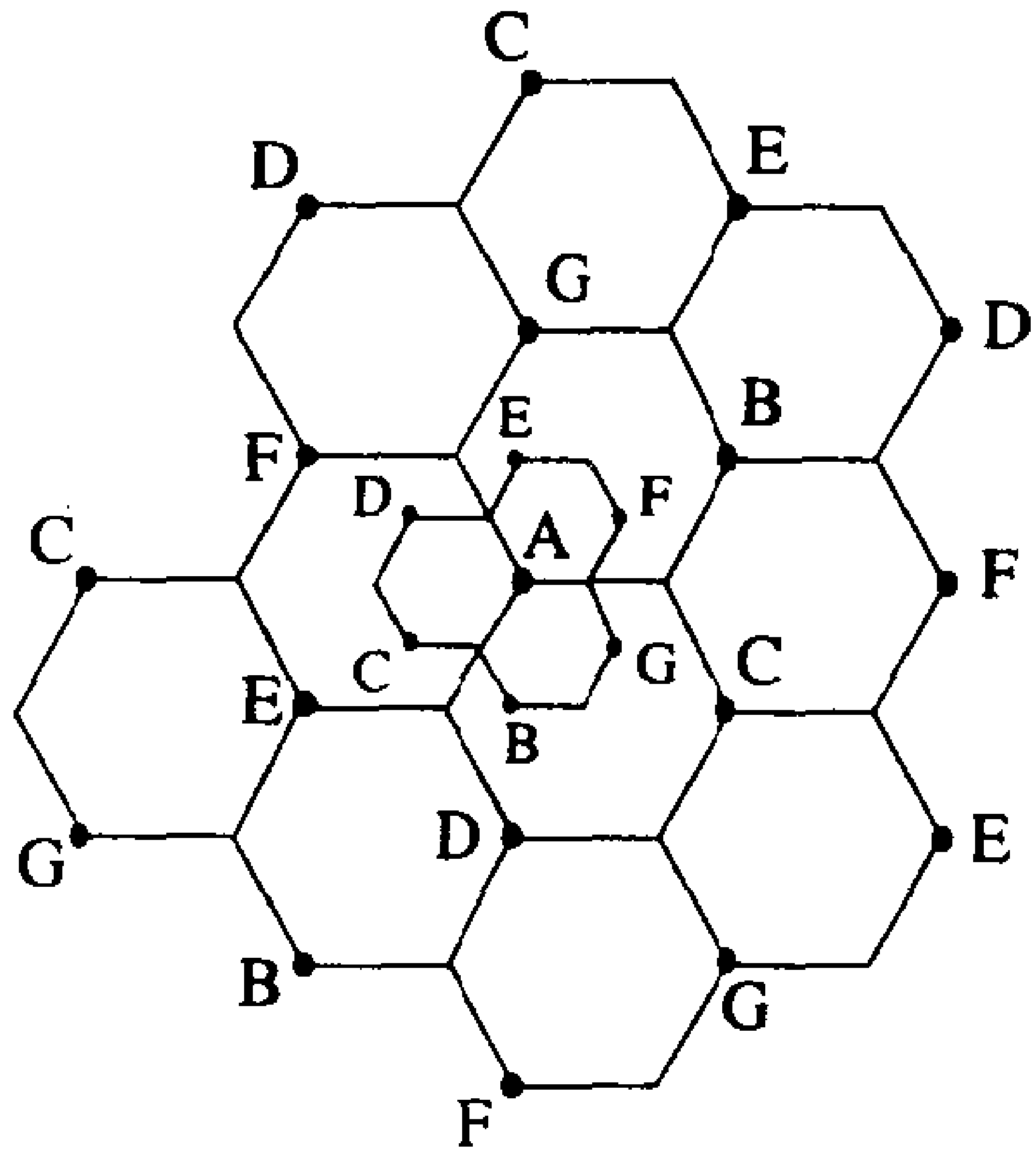
Improving Capacity in Cellular Systems

- Cost of a cellular network is proportional to the number of Base Stations. The income is proportional to the number of users.
- Ways to increase capacity:
  - New spectrum –expensive. PCS bands were sold for $20B.
  - Architectural approaches: cell splitting, cell sectoring, reuse partitioning, microcell zones.
  - Dynamic allocation of channels according to load in the cell (non-uniform distribution of channels).
  - Improve access technologies.

