The Cellular Concept –
System Design Fundamentals
Interference and System Capacity

- Interference is the major limiting factor in the performance of cellular radio systems. It is a major bottleneck in increasing capacity and is often responsible for dropped calls.

- Interference is more severe in urban areas, due to the greater RF noise floor and the large number of base stations and mobiles.

- Interference on voice channels causes cross talk, where the subscriber hears interference in the background due to an undesired transmission.

- On control channels, interference leads to missed and blocked calls due to errors in the digital signaling.
Sources of interference

1. Another mobile in the same cell,

2. A call in progress in a neighboring cell,

3. Any non-cellular system which inadvertently leaks energy into the cellular frequency band.

4. Other base stations operating in the same frequency band. (In practice, the transmitters from competing cellular carriers are often a significant source of out-of-band interference, since competitors often locate their base stations in close proximity to one another in order to provide comparable coverage to customers.)
The two major types of cellular system interference:

1. Co-channel interference

2. Adjacent channel interference.
1. Co-channel Interference

- **Co-channel cells**: cells that use the same set of frequencies in a coverage area (Frequency reuse concept)

- **Co-channel interference**: The interference between signals from co-channel cells.

- Unlike thermal noise which can be overcome by increasing the signal-to-noise ratio (SNR), **co-channel interference cannot be combated by simply increasing the carrier power of a transmitter**.

- This is because an increase in carrier transmit power increases the interference to neighboring co-channel cells.

- To reduce co-channel interference, co-channel cells **must be physically separated by a minimum distance to provide sufficient isolation due to propagation**.
When the size of each cell is the same, and the BSs transmit the same power.

The co-channel interference ratio depends on:

- The radius of the cell \((R)\)
- The distance between centers of the nearest co-channel cells \((D)\).

\[ Q = \frac{D}{R} = \text{co channel reuse ratio} = \text{the spatial separation between co-channel cells relative to the coverage distance of a cell.} \]

- Interference is reduced when \(Q\) is increased (improved isolation of RF energy from the co-channel cell).

- \(Q\) is related to the cluster size \((N)\) for a hexagonal geometry

\[
Q = \frac{D}{R} = \sqrt{3N}
\]
For a hexagon we can define both an inner radius and an outer radius. Both are useful.

\[ R_i = R_o \cos \phi = R_o \cos \frac{2\pi}{12} = R_o \frac{\sqrt{3}}{2} \]

Note that a hexagon has 6 faces or, equivalently, 12 “half-faces.”

**Figure 3.2** Method of locating co-channel cells in a cellular system. In this example, \( N = 19 \) (i.e., \( i = 3, j = 2 \)). (Adapted from [Oet83] © IEEE.)
A large cluster size \(N\) indicates that the ratio between the cell radius and the distance between co-channel cells is large.

Conversely, a small cluster size \(N\) indicates that co-channel cells are located much closer together.

The value for \(N\) is a function of how much interference a mobile or base station can tolerate while maintaining a sufficient quality of communications.

From a design viewpoint, the smallest possible value of \(N\) is desirable in order to maximize “\(C\)”. 

The frequency reuse factor of a cellular system is given by \(1/N\), since each cell within a cluster is only assigned \(1/N\) of the total available channels in the system.
A small value of $Q$ provides larger capacity since the cluster size $N$ is small.
(Smaller $N$ is greater capacity)

A large value of $Q$ higher transmission quality (less co-channel interference)

A trade-off must be made between these two objectives in actual cellular design.

\[
Q = \frac{D}{R} = \sqrt{3N}
\]

### Table 3.1 Co-channel Reuse Ratio for Some Values of $N$

<table>
<thead>
<tr>
<th>Cluster Size ($N$)</th>
<th>Co-channel Reuse Ratio ($Q$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i = 1, j = 1$</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>$i = 1, j = 2$</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4.58</td>
</tr>
<tr>
<td>$i = 2, j = 2$</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>$i = 1, j = 3$</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>6.24</td>
</tr>
</tbody>
</table>
The signal-to-interference ratio (\(S/I\) or \(\text{SIR}\)) for a mobile receiver which monitors a forward channel =

\[
\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i}
\]

\(S\) : the desired signal power from the desired base station

\(I_i\) : the interference power caused by the \(i^{th}\) interfering co-channel cell base station.

