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Aalto University
Comnet

S-72.3216 Radio Communication Systems I (5 cr)

Exam (25th October, 2012)

First Name(s): .... Family Name(s): ....
Student Number: .... Exam Date: 25th October, 2012
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Exc.	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	Sum
max.	6	6	6	6	6	30
pts.						

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Problem 1: *(General concepts within radio communication systems)*

(a) What do the acronyms WLAN, WPAN, and WMAN mean? Present the concept behind each of these terms, putting emphasis on the characteristics, challenges, and goals in each particular case. Identify at least one representative example of a wireless communication technology that falls within each of these categories.

(b) List three concepts that differentiate a mobile communication technology (like LTE) from other wireless communication technologies (like IEEE 802.11b). Explain each of these concepts in a brief but clear way.

(c) Licensed and unlicensed spectrum: difference between these two concepts. Characterize the interference and the regulations that exist for using these bands. Do designers have the same goals/objectives, when defining the technical characteristics of the wireless system that should work in licensed/unlicensed spectrum? Why/why not?

(d) Enumerate the three different phases in which a network planning procedure is usually divided. Explain briefly the main idea behind each of them.

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Problem 2: *(Channel modeling for mobile communication systems)*

(a) List the three approaches that exist for radio channel modeling. Explain each channel modeling approach in a brief but clear way. What are the advantages and disadvantages of each of them? Rank them in order of importance, according to the use that they have in the planning of new mobile network deployments.

(b) Enumerate the three different types of fading that can be be usually differentiated in a clear way, when modeling statistically the instantaneous path loss attenuation of a wireless link. What originates these three different behaviors? Explain the main characteristics of each of these types of fading.

(c) A wireless communication system operates at $f_c = 900$ MHz in small village, which can be considered as a mixed sub-urban and rural environment according to its signal propagation characteristics (see Fig. 1 for more details). The wireless communications system has a single *base station* (BS) located in the center of the village. The height of the BS antenna and the

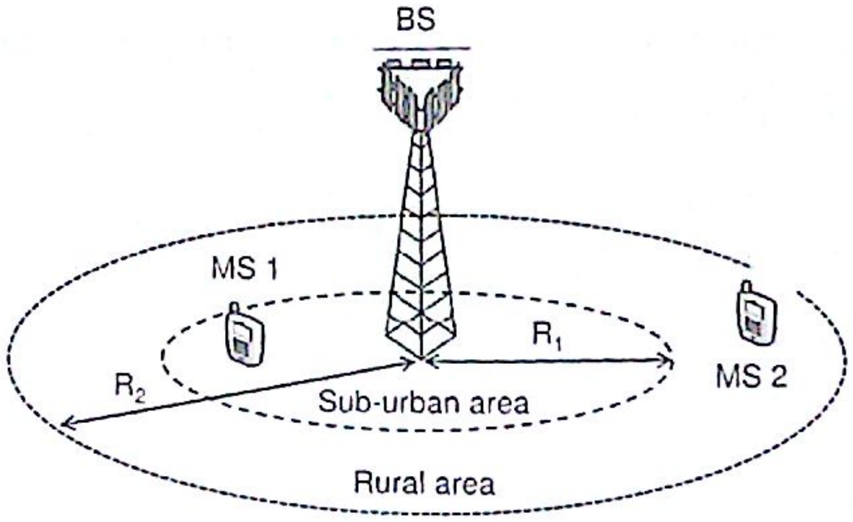

Figure 1: Wireless communication system operating in a mixed wireless environment. *Sub-urban* channel propagation takes place within the circle with radius R_1, while rural channel propagation takes place when being at distances between R_1 and R_2. Base station is located in the center of both "concenteric" circular areas.

height of the *mobile station* (MS) antenna are $h_b = 25\,\text{m}$ and $h_m = 1.5\,\text{m}$, respectively. The environment is modeled as two concentric circles: the inner circle with radius $R_1 = 5\,\text{km}$ correspond to the sub-urban part, and the non-overlapping area of the outer circle with radius $R_2 = 35\,\text{km}$ represents the rural part.

1. Based on Okumura-Hata equations, write down a formula that enables to estimate the average path loss attenuation for any MS located within the coverage area of the whole system (i.e., for distances from 0 to 35 km). It is requested that the formula gives the result in logarithmic scale (i.e., in dB).

2. Assume that BS transmit power is 46 dBm. Determine the mean received signal power that MS 1 will perceive, assuming that it is located at a distance of 2 km from the BS. Similarly, determine the mean received signal power that MS 2 will experience, assuming that it is located at a distance of 10 km from the BS. In both cases, do not consider shadowing and/or fast fading. Present final result in dBm.

