

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.

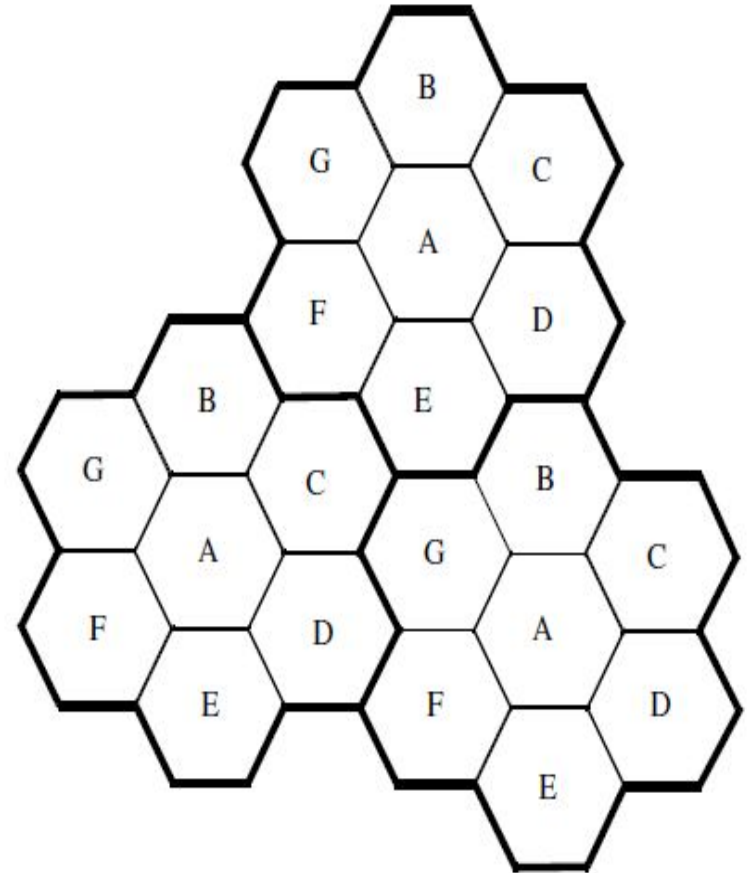


Figure 1: Cell Splitting

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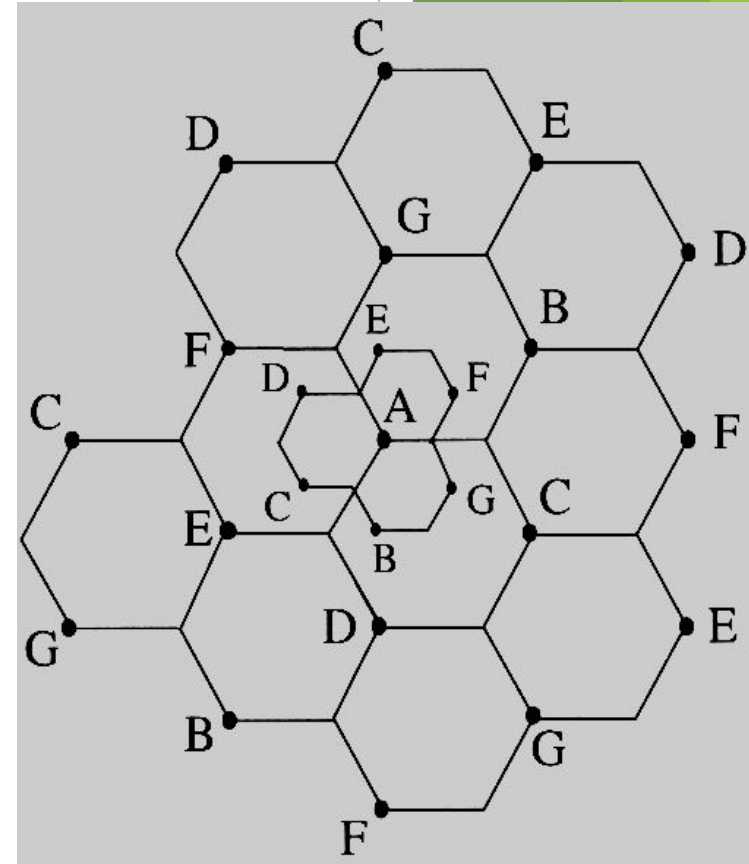


Figure 1: Cell Splitting

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.

