Lecture 6

CS 621
Mobile Computing

Mobile Cellular Systems

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Several slides and images in this presentation have been taken from Prof. Nityananda Sarma's class notes/ppt.
Several images have been taken from the book Mobile Communication by Jochen Schiller.

Propagation Model

- The received signal power depends on the **distance** between the transmitter and the receiver.

$$P_r = P_0 \left(\frac{d}{d_0} \right)^{-\alpha}$$

- P_0 is the power received at a reference distance d_0.

- α is called the path loss exponent.
  - Typically, $3 \leq \alpha \leq 5$.

Worst-case Analysis

- Assumption:
  - The user is located at the corner of a cell.

$$S = P_0\left(\frac{R}{d_0}\right)^{-\alpha}$$

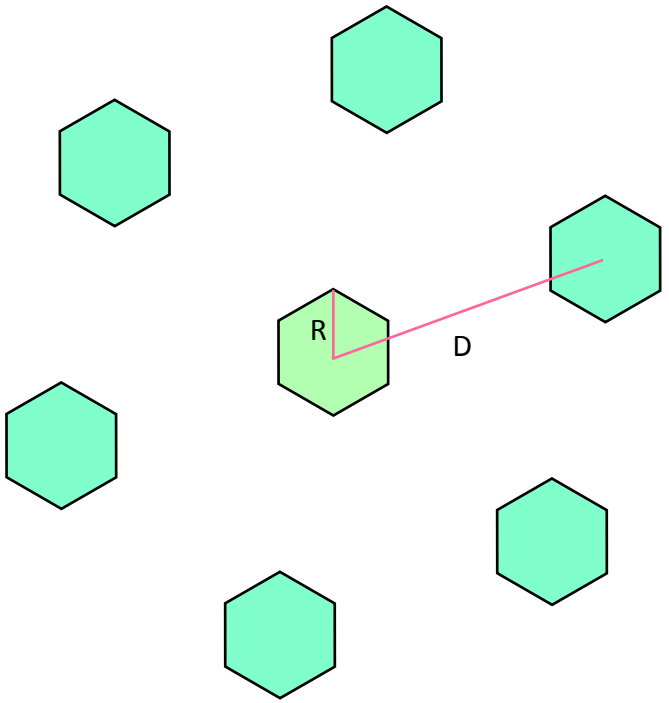
$$\frac{S}{I} = \frac{P_0\left(\frac{R}{d_0}\right)^{-\alpha}}{\sum_i P_0\left(\frac{D_i}{d_0}\right)^{-\alpha}} = \frac{R^{-\alpha}}{\sum_i D_i^{-\alpha}}$$

D_i is the distance between the center of the reference cell and the i-th interfering cell.

Signal-to-Noise (Interference) Ratio (SNR)

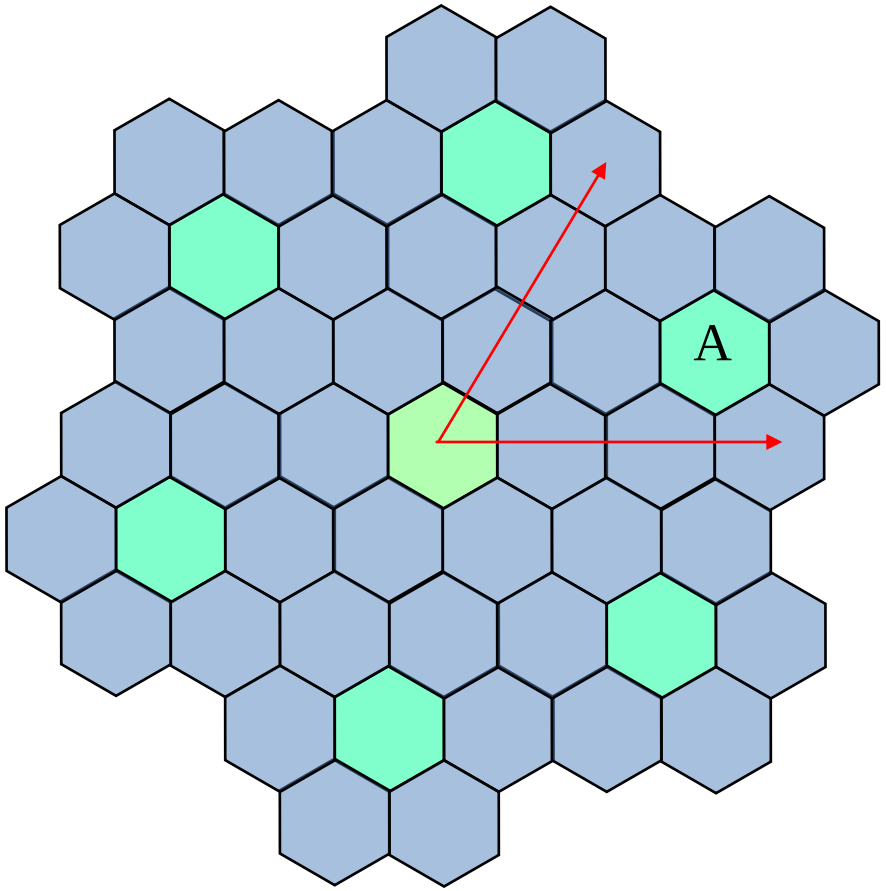
- Consider only the 1st tier of interfering cells