\(i_0\) : the number of co-channel interfering cells.
The average received signal strength at any point decays as a power law of the distance of separation between a transmitter and receiver. (Propagation measurements)

The average received power ($P_r$) at a distance ($d$) $\Rightarrow$ $R$ from the transmitting antenna is approximated by

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

$$P_r \text{ (dBm)} = P_0 \text{ (dBm)} - 10n \log \left( \frac{d}{d_0} \right)$$

where

($P_0$) is the power received at a close-in reference point in the far field region of the antenna at a small distance ($d_0$) from the transmitting antenna, and ($n$) is the path loss exponent. (The path loss exponent typically ranges between 2 and 4 in urban cellular systems.)
Assume:

- **the forward link** where the desired signal is the serving base station and where the interference is due to co-channel base stations.
- The transmit power of each base station is equal
- The path loss exponent is the same throughout the coverage area,
- **S/I for a mobile can be approximated as**

\[
\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}
\]

\(D_i\) is the distance of the \(i^{th}\) interferer from the mobile, \(I_i\) will be proportional to \((D_i)^{-n}\)

Considering only the first layer of interfering cells, if all the interfering base stations are equi-distant from the desired base station and if this distance is equal to the distance \(D\) between cell centers, then:

\[
\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0}
\]

relates \(S/I\) to the cluster size \(N\), also, overall capacity of the system can be obtained from \(N\)

\[C = MkN = MS\]
For Example: the **U.S. AMPS cellular system** which uses FM and 30 kHz channels, subjective tests indicate that sufficient voice quality is provided when **S/I is greater than or equal to 18 dB**.

the **six** closest cells are close enough to create significant interference. assuming a path loss exponent **n = 4**.

Then, the cluster size **N** should be at **least 6.49**, (Thus a minimum cluster size of 7)
Figure 3.5 Illustration of the first tier of co-channel cells for a cluster size of $N = 7$. An approximation of the exact geometry is shown here, whereas the exact geometry is given in [Lee86]. When the mobile is at the cell boundary (point $X$), it experiences worst case co-channel interference on the forward channel. The marked distances between the mobile and different co-channel cells are based on approximations made for easy analysis.
• From the previous figure, it can be seen for a 7-cell cluster, with the mobile unit is at the cell boundary, the mobile is a distance
• \textbf{D-R} from the two nearest co-channel interfering cells
• approximately: \textbf{D + R/2, D, D - R/2, D + R} from the other interfering cells in the first tier.

• Assume \textbf{n=4}, the signal-to-interference ratio for the worst case can be closely approximated as (an exact expression is worked out by)

\[
\frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}}
\]
Equation (2.10) can be rewritten in terms of the co-channel reuse ratio $Q$, as

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

For $N = 7$, the co-channel reuse ratio $Q$ is 4.6, and the worst case $S/I$ is approximated as 49.56 (17 dB) using equation (2.11), whereas an exact solution using equation (2.8) yields 17.8 dB.

Hence for a 7-cell cluster, the $S/I$ ratio is slightly less than 18 dB for the worst case. To design the cellular system for proper performance in the worst case, it would be necessary to increase $N$ to the next largest size, which from equation (2.3) is found to be 12 (corresponding to $i = j = 2$).

This obviously entails a significant decrease in capacity, since 12-cell reuse offers a spectrum utilization of 1/12 within each cell, whereas 7-cell reuse offers a spectrum utilization of 1/7. In practice, a capacity reduction of 7/12 would not be tolerable to accommodate for the worst case situation which rarely occurs. From the above discussion it is clear that co-channel interference determines link performance, which in turn dictates the frequency reuse plan and the overall capacity of cellular systems.
Example 2.2

If a signal to interference ratio of 15 dB is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is (a) $n = 4$, (b) $n = 3$? Assume that there are 6 co-channels cells in the first tier, and all of them are at the same distance from the mobile. Use suitable approximations.
Solution to Example 2.2

(a) $n = 4$

First, let us consider a 7-cell reuse pattern.
Using equation (2.4), the co-channel reuse ratio $D/R = 4.583$.
Using equation (2.9), the signal-to-noise interference ratio is given by

$$S/I = (1/6) \times (4.583)^4 = 75.3 = 18.66 \text{ dB}.$$  

Since this is greater than the minimum required $S/I$, $N = 7$ can be used.

(b) $n = 3$

First, let us consider a 7-cell reuse pattern.
Using equation (2.9), the signal-to-interference ratio is given by

$$S/I = (1/6) \times (4.583)^3 = 16.04 = 12.05 \text{ dB}.$$  

Since this is less than the minimum required $S/I$, we need to use a larger $N$.

Using equation (2.3), the next possible value of $N$ is 12, ($i = j = 2$).
The corresponding co-channel ratio is given by equation (2.4) as $D/R = 6.0$.

Using equation (2.3) the signal-to-interference ratio is given by

$$S/I = (1/6) \times (6)^3 = 36 = 15.56 \text{ dB}.$$  

Since this is greater than the minimum required $S/I$, $N = 12$ can be used.
2. Adjacent Channel Interference

- **Adjacent channel interference**: Interference resulting from **signals which are adjacent in frequency to the desired signal**.

- Results from **imperfect receiver filters** which allow nearby frequencies to leak into the passband.

- The problem can be particularly serious with **the near-far effect**.