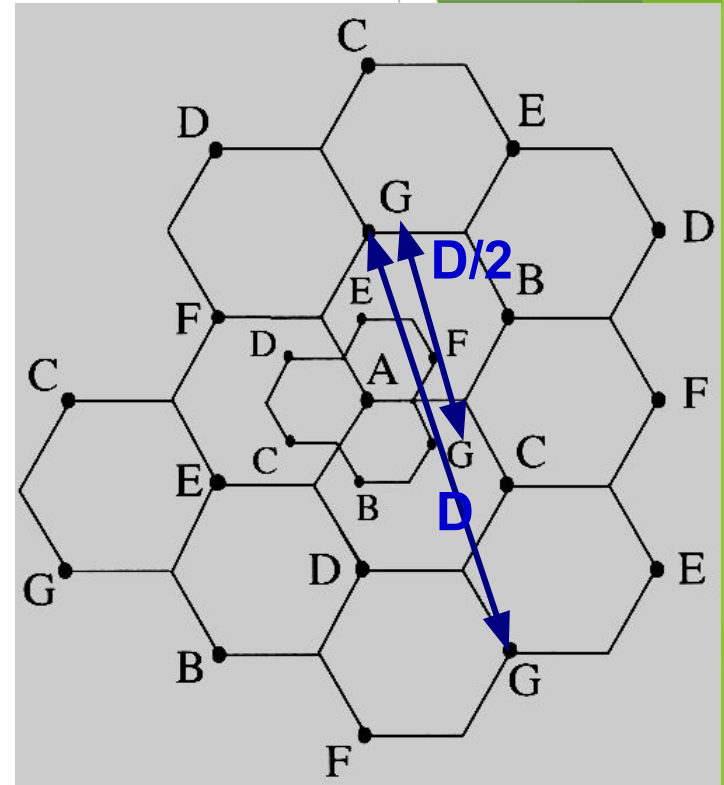


Figure 2: Cell Splitting

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

- The receiving power at the new and old cell boundary

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

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

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

- 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.

