Radio Communication Systems

IK2502 Wireless Networks

Exam 100503, kl 13:00–17:00, Room C21.

Open Book exam with

- J. Zander and S.-L. Kim, *Radio Resource Management for Wireless Networks,* Artech House Publishers.
- Lecture notes (OH-slides only)
- Dictionaries, tables (BETA or similar), and calculators
- Solutions to old exams and hand written material are not allowed.
- Write name and social security number on each sheet handed in.
- Write page number on each sheet handed in.
- Do not solve more than one problem per sheet and only on one side of the paper.

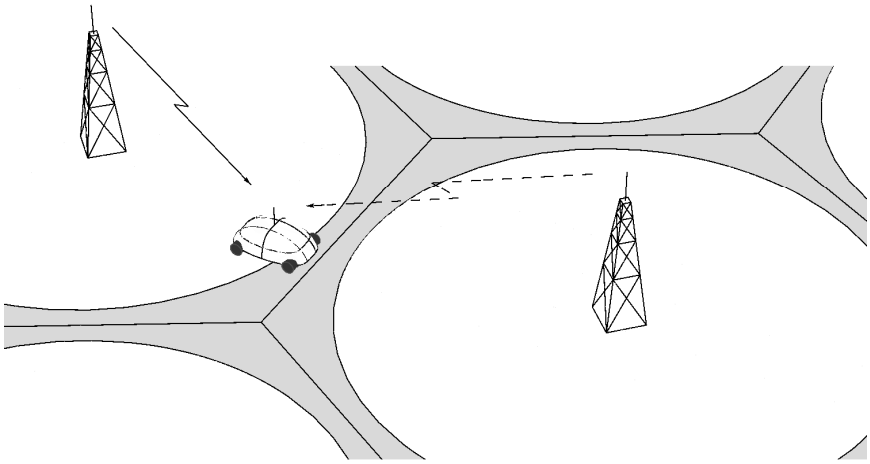
Problem 1

Consider the uplink of a DS-CDMA system that have a processing gain (spreading factor) of $P_g = 128$ and employing a perfect received power control. The number of users within the system are Poisson distributed with a mean of 4 users/cell. Inter cell interference can be considered about 60% of own cell interference.
The assignment failures within the system occur when the system load $L = 1 - \eta$ exceeds 50%.

a) Determine the minimum required signal energy-to noise power spectral density γ_t that ensures an assignment failure rate of 20%.

b) Determine the assignment failure rate if the CDMA system employs voice activity detection with a voice activity factor $q = 0.5$!

Problem 2

2. 

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 and the signal strength can be assumed to decay as r^{-4}. Consider downlink and assume that the mobile stations are uniformly distributed with an activity of 50%.

a. Assume that the system is designed to put the mobile station in soft-handover if the signal-to-interference ratio (SIR) is below 25dB. What is the cell capacity η if the probability of putting a mobile station into soft-handover should be kept below 20%?

b. Now, assume that the cell capacity is 13 channels and that the signal-to-interference ratio is modeled with lognormal distribution according to

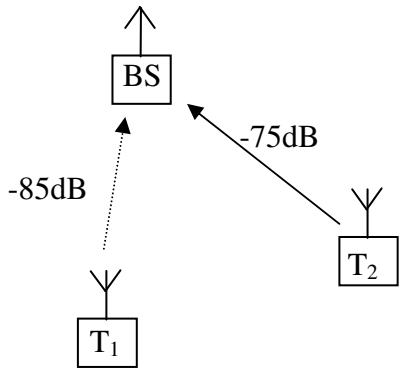
$$\Gamma\,(r) \approx \frac{G_S \frac{1}{r^4}}{G_I \frac{1}{D^4}}, G_S \in \mathrm{LogN}\,(\mu_S, \sigma_S), G_I \in \mathrm{LogN}\,(\mu_I, \sigma_I)$$

where *r* is the distance to the mobile station and *D* is the (average) distance to the first shell of interferers. The signal G_s and interference G_I are assumed to be independent random variables with the following expectation values and standard deviations:

$$\mu_S = 0\mathrm{dB}, \sigma_S = 6\mathrm{dB}, \mu_I = 5\mathrm{dB}, \sigma_I = 4.5\mathrm{dB}$$

What is the probability of being in soft handover at the cell corner?

