Cellular System and Frequency Reuse in Wireless Communication

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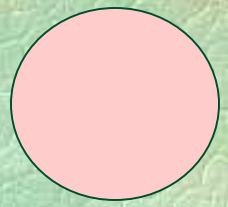
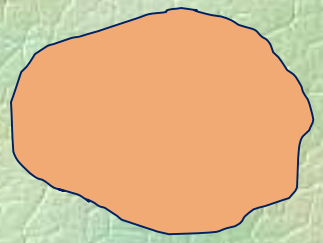
Table of Contents-

Cells and Clustering

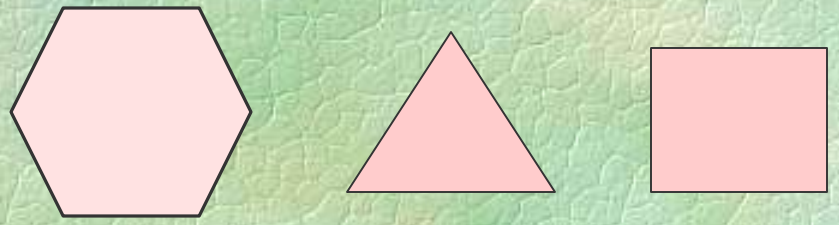
- The **Entire Service Area** is divided into **Cells.**
- Each Cell is served by a **BTS** (**Base Transceiver Station**), also called **Cell-Site** (CS) or **Base Station**.
- **Radius of Cell** varies from **few meters to few Kilometres.**



Ideal Cell



Actual Cell

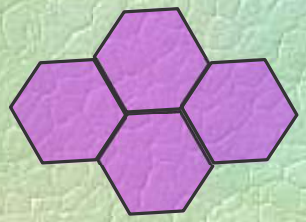


Cell Models for Analysis

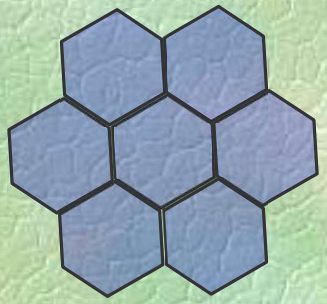
Cells and Clustering…

- **Group of Cells (K) Form Cluster**.
- Each Cluster is assigned a **Set of Frequency which is called RF Spectrum/Channels**.
- Each Cell within a Cluster uses **Disjoint set of Frequency (Channels).**

3 Cells Cluster



4 Cells Cluster



7 Cells Cluster

Cells and Clustering…

Example:- **How many clusters with size 4 are required to cover a service area of size 1765 km^2 where uniform cell size is 7 km^2.**

Sol:- Size of a cluster, K=4

So, Size (Area) of a Cluster = **Cluster Size × Cell Area**

$= 4 \times 7 = 28\ km^2$

So, **no. of Clusters in the Entire Service Area**

$= 1765 \div 28$

$\approx$ 63

Cells and Clustering…

Influencing Factors:-

1. **Environment** (Buildings, Mountains, Valleys, Road Size, etc.)
2. **No. of Users or System Load**
3. Weather Condition
4. **Transmission Power**
5. **Interference**

Cells and Clustering…

- **Cellular System** implements **SDM** (Space Division Multiplexing).
- **Channels Allocation- FCA** (Fixed Channel Allocation), **DCA** (Dynamic Channels Allocation), **BCA** (Borrowing Channel Allocation)
- Cellular System Implements **SDM in combination with FDMA and TDMA**.
- Cellular System using CDM (Code Division Multiplexing) **does not require Channel Allocation Scheme**.