- The base station may have difficulty in discriminating the desired mobile user from the “bleedover” caused by the close adjacent channel mobile.
• Adjacent channel interference can be minimized through **careful filtering** and **channel assignments**.

• Since each cell is given only a fraction of the available channels, **a cell need not be assigned channels which are all adjacent in frequency**. (By keeping the frequency separation between each channel in a given cell as large as possible)

• **If the frequency reuse factor is small**, the separation between adjacent channels **may not be sufficient** to keep the adjacent channel interference level within tolerable limits.
• For example, if a mobile is 20 times as close to the base station as another mobile and has energy spill out of its passband, the signal-to-interference ratio for the weak mobile (before receiver filtering) is approximately

\[
\frac{S}{I} = (20)^{-n}
\]

For a path loss exponent \( n = 4 \), this is equal to 52 dB. If the intermediate frequency (IF) filter of the base station receiver has a slope of 20 dB/octave,

then an adjacent channel interferer must be displaced by at least six times the passband bandwidth from the center of the receiver frequency passband to achieve 52 dB attenuation. Here, a separation of approximately six channel bandwidths is required for typical filters in order to provide 0 dB SIR from a close-in adjacent channel user.

This implies that a channel separation greater than six is needed to bring the adjacent channel interference to an acceptable level, or tighter base station filters are needed when close-in and distant users share the same cell.
AAA: anti aliasing attenuation

\[ \text{AAA} = 20 \, \text{dB} \]

\[ \Rightarrow \text{from } \Omega_m \text{ to } \frac{\Omega_T}{2} - \Omega_m \text{ we need } 20 \, \text{AAA dB} \]

\[ @ \, R0 \, \text{dB/Hz we need } 2 \text{ octaves} \]

\[ \Omega_m \rightarrow 2\Omega_m \rightarrow 4\Omega_m \leq \frac{\Omega_T}{2} - \Omega_m \]

\[ \Rightarrow \text{determines needed filter} \]

\[ \text{OR} \]

\[ \Rightarrow \text{determines } \Omega_T \]

\[ \frac{\Omega_T}{2} \geq 5\Omega_m \]
\[ \frac{\text{AAA}}{\text{Ro}} \text{ octaves} \]

\[ 2 \frac{\text{AAA}}{\text{Ro}} \leq \frac{\Omega}{T} - \frac{\Omega_m}{T} \]

\[ \frac{\text{AAA}}{\text{Ro}} \]

\[ \frac{\Omega_T}{T} \geq \left( 2 + \frac{\text{AAA}}{\text{Ro}} + 1 \right) \frac{\Omega_m}{T} \]

\[ \Omega_T = 7 \Omega_m \]

\[ \text{Separation} = 6 \Omega_m \]

\[ \text{octave} \]

\[ (1) \, \phi_1 \rightarrow 2 \phi_1 \]

\[ (2) \rightarrow 4 \phi_1 \]

\[ (3) \rightarrow 8 \phi_1 \]

\[ \Omega_0 = 20 \text{ de/ct} \Rightarrow \frac{5 \Omega_0}{20} = 0.6 \Rightarrow \frac{\Omega_T}{T} \geq (2 + 1) \frac{\Omega_m}{T} = 25 \frac{\Omega_m}{T} \]
Example 2.3
This example illustrates how channels are divided into subsets and allocated to different cells so that adjacent channel interference is minimized.

The United States AMPS system initially operated with 666 duplex channels, 166 new channels, now 832 channels used in AMPS.

The forward channel (870.030 MHz) along with the corresponding reverse channel (825.030 MHz) is numbered as channel 1.

Similarly the forward channel 889.98 MHz along with the reverse channel 844.98 MHz is numbered as channel 666 (see Figure 1.2).

The extended band has channels numbered as 667 through 799, and 990 through 1023.
<table>
<thead>
<tr>
<th>Channel Number</th>
<th>Center Frequency (MHz)</th>
</tr>
</thead>
</table>
| Reverse Channel | $1 \leq N \leq 799$  
                 | $990 \leq N \leq 1023$ | $0.030N + 825.0$  
                       | $0.030(N - 1023) + 825.0$ |
| Forward Channel | $1 \leq N \leq 799$  
                 | $990 \leq N \leq 1023$ | $0.030N + 870.0$  
                       | $0.030(N - 1023) + 870.0$ |

(Channels 800 - 989 are unused)

Figure 1.2
Frequency spectrum allocation for the U.S. cellular radio service. Identically labeled channels in the two bands form a forward and reverse channel pair used for duplex communication between the base station and mobile. Note that the forward and reverse channels in each pair are separated by 45 MHz.
• two competing operators in every service area: each operator received half of the total channels.

• Out of the 416 channels used by each operator, 395 are voice channels and the remaining 21 are control channels.