Cell Splitting

- Cell Splitting is the process of subdividing the congested cell into smaller cells (microcells),Each with its own base station and a corresponding reduction in antenna height and transmitter power.

- Cell Splitting increases the capacity since it increases the number of times the channels are reused.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An Example

- The area covered by a circle with radius R is four times the area covered by the circle with radius R/2
- The number of cells is increased four times
- The number of clusters the number of channels and the capacity in the coverage area are increased
- Cell Splitting does not change the co-channel re-use ratio Q =D/R

Transmit Power

- New cells are smaller, so the transmit power of the new cells must be reduced
- How to determine the transmit power?
- The transmit power of the new cells can be found by examining the received power at the new and old cell boundaries and setting them equal
- Pr(at the old cell boundary) is proportional to

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

- Pr(at the new cell boundary) is proportional to

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

- If n=4, find Pt_2.

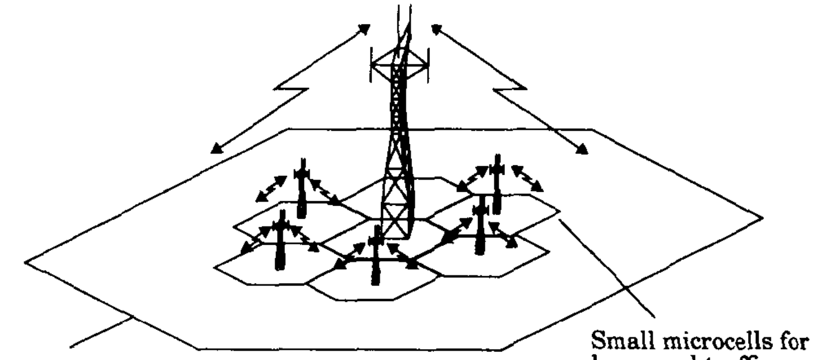
Transmit Power

- Take n=4, we get

$$P_{t2} = P_{t1}/16$$

- We find that the transmit power must be reduced by 16 times or 12 dB in order to use the microcells to cover the original area. While maintaining the same S/I.

Cell splitting



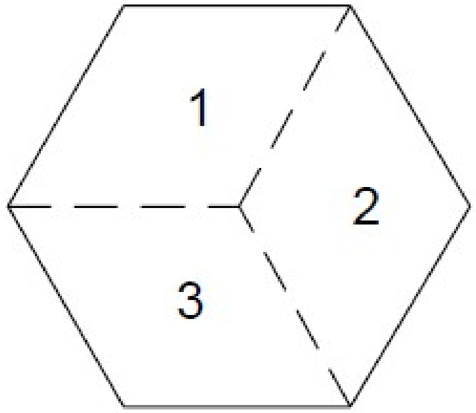
- Not all cells are split at the same time due to real estate issues
- Different cell sizes exist, hence, need to maintain co-channel distance.
- Handoff issues must be addressed so that high and low speed users are accommodated.
- When there are two cell sizes in the same region, we can't simply use original transmit power for all new cells or new transmit power for all old cells.
- Larger transmit power – channels may not be separated from co-channels
- Smaller transmit power --parts of the larger cells left uncovered
- Two groups:
  - one that corresponds to the smaller cell and the other for larger cell reuse requirements

Cell splitting (cont.)

