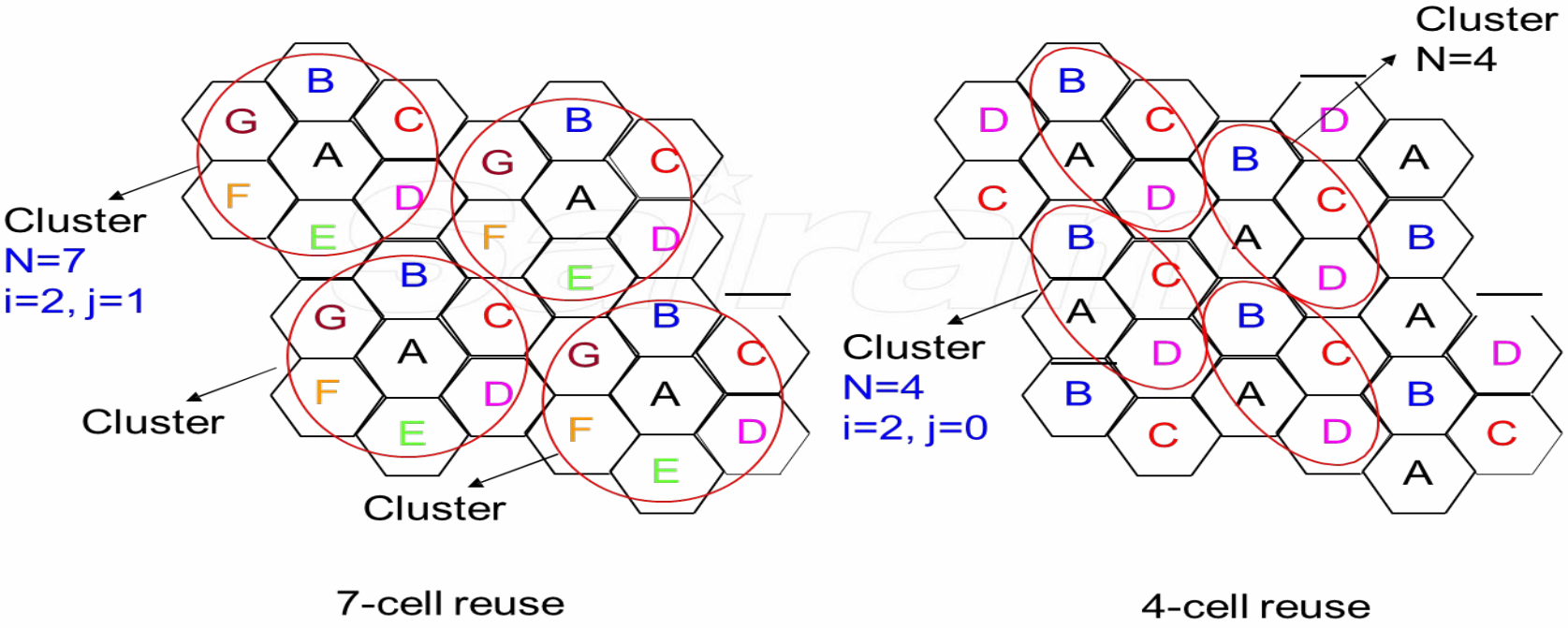
- If cluster size (*N*) is reduced and the geographic area for each cell is kept constant:
  - The geographic area covered by each *cluster* is smaller, so *M* must ↑ to cover the entire coverage area (more clusters needed).
  - *S* remains constant.
  - So *C* increases
  - The smallest possible value of *N* is desirable to maximize system capacity.

System Capacity

✔ Cluster size *N* determines:

- distance between co-channel cells (D)
- level of co-channel interference
- A mobile or base station can only tolerate so much interference from other cells using the same frequency and maintain sufficient quality.
- large N → large D → low interference → but small M and low C !
- Tradeoff in quality and cluster size.
- The larger the capacity for a given geographic area, the poorer the quality.

Frequency Reuse Planning



To find the nearest co-channel neighbors of a particular cell

- Move *i* cells along any chain of hexagons
- then turn 60 degrees and move *j* cells.

19-cell reuse example (N=19)

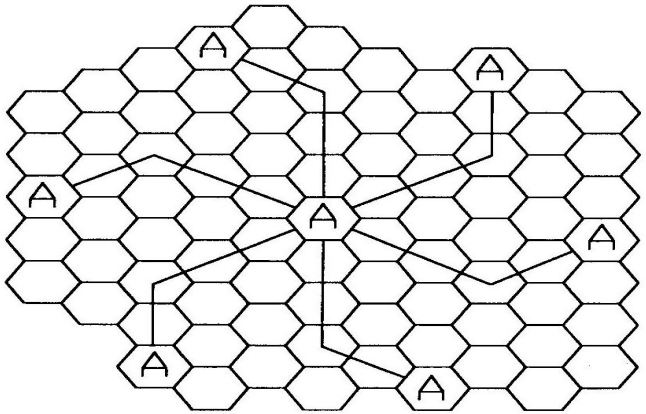


Figure 3.2 Method of locating co-channel cells in a cellular system. In this example, $N = 19$ (i.e., $i = 3$, $j = 2$). (Adapted from [Oet83] © IEEE.)

MULTIPLE CHOICE QUESTIONS