EEENG473 Mobile Communications
Module 2 : Week # (9)

The Cellular Concept –
System Design Fundamentals

3.7.2 Sectoring

- Another way to increase capacity is to keep the cell radius unchanged and **seek methods to decrease the D /R ratio.**

- Is the technique for **decreasing co-channel** interference and thus **increasing capacity** by replacing a single omni-directional antenna at the base station by several directional antennas,

- each radiating within a specified sector and transmit with only a fraction of the available co-channel cells.

- The factor of co-channel interference reduction depends on the amount of sectoring used.

- A **cell** is normally partitioned into **three 1200 sectors or six 60° sectors** as shown in Figure 3.10(a) and (b).

- **the channels** used in a particular cell are **broken down into sectored groups** and are used only within a particular sector

- Assuming 7-cell reuse, for the case of 120° sectors, the number of interferers **in the first tier** is reduced from **6** **to** **2**. This is because only **2 of the 6** co-channel cells receive interference with a particular sectored channel group.

Sectoring improves S/I

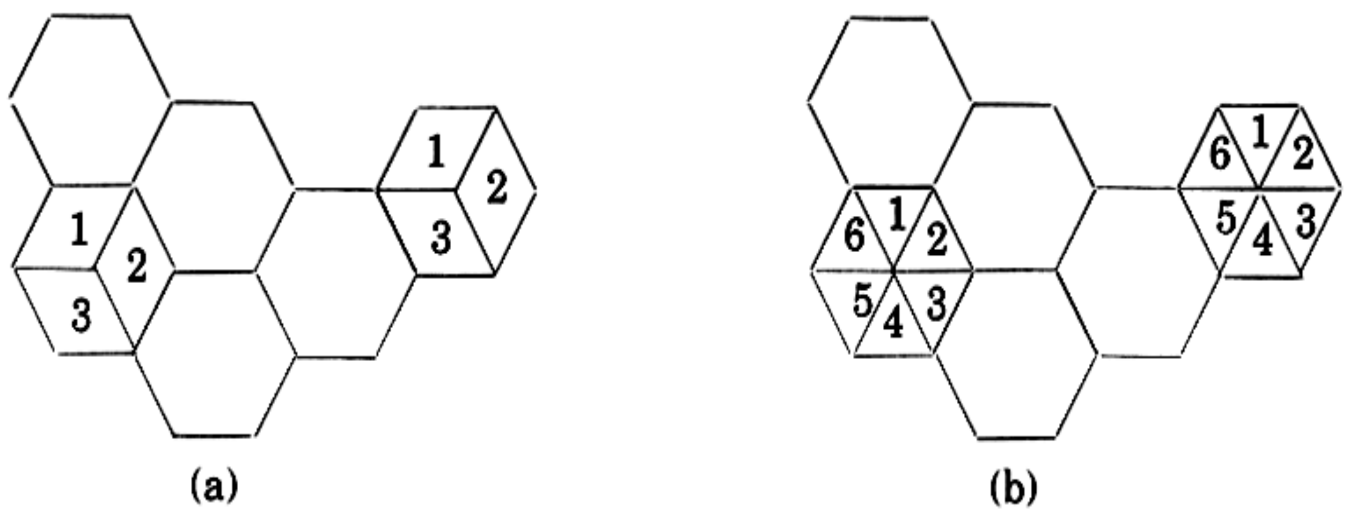


Figure 3.10 (a) 120° sectoring; (b) 60° sectoring.

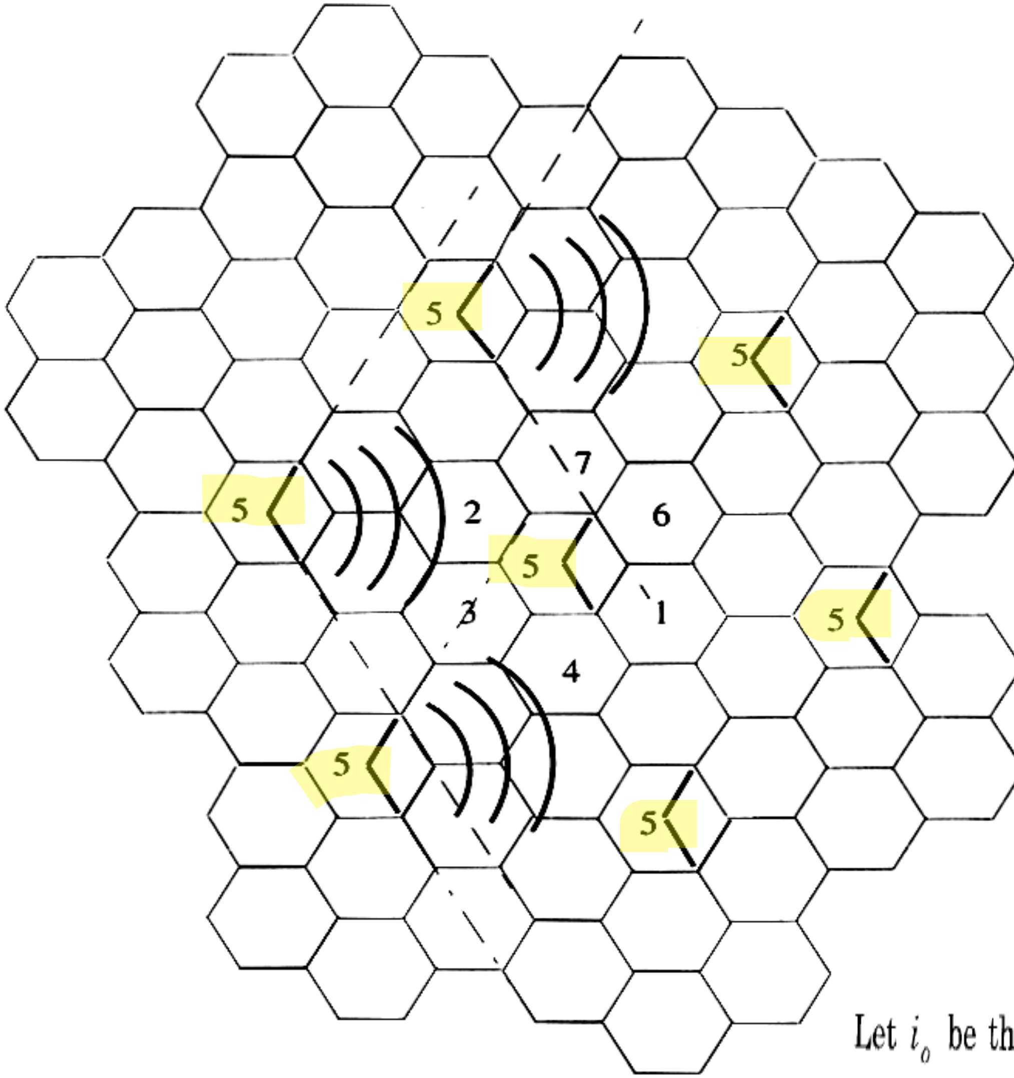
- Figure 3.11, consider the interference experienced by a mobile located in **the right-most sector in the center cell labeled “5”.**

