S-72.2211 Mobile Communication Systems and Services

Exam 17.5. 2010

All five tasks are evaluated and taken into account in the grading. The exam can be written in Finnish, Swedish or English.
This is a closed book exam.

1. Channel structure in GSM
   a) What defines a physical channel in GSM?
   b) The logical channels are divided into control and traffic channels. Into which three subgroups are the control channels divided?
   c) How many TDMA-frames does a traffic channel multiframe consist of? What about a control channel multiframe?
   d) Which control channel is multiplexed together with a full rate speech channel on a traffic channel?

2. Compare a system with omni-directional base station antennas (antennas radiating with equal power to all directions) to a system with sectorized base station antennas. Assume that both systems have base stations at the same positions, and that the reuse factor is one. In the omni-directional system, the system is serving one user per channel per cell, and in the sectorized system, one user per channel per sector is served. The system capacity is estimated as the number of users per km^2 that can reach a given data rate with 50% availability (i.e. not taking fast fading or shadow fading into account). This data rate is selected so that with a uniform distribution of user locations in the cells, 95% of the users in a non-sectorized system reach this data rate. Power control is not used.
   a) Why is the downlink system capacity higher in a sectorized system than in a non-sectorized one?
   b) How does the situation in uplink differ from the situation in downlink, related to the carrier power, the interference power, and the system capacity?
   c) Assume that the base station transmission power in the non-sectorized case is P, and in the sectorized system, the transmission power in each sector is P/3. In the non-sectorized system, it is possible to experience higher carrier-to-interference ratios than in the sectorized system. Why is this?

   (An expected answer to each of the three questions above would consist of a few sentences.)

3. How many percent will the coverage area increase if a gain term in the radio link budget is improved with 5 dB, and the path loss exponent of the single slope average loss model is i) 3.0, ii) 4.0, and iii) 5.0?

4. In WCDMA, the chip rate is 3.84 Mchips/s.

   a) Assume a single cell system with the user bit rate after channel coding 15 kbits/s and the E_b/I_0 requirement for proper reception 5 dB, where E_b is the bit energy and I_0 is the experienced interference. With user activity factor 0.4 and AWGN noise not considered, how many users in a cell, theoretically, can be simultaneously served in the uplink direction?

   b) Repeat the calculation for a multicell system when the other-to-own-cell interference ratio is 0.6.

   Hint: When all users have the same service with constant rate, the capacity in number of users is obtained from the SIR expression $\gamma = \frac{GP}{\rho(1+f)(N-1)P}$, where G is the processing gain, P is the transmit power of the users, N is the number of users and f is the other-cell-to-own-cell interference ratio. Note that the processing gain can be calculated from the chip rate and the user bit rate. In Uplink WCDMA, BPSK modulation is used for data transmission.

5. Assume that downlink power control perfectly compensates average path loss. Path loss is assumed to follow a $r^{-\alpha}$ law, where α is the path loss exponent. The mobiles are assumed to be uniformly distributed in a circular cell with radius R so that the probability density function of the location of the mobiles is

$$p(r, \phi) = \frac{r}{\pi R^2},\ r \in [0, R],\ \phi \in [0, 2\pi] .$$

   Power control operates so that the maximum transmit power $P_{\max}$ is used only when transmitting to users at the cell edge $r = R$. The minimum transmit power is $P_{\min} = 0$. The mean transmit power averaged over the mobile station spatial distribution is

$$P_{\text{txm}} = \int_0^R \int_0^{2\pi} p(r, \phi) P_{\text{tx}}(r)\, d\phi\, dr .$$

   a) All users are within the radius $r = R$. What is the fraction of users within the radius $r = R/2$ and $r = R/4$? (2 points)

   b) How many dB is the average base station power level lower than the maximum level (which would result without power control), when $\alpha = 2, 3, 4,$ and 5? (4 points)