Cellular Wireless Networks

Cellular Network Organization

- Use multiple low-power transmitters (100 W or less)
- Areas divided into cells
  - Each served by its own antenna
  - Served by base station consisting of transmitter, receiver, and control unit
  - Band of frequencies allocated
  - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)

Cellular Network Organization

Adjacent Cells are assigned different frequencies

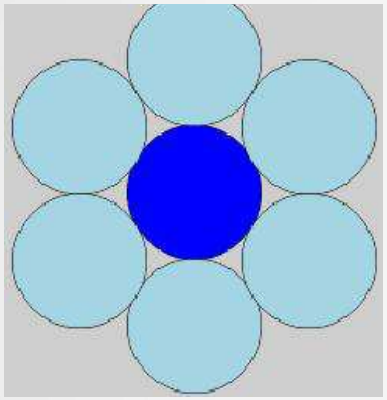
Reuse of radio channel in different cells.

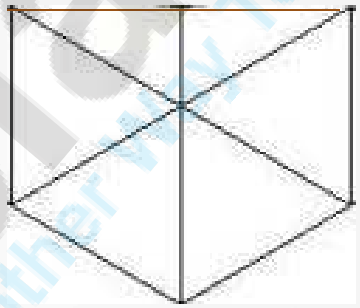
Enable a fix number of channels to serve an arbitrarily large number of users by reusing the channel

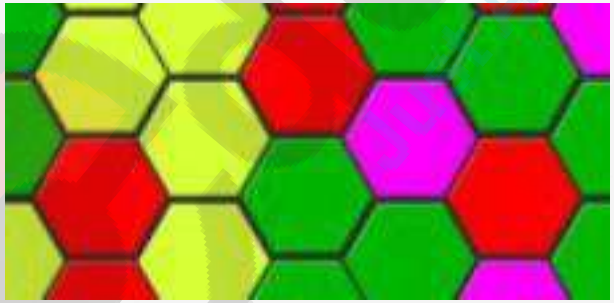
Cellular Concepts

- Advantages:
  - –higher capacity, higher number of users
  - – less transmission power needed – more robust, decentralized
  - –base station deals with interference, transmission area etc. locally
- Problems:
  - –fixed network needed for the base stations
  - –handover (changing from one cell to another) necessary
  - –interference with other cells: co-channel, adjacent-channel
- Important Issues:
  - – Cell sizing
  - – Frequency reuse planning
  - – Channel allocation strategies

Possible cell structures







Shape of Cells

Circle

- Circular shaped cells would leave out few spaces without any coverage.