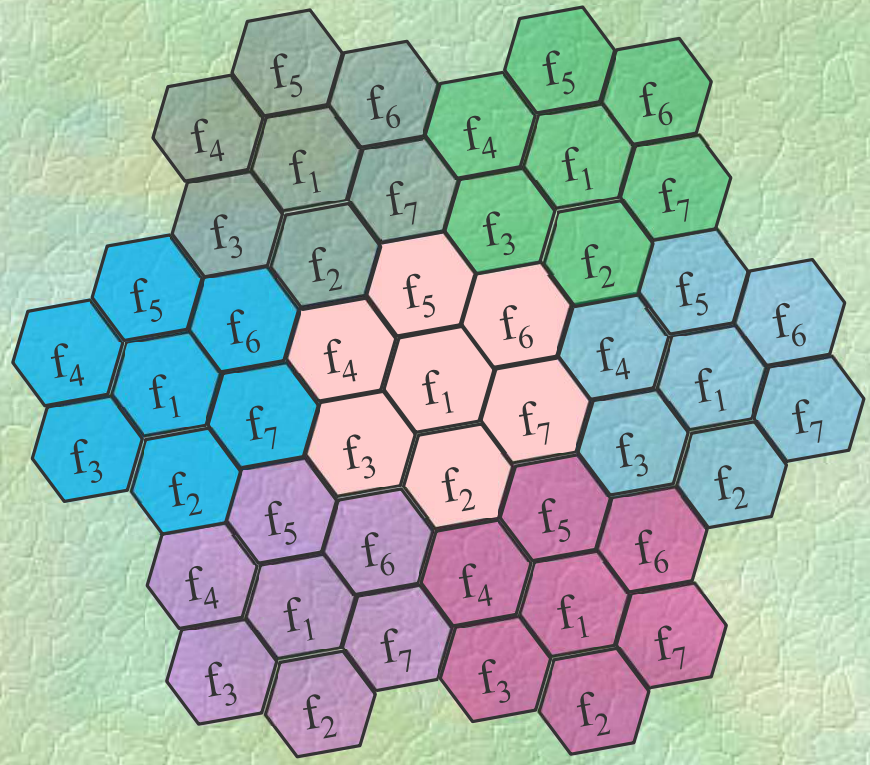
Frequency Reuse

- Cellular System has fixed no. of Channels i.e. Limited RF Spectrum which is Costly.
- It should be utilized wisely to support more and more users.
- System Capacity can be increased with Smaller Cells, Reuse of Frequencies, and Clustering.
- Service Area should be adequately protected from Co-channel and Adjacent-Channel Interference.

Frequency Reuse…

Illustration of Frequency Reuse (Fixed)

Frequency Reuse Factor or Cluster Size is 3



Frequency Reuse Factor or Cluster Size is 7

Frequency Reuse…

System capacity is defined in term of total no. of Channels available and total number of Clusters.

System Capacity=**Total No. of Channels** ×

Total No. of Clusters

Example:-A mobile Communication system is allocated RF spectrum of 20 MHz and uses RF channel bandwidth of 25 KHz. If entire service area is covered by 100 cells and frequency reuse factor is 4 then find the system capacity.

Sol: Total No. of Channels=$\mathbf{20\times10^3 \div 25 = 800}$

Total No. of Clusters= 100 ÷ 4 = 25

System Capacity= 800 × 25 = 20,000

Cluster Size and System Capacity

Suppose **K is the frequency Reuse Factor** i.e. Cluster Size (No. of Cells in a Cluster) and **N** is the **Total No. of Channels** Available.

- **Then Each Cluster can Use N Channels**
- **A Cell in a Cluster can use**

$$J = N \div K$$ **no. of Channels**

Suppose there are **M no. of Clusters** in the System and **C is the System Capacity** then

$$C = M \times N = M \times J \times K$$

- **Minimising K will increase Co-Channel Interference**

Cluster Size and System Capacity…

Example:- Coverage area of a cellular system is **4200** km^2. A total **1001 radio channels** are available for handling traffic. Suppose the coverage area of a cell is **12** km^2. How many clusters of size **7** are required to cover the communication area? Calculate the no. of channels per cell and system capacity.