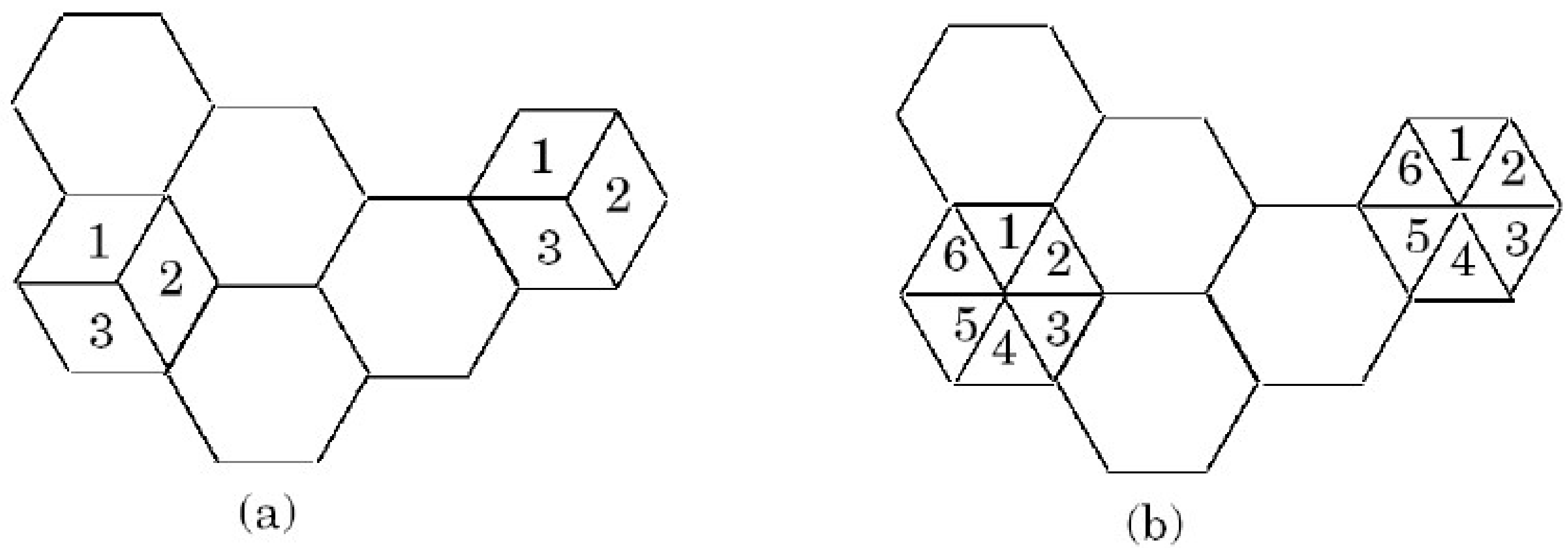
- The sizes of these two groups depend on the stage of the splitting process
- At the beginning, fewer channels will be there in the smaller power group. As the demand grows, smaller groups would require more channels
- Cell splitting continues until all the channels are used in the smaller power group
- Antenna Down tilting
  - To limit the radio coverage of microcells

Cell sectoring

- Another way to reduce the number of cells in a cluster and hence, to reduce Interference is sectoring. Sectoring refers to the use of directional rather than omni antennas. Three 120 degrees sectors are shown as an example



- Analysis: mobile in center cell will experience interference from only 2 cells (not 6). Improvement of 6dB in S/I. Alternatively, try to reduce the reuse factor. Sectoring entails reduced trunking efficiency.



