ECS455 Chapter 2

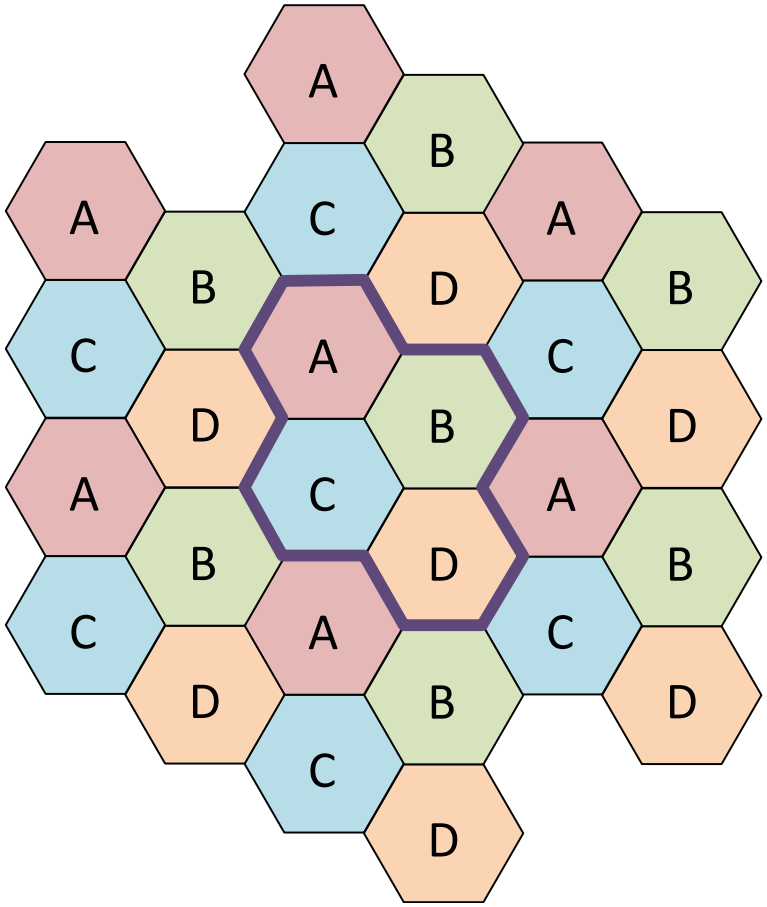
Cellular Systems

2.2 Co-Channel Interference

Office Hours:
BKD 3601-7
Tuesday 15:00-16:00
Friday 14:00-16:00

Co-Channel Interference

- Frequency reuse → co-channel interference
- Consider only nearby interferers.
  - Power decreases rapidly as the distance increases.
- In a **fully equipped hexagonal-shaped** cellular system, there are always K = 6 cochannel interfering cells in the **first tier**.



Review: Simplified Path Loss Model

$$\frac{P_r}{P_t} = K\left(\frac{d_0}{d}\right)^{\gamma} \quad \Rightarrow \quad P_r = \frac{P_t K d_0^{\gamma}}{d^{\gamma}} \propto \frac{1}{d^{\gamma}}$$

- K is a unitless constant which depends on the antenna characteristics and the average channel attenuation
- d_0 is a reference distance for the antenna far-field
  - Typically 1-10 m indoors and 10-100 m outdoors.
- γ is the **path loss exponent**.
  - 2 in free-space model
  - 4 in two-ray model [Goldsmith, 2005, eq. 2.17]

Captures the essence of signal propagation without resorting to complicated path loss models, which are only approximations to the real channel anyway!

Environment	γ range
Urban macrocells	3.7-6.5
Urban microcells	2.7-3.5
Office Building (same floor)	1.6-3.5
Office Building (multiple floors)	2-6
Store	1.8-2.2
Factory	1.6-3.3
Home	3

[Goldsmith, 2005, Table 2.2]

Not the same as the K shown on the previous slide

SIR (S/I): Definition/Calculation

- K = # co-channel interfering cells
- The **signal-to-interference ratio** (S/I or SIR) for a mobile receiver which monitors a ***forward channel*** can be expressed as

$$\text{SIR} = \frac{S}{I} = \frac{S}{\sum_{i=1}^{K} I_i}$$

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- S = the desired signal **power** from the desired base station
- I_i = the interference **power** caused by the ith interfering co-channel cell base station.