Sol:- Total No. of Cells = Coverage Area ÷ Cell Area

= **4200 ÷12=350**

Total No. of Clusters (M) =**No. of Cell** ÷ Cluster Size

= **350** ÷7=50

No. of Channels per Cells =Total No. of Channels ÷ Cluster Size

= **1001 ÷7=143**

System Capacity (C)= No. of Channels × M

= 1001 × 50=50050

Placement of Co-Channels Cells

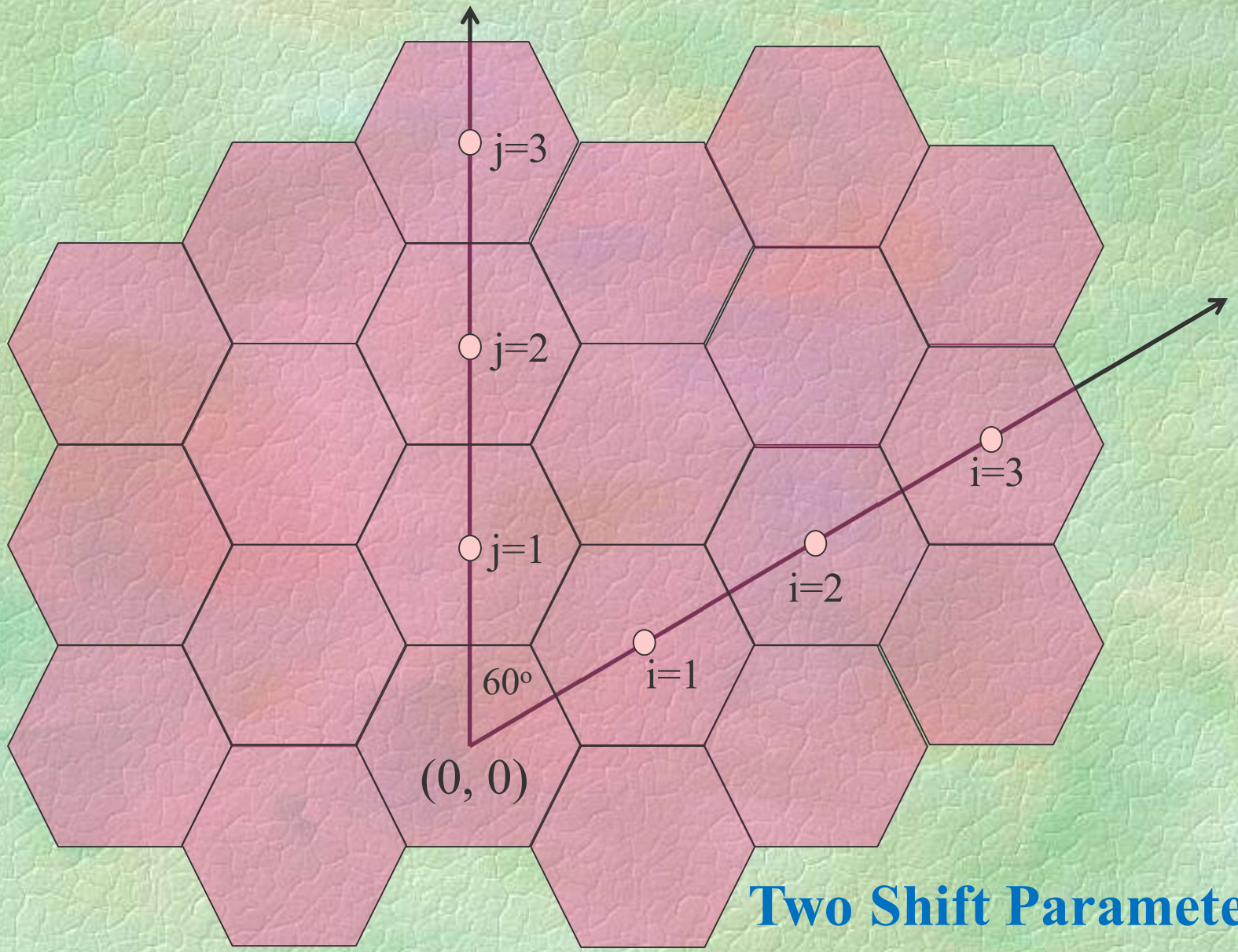
- **Co-Channels Cells-** Cells using same set of Frequency or Channels
- **Two shift parameters (i, j)** are used to locate two nearest co-channels cells in Hexagonal Geometry where i, j are separated with 60^{o}.
- **Parameters (i, j) represent no. of nearest neighboured cells between two co-channels cells.**

