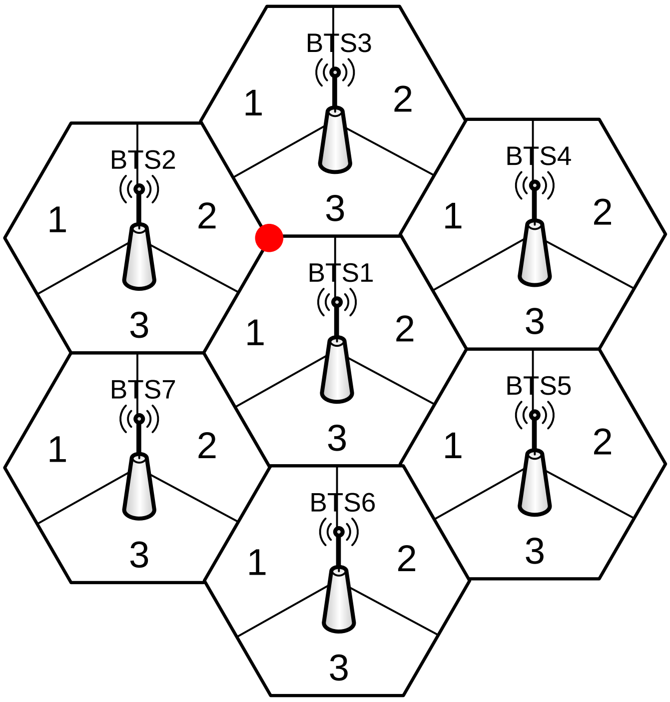
## ABS Seminar no.8

**Cellular network - sectorization and interference from neighboring channels**

**T.1**
**Cellular network - sectorization**

We assume a cellular communication system:




, which consists of seven cells with a radius of: $R$ = 1 km. We are interested in the quality of the received signal at a specific UE location (marked with a red circle), which it receives from each BTS in different configurations.

We assume transmission losses according to the relationship: $L_p(d) = 137,4dB + 35,2\log(d)\ [dB]$

, where $d$ is distance in km.

Fading caused by shielding and fast fading are not included in the calculation. For simplicity, we assume that all BTSs have the same transmission power and each BTS has a three-sector configuration with identical radiation patterns:

$$G(\theta) = \begin{cases} 15\,[dB] & -60° \le \theta < 60° \\ -8\,[dB] & inak \end{cases}$$

We assume that the MS is connected to BTS1.

Calculate in dB:

a) Calculate $SIR$, that perceives the MS if the cluster size is 3 (i.e. each sector uses a different set of frequencies) (i.e. the frequency reuse factor is RF = 1/3).
b) Calculate the new $SIR$ value if the cluster size is reduced to RF = 1/1 (i.e. all sectors use the same frequency sets).
c) We assume that the cluster size is 1 (RF = 1/1), but the MS is now able to apply signal processing, which eliminates the two interfering signals with the highest power. Specify the $SIR$ value for this configuration.
d) Calculate the throughput that the MS is able to support in the previous three cases. Use a modified Shannon relationship:

