CSE 4255
Cellular Network

Lecture 8

Improving Coverage and Capacity

Capacity Problem?

- As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users which leads Capacity Problem.
- We can improve capacity by
  - Adding New Channel
  - Reduce the cluster size
- Therefore, new cellular design techniques are needed to provide more channels per unit coverage area.

Techniques to Improve Capacity:

1. Cell Splitting

2. Cell Sectoring

3. Microcell Zone Concept

1. Cell Splitting :

- It is the process of subdividing the congested cell into smaller cells with
  - their own base station
  - a reduction in antenna height and transmitted power.
- Splitting the cell reduces the cell size thus more number of cells have to be used.
- Cell Splitting allows the system to grow by replacing large cells with smaller cells without changing the co-channel re-use ratio Q.

Process of Cell Splitting

- Base stations are placed at the corners of the cells
- The area served by base station A is assumed to be saturated with traffic.
- Cell Splitting is applied, the original base station A has been surrounded by six new microcell base stations.
- The radius of each new microcell is half that of the original cell.
  - Microcell G was placed half way between two larger stations utilizing the same channel set G.

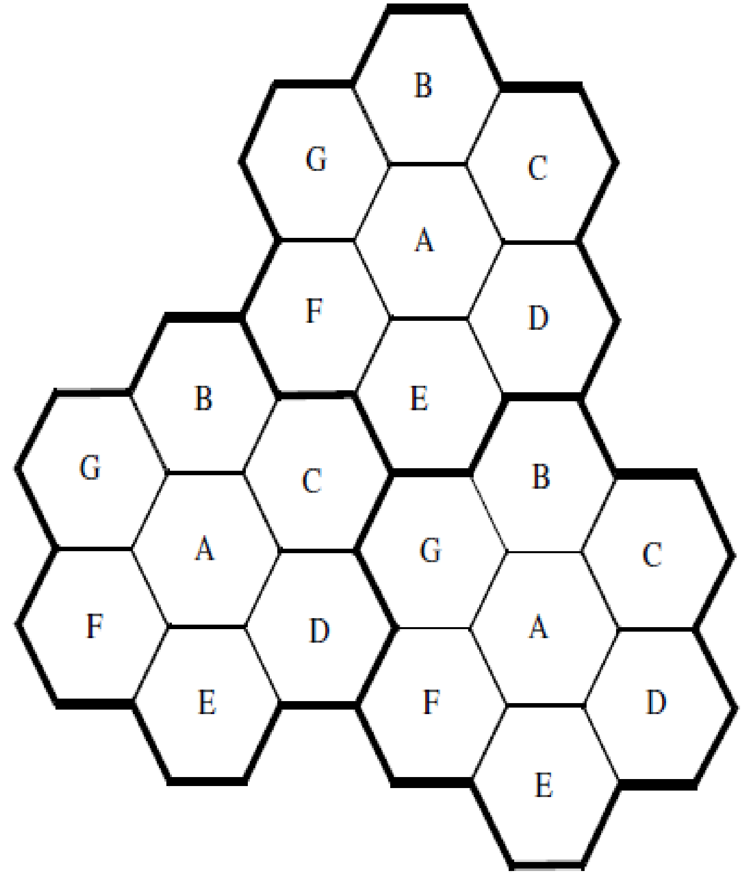

Figure 1: Cell Splitting

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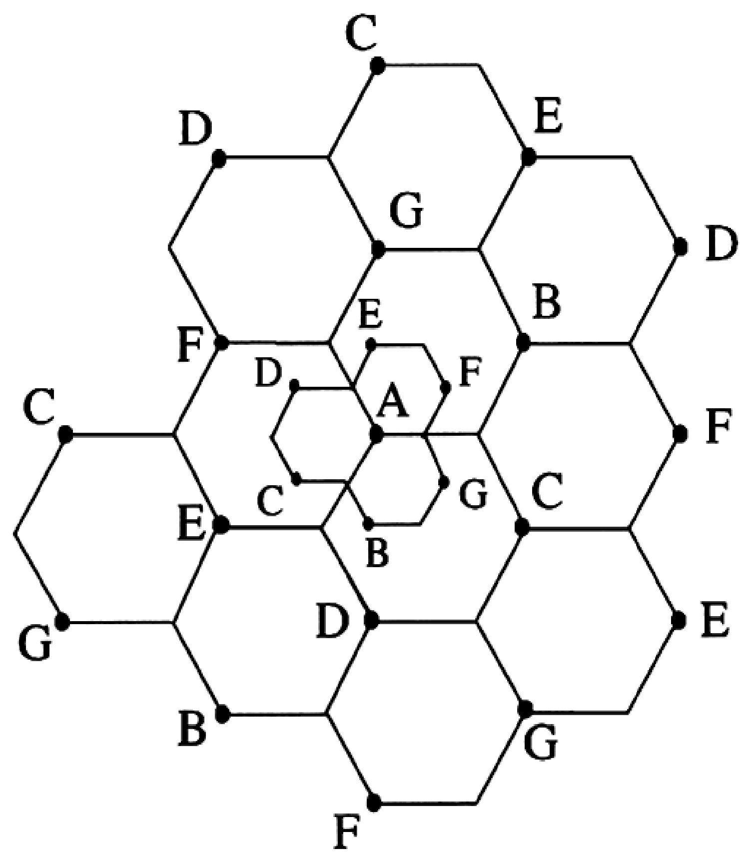


Figure 1: Cell Splitting

Cell Splitting

- By decreasing the cell radius *R*, and keeping the co-channel reuse ratio *D/R* unchanged, cell splitting increases the number of channels per unit area.
- The distance between co-channel cells also reduces to half (D=D/2) as the cell radius is reduced to half (R=R/2). Thus the co-channel reuse ratio(Q=D/R) remains same.

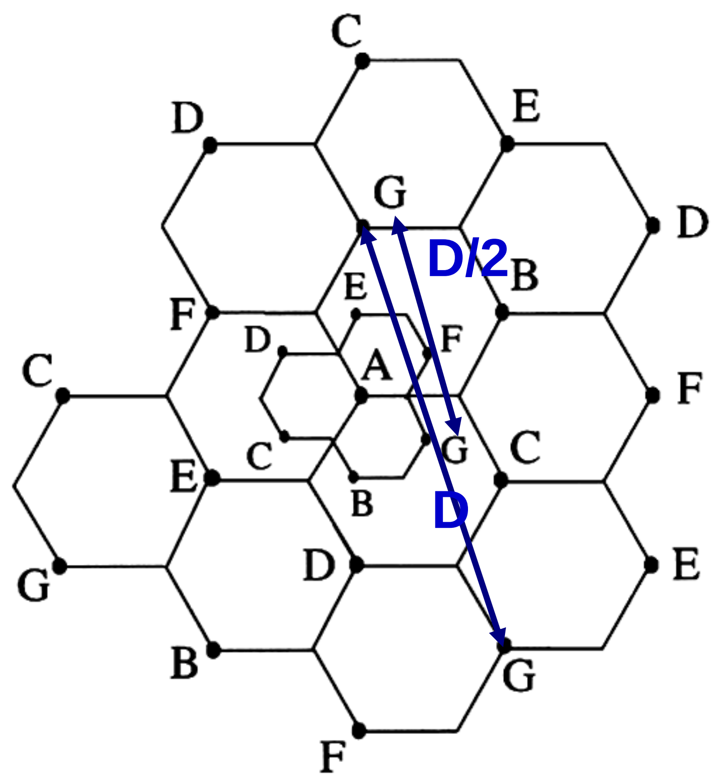


Figure 2: Cell Splitting

How much the transmit power must be reduced for the new smaller cells?

- The receiving power at the new and old cell boundary

$$P_r\ [\text{received power at old cell boundary}] \propto P_{t1}\, R^{-n}$$

$$P_r\ [\text{received at new cell boundary}] \propto P_{t2}\, (R/2)^{-n}$$

$$P_{t2} = P_{t1}(1/2)^{n}$$

- where P_{t1} and P_{t2}, are the transmit powers of the larger and smaller cell base stations, respectively, and n is the path loss exponent.