Method of Locating Co-Channels Cells

(a) Move i>0 no. of Cells along with any chain of Hexagons

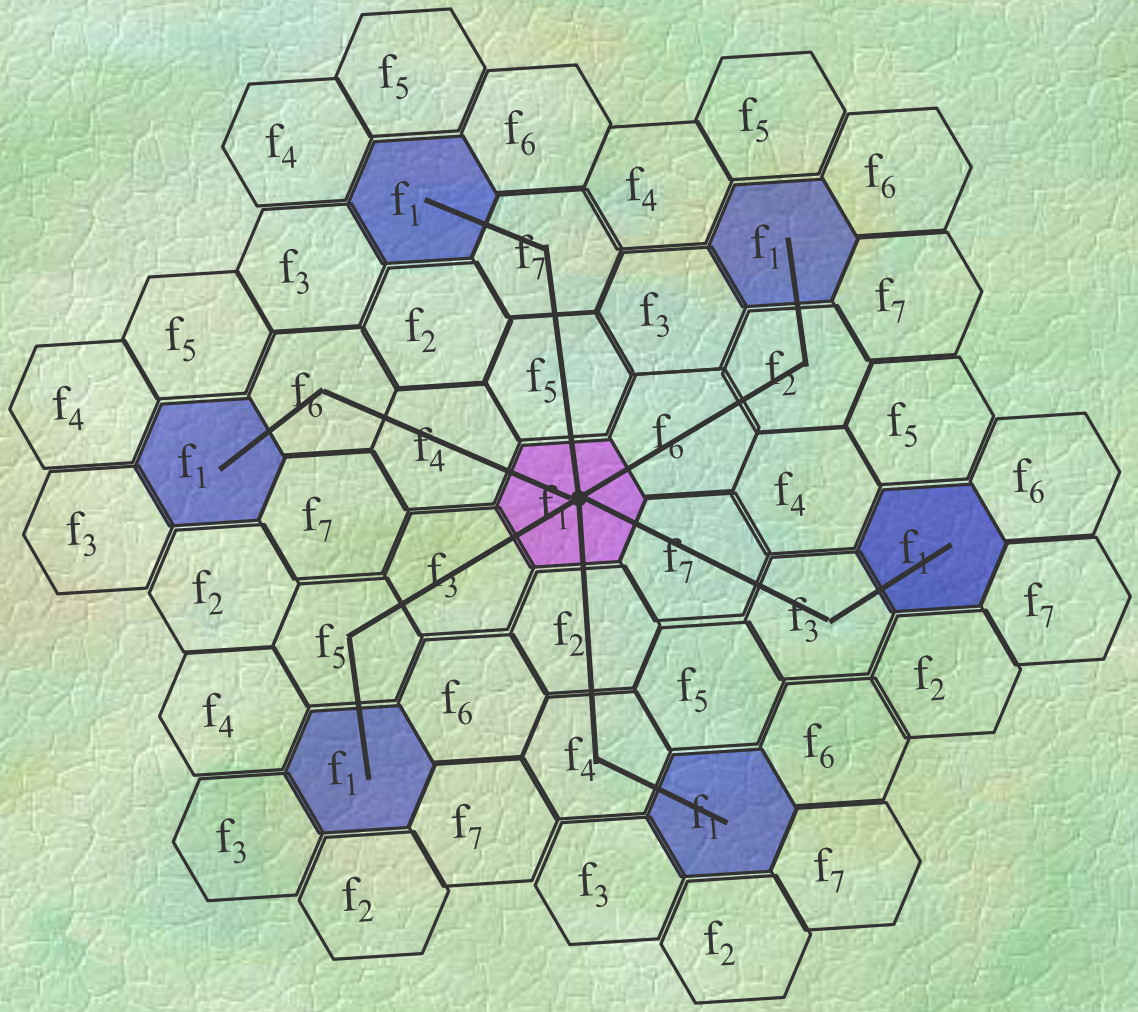
(b) Turn 60^{o} counter clockwise and move j>0 no. of Cells

