
EC307: Mobile Communication and Networks

Module 3: Cellular Interference

Interference is defined as any undesired signal within the band of interest. In a cellular system, interference is the major factor that limits capacity and affects the quality of service (QoS). As frequency spectrum is reused across cells, signals from other users using the same or adjacent frequencies can degrade the desired signal.

There are two main types of interference in cellular systems,

- Co-Channel Interference (CCI)
- Adjacent Channel Interference (ACI)

1 Co-Channel Interference (CCI)

Co-channel interference occurs between cells that reuse the same frequency channels. As the cluster size decreases, CCI increases due to reduced spacing between co-channel cells.

Co-Channel Reuse Ratio

The co-channel reuse ratio Q is defined as:

$$Q = \frac{D}{R}$$

where:

- D = distance between co-channel cells
- R = radius of a cell

Using the cluster size N :

$$Q = \sqrt{3N}$$

A larger N increases Q (less interference), but reduces system capacity.

SIR for Co-Channel Interference

The signal-to-interference ratio (SIR) at the mobile receiver due to CCI is:

$$\text{SIR} = \frac{S}{\sum I_i} = \frac{R^{-n}}{i_0 D^{-n}} = \left(\frac{D}{R}\right)^n \frac{1}{i_0}$$

where:

- n = path loss exponent (typically 3–5)
- i_0 = number of co-channel interfering cells

For a hexagonal cellular layout, the first tier of interferers usually includes 6 co-channel cells. Therefore SIR can be represented as,

$$\text{SIR} = \left(\frac{D}{R}\right)^n \frac{1}{6}$$

Examples:

Example 1:

A cellular system has a total of $C = 110$ channels. The modulation/detection scheme in use requires a minimum signal-to-interference ratio of 19 dB. Assuming a path-loss exponent $n = 4$ and that the dominant interfering tier is the first co-channel tier (i.e. number of first-tier co-channel interferers $i_0 = 6$), determine the number of channels available per cell.

Solution

For a hexagonal cellular layout the reuse distance to cell radius ratio is

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

An approximate expression for the carrier-to-interference ratio (SIR) at the cell boundary, considering i_0 equal-power interferers and path-loss exponent n , is

$$\text{SIR} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0} = \frac{(3N)^{n/2}}{i_0}.$$

Convert required SIR to linear scale

Minimum required SIR = 19 dB:

$$\text{SIR}_{\text{req,lin}} = 10^{19/10} \approx 79.4328.$$

Compute theoretical cluster size

Solving for N :

$$3N = (\text{SIR}_{\text{req,lin}} \times i_0)^{2/n} \implies N = \frac{1}{3} (\text{SIR}_{\text{req,lin}} \times i_0)^{2/n}.$$

Substituting $\text{SIR}_{\text{req,lin}} \approx 79.4328$, $i_0 = 6$, and $n = 4$:

$$N \approx \frac{1}{3} (79.4328 \times 6)^{1/2} = \frac{1}{3} \sqrt{476.5969} \approx 7.2770.$$

Important: N must be one of the allowed hexagonal-cluster integers (1,3,4,7,9,...). Since the computed value 7.2770 is not allowed, we must pick the next allowable cluster size greater than this value:

$$\boxed{N = 9}.$$

Check SIR for chosen cluster size

Using $N = 9$, $n = 4$, $i_0 = 6$:

$$\text{SIR}_{\text{lin}} = \frac{(3N)^{n/2}}{i_0} = \frac{(3 \times 9)^2}{6} = \frac{27^2}{6} = \frac{729}{6} = 121.5.$$

In dB:

$$\text{SIR}_{\text{dB}} = 10 \log_{10}(121.5) \approx 20.85 \text{ dB},$$

which *meets* the required minimum of 19 dB.

(For comparison, had we chosen $N = 7$: $\text{SIR}_{\text{lin}} = \frac{(3 \cdot 7)^2}{6} = 73.5 \Rightarrow 18.66 \text{ dB}$, which is *below* the requirement.)