- There are **3 co-channel cell** sectors labeled **“5” to the right** of the center cell, and **3 to the left** of the center cell.

- Out of these 6 co-channel cells, **only 2 cells have sectors with antenna patterns** which radiate into the center cell, and hence a mobile in the center cell will experience interference on the forward link from only these two sectors.

- The resulting S/I for this case can be found using equation (3.8) to be **24.2 dB**, which is a significant improvement over the omni-directional case in Section 3.5, where the worst case S/I was shown to be **17 dB**.

Sectoring improves S/I



(3.8)

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}$$

Let i_0 be the number of co-channel interfering cells.

Figure 3.11 Illustration of how 120° sectoring reduces interference from co-channel cells. Out of the 6 co-channel cells in the first tier, only two of them interfere with the center cell. If omnidirectional antennas were used at each base station, all six co-channel cells would interfere with the center cell.

- The minimum required S/I of **18 dB** can be easily achieved that with **120° sectoring, with 7-cell reuse or 12-cell reuse in the unsectored case** (for the worst possible situation see Section 3.5.1).

- **Thus, sectoring reduces interference which amounts to an increase in capacity by a factor of 12/7, or 1.714.**

- In practice, the reduction in interference offered by sectoring **enable planners to reduce the cluster size N**, and provides an additional degree of freedom in assigning channels.

The penalty of sectoring

1. the number of handoffs increases.

   (Fortunately, many modern base stations support sectorization and allow mobiles to be handed off from sector to sector within the same cell without intervention from the MSC, so the handoff problem is often not a major concern.)

2. decrease in trunking efficiency,

   (see next example)

Example 3.9

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 X 336 = 1008 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.**

- It can be found that using **60° sectors** improves the S/I even more. In this case the number of first tier interferers is reduced from **6 to only 1**. This results in **S/I 29 dB for a 7-cell system** and **enables 4-cell reuse**.

- **Of course, using 6 sectors per cell reduces the trunking efficiency and increases the number of necessary handoffs even more.**

- If the unsectored system is compared to the 6 sector case, the degradation in trunking efficiency can be shown to be 44 %

  (The proof of this is left as an exercise).

2.7.3 A Novel Microcell Zone Concept

- Proposed by [Lee] as a solution to the problem of increased number of handoffs required when sectoring is employed as illustrated in Figure 3.12.

- In this scheme, **each of the 3 (or more) zone sites (represented as Tx/Rx in Figure 3.13) are connected to a single base station and share the same radio equipment.**

- The zones are connected by **coaxial cable, fiber optic cable (Radio over fiber), or microwave link** to the base station. Multiple zones and a single base station make up a cell.

- As a mobile travels within the cell, it is served by the zone with the strongest signal.

- This approach is superior to sectoring since antennas are placed at the outer edges of the cell, and any base station channel may be assigned to any zone by the base station