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

Shape of Cells

Hexagon

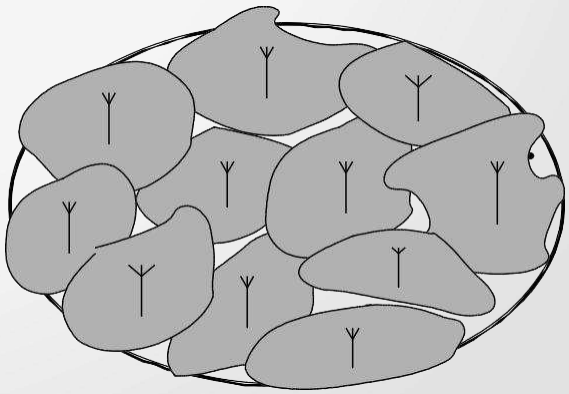
Provides equidistant antennas

Radius defined as radius of circumscribing circle

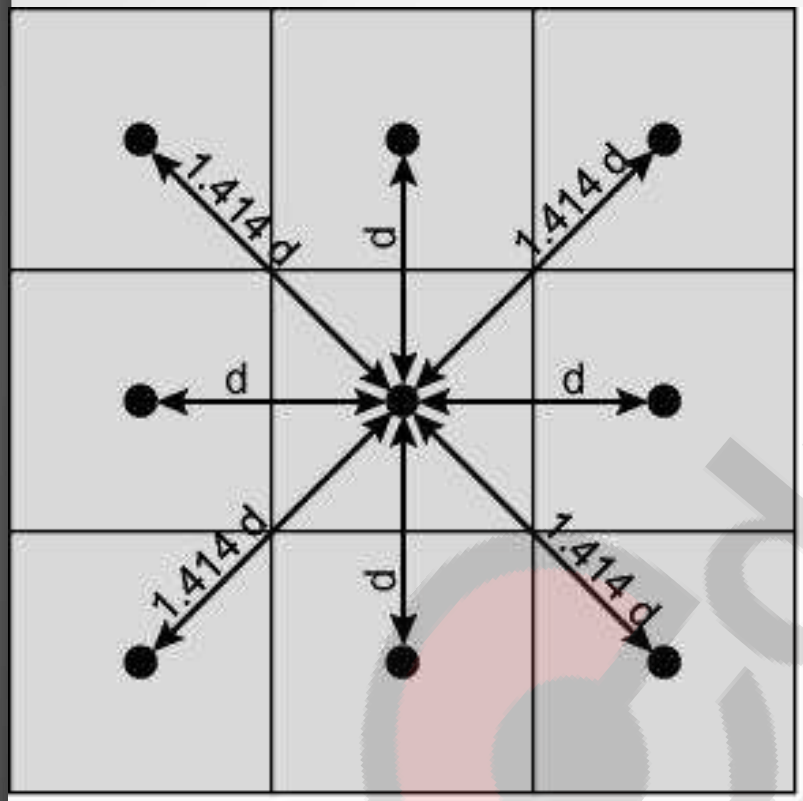
- Distance from center to vertex equals length of side

Distance between centers of cells radius *R* is $\sqrt{3}$ R

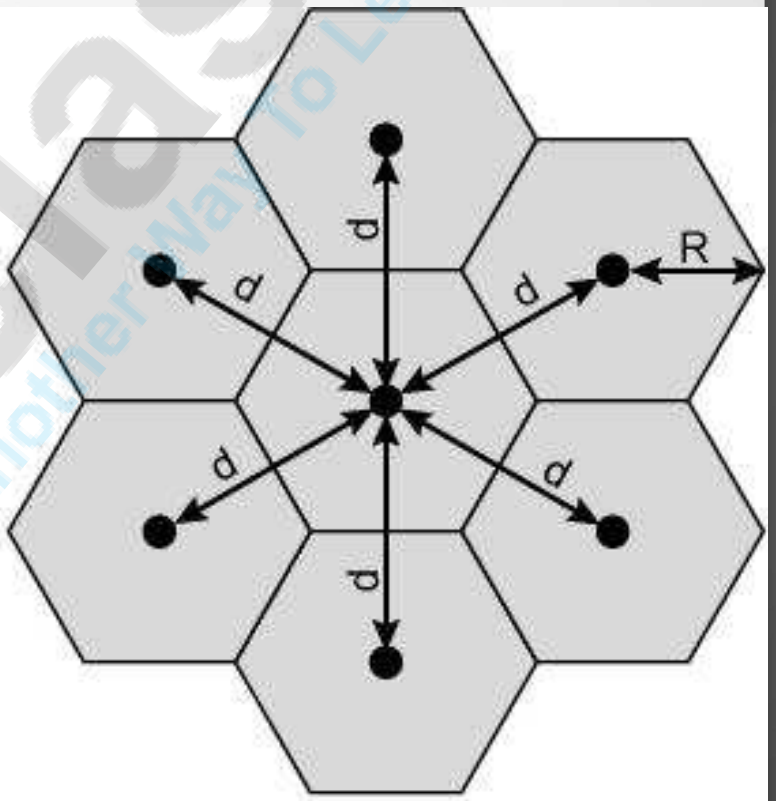
- Not always precise hexagons
  - Topographical limitations
  - Local signal propagation conditions
  - Location of antennas



Cellular Geometries



(a) Square pattern



(b) Hexagonal pattern

Types of cells

- Macro cell – their coverage is large (aprox. 6 miles in diameter); used in remote areas, high-power transmitters and receivers are used
- Microcell – their coverage is small (half a mile in diameter) and are used in urban zones; low-powered transmitters and receivers are used to avoid interference with cells in another clusters
- Pico cell – covers areas such as building or a tunnel

Typical Parameters for Macrocells and Microcells

Parameters	Macrocell	Microcell
Cell radius	1 to 20 km	0.1 to 1 km
Transmission power	1 to 10 W	0.1 to 1 W
Average Delay Spread	0.1 to 10 microsec	10 to 100 nsec
Maximum bit rate	0.3 Mbps	1 Mbps

