KTH Information and Communication Technology

IK2510 Wireless Networks

Exam 2012-10-20, 14:00–18:00, Room 539, 540.

Teacher in charge: Jens Zander, 0708-521461

Open Book exam: Text Books, formula sheets (BETA or similar), printed lecture notes/slides, dictionaries, tables are allowed. *Solutions, own notes or other hand written* material are **not** allowed. Calculators are allowed, but all other electronic equipment, such as mobile phones, tablets etc must be switched off and may not be brought to the seat.

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1. A cellular system uses a hexagonal cell pattern employing symmetric frequency reuse with a total of C=120 channels. The base stations are located in the center of the cell, 1 km apart. The required SIR threshold for a service is $\gamma_t = 10$ dB.
   a) The signal strength can be assumed to decay as r^{-4}. Estimate the capacity (# ch/km^2) of the system if we add an 11 dB fade margin.
   b) We want to support 60% relative traffic load. What is then the blocking probability p_b?
   c) Introduce the following stochastic fading model

$$S \propto G_0 R^{-4}, I \propto G_I D^{-4}$$

   where S is the signal strength, $G_0 \in \text{logN}(\mu\text{dB}, \sigma\text{dB}) = \text{logN}(0dB, 6dB)$ is a lognormal random variable, R is the distance to the cell corner. I is the total interference power, $G_I \in \text{logN}(11\text{dB}, 3\text{dB})$ and D is the distance to the closest interferer.
   What is then the outage probability?

2) Consider the uplink of a single-cell Slotted ALOHA wireless packet data system. The base station is placed in the middle of the cell and the users are uniformly distributed over the cell area. The system uses constant received power control and all users will achieve the same data rate, 1024 kbps, if the transmission succeeds. A packet is successfully received at the base station if there is no collision. Each user needs to send 10-kbit messages on average every 10 seconds following the Poisson process, even if the previous messages have not yet been sent.
   a) What is the maximum number of users the system can support such that the expected packet delay is finite?
   b) If Pure ALOHA is used, what's the maximum number of users the system can support?
   c) If the BS schedules the transmission of all users in an independent control channel using the Round-Robin scheduler, what's the maximum number of users the system can support?

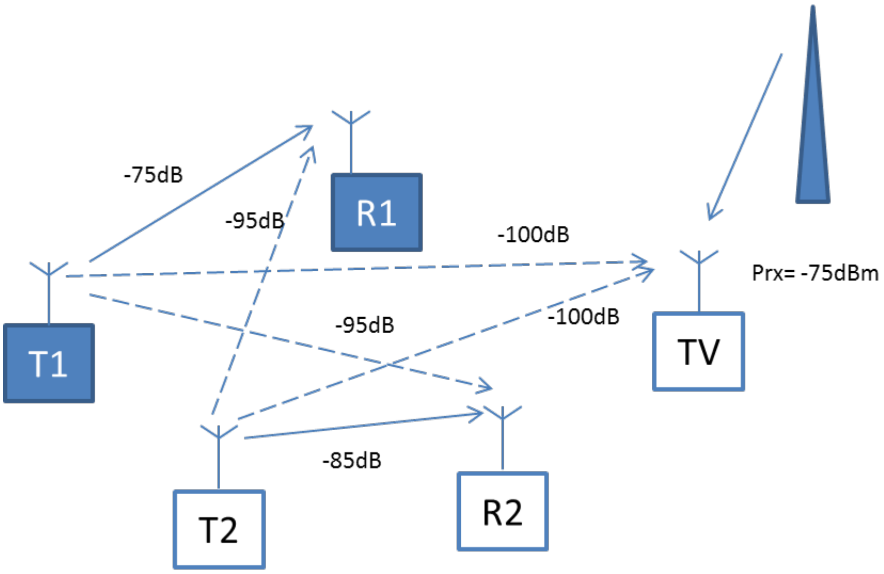


Fig 1. Problem 3

3) Two radio links are operating the TV-band and are required to protect TV receivers from harmful interference. The TV set in question receives a signal level of -75dBm and requires an SIR of at least 20dB to avoid picture distortion. The path gains are given in fig 1. The maximum (unrestricted) transmitter power of the radio transmitters T1 and T2 is 1 W and the total (external) noise level is -100 dBm. The data rate in each link is dependant on the signal-to-interference+noise ratio γ and is given by

$$R = 2\log_2(1+\gamma) \text{ Mbits/s}$$

a) Determine the maximal rates in link 1 and 2 if T1 and T2 transmit simultaneously using the highest possible power that will protect the TV set?
b) Compare the total data rate in a) with the data rate that be achieved by "time-sharing" letting one of the transmitters transmit at the time, 50% of the total time each?