(a) 120° sectoring; (b) 60° sectoiring

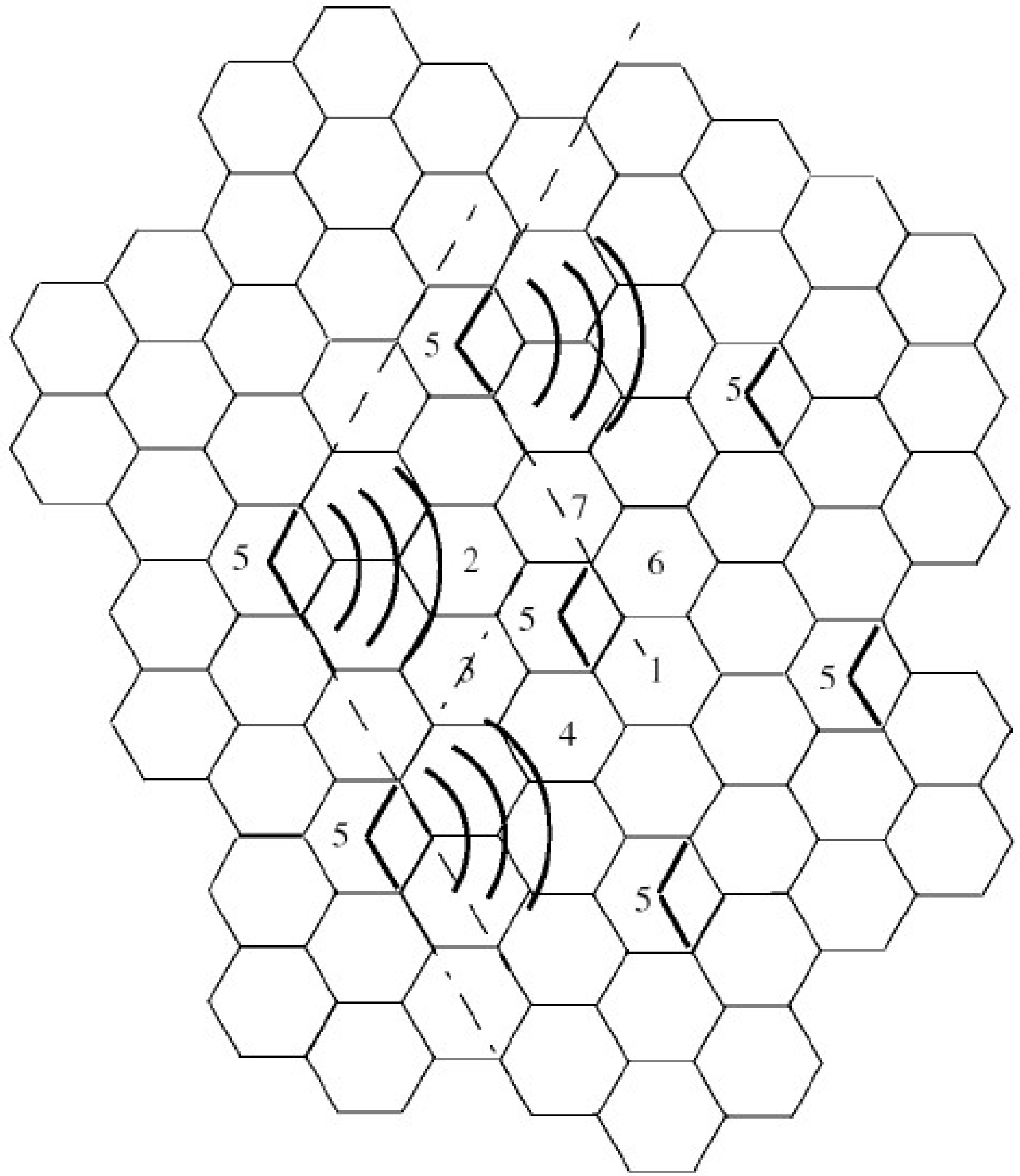


Figure 3.11 Illustration of how 120° sectoring reduces interference from co-channel cells. Out of the 6 co-channel cells in the first tier, only two of them interfere with the center cell. If omnidirectional antennas were used at each base station, all six co-channel cells would interfere with the center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

Example of Cell Sectoring

- With omni directional antennas

$$C/I = \frac{(D/R)^n}{6} = \frac{(\sqrt{3N})^n}{6} \qquad \frac{C}{I} = \frac{9}{6}N^2$$

Where we assumed that the power attenuation n = 4.