Placement of Co-Channels Cells…

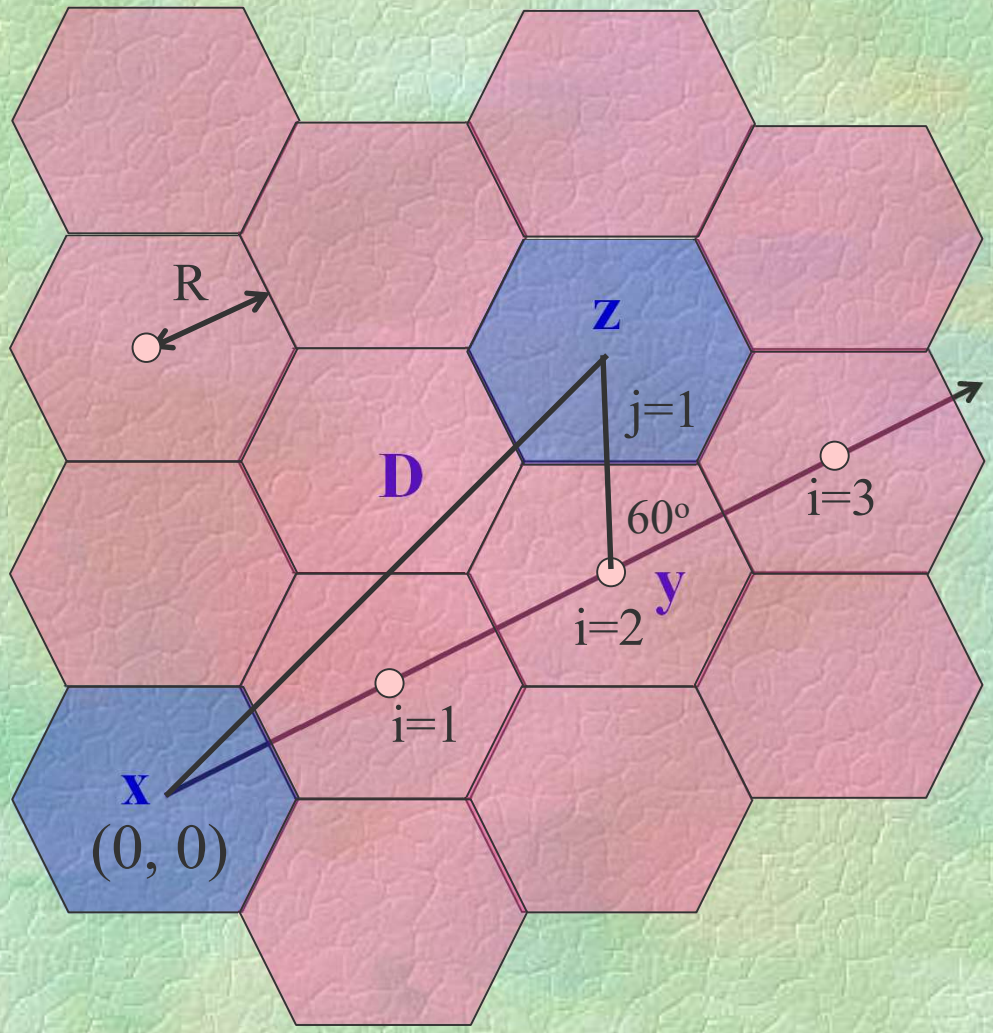


Two Shift Parameters (i, j)

Placement of Co-Channels Cells…



Placement of Co-Channels Cells…



Distance between Centre of two Adjacent Cells $\mathbf{d = \sqrt{3}\ R}$, where R is Radius of a Hexagon Cell