In-building deployment is the next great growth phase

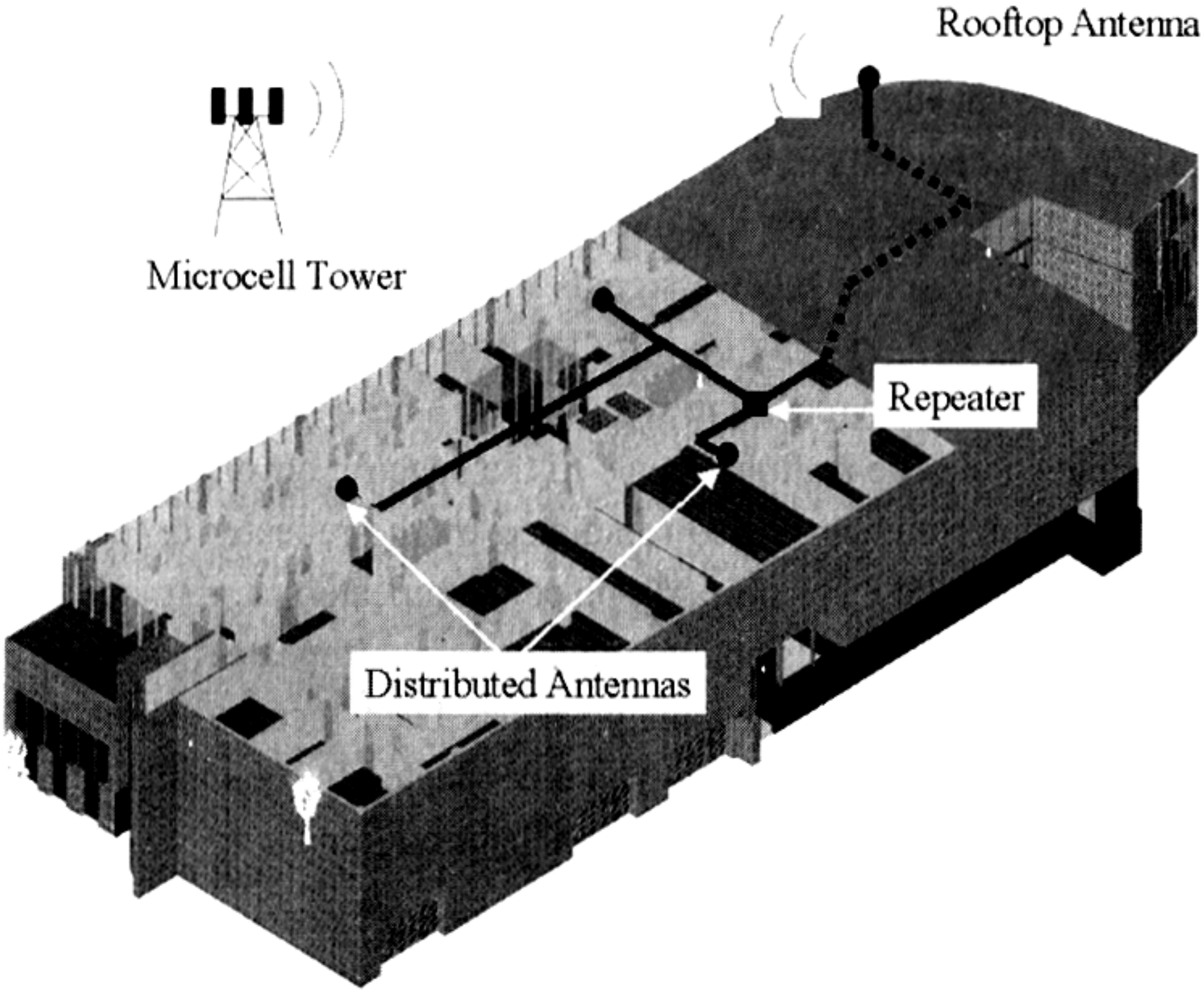


Figure 3.12 Illustration of how a distributed antenna system (DAS) may be used inside a building. Figure produced in SitePlanner®. (Courtesy of Wireless Valley Communications Inc.)

The Zone Cell Concept

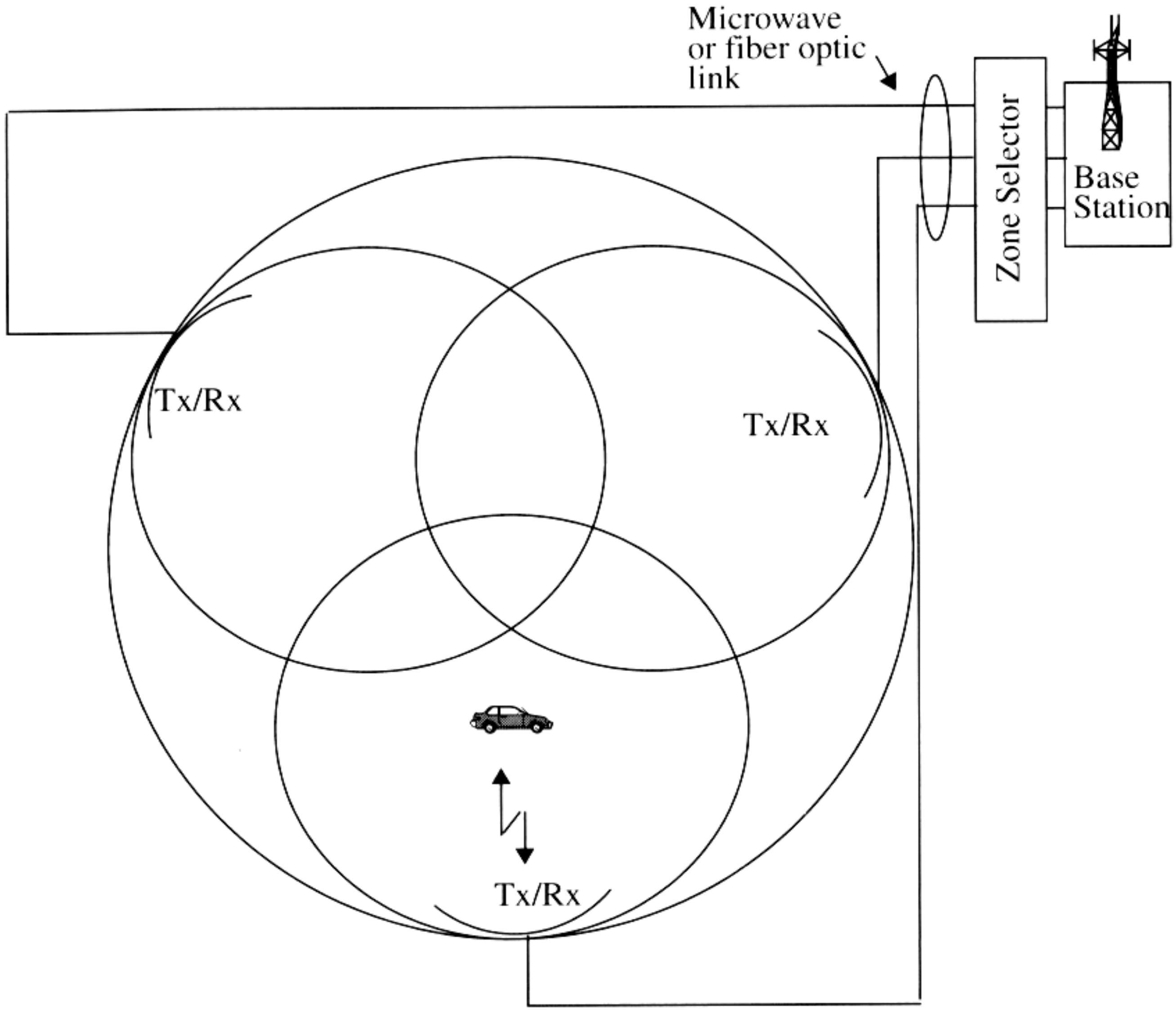


Figure 3.13 The microcell concept [adapted from [Lee91b] © IEEE].

- **As a mobile travels** from one zone to another within the cell, **it retains the same channel**. The base station simply switches the channel to a different zone site. (Thus, unlike in sectoring, a handoff is not required at the MSC when the mobile travels between zones within the cell.)

