

# EE 360 - Multiuser Wireless Systems and Networks - Winter 2014

## Homework 1: Due Feb 19, 5pm.

Up to three people can collaborate on this homework.

(Total: 200 pts.)

January 29, 2014

1. **Make your own: [20 pts]** Design a homework problem based on any of the material covered in class or in the required or suggested reading, and solve it.
2. **Project Peer Reviews: [20 pts]** Read the project proposal posted to the class web page that is directly below yours (the proposer of the last proposal should review the first one). Email comments and suggestions to the proposal author along with at least two relevant references, and send a copy of your email (for this problem only each person must do this individually rather than collaborate with their other HW partners) to the course staff.
3. **Spread Spectrum Multiple Access: [20 pts]** Problem 14-3 in the textbook.
4. **Time-Varying Broadcast Channel Capacity: [20 pts]** Problem 14-14 in the textbook.
5. **MAC Channel Capacity: [20 pts]** Problem 14-16 in the textbook.
6. **Sum-Rate AWGN MAC Channel Capacity: [15 pts]** Problem 14-17 in the textbook.
7. **Capacity of CDMA systems: [20pts]** This problem is based on the paper “On the capacity of a cellular CDMA system,” by Gilhousen, Jacobs, Padovani, Viterbi, and Weaver. Neglecting noise, this paper derives a formula for the effective  $E_b/N_0$  of each user on the reverse link as (Equation 12)

$$\frac{E_b}{N_0} = \frac{W/R}{\sum_{i=1}^{N_s-1} \chi_i + (I/S)},$$

where  $W$  is the total signal bandwidth,  $R$  is the data rate of each user, the  $\chi_i$  follow a Bernoulli distribution with probability  $\alpha = p(\chi = 1)$  equal to the voice activity factor, and the  $I/S$  is assumed Gaussian with mean  $0.247N_s$  and variance  $0.078N_s$ . The paper uses numerical integration to find the outage probability, defined as

$$P_{out} = p\left(\sum_{i=1}^{N_s-1} \chi_i + (I/S) > \delta = \frac{W/R}{E_b/N_0}\right),$$

where  $E_b/N_0$  is the target value needed to obtain the desired BER.

- (a) Compute the outage probability for  $N_s = 35$  users assuming a voice activity factor of 0.5. Other than the voice activity you should use the same parameters as in the paper (e.g. for  $\delta$  and  $E_b/N_0$ ). Compare this with the outage probability obtained in the paper under a voice activity of 3/8 (Figure 3).

- (b) We now use an approximation to simplify the outage probability calculation. Assume that  $N_s$  is sufficiently large so that the random variable  $\sum_{i=1}^{N_s-1} \chi_i$  can be approximated as a Gaussian random variable. Under this approximation, what is the distribution of  $\sum_{i=1}^{N_s-1} \chi_i + (I/S)$  as a function of  $N_s$ .
- (c) Using the approximation obtained in part (b), compute the outage probability for  $N_s = 35$  assuming the same parameters as in the paper, including the 3/8 voice activity factor. Compare your result to that in the paper.
- (d) Using the same approximation as in parts (b) and (c), find the outage probability for  $N_s = 35$  assuming a  $10^{-6}$  BER is desired for each user. Assume you need  $E_b/N_0 = 10$  for this BER. Keep all the other parameters the same as you had in part (c).
- (e) We now determine the accuracy of our approximation. Plot the true distribution of  $\sum_{i=1}^{N_s-1} \chi_i$  for  $N_s = 35$  and compare it against the Gaussian distribution with the same mean and variance. You need only plot the distributions for 3 standard deviations about the mean. Is our approximation accurate?
8. **Area spectral efficiency:** [20 pts] Problem 15-11 in the textbook.
9. **Uplink per user capacity:** [20 pts] Problem 15-12 in the textbook.
10. **Next generation cellular:** [25 pts] The next generation of cellular systems will need to support the “Internet of Things”, billions of devices transmitting small amounts of data to the web. Some contenders for the air interface of these systems are CDMA, TDMA, OFDMA, and hybrid techniques. Moreover, there is debate about whether cellular systems should continue to have a star architecture with a single-hop to the base station or use multihop routing to the base. Pick a technology for the air-interface and network topology (single-hop or multihop) and prepare an argument as to why this should be chosen as the basis of the next generation systems. This argument should include a discussion of the relative strengths and weaknesses of other techniques under realistic assumptions about the system (e.g. expected channel impairments, interference mitigation techniques, expected traffic, etc.) along with an argument as to why your proposed techniques win out in this comparison. You need not focus on the exact details of the standards, just their general properties. For this HW problem you should write at least a 1 page summary of your arguments.