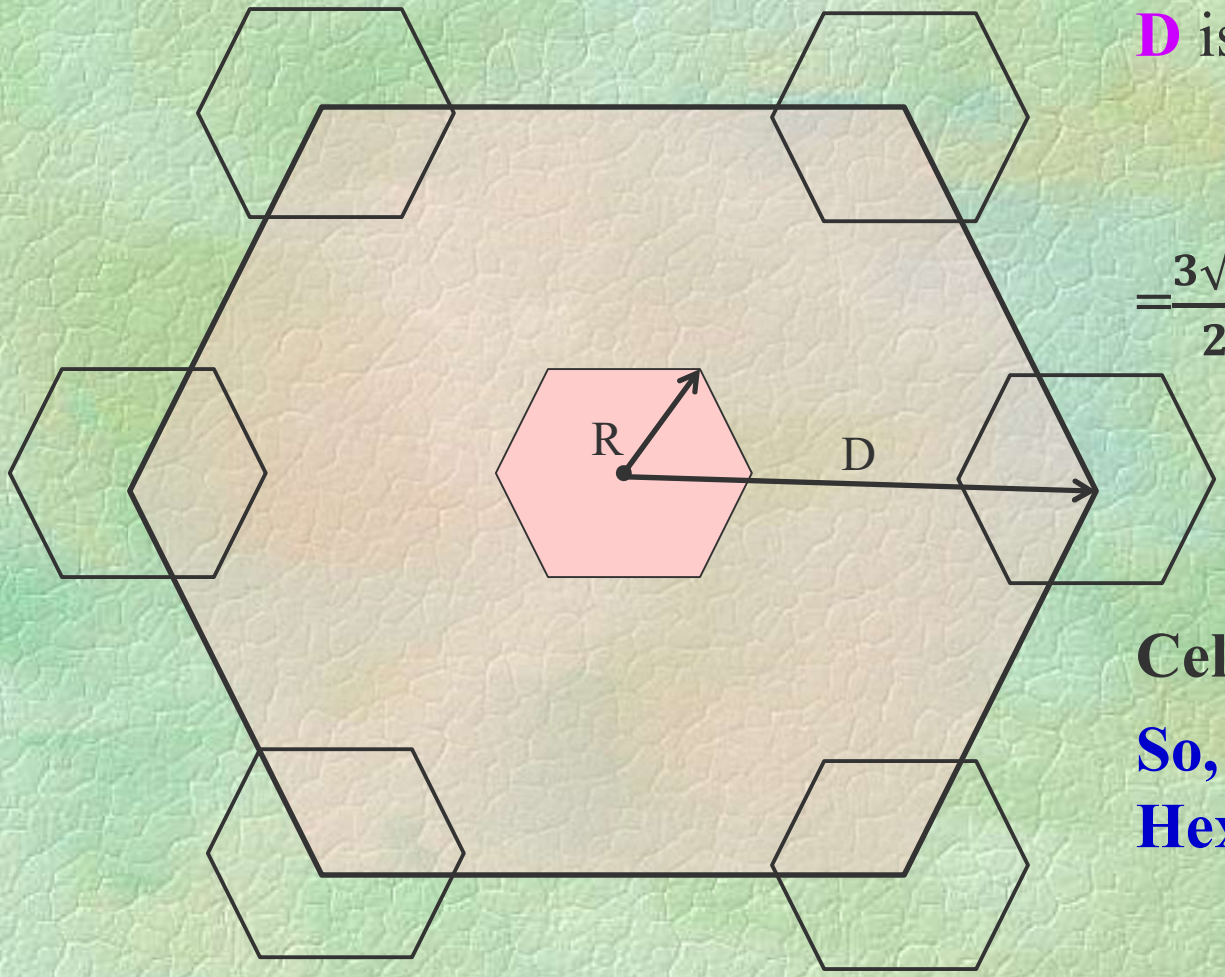
$$\mathbf{xz^2 = xy^2 + yz^2 - 2xy \times yz \cos 120^o}$$