SIR Thresholds

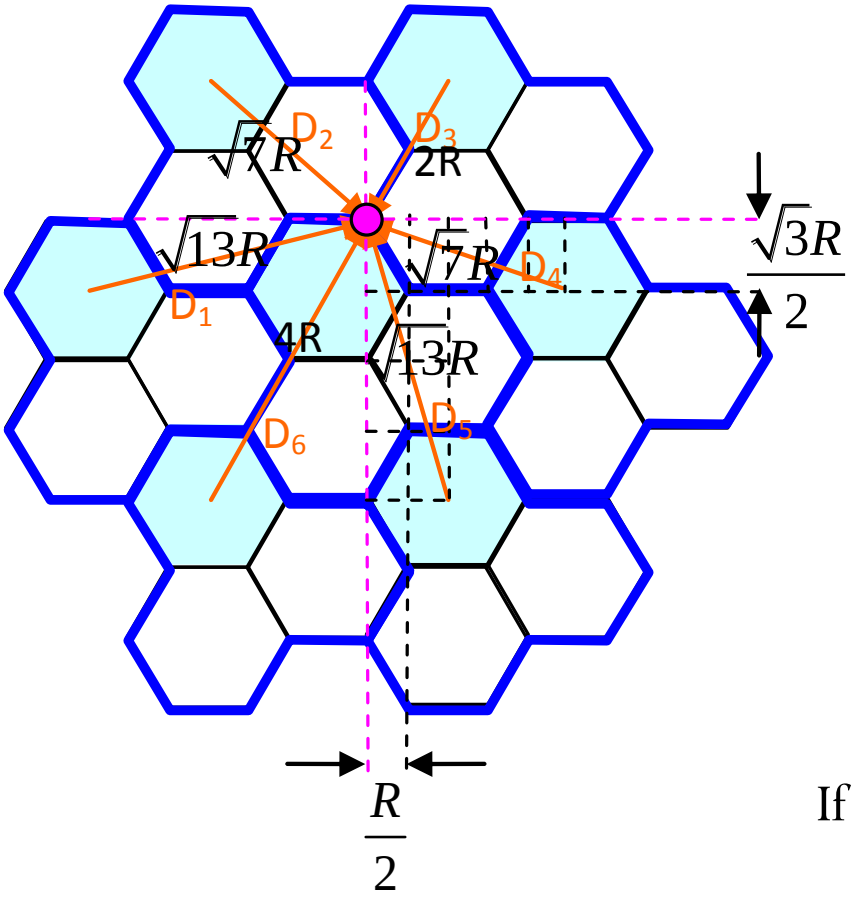
- The SIR should be greater than a specified threshold for proper signal operation.
- In the 1G **AMPS** system, designed for voice calls, the desired performance threshold is SIR equal to **18 dB**.
- For the 2G digital AMPS system (D-AMPS or IS-54/136), a threshold of 14 dB is deemed suitable.
- For the **GSM** system, a range of **7–12 dB**, depending on the study done, is suggested as the appropriate threshold.

[Schwartz, 2005, p 64]