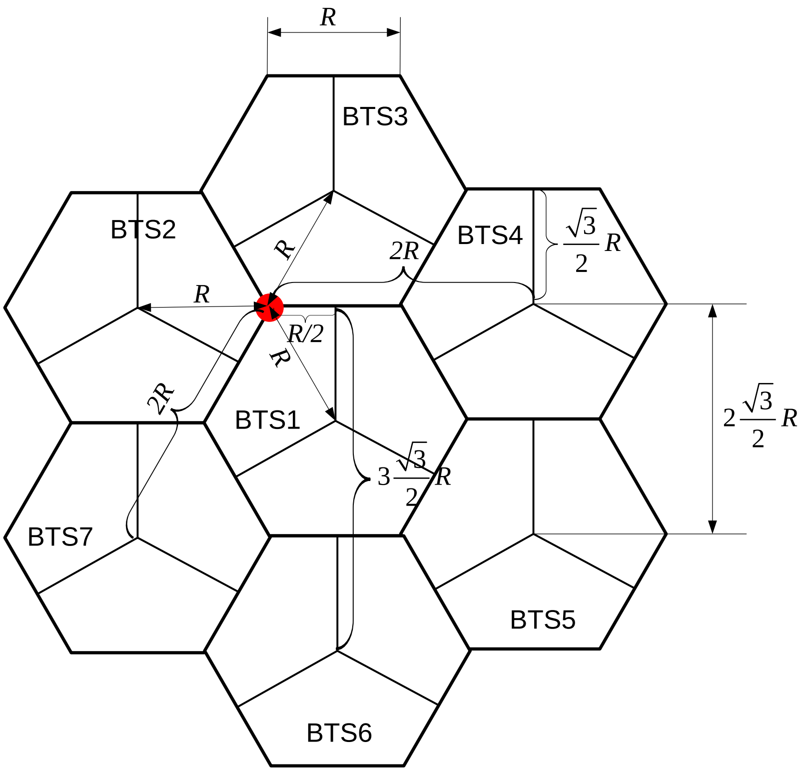
$$R_{th} = W.\gamma.\log_2\left(1+B.SIR\right)\ [b/s]$$

, where $\gamma$ bandwidth utility factor ($\gamma$ = 0,88) and $B$ is $SIR$ utilization factor ($B$ = 0,8).

Bandwidth per sector is:

$W = 20\ MHz$ if: $RF$ = 1/1
$W = 20/3\ MHz$ if: $RF$ = 1/3

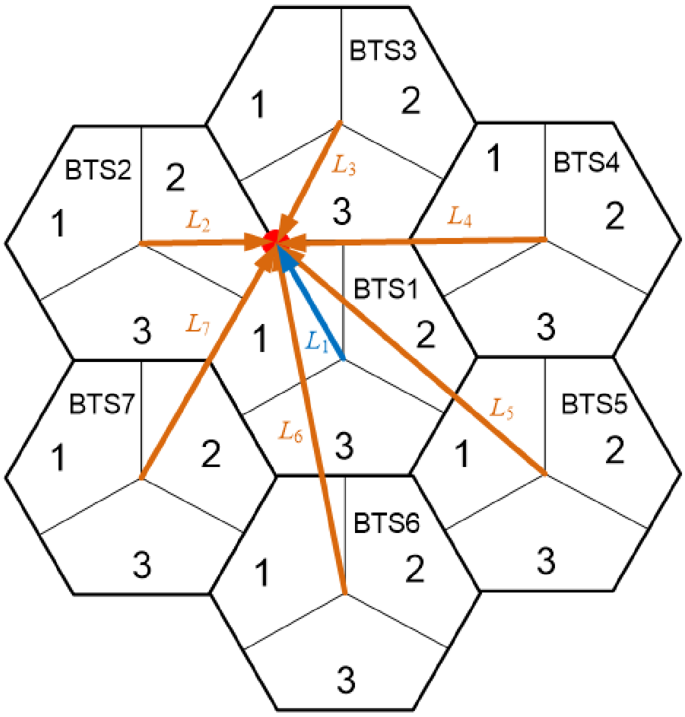
First, calculate the distances between the MS and each BTS. From the figure it follows that:

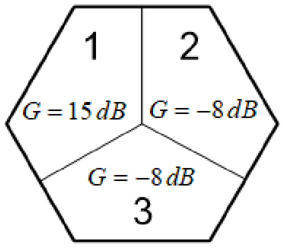



Then the transmission losses $L_{p1}$, $L_{p4,}$ $L_{p5}$ can be calculated.

a)
The cluster size is 3 (i.e. each sector uses a different set of frequencies).
If the cluster size is 3, then only the sectors marked "1" are the source of interference. The total attenuation (loss) of the signal in this configuration (if transmission losses and antenna gain are included) is given by:

$$L_i = L_{pi} - G(\theta)$$




this pattern repeates in each cell

Based on the above picture loss for the desired signal from sector 1 $L_1^a$ can be calculated, as well as losses of the interfering signals from cells 2,3,4,5,6,7: $L_{2,3,4,5,6,7}^a$