- The base station radiation is localized and interference is reduced. The channels are distributed in time and space by all three zones and are also reused in co-channel cells in the normal fashion.

- This technique is particularly useful for urban traffic

- **Decreased co-channel interference** improves the signal quality and also leads to an **increase in capacity, without the degradation in trunking efficiency** caused by sectoring.

- As mentioned earlier, an S/I of **18 dB** is typically required for satisfactory system performance in narrowband FM. For a system with N = 7, a D/R of 4.6 was shown to achieve this.

- With respect to the zone microcell system, since transmission at any instant is confined to a particular zone, this implies that a **Dz/Rz of 4.6** (where Dz is the minimum distance between active co-channel zones and Rz is the zone radius) can achieve the required link performance.

Zone Cell Concept

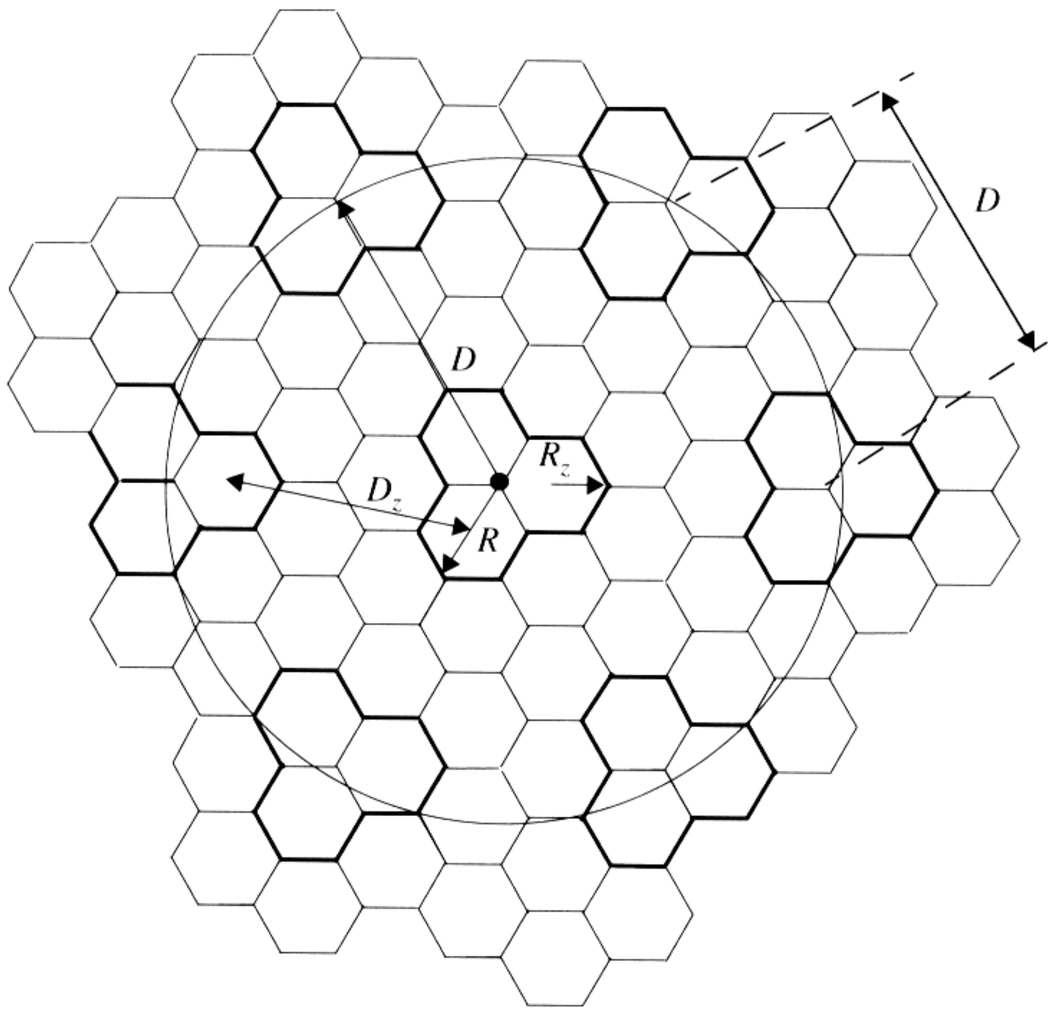


Figure 3.14 Define D, D_z, R, and R_z for a microcell architecture with $N = 7$. The smaller hexagons form zones and three hexagons (outlined in bold) together form a cell. Six nearest co-channel cells are shown.

- In Figure 3.12, let each individual hexagon represents a zone, while each group of three hexagons represents a cell.

- The zone radius R is approximately equal to one hexagon radius. Now, the capacity of the zone microcell system is directly related to the distance between co-channel cells, and not zones. This distance is represented as D in Figure 3.14.

- For a Dz/Rz value of 4.6, it can be seen from the geometry of Figure 3.14 that the value of co-channel reuse ratio, D/R, is equal to 3, where R is the radius of the cell and is equal to twice the length of the hexagon radius.

- Using equation (3.4), D/R = 3 corresponds to a cluster size of N = 3. This reduction in the cluster size from N = 7 to N = 3 amounts to a 2.33 times increase in capacity for a system completely based on the zone microcell concept.

- **Hence for the same S/I requirement of 18 dB, this system provides a significant increase in capacity over conventional cellular planning.**

- By examining Figure 3.13 and using equation (3.8) [Lee] the exact worst case S/I of the zone microcell system can be estimated to be **20 dB**.

- Thus, in the worst case, the system provides a margin of 2 dB over the required signal-to- interference ratio while increasing the capacity by 2.33 times over a conventional 7-cell system using omni-directional antennas.

- **No loss in trunking efficiency is experienced.**
  Zone cell architectures are being adopted in many cellular and personal communication systems.

Summary of Chapter (3)

- the fundamental concepts of handoff,
- frequency reuse,
- trunking efficiency and GOS,
- frequency planning.
- The capacity of a cellular system.
- The S/I limits.
- cell splitting,
- sectoring,
- zone microcell technique

The radio propagation characteristics influence the effectiveness of all of these methods in an actual system. Radio propagation is the subject of the following two chapters.

