Radio Communication Systems

IK2510 Wireless Networks

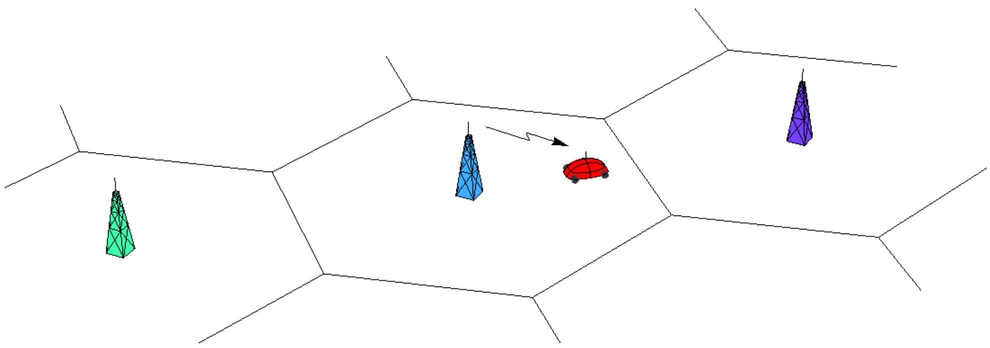
Final Exam: Fri 25 oct 09:00-13:00, Ka-532 (Ka-Forum 532), Ka-533 (Ka-Forum 533)

Teacher in duty: Guowang Miao, 0709557376

Open Book exam: Text books, formula sheets, 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.

Student Name:_______________________________Personal Number:________________

Problem 1 (6 points)



Consider a hexagonal cellular system with omnidirectional base stations and a static channel allocation scheme. The average signal-to-noise ratio (SNR) at the cell corner is 40 dB. In order to deliver a certain service the signal-to-interference-and-noise ratio (SINR) has to be better than γ = 13 dB.

a) The operator can use 128 channels and has decided to use the following path loss model:
   $L_{dB}=48+40*\log_{10}(r)$ [m]

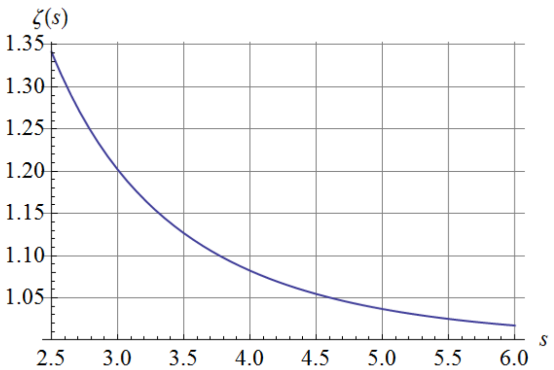
If we are aiming for at least 5 users/km^2, estimate how many base stations are needed to cover a region of 1000 km^2. Assume all transmitters have the same power, use a downlink calculation and reasonable simplifications.

b) Now, choose a stochastic model for the SINR

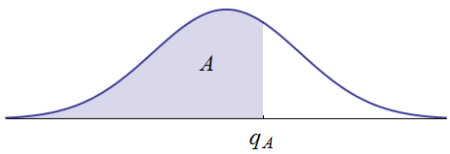
$\Gamma = G\,\gamma_0$

where γ_0 is the average SINR and G is lognormal with expectation value 0 dB and standard deviation 4 dB. We want 98 % availability (downlink) at the cell corner. How will this affect the number of base stations needed?

Riemann Z function



Quantile for standard normal distribution



$\text{Prob}(X \le q_A) = \Phi(q_A) = A$

$q_A = \Phi^{-1}(A), \; q_A + q_{1-A} = 0$

A	0.9	0.95	0.975	0.98	0.99	0.995	0.999	0.9995	0.9999	0.99995	0.99999
q_A	1.2816	1.6449	1.9600	2.0537	2.3263	2.5758	3.0902	3.2905	3.7190	3.8906	4.2649

Solution:

Problem 2 (6 points + 2 bonus points):

1. Consider the uplink of a packet radio system. A large number of users are uniformly distributed over the circular cell area accessing the BS in the center. The cell area has a radius 100 meters. Slotted ALOHA is used as the medium access scheme. The system uses a power control scheme such that a constant signal power, P_r=15e-10 mW, is received at the BS for all users. Assume that the signal level decays as the 4-th power of the distance, i.e. $P_r = P_t/d^4$. The noise power is N_o=*1e-10 mW*, and the system bandwidth *W* is 10 kHz. An ideal channel coding is used and the channel capacity, $R = Wlog_2(1+SNR)$, can be achieved once the transmission succeeds. A packet is successfully received at the base station if and only if there is no collision. Each user needs to send a 10-kbit message on average every 10 seconds following the Poisson process, even if the previous messages have not yet been sent. The power amplifier efficiency of each user is 0.5. When sending data in the active mode, each user consumes 10 mW circuit power in addition to the transmission power. Each user goes to the sleep mode immediately when there is no data transmission and consumes only 1 mW circuit power. Similarly a sleeping user can switch to the active mode and send data immediately when it needs to send a packet.

   (a). Determine the cumulative distribution function (CDF) of the transmission power of a user when the user is sending data (2 points).
   (b). If there is only one user in the network, determine the CDF of the individual average power consumption (2 points).
   (c). What is the maximum number of users that the system can support (2 points)?
   (d). If there is the maximum number of users in the network, given in (c), determine the CDF of the individual average power consumption of all users (2 bonus points).

