Aalto University
Comnet

ELEC-E7120 Wireless Systems (5 cr)

Final Exam (19th October, 2015)

Exc.	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	**Sum**
max.	3	3	3	3	3	15

Exam rules and regulations: The only materials that you are allowed to have on your desk are writing instruments and calculator with basic scientific features. All electronic devices, including cell phones and laptops, are prohibited. Any other personal items must be set aside before exam starts. Remember to indicate clearly in your paper which is the question that you choose to do not answer (1 question per problem). Individual questions per topic are guidelines to elaborate the answer as a single statement: You do not need to answer them separately. You have 3 hours to work on the exam.

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Problem 1: *(General concepts related to wireless systems)*

You need to answer only 2 questions in this problem. Please, indicate clearly in your exam paper the question that you are not aiming to solve (max. 3 points)

(a) What does the acronym IMT-2000 mean? Specify the name of the international organization that is behind its development. What were the goals expected to be achieved in IMT-2000? How many proposals (technologies) were presented as response to IMT-2000 document? What kind of multiple-access methods do these proposals (technologies) use? Do all these proposals (technologies) share more similarities of dissimilarities? Why do you think so? Justify your position in a simple but clear way (1.5 points)

(b) Difference between '*roaming*' and '*handover*': Present the idea behind each of these concepts clearly. Explain with your own words why these characteristics are essential in mobile communication systems. Finally, make emphasis on the difference that exists between both concepts (1.5 points)

(c) What does the ISM acronym mean? Are these ISM bands used for licensed or unlicensed wireless services? Who is in charge of regulating the use of ISM bands (national or international authorities)? What are the tools that designers have to control co-channel interference of co-located wireless systems using ISM spectrum? Would you recommend the use of ISM spectrum to provide wireless services in local area or wide area networks? Why do you think so? Finally, name two wireless communication technologies that use ISM spectrum for communication (1.5 points)

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Problem 2: *(Wireless channel modeling)*

You need to answer only 2 questions in this problem. Please, indicate clearly in your exam paper the question that you are not aiming to solve (max. 3 points).

(a) In which situation can the physical channel modeling be used? What are the *'physical principles'* that are used to model the propagation of radio waves using this approach? Mention the advantages and disadvantages of the physical channel modeling. Does it make more sense to use it in the near- or far-field region of the radio equipment antenna? Why? (1.5 points)

(b) Explain briefly Okumura-Hata (O-H) model. Why is O-H model so popular after so many years of being developed? What kind of fading does it model? What are the radio system parameters that O-H model takes into account? What are the limitations of O-H model? How are these limitations solved when dimensioning links in contemporary networks? (1.5 points)

(c) A mobile communication system working in 900 MHz is designed to provide 90 % successful communications on the coverage fringe (cell-edge). The system operates in an environment that can be categorized as sub-urban, with a standard deviation of location due to shadow fading equal to 7 dB. When no antenna gains are considered, the maximum acceptable path loss for the system is 140 dB. Antenna heights are $h_{\mathrm{bs}} = 30\,\mathrm{m}$ and $h_{\mathrm{ms}} = 1.5\,\mathrm{m}$ for the base station and mobile station, respectively. Determine the range of the system if omnidirectional antennas of gain 3 dBi and 0 dBi are placed at the base station and mobile station, respectively. (1.5 points)

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Problem 3: *(Elements of wireless transmission)*

You need to answer only 2 questions in this problem. Please, indicate clearly in your exam paper the question that you are not aiming to solve (max. 3 points)

(a) Explain the functionality of the channel encoder and source encoder blocks in the context of a wireless communication system. What is the main difference that exists between them? In which order should these encoders be placed in the transmitter chain? Why? What is the purpose of combining an interleaving block with a channel encoder block? How should the size of the interleaving block be selected? Justify your answer properly (1.5 points)

(b) Consider a flat fading channel with independent and identically distributed (i.i.d.) states, which generate the following values of received SNR at the mobile: $\gamma_1 = 0.9$ with probability $p(\gamma_1) = 0.15$, $\gamma_2 = 3$ with probability $p(\gamma_2) = 0.6$, and $\gamma_3 = 100$ with probability $p(\gamma_3) = 0.25$. Find the average Shannon capacity for 30 kHz channel bandwidth (1.5 points)

(c) Describe at least two advantages and two disadvantages of the following multiple access techniques: (1) CDMA and (2) OFDMA (1.5 points)

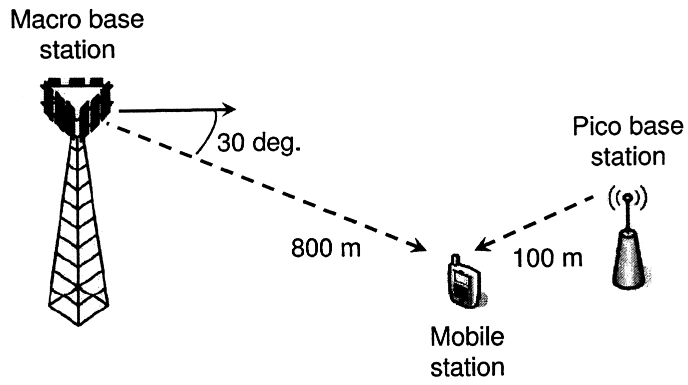

Figure 1: Wireless communication system with one MBS, one PBS, and one MS. Macro base station applies sectorization, using a directional antennas with pre-defined gain pattern. Pico base station is equipped with an omnidirectional antenna, that irradiates with equal gain in all directions.