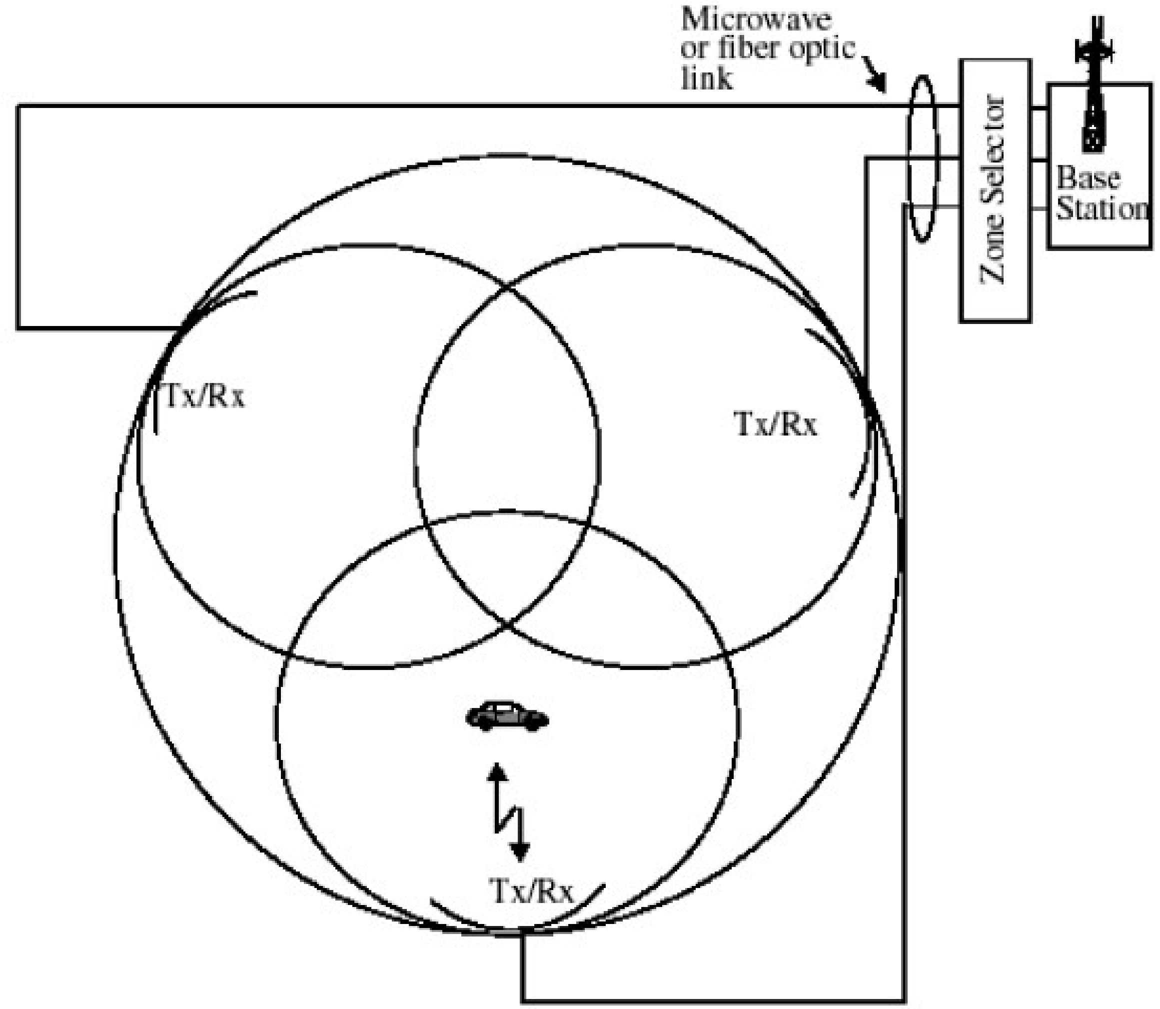
- For N = 4, we obtain S = 13.8 dB.
- For N = 4 and with 3 sectors, we get S = 19. 9 dB:

$$\frac{C}{I} = \frac{9}{2}N^2$$

Microzones

- Multiple zones and a base station make up a cell
- As a mobile travels within the cell, it is served by the zone with the strongest signal
- This technique is superior to sectoring because antennas are placed at the outer edges of the cell, and any base station channel can be assigned to any zone by the base station

Microzoning



ADVANTAGES

- No handoffs is required at the MSC
- The base station radiation is localized and interference is reduced. A given channel is active only in the particular zone in which the mobile is traveling
- The co-channel interference is also reduced

- Decreased co-channel interference improves signal quality which leads to an increase in capacity without any degradation in trunking efficiency caused by sectoring

- For example

  We know an (S/I) of 18dB is required for satisfactory system performance in narrowband FM

EXAMPLE

- If a system with N=7 and (D/R)=4.6,it can achieved a (S/I) of 18dB
- For a microcell zone system, since transmission at any instant is confined to a particular zone, this implies that a (Dz/Rz) of 4.6 can achieve the required performance
- where,