Example-1

Consider Figure; Assume each base station uses 60 channels, regardless of cell size. If each original cell has a radius of 1 Km and each microcell has a radius of 0.5 Km, find the number of channels contained in a 3 Km by 3 Km square centered around ***A*** under the following conditions:

a) without the use of microcells;

b) when the lettered microcells as shown in Figure 3 are used, also calculate increase in capacity; and

c) if all the original base stations are replaced by microcells. Assume cells on the edge of the square to be contained within the square.

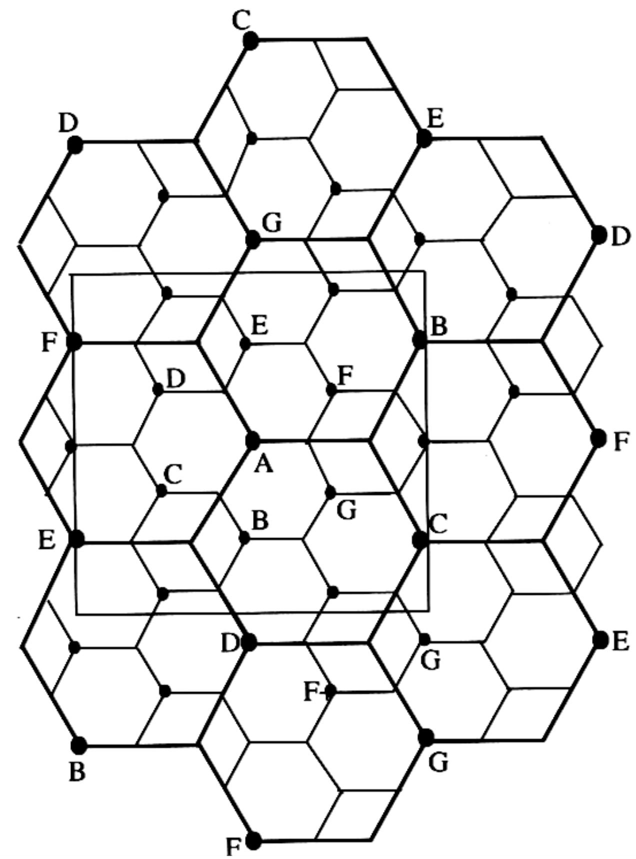


Figure 3: Figure for Example

Solution

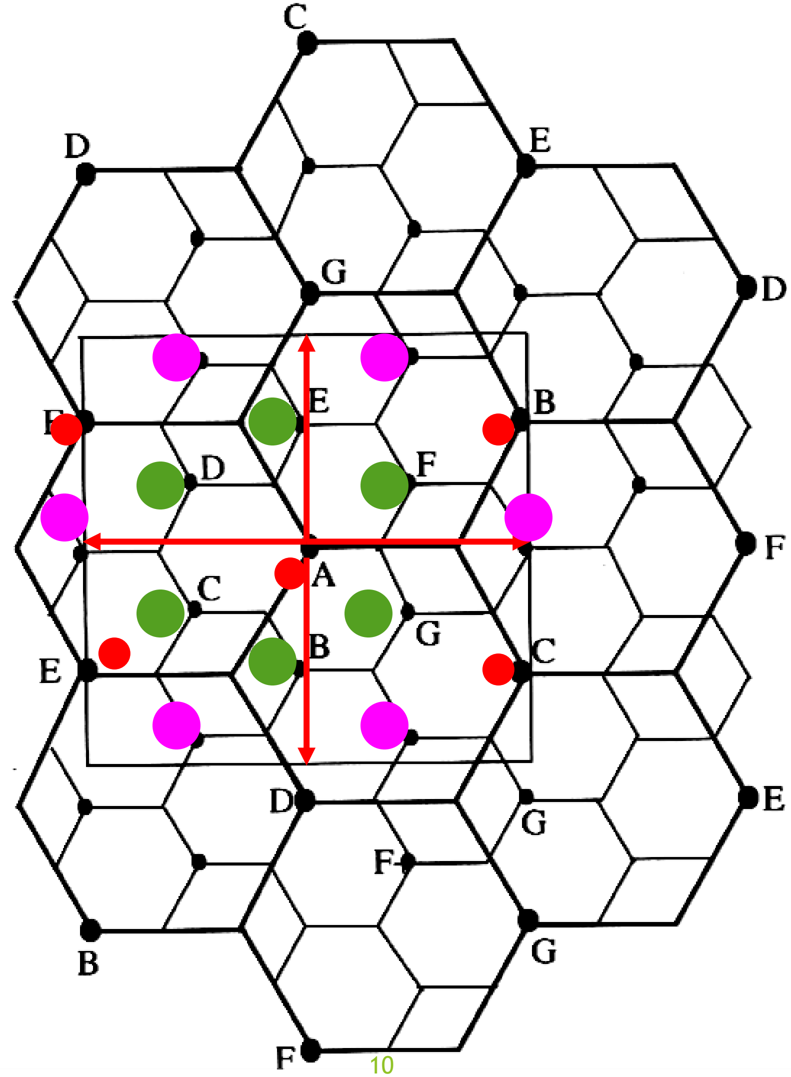
(a) 5x60 = 300 channels

(b) 5+6 = 11

11 x 60 = 660 channels

(c) 5 + 12 = 17 channels

17 x 60 = 1020 channels



Cell Splitting: Problems

- Cell splitting increases the number of base stations in order to increase capacity.
- Decreasing the cell radius in different size may increase CCI.
- Handoff issues must be addressed so that high speed and low speed traffic can be simultaneously accommodated (the umbrella cell approach is commonly used).

2. Cell Sectoring

- The technique for decreasing co-channel interference and for increasing system performance by using directional antennas is called sectoring.
- As opposed to cell splitting, where D/R ratio is kept constant while decreasing R, sectoring keeps the R untouched and reduces the D/R.
- Capacity improvement is achieved by reducing the number of cells per cluster, thus increasing frequency reuse.

Process of Cell Sectoring

- In Sectoring, cells are divided into a number of wedge-shaped sectors--typically three or six sectors per cell.
- Replacing a single omnidirectional antenna at the base station by several directional antennas.
- Directional antennas are used at the base station to focus on each sector.
- Each sector is assigned a separate subset of the cell's channels
- A cell is normally partitioned into three 120° sectors or six 60°