SIR: N = 3

$$SIR = \frac{S}{\sum_i I_i} \leftarrow \text{worst-case}$$

$$P_r = \frac{k}{d^\gamma} = k d^{-\gamma}$$



$$\text{SIR} = \frac{k/R^\gamma}{\sum_i k/D_i^\gamma}$$

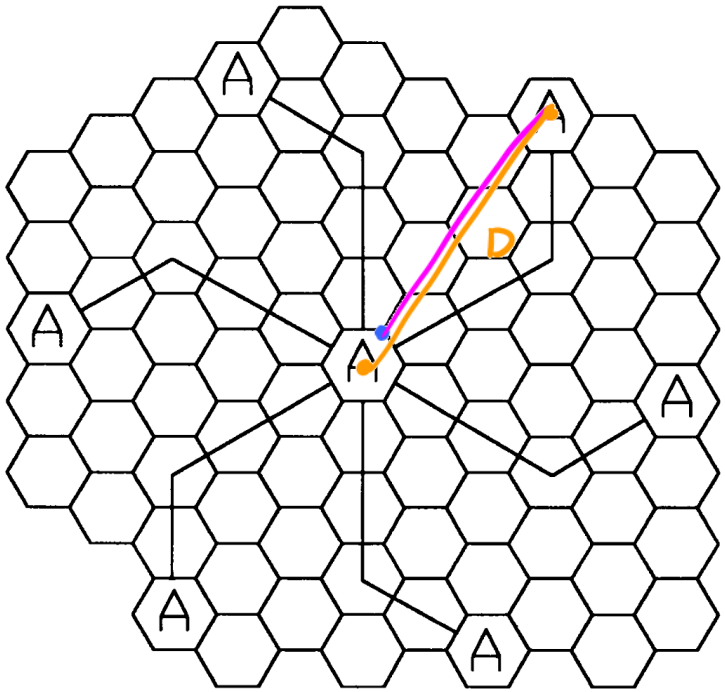
$$= \frac{1}{2\left(\sqrt{7}\right)^{-\gamma} + 2\left(\sqrt{13}\right)^{-\gamma} + 2^{-\gamma} + 4^{-\gamma}}$$

If N = 19, will the SIR be better or worse?

larger.

Crude

Approximation



$$\text{SIR} = \frac{k/R^{+\gamma}}{\sum_i k/D_i^{+\gamma}} = \frac{1}{\sum_i 1/\left(\frac{D_i}{R}\right)^{+\gamma}}$$

(1) Consider only 1st tier.
(2) worst-case distance

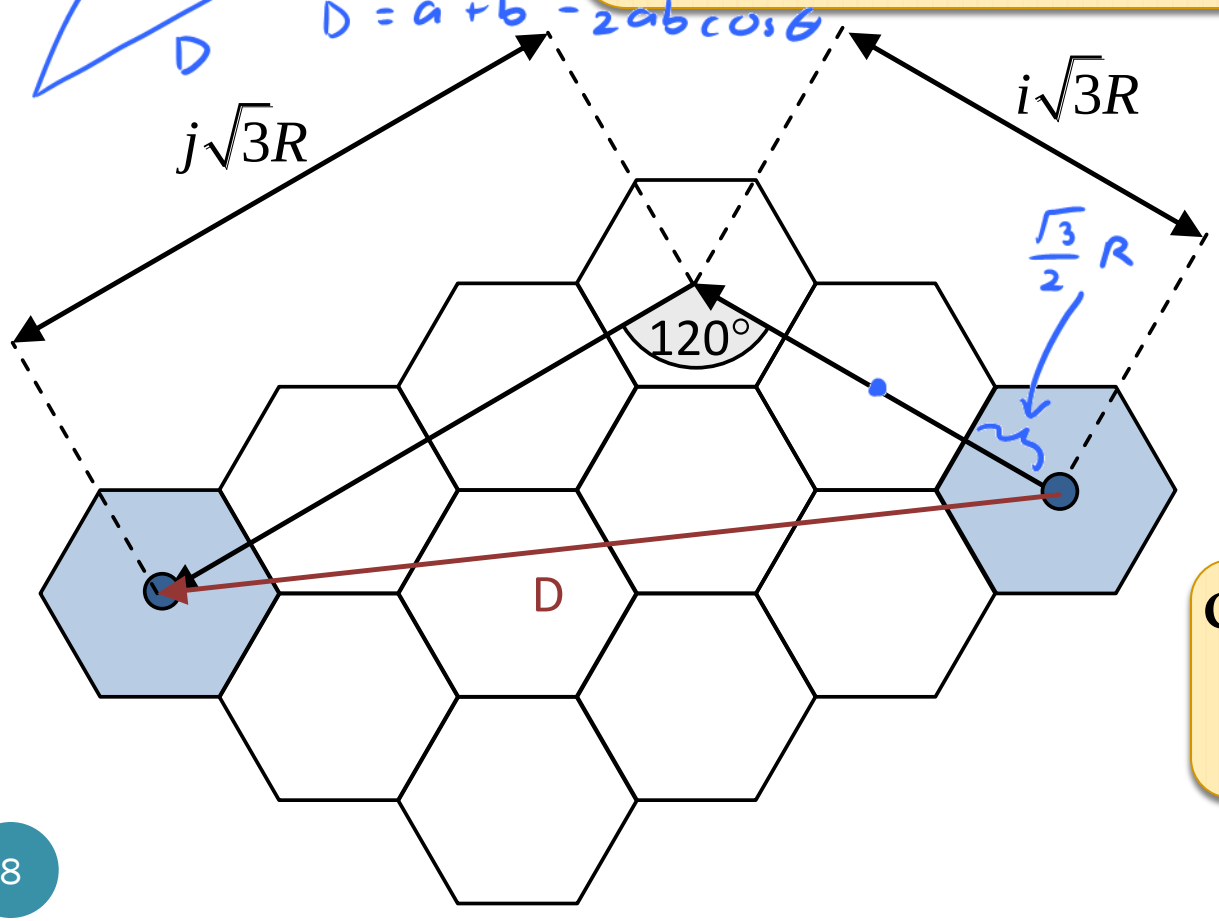
} same as previous calc.