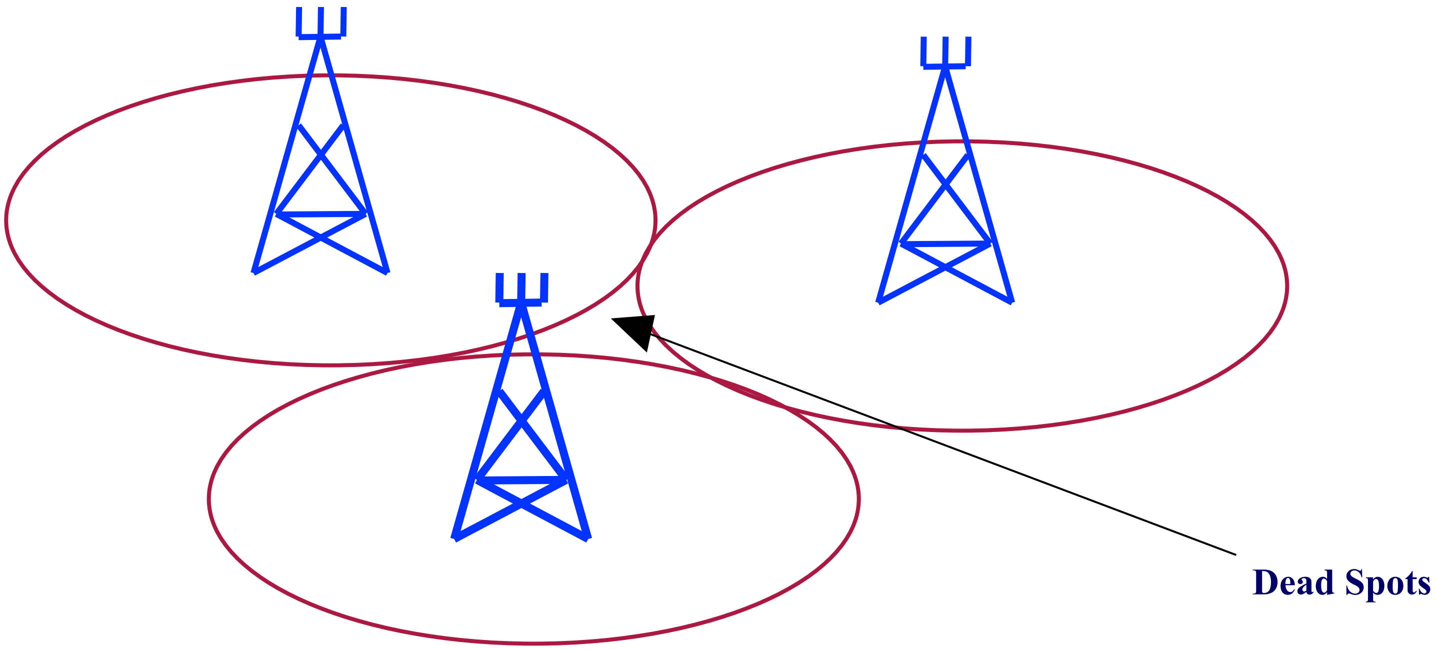
- Slides from Vodafone seminar

(taken from source with permission)

Radio Coverage

A visible pattern of sound waves

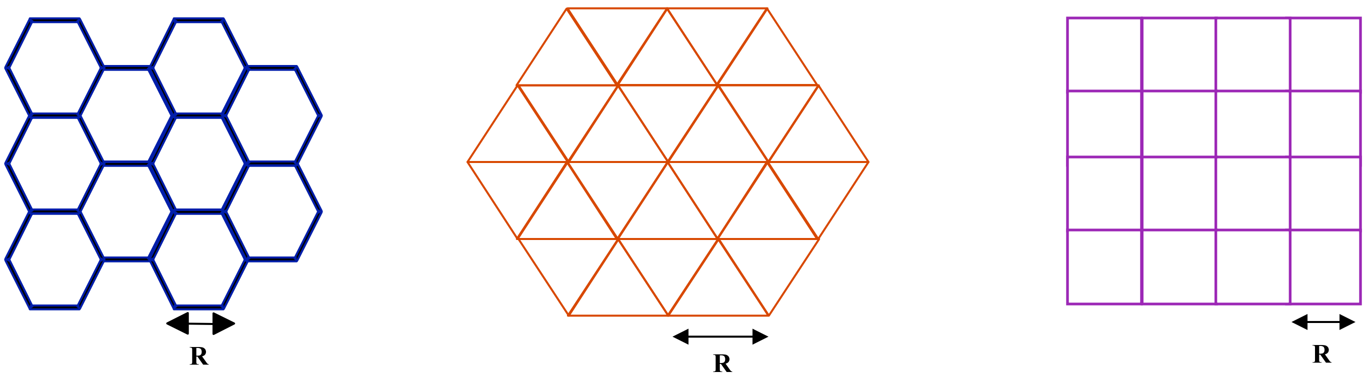
Cell Geometry



Problem of omni directional antennas

Cell Geometrical Shape

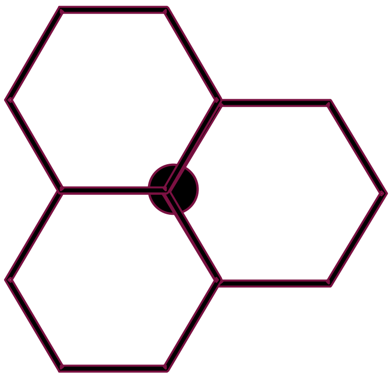
To solve the dead spot problem



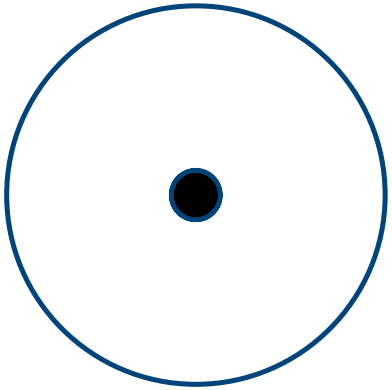
Tradeoffs

- **The number of cells required to cover a given area.**
- **The cell transceiver power.**