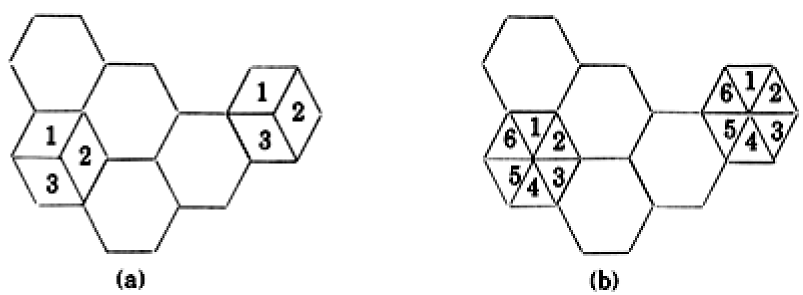


Figure : Cell Sectoring (a)120 degree (b) 60 degree

Cell Sectoring: Reduce CCI and Increase SIR

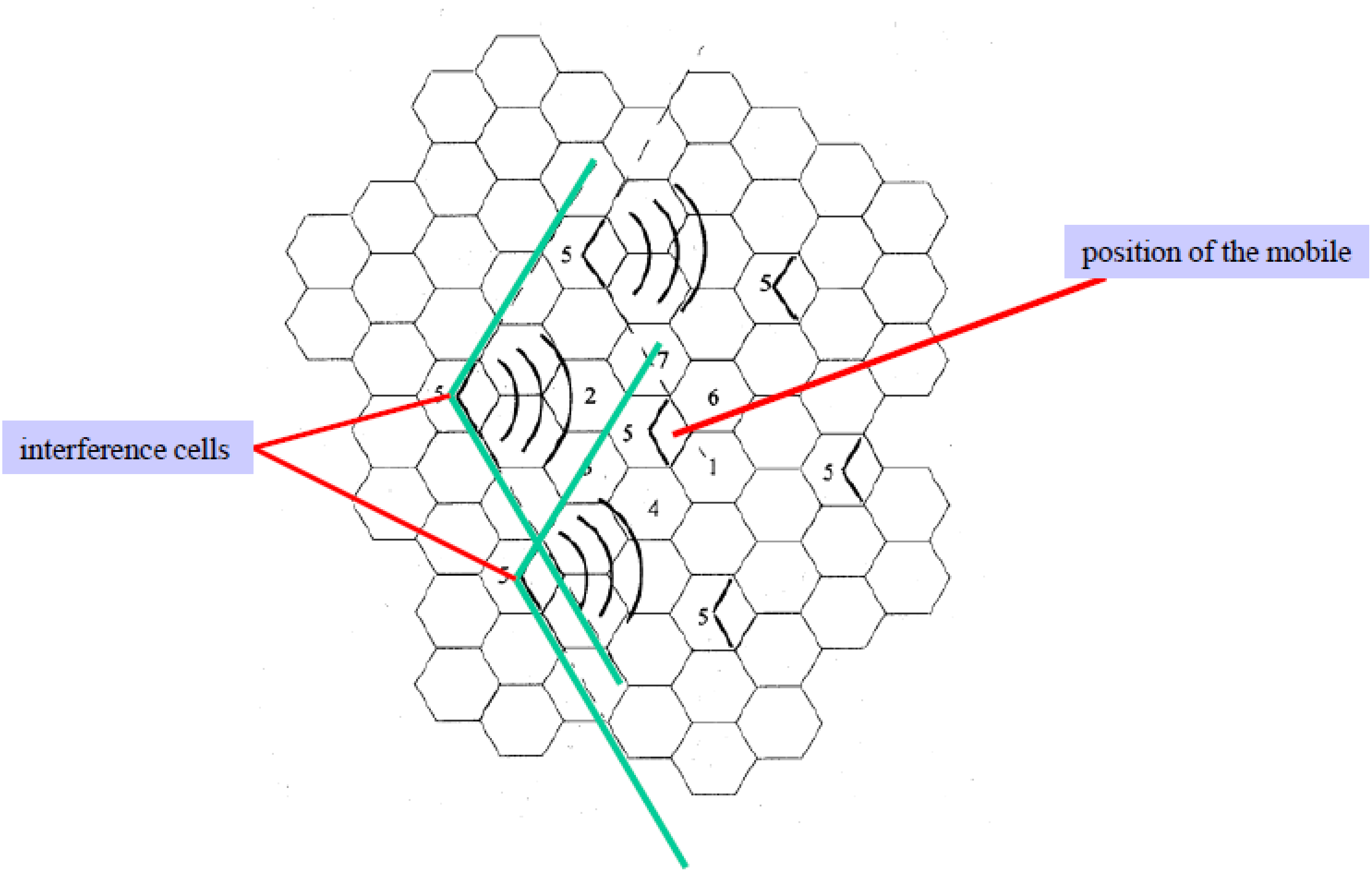


Figure 5: Improving SIR

Cell Sectoring: Decrease Trunking Efficiency

Consider a cellular system in which:

- An average call lasts 2 minutes, the probability of blocking is to be no more than 1%. Assume that every subscriber makes 1 call per hour, on average.
- If there are a total of 395 traffic channels for a 7-cell reuse system, there will be about 57 traffic channels per cell.
- Assume that blocked calls are cleared so the blocking is described by the Erlang B distribution. From the Erlang B distribution, it can be found that **the unsectored system** may handle

44.2 Erlangs or 1326 calls per hour.

- Now employing **120° sectoring**, there are only **19 channels per antenna sector (57/3 antennas).**
- For the same probability of blocking and average call length, it can be found from the Erlang B distribution that each sector can handle

11.2 Erlangs or 336 calls per hour.

- Since each cell consists of 3 sectors, this provides a cell capacity:

$$\boxed{\mathbf{3 \times 336 = 1008 \text{ calls per hour,}}}$$

which amounts to a **24%** decrease compared to the unsectored case.

- **Thus, sectoring decreases the trunking efficiency while improving the S/I for each user in the system.**

Cell Sectoring: Disadvantages

- Increased number of antennas at each base station
- Decrease in trunking efficiency due to channel sectoring at each base station
- As sectoring reduces the coverage area of a particular group of channels, the number of handoffs increase.