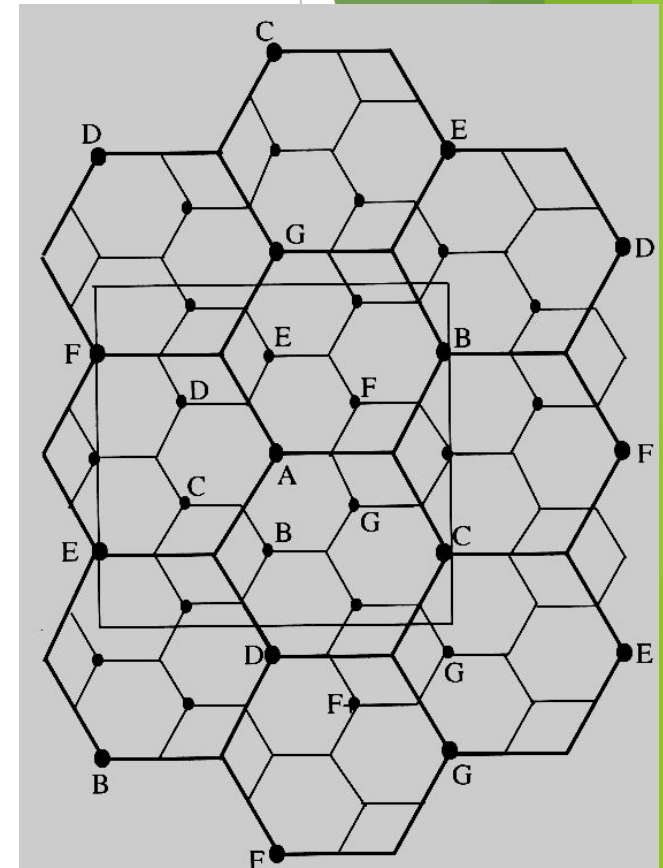


Figure 3: Figure for Example

Solution

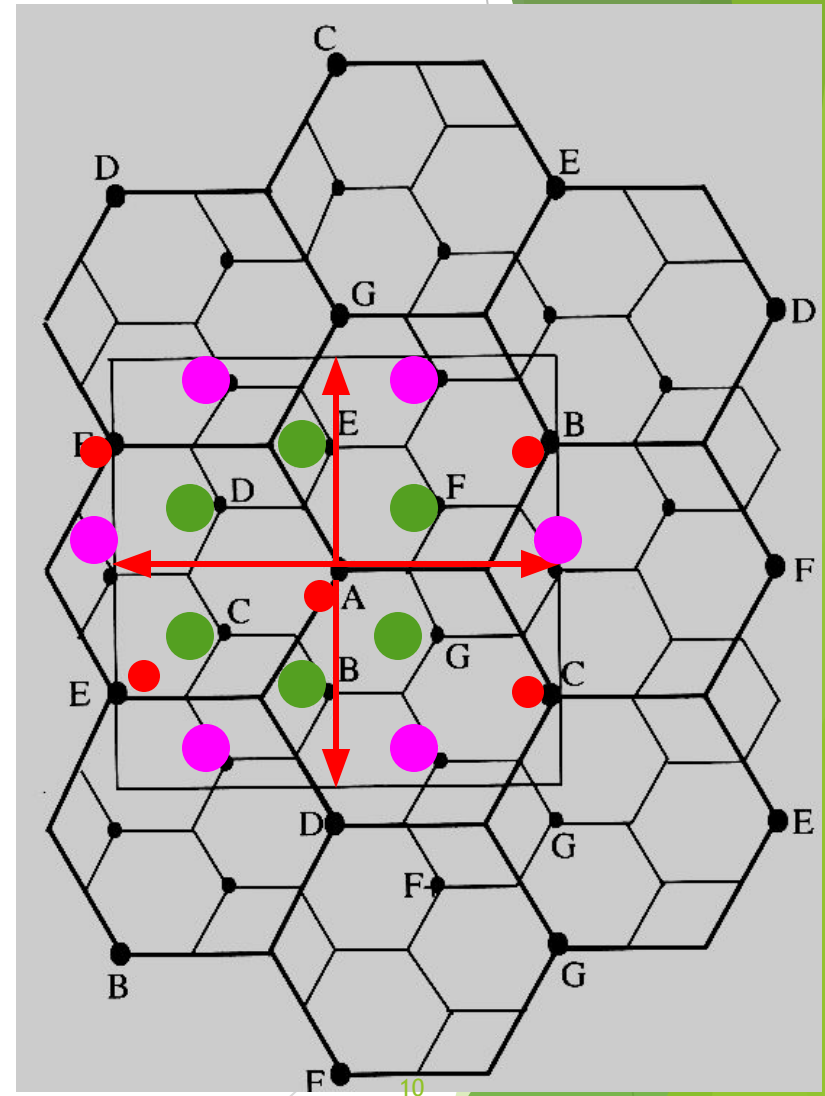
(a) $5 \times 60 = 300$ channels

(b) $5 + 6 = 11$

$11 \times 60 = 660$ channels

(c) $5 + 12 = 17$ channels

$17 \times 60 = 1020$ 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°