Transceiver Antenna

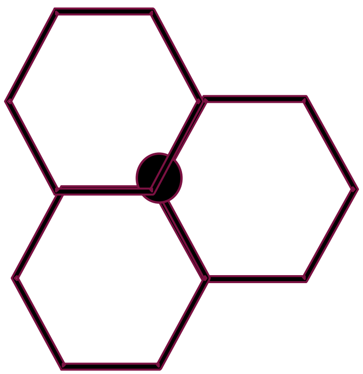


Sectorial Antenna

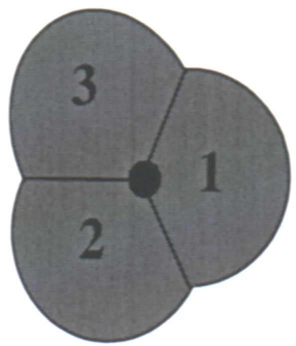


Omni-Directional Antenna

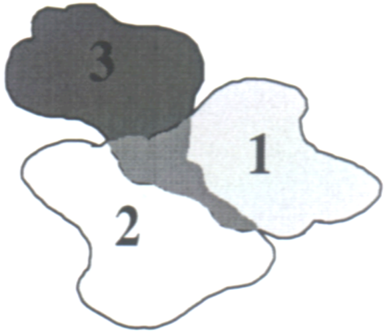
Sectorial Antenna



Sectorial Antenna



Theoretical

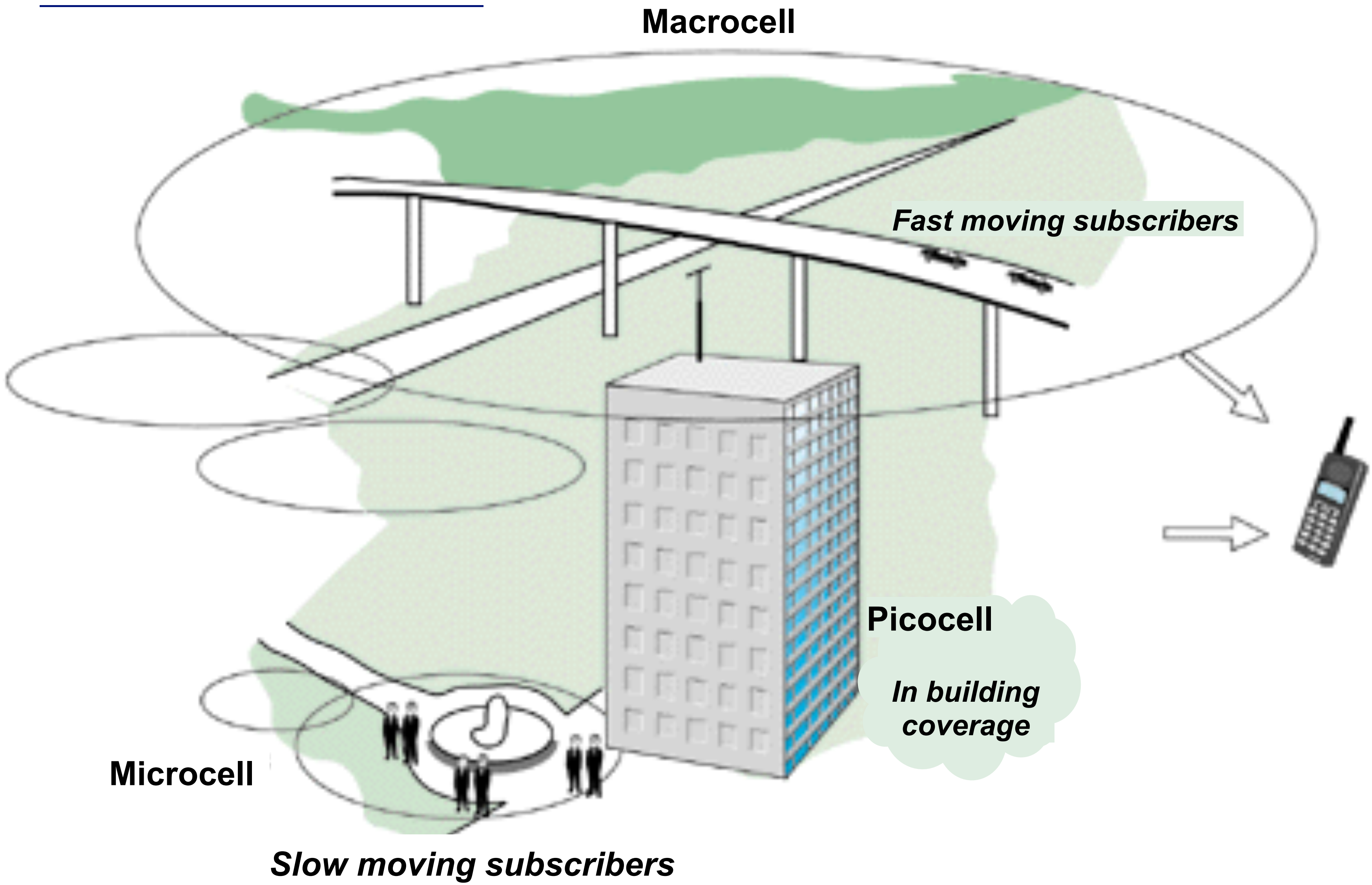


Actual

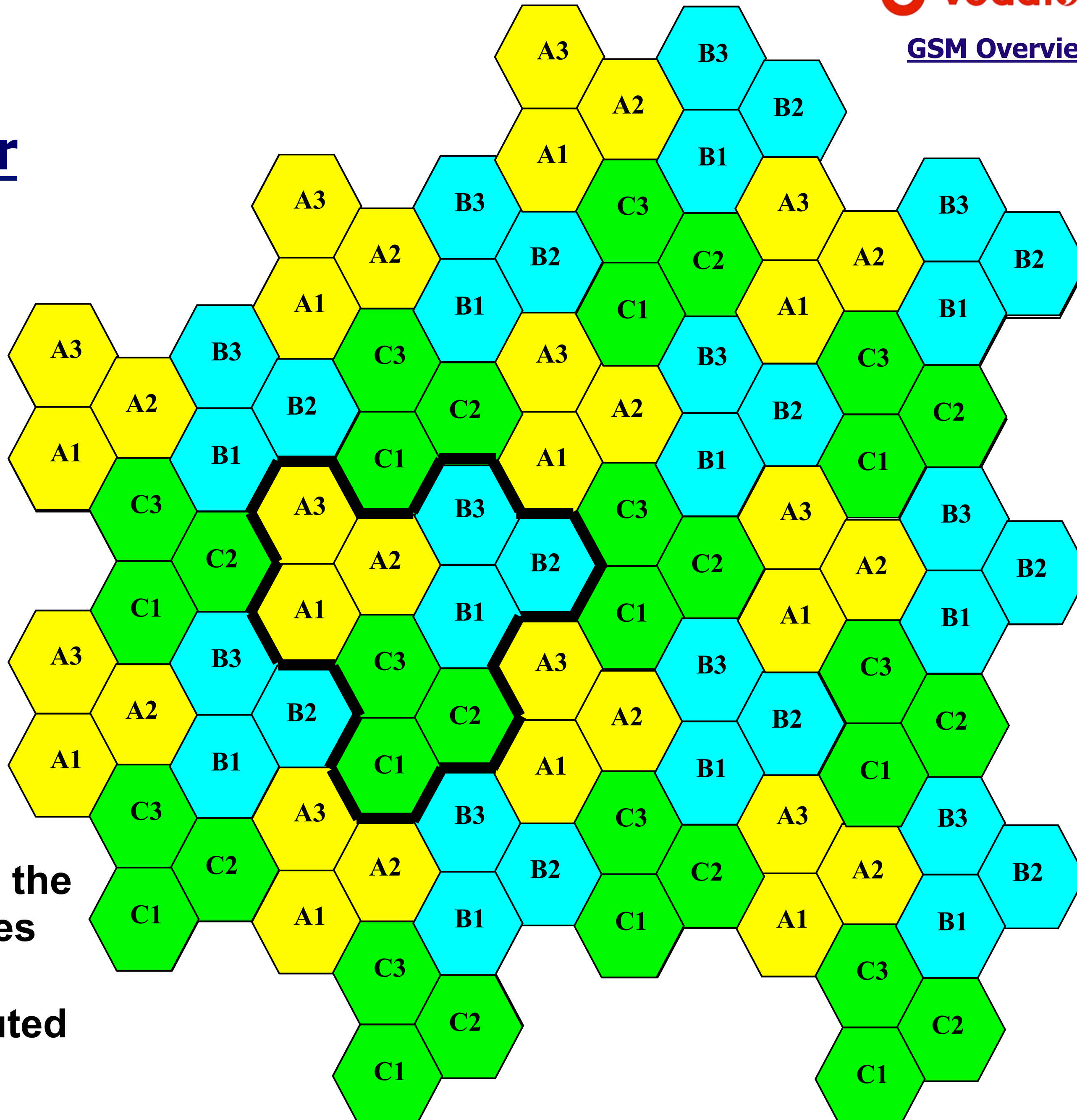
The cells will take the form of overlapping circles.