$$\frac{S}{I} = \frac{1}{6}\left(\frac{D}{R}\right)^{\alpha}$$



GEOMETRY OF HEXAGONAL CELLS

Coordinate System



Use (*i*,*j*) to denote a particular cell.

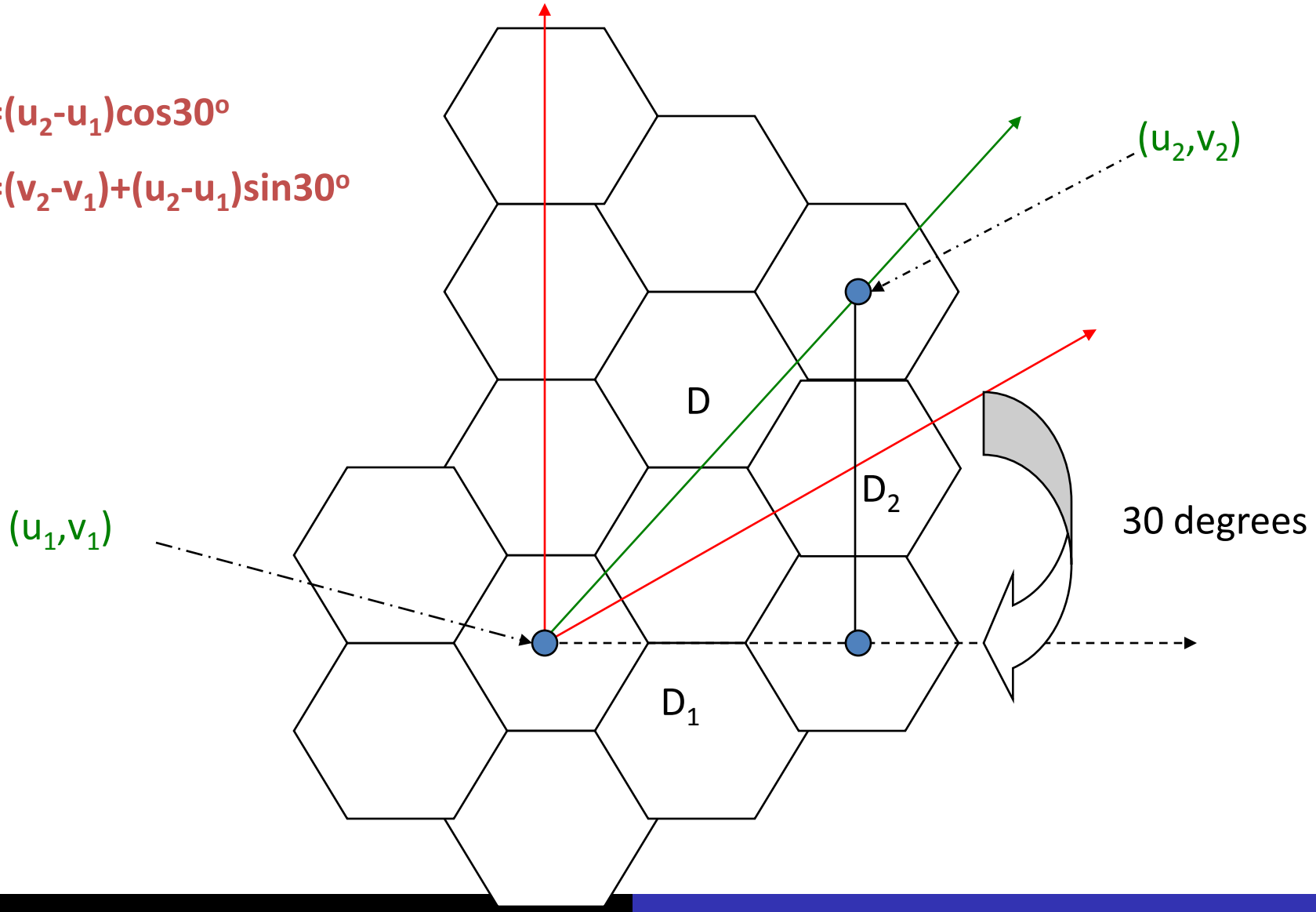
Example:

Cell A is represented by (2,1).

Geometry of Hexagonal Cell

$D_1=(u_2-u_1)\cos 30^o$

$D_2=(v_2-v_1)+(u_2-u_1)\sin 30^o$



Distance calculation

- (u_1,v_1) and (u_2,v_2) are centers of two cells
- Distance D (in Cellular Coordinate System)

$D^2 = [\ (u2-u1)^2\ (\cos 30)^2 +$

$\{(v2-v1)+(u2-u1)\ \sin 30\}^2]$

$= [\ (u2-u1)^2+(v2-v1)^2 +$

$(v2-v1)(u2-u1)\ ]$

$= [I^2 + J^2 + IJ]$ where

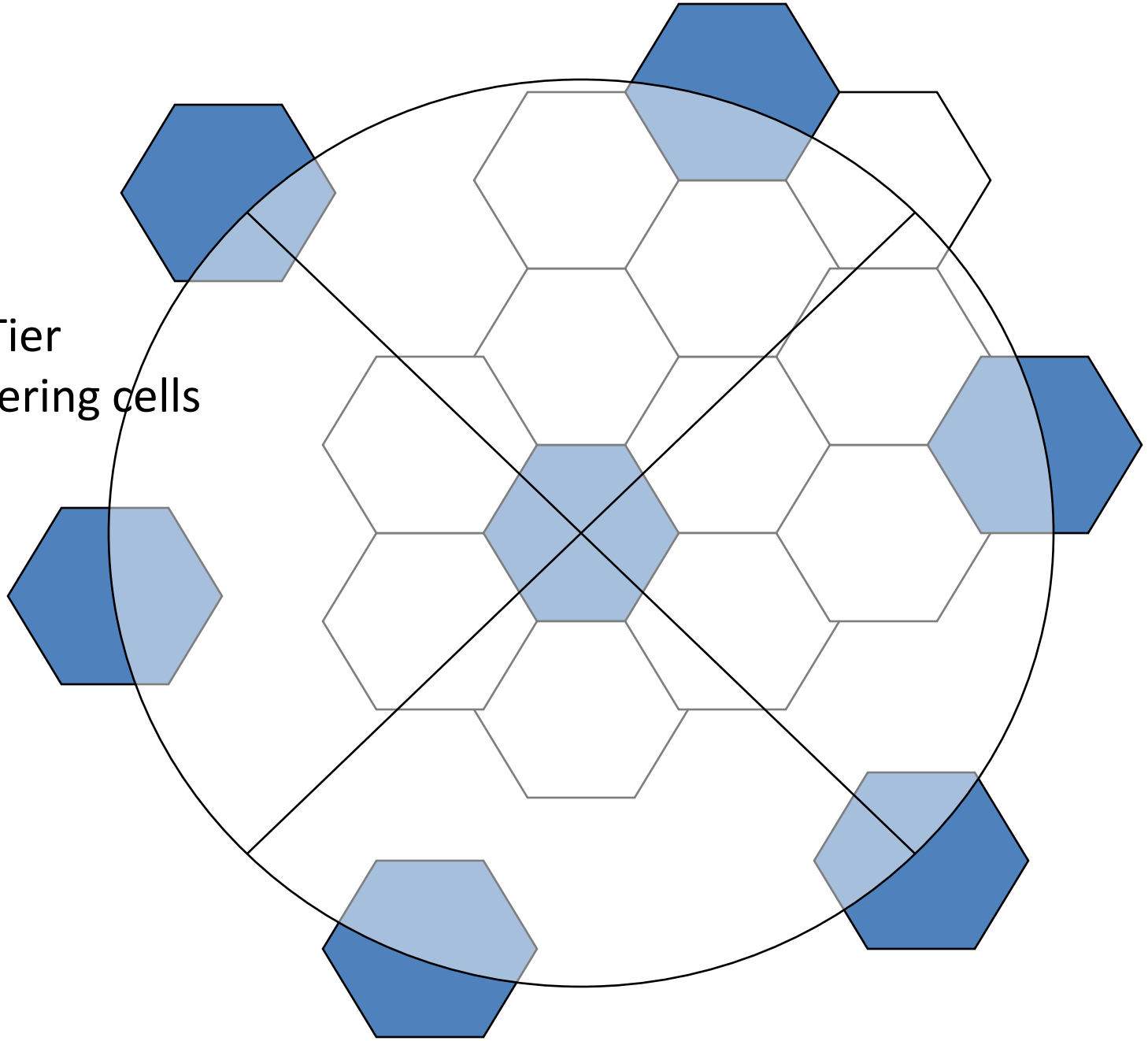
$(u_1,v_1) = (0,0)$ and $(u_2,v_2) = (I,J)$

