Mobile Communications
Problem Set 3

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1. Name and explain the different multiplexing procedures known from the lecture.

   Solution:

   - Time division multiplexing: all senders use the same frequency but at different times, synchronization is needed
   - Frequency division multiplexing: senders use different frequency bands at the same time
   - Code division multiplexing: each user uses an individual code, orthogonal codes
   - Space division multiplexing: spatial reuse of resources (in combination with FDM/TDM), deployed in cellular mobile systems, needs handover techniques and resource reuse planning

2. What is the limiting factor for the number of users in TDM/FDM and CDM systems?

   Solution:

   - TDM: Number of time slots
   - FDM: Number of frequency bands
   - CDM: The signal to noise ratio (SNR). In CDM systems additional users add to the noise such that new users are only admitted as long as the SNR is sufficient for signal decoding.

3. What is described by the term "cell breathing"?

   Solution:

   In practice the cell coverage depends on multiple conditions that impact the propagation of radio waves such as the environment as well as the weather. These conditions may variate with time. For CDM systems the system load influences the cell size. With increasing load, i.e., additional users, the signal to noise ratio decreases and users at the cell edge drop out of the cell. This is due to the fact that the code of one user contributes to the interference at the other users.

4. You are a mobile network operator assigned to cover the island of Rügen with an area of nearly $A = 1000$ km^2. The bidding regulation enforces that your network must support at least $2 \cdot 10^4$ simultaneous connections over the whole island. To provide reasonable performance you demand a cochannel interference ratio of at least $\frac{S}{I} = 12$ dB. The mobile communication system that you implement has the following properties:

- area coverage of one cell: $A_{cell} = 2\ \text{km}^2$
- 200 channels available per cluster
- assume a loss coefficient of $\gamma = 4$

How would you dimension the deployed clusters?

(Hint: Use the theory provided in lecture 3 for calculating the cluster size N. Assume the following possible values for N: $N \in \{1, 3, 4, 7, 9\}$.)

Solution:

From the lecture we know that $D/R = \sqrt{3N}$ where D is the cochannel separation and R is the cell radius. D/R is called the reuse ratio. We reproduce the following table from the lecture for the possible N values

N	D/R
1	1.7
3	3.0
4	3.5
7	4.6
9	5.2

Next we use M to denote the number of clusters and write the following constraint

$$MNA_{cell} \geq A \tag{1}$$

to provide full coverage to the island. We include in the table above the minimum number of clusters M needed to cover the area of the island A for given cluster size N.

N	D/R	M
1	1.7	500
3	3.0	167
4	3.5	125
7	4.6	72
9	5.2	56

Since we have 200 channels available per cluster we can calculate the number of simultaneous connections that are supported by each configuration. We add this information to our table such that

N	D/R	M	max. conn
1	1.7	500	100k
3	3.0	167	33.4k
4	3.5	125	25k
7	4.6	72	14.4k
9	5.2	56	11.2k

We calculate the cochannel interference ratio as given in the lecture as

$$\frac{S}{I} = 10 \log_{10} \left[\frac{1}{6} \left(\frac{D}{R} \right)^{\gamma} \right]$$

in dB and find

N	D/R	M	max. conn	S/I [dB]
1	1.7	500	100k	1.4
3	3.0	167	33.4k	11.3
4	3.5	125	25k	13.9
7	4.6	72	14.4k	18.7
9	5.2	56	11.2k	20.8

Now we return to our scenario constraints. The first is the support of at least 20k simultaneous connections which is satisfied for cluster sizes $N \in \{1, 3, 4\}$. The second constraint is on the quality of service and requires a minimum cochannel interference ratio of 12 dB. This demands a cluster size from the set $N \in \{4, 7, 9\}$. The cluster size wich satisfies both constraint is $N = 4$.