  Dz = minimum distance between active co-channel zones and

  Rz = zone radius

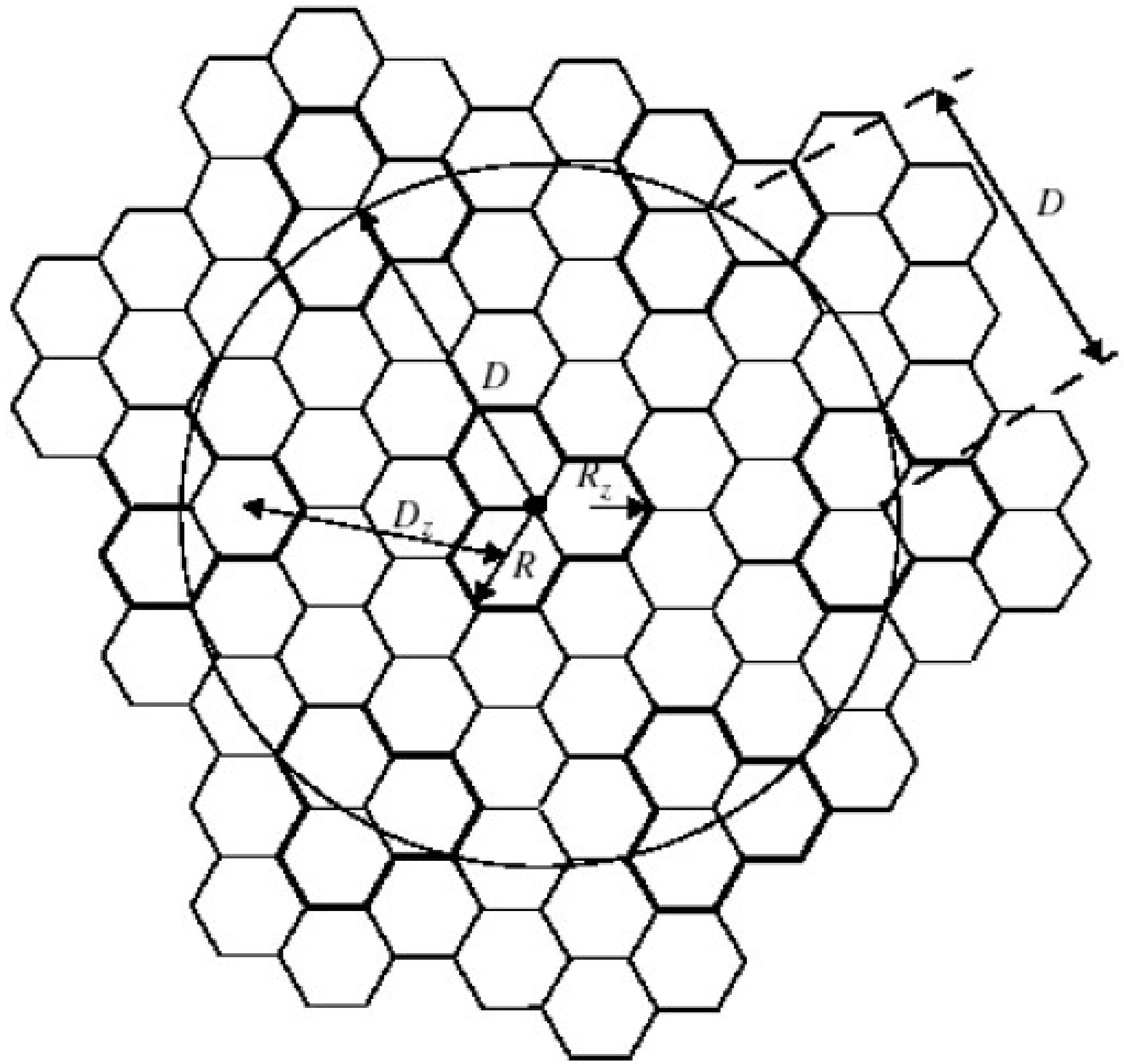


Figure 3.14 Define D, D_z, R, and R_z for a microcell architecture with $N = 7$. The smaller hexagons form zones and three hexagons (outlined in bold) together form a cell. Six nearest co-channel cells are shown.

EXAMPLE (cont.)

- In the Figure, let each hexagon represents a zone while the group of three hexagons represent a cell
- The zone radius, R_z is approximately equal to one hexagon radius
- Now, the capacity of the microcell system is directly related to the distance between co-channel cells(in the Figure is D) and not zones.
- From the geometry of the figure , the value of the co-channel reuse ratio ***(D/R)*** is ***3*** where R is the radius of the cell

- When $(D/R) = \sqrt{3N} = 3$

  we get N=cluster size=3
- This reduction in cluster size from 7 to 3 amounts to 2.33 times increase in the capacity
- The worst case , the (S/I) of this system is

  20 dB, provides a margin of 2 dB over the required (S/I) and at the same time increases the capacity by 2.33 times over the conventional 7-cell system using omni-directional antennas

Repeaters for Range Extension

- Repeaters are radio re-transmitters used to provide coverage for hard-to-reach areas, such as within buildings or in valleys or tunnels

- Repeaters are bidirectional. Upon receiving signals from base station, then amplifies and reradiates the base station signals to the specific coverage region. Also it will send signals to the serving base station.

- The repeaters do not add capacity to the system-it simply serves to reradiate the base station signal into specific locations

Repeaters for Range Extension