Therefore, D (in Euclidian distance)

$= \text{Sqrt}\ (I^2 + J^2 + IJ)\ * \text{Sqrt}(3) * R\ ,\ D = \sqrt{3K}R$

- Radius is R for a cell.
- Distance between adjacent cells is 1.732 R

First Tier
Interfering cells



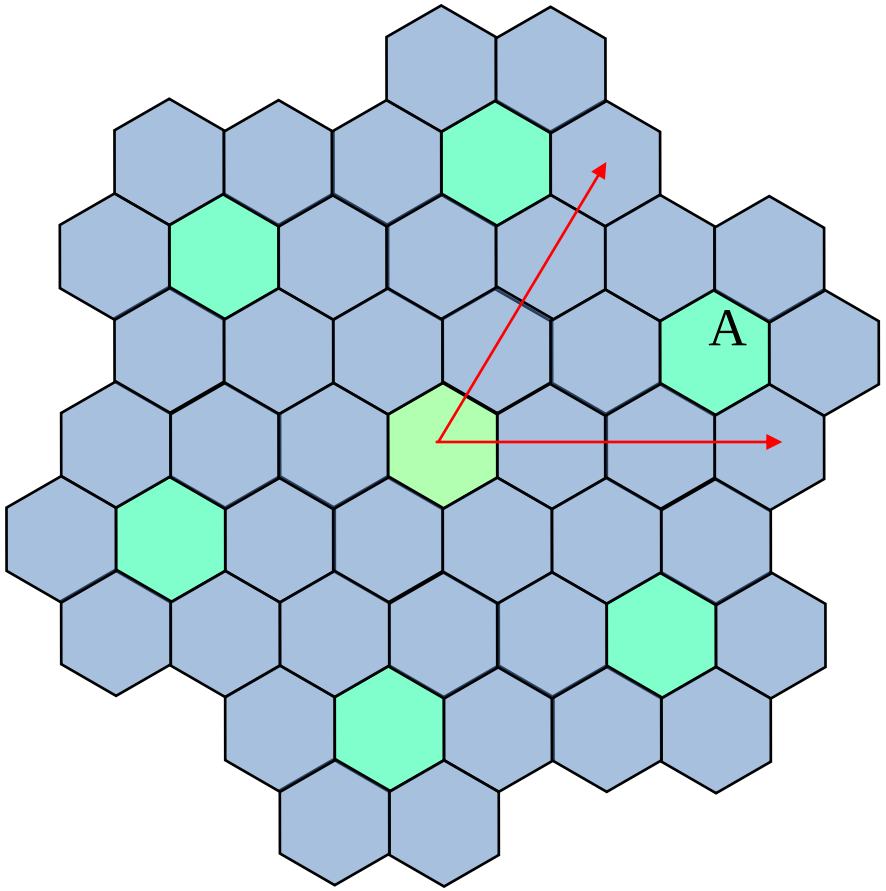
Example

- Suppose the SNR is required to be greater than 18 dB.
- What is the minimum reuse factor?

  (assume $\alpha = 4$)

- Before answering this question, we need some results obtained by geometry…

Coordinate System



Use (*i*,*j*) to denote a particular cell.