Due to the obstacles in the coverage area the actual shape of the cells would be Random.

Cell Classification



3/9 Cluster



3/9 cluster in which the available frequencies are divided into 9 groups and distributed between 3 sites

Radio Coverage

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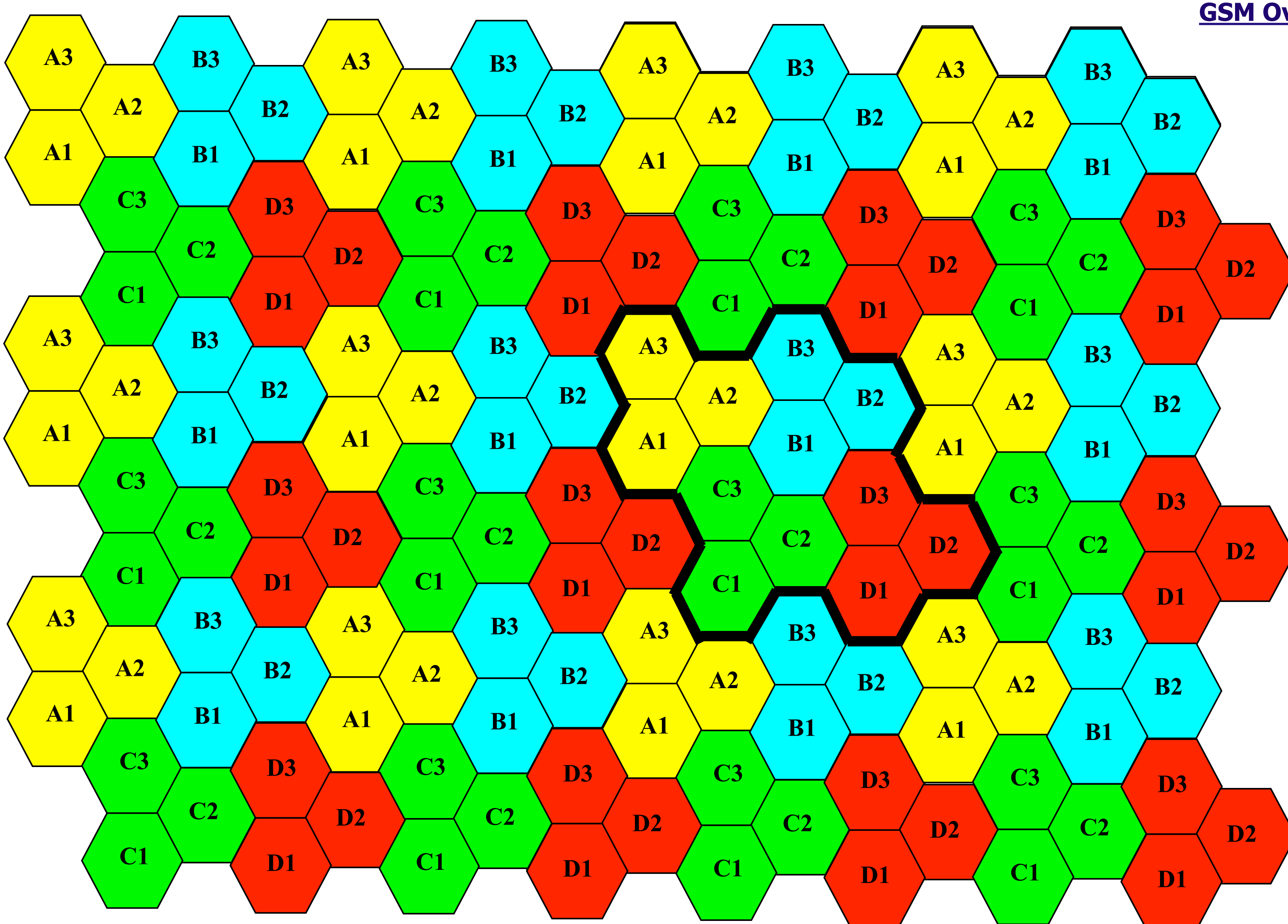
GSM Overview