Solution:

Problem 3 (6 points):

A cellular operator has installed a small mobile telephone system along a street. The system has only 4 base stations (BSs) located at the following distances (coordinates), measured from one end of the street:

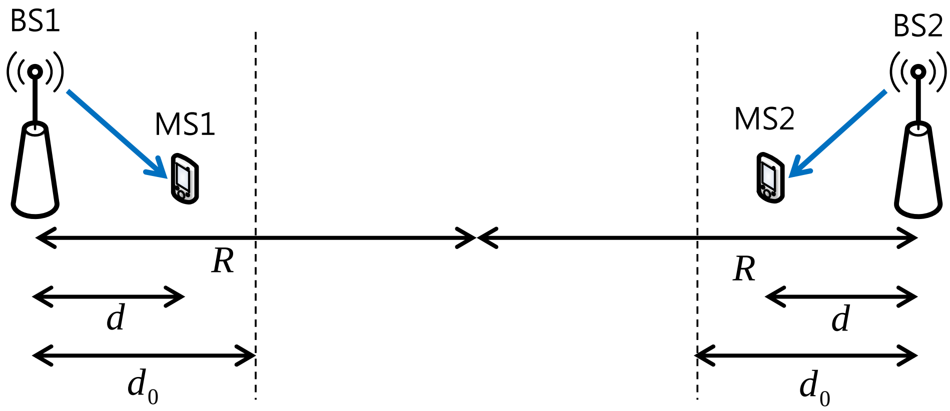
(100,200,300,400).

The system uses only one channel. The propagation loss is proportional to the fourth power of the distance, i.e. $P_r = P_t/d^4$. At one time, two terminals, A and B, at (150, 280), are connected. BSs that do not serve any terminal are kept off.

(a) Determine the link gain matrix in dB scale for this channel set (2 points).
(b) Assume the BSs and the terminals use the same transmit power. The two terminals are connected to the BSs such that their uplink SIRs are maximized. Determine the SIRs for all base stations and terminals (2 points).
(c) Observe the uplink. Assume the two terminals can have a maximum transmit power of 1 W. We require terminal A to have a minimum SIR of 20 dB. What is the maximum SIR of terminal B? What power values should the two terminals use? (2 points)

Solution:

Problem 4 (6 points):



Consider the downlink of a one-dimensional cellular system consisting of two identical access points (APs) with the coverage distance R as illustrated in the above Figure. Mobile station (MS) 1 is associated with AP1 and MS2 with AP2. MS1 and MS2 are assumed to be at the same distance (d) from their corresponding APs. The two APs share 10 MHz system bandwidth according to the following resource utilization rule: if $d \le d_0$, both APs transmit simultaneously on the full bandwidth (resource sharing); otherwise, AP1 and A2 use half of the bandwidth respectively (resource division). Assume:

- Path loss exponent is 4. Fading and shadowing effects are neglected.
- Noise power is 3dB lower than the power received at the cell border (midpoint) from one AP.
- Shannon's data rate is achieved in the system.

(a) Express the SINR of MS1 as a function of d .

(b) Assume that the two MSs are located at $d = 0.5R$. To achieve the highest sum rate, which resource utilization scheme should be used?

(c) When the MSs are at the cell border ($d = R$), resource division performs better. Keeping the same noise power, which resource utilization scheme should be used if the transmit power of the APs is reduced by half?

NOTE: Answers to (b) and (c) must be supported by quantitative analysis, otherwise zero point.

Solution:

Problem 5 (6 points)

Cellular CDMA systems employ soft handover for both coverage and link reliability. A mobile receiver within an IS-95 system has been communicating for a while and receives the pilot signals shown in Figure 1. We assume that this mobile receiver is in soft handover and your task is to identify the set of cells that are in the active set of the mobile unit at time $\tau = \tau_0$.
The handover drop time is 10 seconds and the handshaking time between the base station and the mobile can be neglected.

a) Going through each pilot signal, identify the status (in the active set , candidate set, or neighbor set) of each pilot signal at time τ_0! Clearly explain your results. (4p)

b) Deduce the set of cells that are in the active set of the mobile unit at time τ_0! (2p)

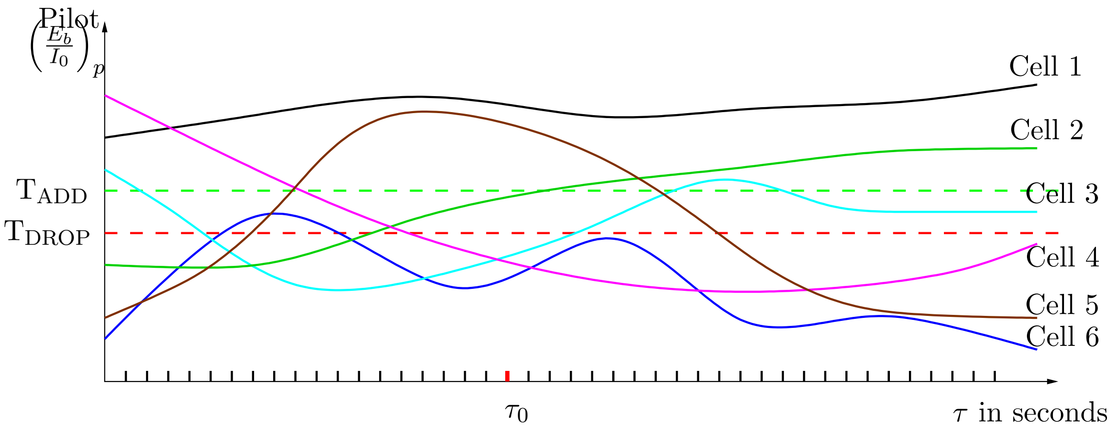


Figure 1: Illustration for Problem 2.