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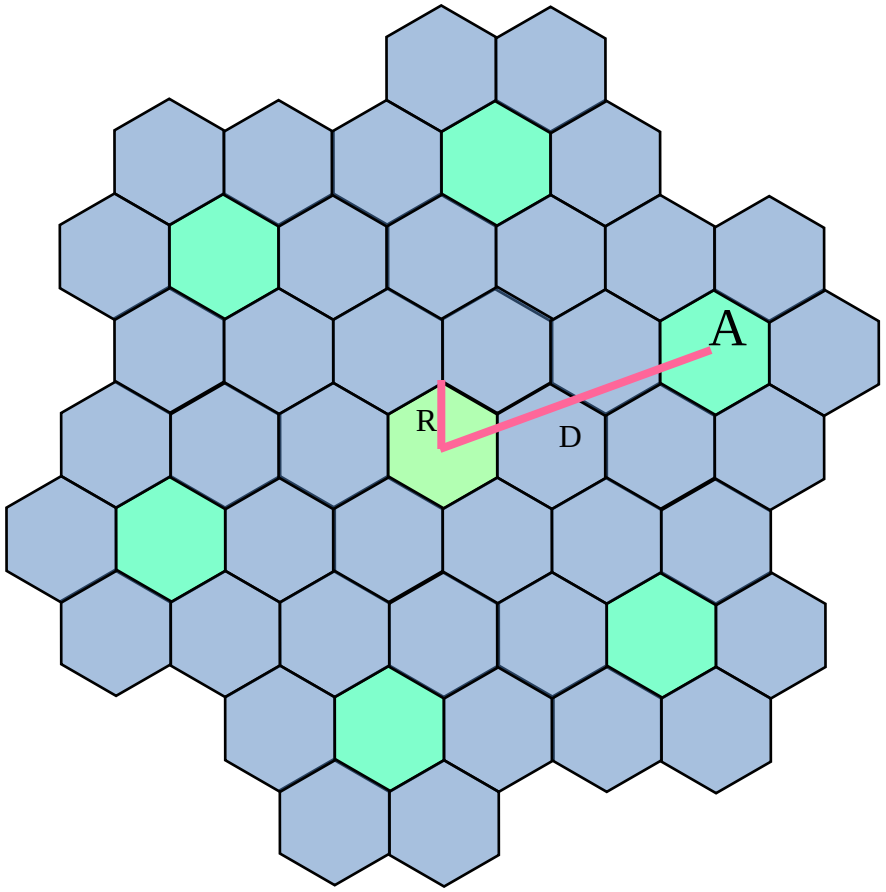
Distance Formula



$$D = \sqrt{3(i^2 + ij + j^2)}R$$

$$= \sqrt{3K}R$$

where

$$K = i^2 + ij + j^2$$

Reuse factor

Note: *i* and *j* are integers

Solution

$$\frac{1}{6}\left(\frac{D}{R}\right)^{\alpha} \geq 18\,\text{dB} = 10^{1.8} \approx 63$$

$$D \geq 4.4R$$

$$\boxed{D = \sqrt{3K}\,R}$$

$$\sqrt{3K} \geq 4.4$$

$$K \geq 6.5$$

Choose $i = 2, j = 1$ or $i = 1, j = 2$.

Ans: $K = 7$

Co-channel interference

- It is a function of q = D/R where R is the cell radius and D is the co-channel separation distance.
- Notice D is a function of n and S/I, where n is the number of interfering channels in the first tier and S/I is signal to interference ratio.
- In a fully equipped hexagonal-shaped system n is always 6.

D2 / R2

- Because of the hexagonal shape the total number of cells included in first tier is

  $K + 6\,(K/3) = 3K$

- Therefore
  - $D^2 / R^2 = 3K = 3(I^2+J^2+IJ)$

S/I Ratio

- There are 6 interfering co-channels each gives $i = (D/R)^{-\gamma}$ where $2 <= \gamma <= 5$ and it is called propagation path-loss slope and depends upon the terrain. (choose 4!)
- S/I = S/(6i)
  - Experiment with actual users show that we need S/I to be at least 18 dB (or 63.1)

Substituting, we get q = (6*63.1)^0.25 = 4.41

We then get N = q^2/3 = 6.49 approximates to 7.

Cell reuse factor vs Mean S/I

Cell reuse factor K	q = D/R Co-channel reuse ratio	Voice Channels per cell	Calls per Cell per Hour	Mean S/I dB
4	3.5	99	2610	14.0
7	4.6	56	1376	18.7
12	6.0	33	739	23.3

THANKS!