Channels per cell

Total channels $C = 110$. With cluster size $N = 9$,

$$\text{Channels per cell} = \frac{C}{N} = \frac{110}{9} \approx 12.222 \dots$$

In practical integer allocation the system can assign at most

$$\boxed{12 \text{ channels per cell}}$$

with remainder $110 - 9 \times 12 = 2$ channels left over (held as spare/guard channels or assigned otherwise).

Reduction of Co-Channel Interference

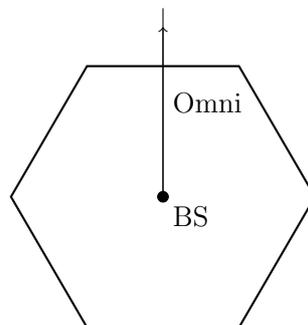
Several techniques are used in cellular networks to reduce interference:

Cell Sectoring

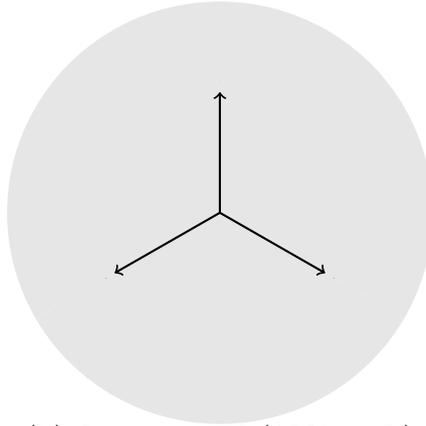
Cells are divided into 3 or 6 sectors using directional antennas.

- Reduces CCI by limiting the radiation pattern to a sector
- Improves SIR

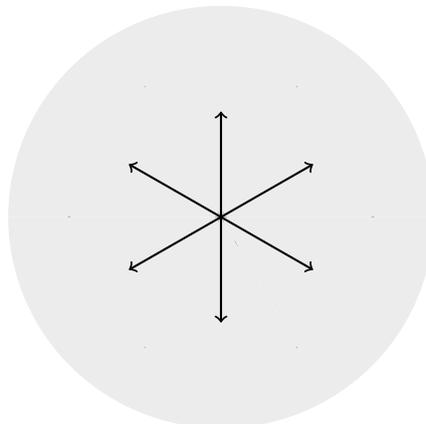
Cell sectoring divides an omnidirectional cell into directional sectors (commonly 3 or 6). The diagrams below illustrate an omnidirectional cell, a 3-sector cell (120° each), and a 6-sector cell (60° each).



(a) Omnidirectional cell (360°)



(b) 3-sector cell (120° each)



(c) 6-sector cell (60° each)

Illustration: Reduction of Effective Interferers

In an omnidirectional cell the first-tier co-channel interferers number $i_0 = 6$. By sectoring, the number of effective interferers reduces because only sectors pointing toward the victim user contribute significant interference. Typical reductions:

- Omnidirectional: $i_0 = 6$ (all first-tier cells)
- 3-sector (120°): $i_0 \approx 2$ (two co-channel sectors point towards the user)
- 6-sector (60°): $i_0 \approx 1$ (one dominant co-channel sector)

The SIR improvement for sectoring (assuming same reuse distance D and path-loss exponent n) is approximately:

$$\text{SIR}_{\text{sector}} = \frac{(D/R)^n}{i_{0,\text{sector}}}$$

so that the SIR gain (in dB) relative to omnidirectional operation is:

$$\Delta_{\text{dB}} = 10 \log_{10} \left(\frac{i_{0,\text{omni}}}{i_{0,\text{sector}}} \right).$$

Example 2

A cellular service provider uses a TDMA scheme. The worst-case required SIR is 16 dB. Assume path loss exponent $n = 4$. Find the minimum reuse factor N for:

- i. Omnidirectional antenna
- ii. 120° sectoring
- iii. 60° sectoring

Solution

For a hexagonal cell layout the first tier co-channel distance is $D = \sqrt{3N} R$. Approximating first-tier interference and sectoring into S sectors per cell, the cell-edge SIR (linear) is

$$\frac{S}{I} \approx \frac{S(3N)^{n/2}}{6}.$$

Require $\frac{S(3N)^{n/2}}{6} \geq \left(\frac{S}{I}\right)_{\min}$. Hence

$$N \geq \frac{1}{3} \left[\frac{6}{S} \left(\frac{S}{I}\right)_{\min} \right]^{2/n}.$$

Given $(S/I)_{\min} = 16 \text{ dB} = 10^{16/10} \approx 39.8107$ and $n = 4$,

$$N_{\min} = \frac{1}{3} \sqrt{\frac{6}{S}} \times 39.8107.$$

- Omnidirectional ($S = 1$): $N_{\min} \approx 5.152 \Rightarrow$ choose $N = 7$ (allowed cluster sizes: 1, 3, 4, 7, ...).
- 120° ($S = 3$): $N_{\min} \approx 2.974 \Rightarrow$ choose $N = 3$.
- 60° ($S = 6$): $N_{\min} \approx 2.103 \Rightarrow$ choose $N = 3$.

Note:

Omni: $N = 7$. 120° : $N = 3$. 60° : $N = 3$. Sectoring (120° or 60°) is better than omni; 60° gives the largest interference suppression but higher cost/complexity.

2 Adjacent Channel Interference (ACI)

Adjacent Channel Interference (ACI) occurs when signals transmitted on **neighboring frequency channels** overlap or spill into the desired channel due to imperfect filtering, insufficient frequency spacing, or nonlinearities in RF components.

Causes of ACI

- **Transmitter imperfections:** Nonlinear power amplifiers cause spectral regrowth; poor filtering leaks sidebands.
- **Receiver imperfections:** Limited selectivity of RF/IF filters.
- **Narrow channel spacing:** Spacing only slightly greater than the bandwidth.
- **Improper channel assignment:** Adjacent channels assigned to nearby cells or sectors.

Mathematical Expression for ACI

The total interference from adjacent channels can be written as:

$$I_{\text{ACI}} = \sum_{i=1}^{N_{\text{adj}}} P_i \cdot L_i,$$

where

- P_i = power of interfering adjacent channel,
- L_i = leakage factor (depends on filter roll-off),
- N_{adj} = number of adjacent interfering channels.

The Adjacent Channel Leakage Ratio (ACLR) is defined as:

$$\text{ACLR} = \frac{P_{\text{wanted}}}{P_{\text{leaked}}}.$$

Higher ACLR implies better spectral purity and lower ACI.

Effects of ACI

- Lower Signal-to-Interference Ratio (SIR)
- Increased Bit Error Rate (BER)
- Reduced data throughput
- Call drops in mobile networks
- Lower system capacity

Methods to Reduce ACI

- Use of high-quality, sharp-cutoff filters
- Proper frequency planning to separate adjacent channels
- Avoid using adjacent channels in the same cell

3 Interference Reduction Techniques (General)

Impact of Interference on System Performance

Interference affects:

- Call drop rate
- Bit Error Rate (BER)
- Voice quality and data throughput
- Overall network capacity

Several techniques are used in cellular networks to reduce interference:

Cell Sectoring

Cells are divided into 3 or 6 sectors using directional antennas.

- Reduces CCI by limiting the radiation pattern to a sector
- Improves SIR

Cell Splitting

Large cells are split into smaller cells:

- Increases capacity
- Reduces transmit power

Power Control

Adjusting transmit power of mobile stations reduces:

- Interference to neighboring cells
- Battery consumption

Dynamic Channel Allocation

Channels are assigned based on:

- Real-time traffic load
- Interference conditions

Frequency Hopping

Used in GSM and FH-CDMA:

- Distributes interference over many frequencies
- Reduces the effect of persistent interferers