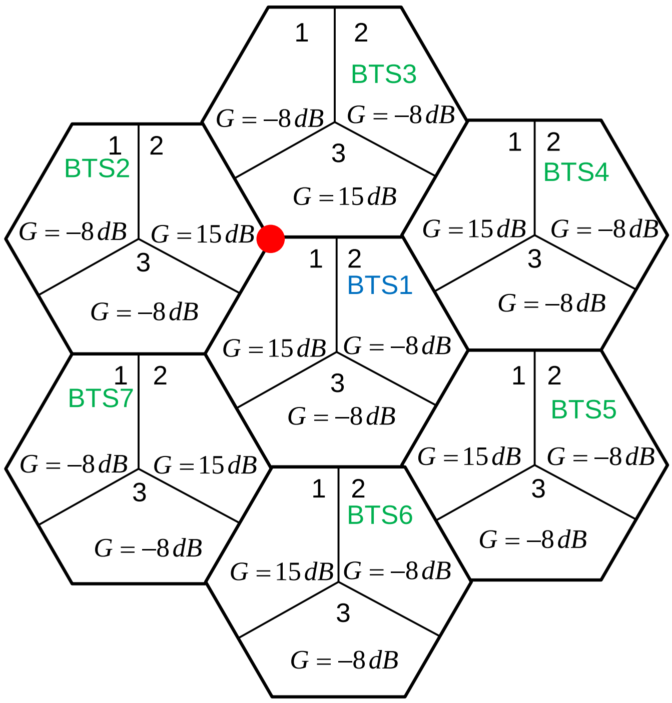
Since all BTSs transmit with the same power, then:

$$SIR_i = \frac{\frac{P_{TXi}}{L_i}}{\sum_{k \neq i} \frac{P_{TXk}}{L_k}} = \frac{P_{TXi}}{L_i} \frac{1}{P_{TXk} \sum_{k \neq i} \frac{1}{L_k}} = \frac{1}{L_i} \frac{1}{\sum_{k \neq i} \frac{1}{L_k}}$$

b)

The cluster size is 1 (i.e. all sectors use the same set of frequencies).

If the cluster size is 1, then we must consider transmission losses in all sectors separately:




It is necessary to calculate:

Cell 1:

$L^b_{1,1}$ - desired signal from sector 1 and $L^b_{1,2}, L^b_{1,3}$ - interference from sectors 2 and 3

Cells 2 and 3:

$L^b_{2,2}, L^b_{3,3}$ - interference from cells 2, 3 from sectors 2 and 3

$L^b_{2,1}, L^b_{2,3}, L^b_{3,1}, L^b_{3,2}$ - interference from cells 2, 3 from sectors 1, 2 and 3

Cells 4 and 7:

$L^b_{4,1}, L^b_{7,2}$ - interference from cells 4, 7 from sectors 1 and 2

$L^b_{4,2}, L^b_{4,3}, L^b_{7,1}, L^b_{7,2}$ - interference from cells 4, 7 from sectors1, 2 and 3

Cells 5 and 6:

$L^b_{5,1}, L^b_{6,1}$ - interference from cells 5, 6 from sector 1

$L^b_{5,2}, L^b_{5,3}, L^b_{6,2}, L^b_{6,3}$ - interference from cells 5, 6 from sectors 2 and 3

Calculate $SIR_1$ For BTS1:

c)
The MS uses signal processing to eliminate interference, which allows the level of the received useful signal to be increased. Then the signals from cell 2 of sector 2 and from cell 3 of sector 3 are eliminated.