(3) ~~D_i~~ → D = center-to-center distance btw closet interfering cells.

Center-to-center distance (D)

$$D = \sqrt{\left(i\sqrt{3}R\right)^2 + \left(j\sqrt{3}R\right)^2 - 2\left(i\sqrt{3}R\right)\left(j\sqrt{3}R\right)\cos\left(120^\circ\right)}$$

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



This distance, D, is called **reuse distance**.

Co-channel reuse ratio

$$Q = \frac{D}{R} = \sqrt{3N}.$$

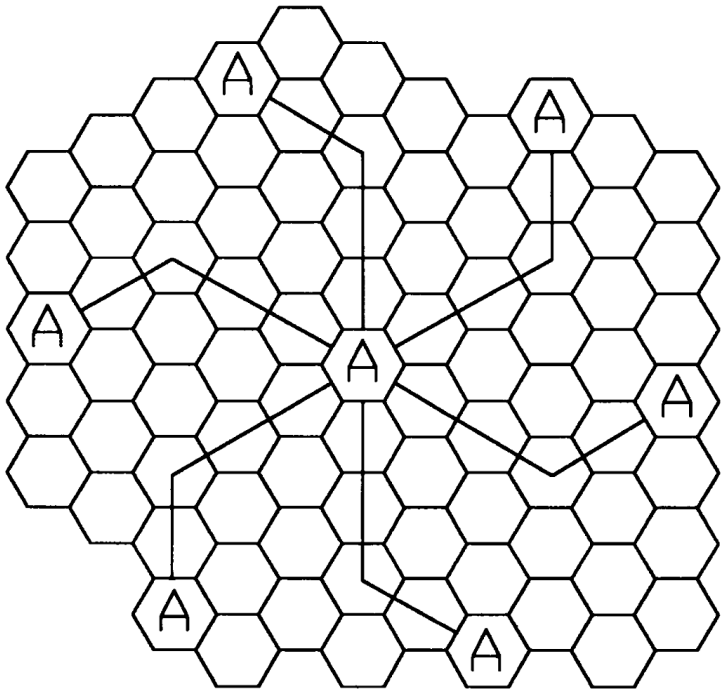
Q and N

Co-channel reuse ratio

$$Q = \frac{D}{R} = \sqrt{3N}.$$

	Cluster Size (N)	Co-channel Reuse Ratio (Q)
$i = 1, j = 1$	3	3
$i = 1, j = 2$	7	4.58
$i = 0, j = 3$	9	5.20
$i = 2, j = 2$	12	6