Problem 3: *(Functional blocks of a radio link and channel capacity concepts)*

(a) Describe the concept of interleaving. Explain why does interleaving improve the performance of channel coding in wireless communication systems.

(b) Explain the functionality of the source coder block and channel coder block in the context of a radio communication system. What is the main difference between these two coding blocks?

(c) Define the concepts of throughput, channel capacity, and goodput. What is the relationship that exists between each of these concepts?

(d) Define the concept of *cyclic prefix* (CP). Give a brief explanation of the use of CP in OFDMA.

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Problem 4: *(Multiple access and duplexing)*

(a) Describe at least two advantages and two disadvantages of the following multiple access techniques:

1. FDMA
2. TDMA

(b) What is the difference between a synchronous CDMA system and an asynchronous CDMA system? Are both approaches suitable for both, uplink and downlink directions? Why/why not? Mention the advantages and disadvantages when comparing them

(c) Describe at least two advantages and two disadvantages of the following duplexing methods:

1. FDD
2. TDD

(d) What generates the so-called cross-slot interference problem? In what kind of of wireless systems does it take place? How can it be prevented?

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Problem 5: *(Co-channel interference in mobile systems)*

(a) Adjacent channel interference: explain the origin of this impairment, and how can it be controlled

(b) Co-channel interference: explain the origin of this impairment, and how can it be controlled

(c) Consider the system presented in Fig. 2, composed by one *macro base stations* (MBS), one *pico base station* (PBS), and one *mobile station* (MS). Assume that the MBS apply sectorization using directional antennas. The main direction of the irradiated power at the MBS is denoted in the figure by a (black) solid arrow. The PBS do not apply sectorization: it deploys an omnidirectional antenna with 3.5 dBi gain in all directions.

1. Calculate the received SIR in the MS towards the stronger BS (i.e., the BS whose signal is received with best quality). Assume that MBS transmit power is 46 dBm, and PBS transmit power is 30 dBm.

   For sake of simplicity, we use the same average path loss attenuation formula (in dB scale) for both, macro and pico links, i.e.,

$$L(d) = 137,4 + 35,2 \log_{10}(d) \qquad d > 0, \tag{1}$$

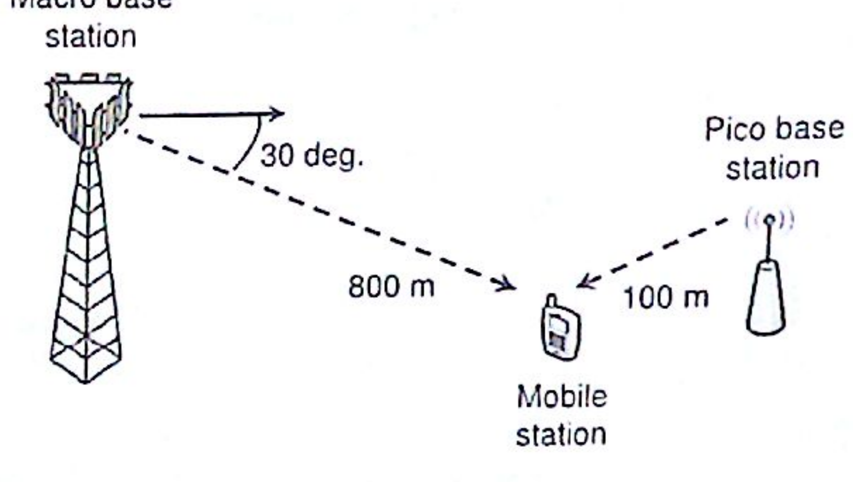

Figure 2: Wireless communication system with one macro base station, one pico base station, and one mobile station. Macro base station applies sectorization, using a directional antennas with pre-defined gain pattern. Pico base station is equipped with an omnidirectional antenna, that irradiates with equal gain in all directions.

where d is the distance between transmitter and receiver in kilometers.

The antenna gain pattern at MBS attains the form

$$G(\theta) = G_{\max} + \max\left\{-12\left(\frac{\theta - \theta_0}{\theta_{3\text{dB}}}\right)^2, -G_{\text{fb}}\right\}, \tag{2}$$

where θ is the angle of arrival/departure [degrees], $G_{\max} = 16\,\text{dBi}$ is the maximum antenna gain, θ_0 is the main direction of the irradiated power [degrees], $\theta_{3\text{dB}} = 60^\circ$ is the beam width at 3 dB, and $G_{\text{fb}} = 25\,\text{dB}$ is the front-to-back ratio for the antenna.