Microcell Zone Concept

- The Problems of sectoring can be addressed by Microcell Zone Concept
- A cell is conceptually divided into microcells or zones
  - Each microcell (zone) uses a directional antenna. Antennas are placed at the outer edges of the cell and radiates power into the cell.
  - Each zone is connected to the same base station(fiber/microwave link).
  - Any channel may be assigned to any zone by the base station and MS is served by strongest zone.
  - As mobile travels from one zone to another, it retains the same channel, i.e no hand off.
  - The BS simply switches the channel to the next zone site.

Microcell Zone Concepts

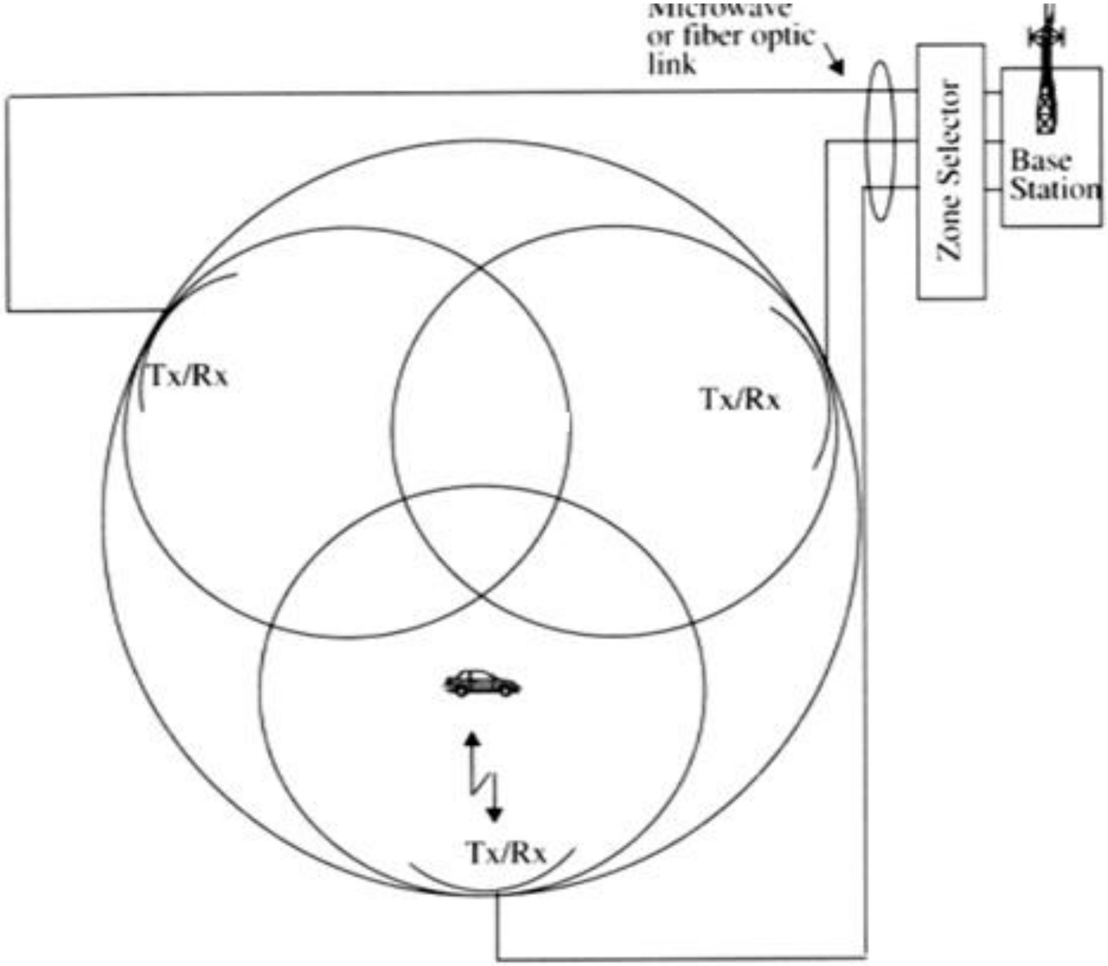
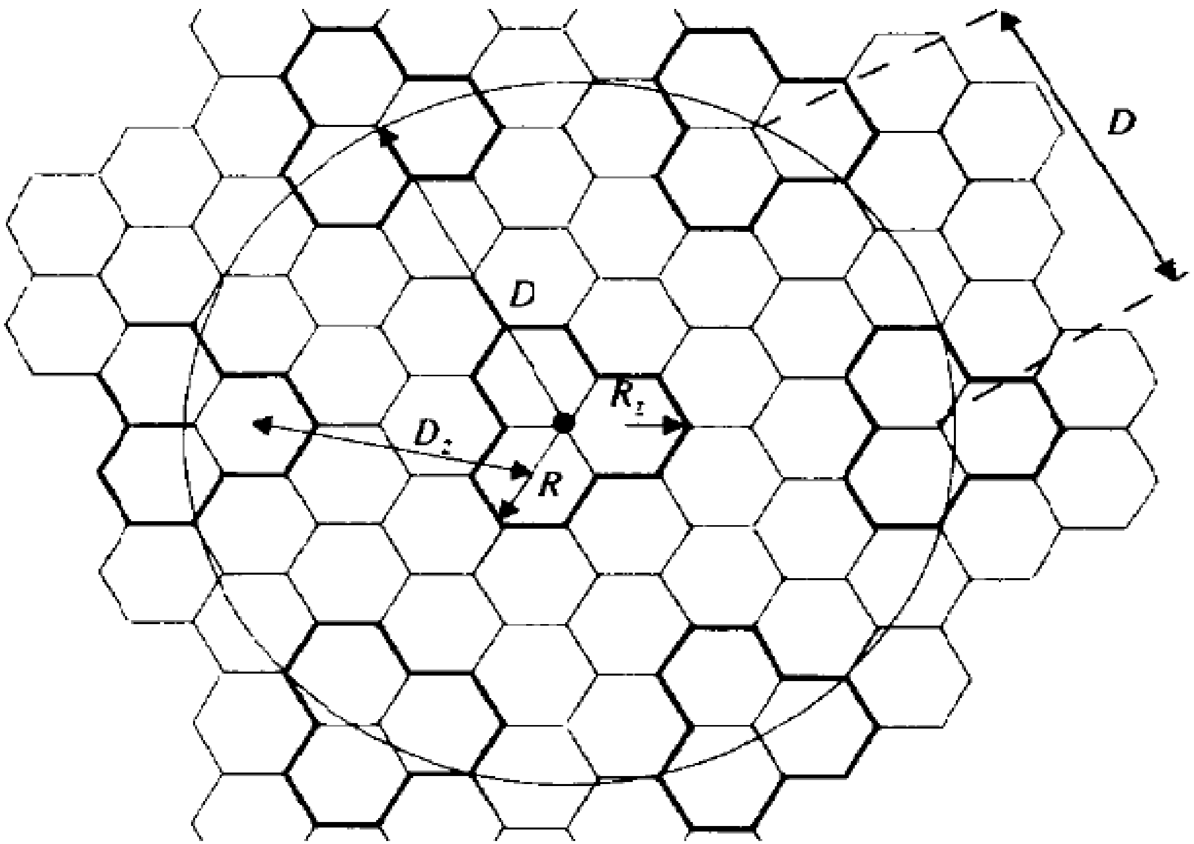


Figure 3.13 The microcell concept [adapted from [Lee91b] © IEEE].

Advantage of Microcell Zone Concept

- Co-channel interference is reduces since a large central base station is replaced by several lower powered transmitter on the edges of the cell.
- Decrease of co-channel ratio, increase SIR which in turn decrease the cluster size N hence increase the capacity.



Problem 1

- A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal to interference ration 15 dB in the worst case. Find the optimal value of N for
  a) Omni directional antenna
  b) 120 degree sectoring and
  c) 60 degree sectoring.
  d) Should sectoring be used?
  e) If so, which case (120 degree or 60 degree) should be used? (Assuming a path loss factor n = 4 and consider trunking efficiency.)