4) Consider a system consisting of four base stations (BSs) as in fig 2. The BSs are placed to have the equal distance (d) from the point A as illustrated in the Figure. The system employs total bandwidth of 10MHz. Your task is to evaluate performances of different resource division schemes with or without multi-cell cooperation. There would exist lots of combinations of resource division and cooperation schemes. Here, we consider the three schemes described below:

- Scheme 1: frequency reuse of 1 without cooperation
- Scheme 2: joint transmission of all four BSs with signal power combining
- Scheme 3: cooperation of two-cell clusters, i.e. BSs 1 & 4 form cluster 1 and BSs 2 & 3 form cluster 2. Two clusters use the same frequency. Inside a cluster, joint transmission with signal power combining is adopted.

In the following, for simplicity we make the following assumptions:

- Path loss exponent is 2. Fading effects are neglected.
- All BSs have the same transmission power.
- The noise power is 6dB lower than the power received from one BS at the point A.

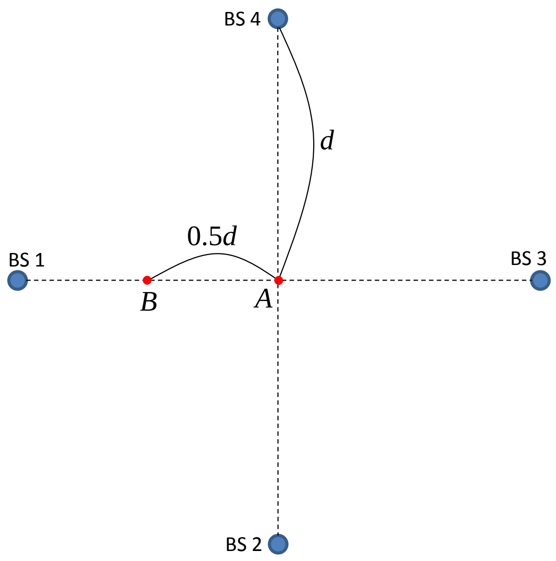


Fig 2. Problem 4

a) Consider a mobile at the point A. It is attached to BS 1. Identify the best and worst scheme from the viewpoint of achievable downlink capacity for the mobile. Assume that all cells are fully loaded, i.e. BSs 2, 3, and 4 also have their own users to serve. In each cluster, cooperating BSs employ an equal time-division between them.

b) Consider a mobile at the point B who is attached to BS 1. Which one is better between the scheme 1 and scheme 2?

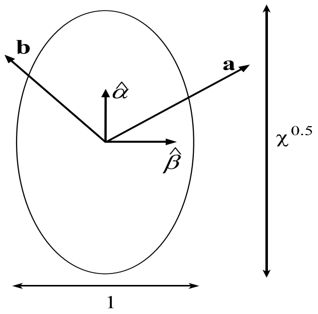
c) Consider a mobile at the point B again. The difference is that not all BSs are fully loaded any more. Assume that BSs 3 & 4 momentarily have no user to serve. Which one is better between the scheme 1 and scheme 3? Note that, for cooperation, BSs in a cluster do not need to share the resources with non-loaded BSs.

NOTE: your answer must be supported by quantitative results. For the case of (c), you may get extra points if you can add a qualitative reasoning.

5) The network company *NetTwo* is to deploy a radio network in the rural parts of Sweden at 450MHz. The question for the company is whether to build space- or polarization diversity and what tower heights to use?
   a. What horizontal antenna beam width is optimal to deploy in this environment (1p)
   b. Due to wind load in the tower, the antenna length is limited to 2m. What is the maximum antenna gain that then can be achieved assuming that the cable losses are 0.5db/m (1p)
   c. What is the minimum distance between antennas needed for a space diversity configuration in order to cover twice the area as polarization diversity in this environment (1p)

Assumptions (Problem 5):

1. Assume that the towers are high and that the channel cross polar discrimination χ =6dB
2. That the propagation constant α=2



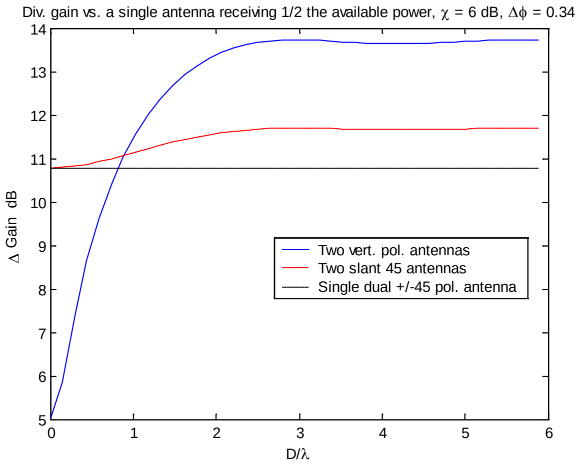


Fig.3: Comparison of MRC diversity gain relative a single antenna receiving ½ the available power. χ=6dB