4/12 cluster in which the available frequencies are divided into 12 groups and distributed between 4 sites

4 / 12 Cluster

Radio Coverage

7 / 21 cluster in which the available frequencies are divided into 21 groups and distributed between 7 sites

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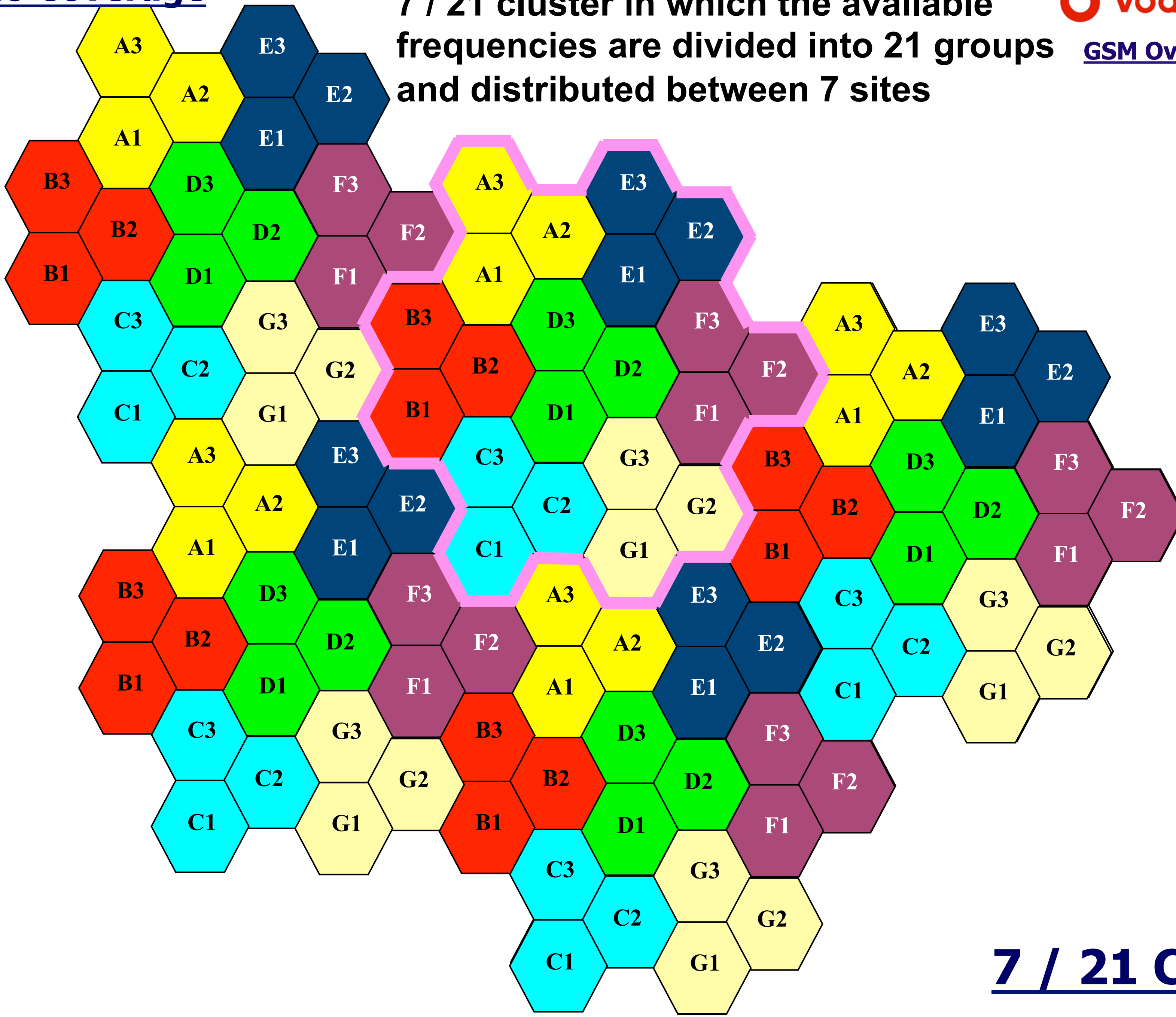
GSM Overview



7 / 21 Cluster

Which Cluster Size to use?

Carrier to interference ratio

It's the difference in power level between the carrier in a given cell and the same carrier received from the nearest cell that reuses the same frequency.

	Number of frequencies per site	Traffic Channels	C/I Ratio
3/9	High	High	Low
4/12	Medium	Medium	Medium
7/21	Low	Low	High

Chapter 3 (problems) 3^{nd} Edition

- 3.1
- 3.3
- 3.5
- 3.8
- 3.9 (XXX)
- 3.10
- 3.15