$$\mathbf{D^2} = (i \times d)^2 + (j \times d)^2 + (i \times d)(j \times d)$$

$$= d^2(i^2 + j^2 + i \times j)$$

$$= \mathbf{3R^2(i^2 + j^2 + i \times j)}$$

Placement of Co-Channels Cells…



Area of a Large Hexagon Cell with **Centre Distance D** is given as-

$$A_{Large} = \frac{3\sqrt{3}}{2} D^2$$

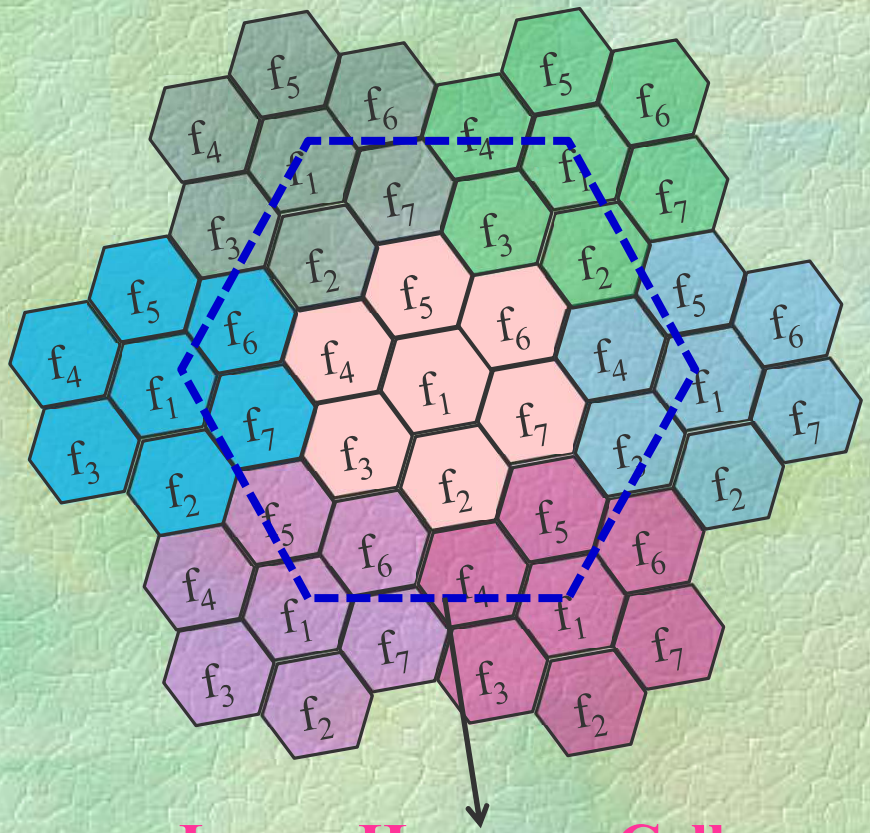
$$= \frac{3\sqrt{3}}{2} \times 3R^2\left(i^2 + j^2 + i \times j\right)$$

Area of a small Cell $= \frac{3\sqrt{3}}{2} \times R^2$

So, No of Cells in a Large Hexagon Cell

$$L = 3\left(i^2 + j^2 + i \times j\right)$$

Cluster Size (K) and Area of Large Hexagon Cell



It clear from Fig. that K=7 and Area of Large Cell is covered by K cells and $^1/_3$ of 6 clusters.

So $L = K + {}^1/_3 \times 6K$

$= 3K$

Since, $L = 3(i^2 + j^2 + i \times j)$

So, $K = (i^2 + j^2 + i \times j)$

Cluster Size (K) and Area of Large Hexagon Cell

Example:- Determine the no. of cells in a cluster with shift parameters i=3 and j=4 in a regular Hexagon geometry pattern.

Sol:- Let no. of cells in a Cluster is K then

$$\mathbf{K} = (i^2 + j^2 + i \times j)$$

$$= 3^2 + 4^2 + 3 \times 4 = \mathbf{37}$$

Note: (a) **(i, j)=(0, 0) then K=0 is meaningless**

(b) **(i, j)=(0, 1) or (1, 0) then K=1 is applicable for CDMA only**

Frequency Reuse Ratio/Distance

D- Distance between two nearest Co-channels Cells

R- Radius of a regular Hexagon Cell

Then **Frequency Reuse Ratio** **q=D/R**

q is also known as Co-channel reuse Ratio or Factor or Co-channel Interference Reduction Factor or Frequency Reuse Ratio.

Example:- Determine the distance from nearest co-channel cells where radius of a cell is 0.64 km and co-channel reuse factor is 12.

Sol:- **Distance D=q×R=12 ×0.64=7.68 km**

Frequency Reuse Factor (q) and Cluster Size (K)

- K- Cluster Size
- q- Frequency Reuse Factor (**q=D/R**)
- D- Distance between two nearest Co-channels Cells
- R- Radius of a regular Hexagon Cell
- (i, j)- Shift Parameters

We have already derived-

K= $(i^2 + j^2 + i \times j)$ and $D^2 = 3R^2(i^2+j^2+i \times j)$

Therefore, $q = {}^{D}/_{R} = \sqrt{3K}$

Conclusion

C- Carrier Signal, I- Interference, N-Noise

(a) **If C/I > 18 dB is Desirable and cellular system is properly designed.**

(b) **If C/I<18 dB and C/N>18 dB then Co-channel Interference.**

(c) If C/I <18 dB and C/N < 18 dB and C/I≈ C/N then Radio Coverage Problem

(d) **If C/I <18 dB and C/N < 18 dB and C/I < C/N then Radio Coverage Problem and Co-channel Interference**

(e) **Increase in Cluster Size (K) results in more System Capacity**

(f) **Minimising K will increase Co-channel Interference**

(g) Increasing K will result in more Infrastructure Cost

THANKS!