Approximation: Crude formula



$$\mathrm{SIR} = \frac{k/R^{+\gamma}}{\sum_i k/D_i^{+\gamma}} = \frac{1}{\sum_i 1/\left(\frac{D_i}{R}\right)^{+\gamma}}$$

$$\approx \frac{1}{6/\left(\frac{D}{R}\right)^{+\gamma}} = \frac{1}{K}\left(\frac{D}{R}\right)^{\gamma}$$

$$= \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma} = \frac{1}{K}(3N)^{\frac{\gamma}{2}}$$

Summary

frequency
FDD

S = total # available duplex radio channels for the system

Frequency reuse with **cluster size N**

"Capacity" $C = \frac{A_{total}}{A_{cell}} \times \frac{S}{N}$ ⟺ Tradeoff $\frac{S}{I} \approx \frac{kR^{-\gamma}}{K \times (kD^{-\gamma})} = \frac{1}{K}\left(\frac{D}{R}\right)^{\gamma} = \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$

↑ the ability to handle simultaneous # of calls.

m = # channels allocated to each cell.

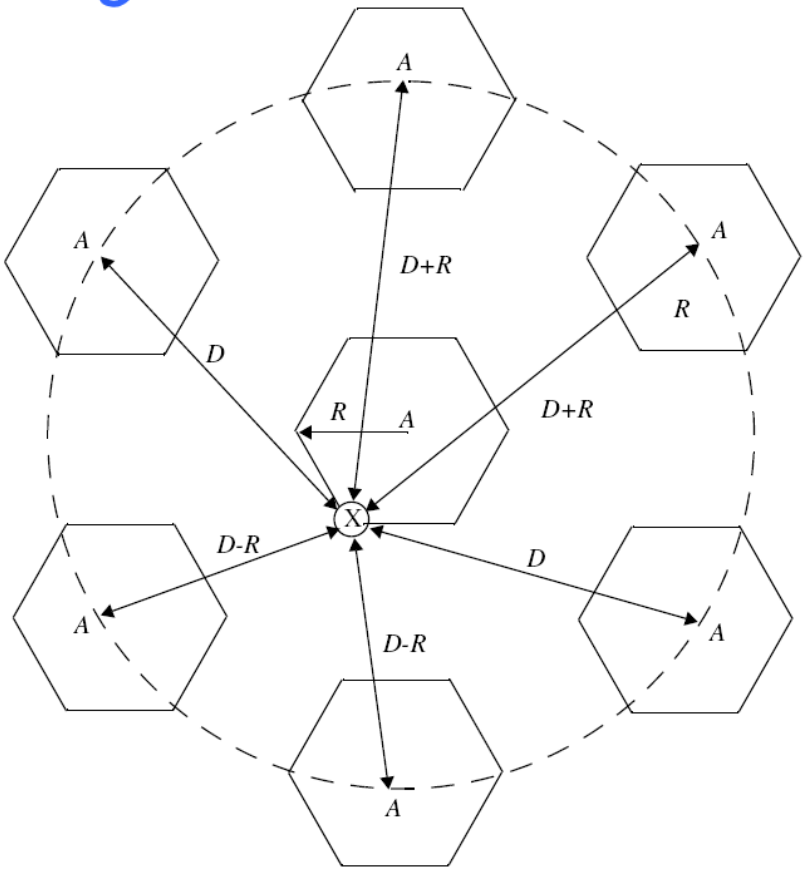
This is only 1/2 of the story!!

Quantity vs. Quality

SIR: N = 7

$SIR = \frac{1}{6}(\sqrt{3\times 7})^{\gamma}$

$\gamma = 4$



More accurate calculation…

$$\frac{S}{I} \approx \frac{R^{-4}}{2(D-R)^{-4}+2(D+R)^{-4}+2D^{-4}}$$

$$\frac{S}{I} \approx \frac{1}{2(Q-1)^{-4}+2(Q+1)^{-4}+2Q^{-4}}$$