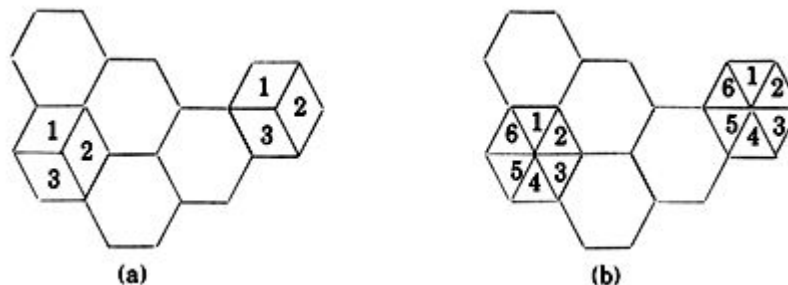


Figure : Cell Sectoring (a)120 degree (b) 60 degree

Cell Sectoring: Reduce CCI and Increase SIR

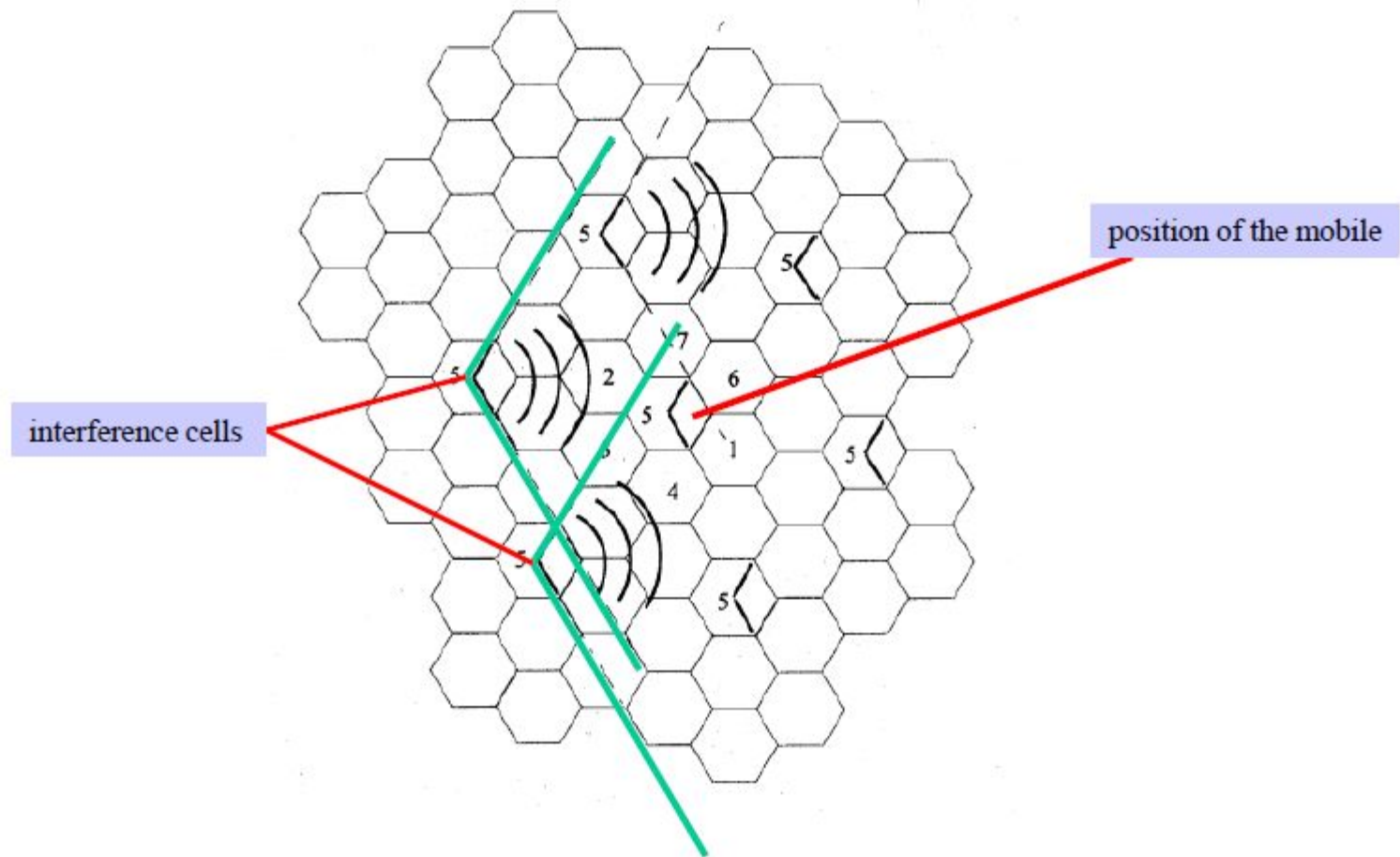


Figure 5: Improving SIR

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:

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

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

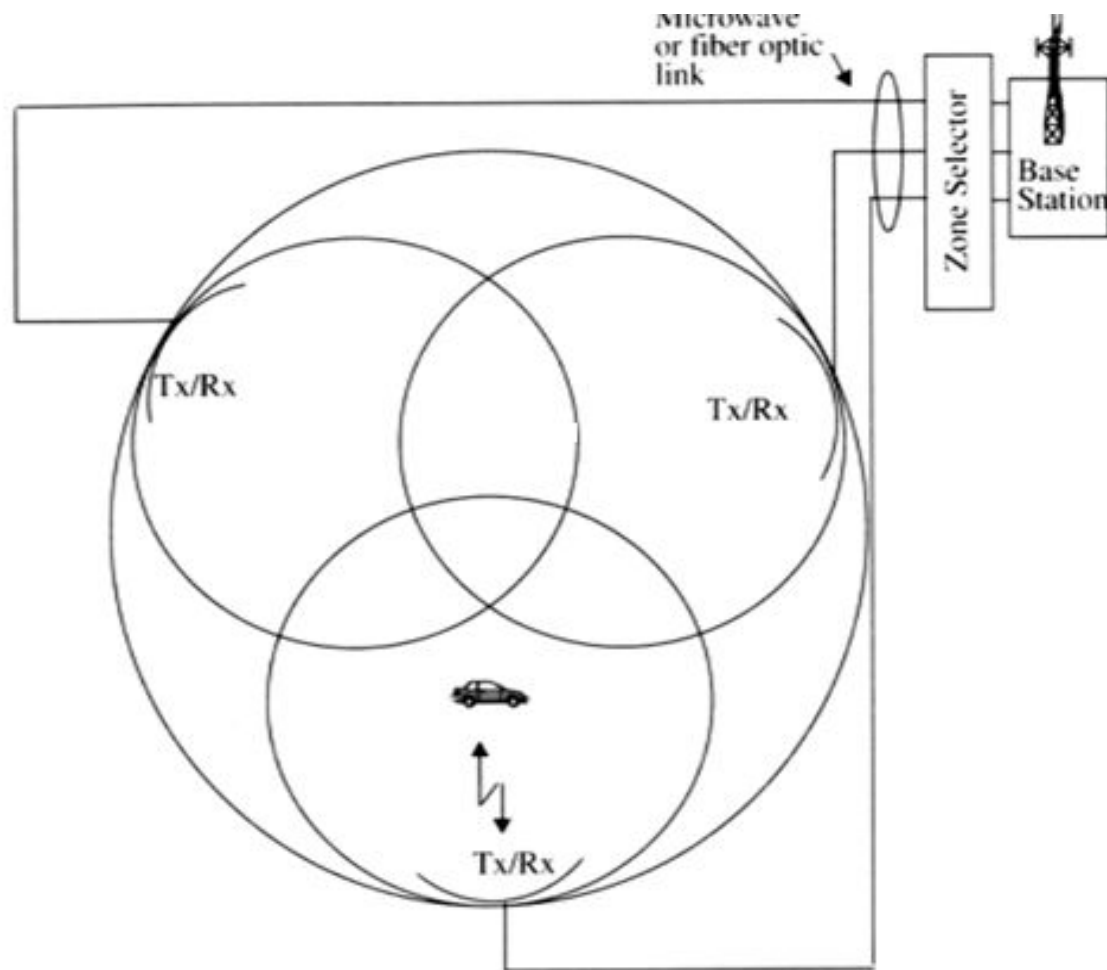
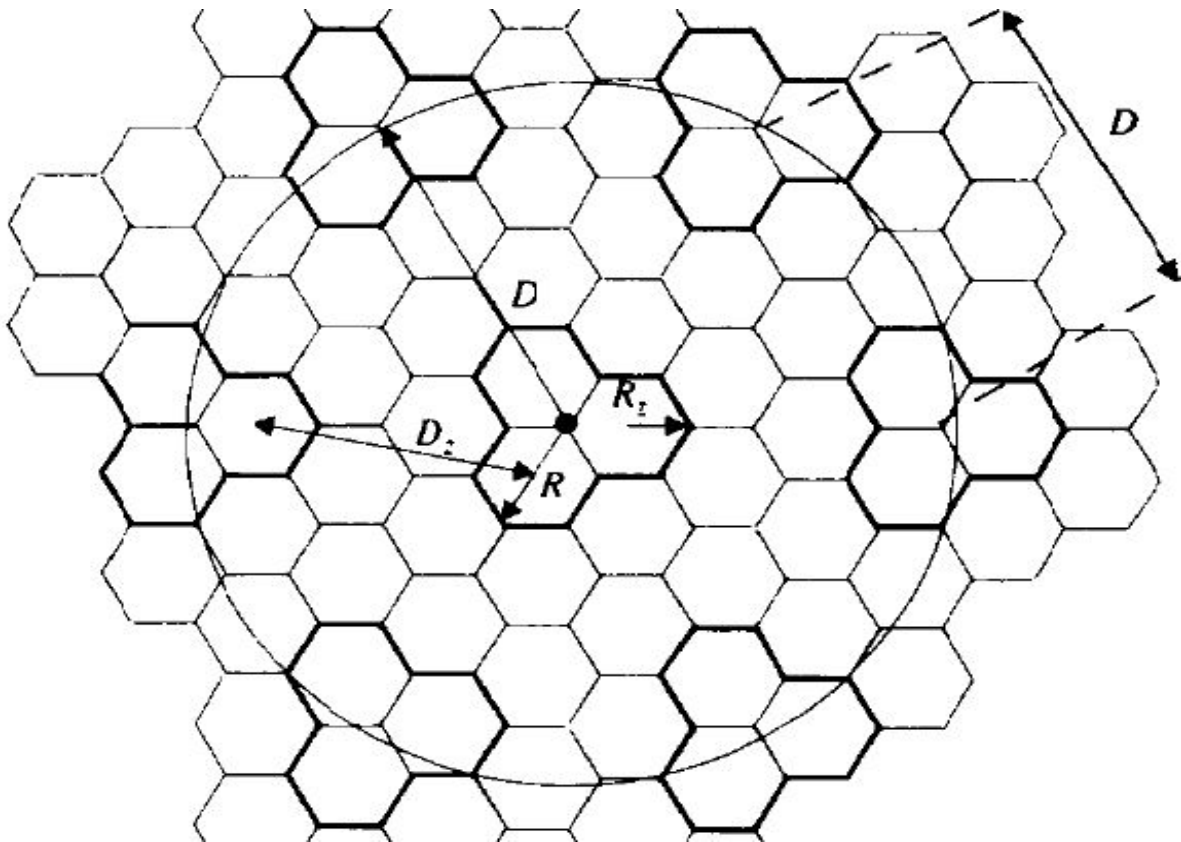


Figure 3.13 The microcell concept [adapted from [Lee91b] © IEEE].

Advantage of Microcell Zone Concept

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



Problem 1

- ▶ A cellular service provider decides to use a digital TDMA scheme which can tolerate a signal to interference ratio 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.)