Problem 3



P1 In a wireless network two terminals transmit data to a base station using a single carrier CDMA system with processing gain η =20 dB. The path gains are given by the figure. The maximum transmitter power is 1 W and the total (external) noise level is -110 dBW. The data rate in each link is dependent on the signal-to-interference+noise ratio γ and is given by

$$R = 100\log_2(1+\eta\gamma) \text{ kbits/s}$$

Assuming that we want to design a fair system giving the same data rate to both terminals

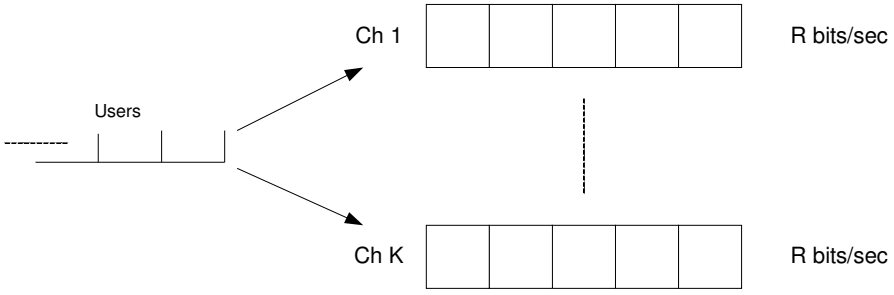
a) Determine the maximal average sum rate for both links if simultaneous transmission with constant received power control is used (1p)

b) Propose a power control/scheduling scheme that achieves a higher a average rate (2p)

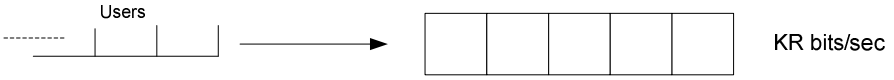
Problem 4

Wireless access is provided across a given area, the system operates according to the slotted Aloha protocol.

a) Assume that you have infinite users and K separate slotted channels with slot boundaries synchronized; each channel has a fixed rate R. Each user selects randomly one of the K channels and performs all its activity on that channel. Find the expression for the system throughput.



b) Assume that you have infinite users who access one channel with fixed rate KR. Find the expression for the system throughput and compare with (a).



Problem 5

A facility owner will build a new office area called Kista 2.0 with an estimated number of 10 000 workers from start. The facility owner wants to investigate the possibility to offer Internet over wireless connections and need to estimate the cost for deploying a new radio access networks. The facility owner has been in contact with 3 different operators that will offer different solutions. From the initial discussions the facility owner has some information about the three operators and now wants to get an initial cost estimate.

Your task is to help the facility owner and make this initial cost estimate for the estimated low and the high demand levels and based on the information provided below.
Which operator will most likely be able to offer the services at the lowest cost?

The demand

10 000 workers are to be served from year 1 in the 1 km2 area. Two levels of demand are of interest; 1,44 GB and 7,2 GB per month and user for low and high level respectively. For the dimensioning assume that the data is consumed during 8 busy hours (all equally busy) for 20 work days per month.

Data for operator A deployment

The incumbent operator A has 4 macro base stations sites that can be re-used, in the area. In case new macro base station sites are needed the operator A has all necessary building permits. Operator A has access to 10 MHz of spectrum in this frequency band and will use the radio access technology WAD suitable for wide area deployment.

Data for operator B deployment

Operator B has no base stations sites at all in the area. New sites are needed and operator B has all necessary building permits. Operator B has access to 20 MHz of spectrum in this frequency band and will also use the radio access technology WAD.

Data for operator C deployment

The new operator C will offer an indoor solution based on deployment of a number of small pimentocell access points using the LAD radio access technology. The operator has a 20 MHz license for operating LAD equipment in this frequency band; hence cell planning can be made in order to avoid inter-cell interference. All access points and required transmission need to be installed from the beginning.

The radio access technology

The technical data and performance is shown in table 1. WAD has a re-use factor of 1. One WAD TRX module supports a three sector site and system bandwidth up to 20 MHz. The link budget for WAD is calculated to allow for 20 dB wall penetration losses which are sufficient for all locations in all buildings in the area.
In order to satisfy the coverage requirements in the buildings one pimentocell access point need to be deployed for every 10 user as long as the capacity requirements are met.

Table 1: Technical data for radio access technologies

Type of deployment	Radio access technology	System bandwidth	Spectral efficiency	Max cell range (for all bandwidths)
Indoor pimentocell	LAD	1 – 5	3	50 m
Outdoor macro site	WAD	5 – 20	1,67	600 m

Cost calculation

Estimate the total cost as the CAPEX plus the OPEX for years 1 to 5 assuming a discount rate of 0 %. All network build out is made year 0. Derive CAPEX numbers from data in tables 2. For macrocell deployment the annual OPEX is estimated to be 10 % of the total CAPEX including radio equipment, installation and all *new* macro base stations sites. For the pimentocell deployment the annual OPEX is estimated to be 20% of the total CAPEX including access point equipment, cabling, planning and installation.

Table 2: Cost estimates

WAD Radio equipment and installation	**Costs**
TRX supporting 3 sectors and up to 20 MHz, first TRX	10 k€
TRX supporting 3 sectors and up to 20 MHz, additional TRX	10 k€
Installation of the first TRX	10 k€
Deployment and macros site build out	
Site construction	70 k€ per site
Non-telecom equipment	20 k€ per site
Transmission costs	10 k€ per site
Pimentocell equipment and installation	
One access point, omnidirectional antenna, supports 5 MHz	300 €
Planning and installation of one access point	300 €
Cabling for one access point	400 €