Express the final result in dB.

2. Assume that the throughput can be approximated using the formula

$$R = N_{\text{RB}}\,W_{\text{RB}}\,A\,\log_2(1 + B\,\text{SIR}), \tag{3}$$

where N_{RB} is the number of assigned *resource blocks* (RBs), $W = 180\,\text{kHz}$ is the bandwidth of a single RB, and $A = 0.88$ and $B = 1/1.25$ are parameters that take into account the bandwidth and SINR efficiencies of LTE, respectively.

How many RBs are needed to achieve a data rate of 2 Mbps for the MS? (based on the SIR value calculated in the first part of the problem)

Appendix Information: *(Formulas and Curves that MAY be required)*

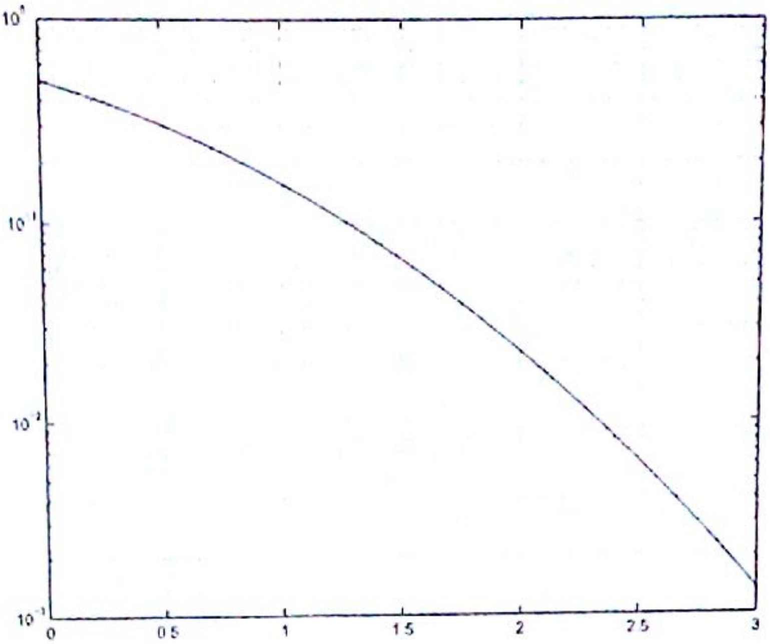

Figure 3: Plot for the Marcum Q-function.

$$f(L_s) = \frac{1}{\sqrt{2\pi}\sigma_s} e^{-\frac{L_s^2}{2\sigma_s^2}} \tag{4}$$

$$\Pr\{L_s < L_0\} = \int_0^{L_0} f(t)\,dt = 1 - Q\left(\frac{L_0}{\sigma_s}\right) \tag{5}$$

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{+\infty} e^{-\frac{t^2}{2}}\,dt = \frac{1}{2}\,\mathrm{erfc}\left(\frac{x}{\sqrt{2}}\right) \tag{6}$$

$$\left(1 - \frac{1}{z^2}\right) \frac{1}{z\sqrt{2\pi}} e^{-\frac{z^2}{2}} \leq Q(z) \leq \frac{1}{z\sqrt{2\pi}} e^{-\frac{z^2}{2}} \tag{7}$$

$$\begin{aligned} L_{\text{Hata}}\,[\text{dB}] &= 69,55 + 26,16 \log_{10}(f\,[\text{MHz}]) - 13,82 \log_{10}(h_b\,[\text{mt}]) \\ &- a_i(h_m\,[\text{mt}]) + [44,9 - 6,55 \log_{10}(h_b\,[\text{mt}])] \log_{10}(r\,[\text{km}]), \end{aligned} \tag{8}$$

Large sized city (i.e., $i = 1$):

$$a_1(h_m) = 3,2\,[\log_{10}(11,75\,h_m)]^2 - 5,0 \qquad 200\,\text{MHz} \leq f \leq 1500\,\text{MHz} \tag{9}$$

Medium/small city (i.e., $i = 2$):

$$a_2(h_m) = 0,8 + [1,1\,\log_{10}(f) - 0,7]\;h_m - 1,56 \log_{10}(f) \tag{10}$$

Suburban area (i.e., $i = 3$):

$$a_3(h_m) = a_2(h_m) + 2\left[\log_{10}\left(\frac{f}{28}\right)\right]^2 + 5,4 \tag{11}$$

Rural/open area (i.e., $i = 4$):

$$a_4(h_m) = a_2(h_m) + 4,78\,[\log_{10}(f)]^2 - 18,3 \log_{10}(f) + 40,9 \tag{12}$$