• Channels 1 through 312 (voice channels) and channels 313 through 333 (control channels) are block A channels, and channels 334 through 354 (control channels) and channels 355 through 666 (voice channels) are block B channels.

• Channels 667 through 716 and 991 through 1023 are the extended Block A voice channels, and channels 717 through 799 are extended Block B voice channels.
• Each of the **395 voice channels** are divided into **21 subsets**, each containing about **19 channels**. In each subset, the closest adjacent channel is **21 channels** away.

• In a **7-cell reuse system**, each cell uses **3 subsets of channels**. The 3 subsets are assigned such that every channel in the cell is assured of being separated from every other channel by **at least 7 channel spacings**.

• This channel assignment scheme is illustrated in Table 2.2. As seen in Table 2.2, each cell uses channels in the subsets, **iA + iB + iC**, where **i** is an integer from **1 to 7**.

• The total number of voice channels in a cell is about **57**. The channels **listed in the upper half of the chart belong to block A** and those in the lower half belong to block B.

• The shaded set of numbers correspond to the control channels which are standard to all cellular systems in North America.
# AMPS Duopoly Channels

## Table 3.2 AMPS Channel Allocation for A and B Side Carriers

<table>
<thead>
<tr>
<th></th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
<th>1B</th>
<th>2B</th>
<th>3B</th>
<th>4B</th>
<th>5B</th>
<th>6B</th>
<th>7B</th>
<th>1C</th>
<th>2C</th>
<th>3C</th>
<th>4C</th>
<th>5C</th>
<th>6C</th>
<th>7C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>34</td>
<td>45</td>
<td>56</td>
<td>67</td>
<td>78</td>
<td>89</td>
<td>910</td>
<td>112</td>
<td>134</td>
<td>157</td>
<td>179</td>
<td>192</td>
<td>213</td>
<td>235</td>
<td>257</td>
<td>279</td>
<td>302</td>
<td>324</td>
<td>346</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>123</td>
<td>345</td>
<td>456</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>456</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
</tr>
<tr>
<td>4</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
</tr>
<tr>
<td>5</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
</tr>
<tr>
<td>6</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
<td>5676</td>
</tr>
<tr>
<td>7</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
<td>5676</td>
<td>6082</td>
</tr>
</tbody>
</table>

**A SIDE**

<table>
<thead>
<tr>
<th></th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
<th>1B</th>
<th>2B</th>
<th>3B</th>
<th>4B</th>
<th>5B</th>
<th>6B</th>
<th>7B</th>
<th>1C</th>
<th>2C</th>
<th>3C</th>
<th>4C</th>
<th>5C</th>
<th>6C</th>
<th>7C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>34</td>
<td>45</td>
<td>56</td>
<td>67</td>
<td>78</td>
<td>89</td>
<td>910</td>
<td>112</td>
<td>134</td>
<td>157</td>
<td>179</td>
<td>192</td>
<td>213</td>
<td>235</td>
<td>257</td>
<td>279</td>
<td>302</td>
<td>324</td>
<td>346</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>123</td>
<td>345</td>
<td>456</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>456</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
</tr>
<tr>
<td>4</td>
<td>567</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
</tr>
<tr>
<td>5</td>
<td>678</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
</tr>
<tr>
<td>6</td>
<td>789</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
<td>5676</td>
</tr>
<tr>
<td>7</td>
<td>8910</td>
<td>9112</td>
<td>1013</td>
<td>1215</td>
<td>1417</td>
<td>1619</td>
<td>1822</td>
<td>2124</td>
<td>2327</td>
<td>2530</td>
<td>2733</td>
<td>2936</td>
<td>3139</td>
<td>3442</td>
<td>3645</td>
<td>4048</td>
<td>4456</td>
<td>4864</td>
<td>5270</td>
<td>5676</td>
<td>6082</td>
</tr>
</tbody>
</table>

**B SIDE**

### Notes
- Table 3.2 illustrates the AMPS channel allocation for A and B Side Carriers, distinguishing between two sets of allocations labeled A SIDE and B SIDE.
- The table entries indicate the specific channels allocated to each side, with channels for 1A to 7C clearly defined in a grid format.
2.5.3 Power Control for Reducing Interference

- In practical cellular radio and personal communication systems, the power levels transmitted by every subscriber unit are under constant control by the serving base stations.

- This is done to ensure that each mobile transmits the smallest power necessary to maintain a good quality link on the reverse channel.

- Power control not only helps (1) prolong battery life for the subscriber unit, but also (2) dramatically reduces the reverse channel S/I in the system.

- Power control is especially important for emerging CDMA spread spectrum systems that allow every user in every cell to share the same radio channel.
Home work # (3)

• Prove that: $Q = \sqrt{3N}$ for hexagonal cells. (bonus)

• Solve Question # 3.5 (Rappaport book)