Calculate $SIR_1$ For BTS1:

d)
To determine the throughput, use Shannon's formula: $R_{th} = W.\gamma.\log_2(1+B.SIR)$

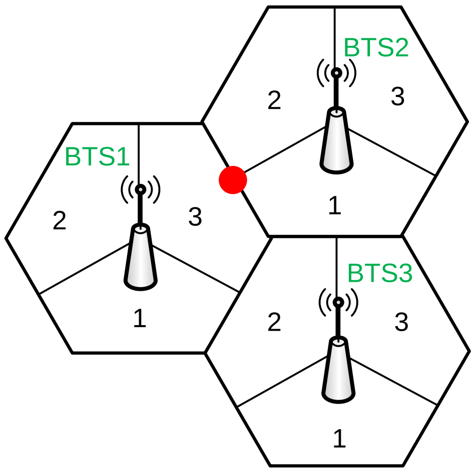
for cluster size = 1 ($RF$ = 1/1):

for cluster size = 3 ($RF$ = 1/3):

for cluster size = 1 ($RF$ = 1/1) and signal processing in MS to eliminate the strongest interference:

**T.2**
**Cellular network - interference from neighboring channels**

We assume an LTE cellular communication system (MS is shown by a red circle):




We assume the radius of the cell: $R = 500\,m$. The quality of the received signal for the MS from the serving cell in different system configurations needs to be determined. All BTSs transmit with the same power. The sectors are the same, divided into 120°. The radiation pattern of the antenna system is as follows:

$$G(\theta) = G_{max} + \max\left\{-12\left(\frac{\theta-\theta_0}{\theta_{3dB}}\right)^2, -G_{fb}\right\}$$

, where: $\theta$ is the angle at which the signal is received/transmitted from the antenna in [°], $G_{max} = 18\,dBi$ is the gain of the antenna in the direction of maximum radiation, $\theta_0$ is the direction of the main radiation in [°], $\theta_{3dB} = 60°$ is the width of the radiating beam for a drop of 3 dB, $\theta_{fb} = 25\,dB$ is front-to-back ratio.

We assume that the MS is always connected to the BTS from where it has the best *SIR*.

We assume transmission losses according to the relationship:

$$L_p(d) = 137{,}4\,dB + 35{,}2\log(d)\ [dB]$$

, where $d$ is distance in km. Fading caused by shielding and fast fading are not included in the calculation.

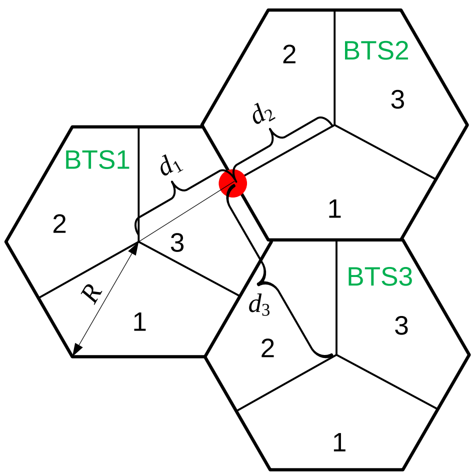
The throughput of the MS can be approximated as:

$$R_{th} = N_{RB}.W_{RB}.\gamma.\log_2(1+B.SIR)\ [b/s]$$

, where: $N_{RB}$ is the number of RBs used, $W_{RB} = 180\,kHz$ , $\gamma = 0{,}88$ is bandwidth utility factor, $B$ is *SIR* utility factor ($B$ = 0,8).

a) Estimate the throughput of the MS if the usable bandwidth is assumed $W = 10\,MHz$ if $RF$ = 1/3
b) Estimate the throughput of the MS if the usable bandwidth is assumed $W = 10\,MHz$ if $RF$ = 1/1

First, calculate the distances between the MS and each BTS:



Then calculate the transmission losses: $L_{p1}(d), L_{p2}(d)$ and $L_{p3}(d)$, $SIR$ and throughput.

a)
If $RF$ = 1/3 then interference is coming only from sectors „3". We assume that MS communicates with BTS1 v sectore 3 (the best SIR). We don't assume frequency reuse. Calculate signal losses: $L_{1,3}$ and the interference from BTS2 and BTS3: $L_{2,3}, L_{3,3}$

b)
If RF = 1/1 then the interference comes from all sectors. We assume that the MS communicates with BTS1 in sector 3 (hence the best SIR). We do not assume the use of the same frequency again in the calculation. The procedure is the same as in a).