Frequency Reuse

- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
  - Each cell is assigned a frequency band.
  - Transmission power is controlled to limit power at that frequency escaping to adjacent cells
  - The issue is to determine how many cells must intervene between two cells using the same frequency
- A cluster is a group of adjacent cells where no frequency reuse is done
- The frequency spectrum is divided into sub bands and each sub band is used within one cell of the cluster

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
- *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

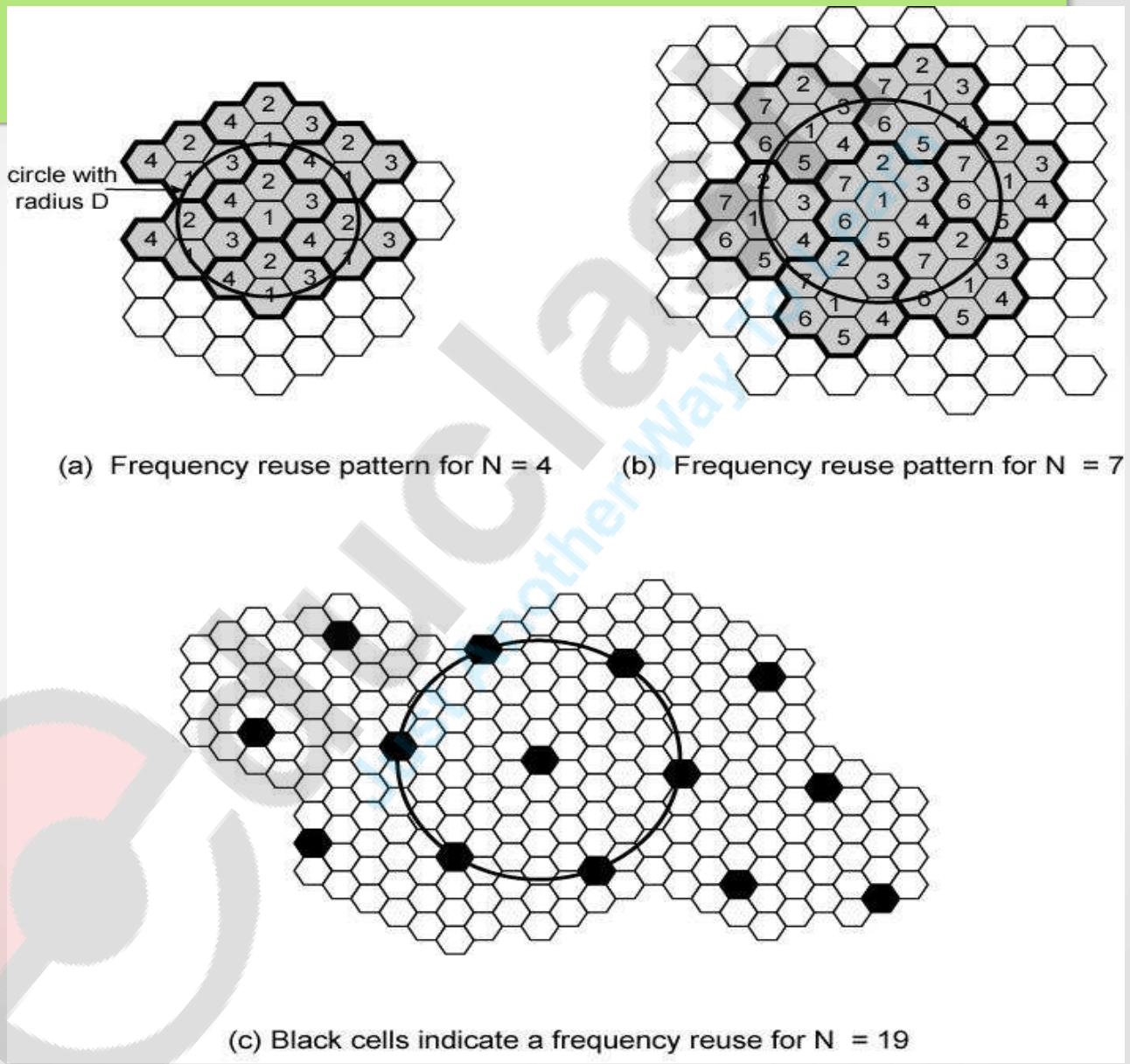
Characterizing Frequency Reuse

- D = minimum distance between centers of cells that use the same band of frequencies (called co-channels)
- R = radius of a cell
- d = distance between centers of adjacent cells ($d = \sqrt{3}R$)
- 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

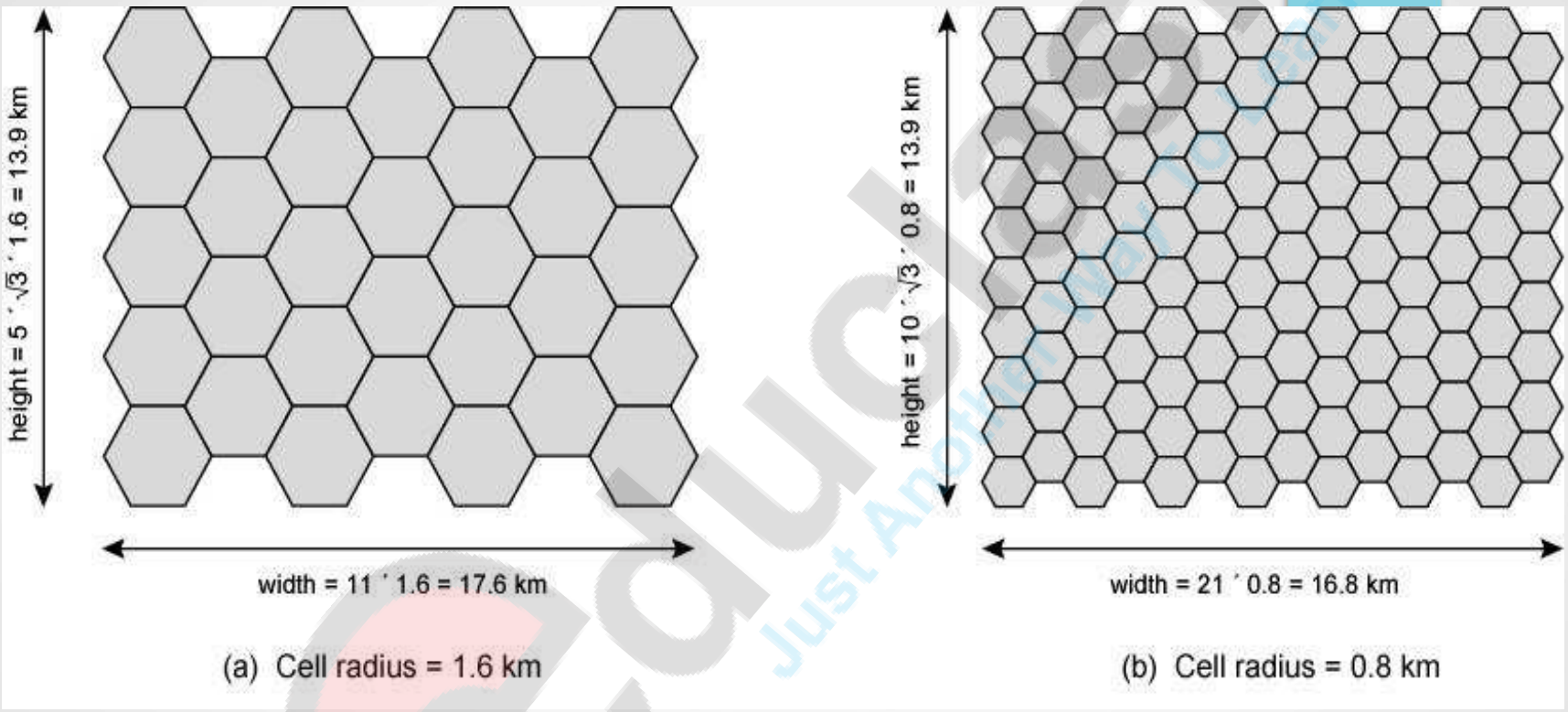


(a) Frequency reuse pattern for N = 4

(b) Frequency reuse pattern for N = 7

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

Frequency Reuse Example



48 channels per cell in both cases. Area in both cases is 213 sq. km
Figure a has 32 cells giving 1536 channels, b has 128 cells, 6144 channels