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Problem 4: *(Wireless cellular networks)*

You need to answer only 2 questions in this problem. Please, indicate clearly in your exam paper the question that you are not aiming to solve (max. 3 points)

(a) Define Adjacent Channel Interference (ACI) and Co-Channel Interference (CCI). Give a brief explanation of their nature and characteristics. Describe briefly the tools that hardware and network designers have to keep these impairments under control in the context of a mobile (cellular) radio access network (1.5 points)

(b) Consider the system presented in Fig. 1, 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 2.5 dBi gain in all directions.

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

$$L(d) = 137.4 + 35.2 \log_{10}(d) \qquad d > 0, \tag{1}$$

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

Assume that the antenna gain pattern of MBS in 'dB' scale attains the form

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

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], $\theta_{3\,\text{dB}} = 60°$ is the beam width at 3 dB, and $G_{\text{fb}} = 25\,\text{dB}$ is the front-to-back ratio for the antenna.

- Determine the received SIR at the MS towards the stronger BS (i.e., the BS whose signal is received with best quality). Assume that MBS transmit power is 40 Watt and PBS transmit power is 1 Watt. Express the final result in dB (1.5 points)

(c) Enumerate the three different phases in which a network planning procedure is usually divided. Explain briefly the main idea behind each of them. What kind of information do designers need to implement each of these phases? What kind of tools do designers have to carry out them? Justify your answer in a clear way (1.5 points)

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Problem 5: *(Wireless local and personal area networks)*

You need to answer only 2 questions in this problem. Please, indicate clearly in your exam paper the question that you are not aiming to solve (max. 3 points)

(a) What is the hidden node problem? What kind of problems can it generate? What is the solution that Wi-Fi (IEEE 802.11) uses to address this problem? Why is the hidden node problem so common in wireless networks (like Wi-Fi) and not in mobile cellular networks (like LTE)? (1.5 points)

(b) What are the different methods that were defined to keep information exchange secure when Wi-Fi (IEEE 802.11) standard was ratified in 1997? Give a brief explanation of each of them, focusing on the comparative advantages and disadvantages in each case from both network administrator's and end-user's perspective. Which one of these methods would you recommend to guarantee data secrecy in a private wireless network that is deployed in a small company? Justify your choice in a simple but clear way (1.5 points)

(c) What is the difference between the *'piconet'* and *'scatternet'* concepts within Bluetooth standard? How many master and slave devices can a Bluetooth piconet and scatternet have? How is co-channel interference controlled in each case (*i.e.*, intra-piconet and intra-scatternet interference)? What happens with the aggregate throughput of a Bluetooth piconet as the number of devices grows? Does the same effect take place when the number of devices in a Bluetooth scatternet increases? Justify your answer properly (1.5 points)

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

$$f(L_s) = \frac{1}{\sqrt{2\pi}\sigma_s} e^{-\frac{L_s^2}{2\sigma_s^2}} \tag{3}$$

$$\Pr\{L_s < L_0\} = \int_0^{L_0} f(t)\, dt = 1 - Q\left(\frac{L_0}{\sigma_s}\right) \tag{4}$$

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{+\infty} e^{-\frac{t^2}{2}}\, dt = \frac{1}{2} \operatorname{erfc}\left(\frac{x}{\sqrt{2}}\right) \tag{5}$$

$$\left(1 - \frac{1}{z^2}\right) \frac{1}{z\sqrt{2\pi}} e^{-\frac{z^2}{2}} \leq Q(z) \leq \frac{1}{z\sqrt{2\pi}} e^{-\frac{z^2}{2}} \tag{6}$$

$$P_{e,\text{awgn}}(\text{SNR}) = Q(\sqrt{2\,\text{SNR}}) \tag{7}$$

$$\begin{aligned} P_{e,\text{fading}}(\text{SNR}) &= \mathbb{E}\{Q(\sqrt{2\,\gamma\,\text{SNR}})\} = \int_0^{\infty} Q(\sqrt{2\,\gamma\,\text{SNR}}) f_\gamma(\gamma)\, d\gamma \\ &= \frac{1}{2}\left(1 - \sqrt{\frac{\text{SNR}}{1+\text{SNR}}}\right) \end{aligned} \tag{8}$$

$$L_{\text{free space}}\,[\text{dB}] = 32.44 + 20\log_{10}(f\,[\text{MHz}]) + 20\log_{10}(r\,[\text{km}]). \tag{9}$$

$$\begin{aligned} L_{\text{Hata}}\,[\text{dB}] &= 69.55 + 26.16\log_{10}(f\,[\text{MHz}]) - 13.82\log_{10}(h_b\,[\text{m}]) \\ &- a_i(h_m\,[\text{m}]) + [44.9 - 6.55\log_{10}(h_b\,[\text{m}])]\log_{10}(r\,[\text{km}]) \end{aligned} \tag{10}$$

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

$$a_1(h_m) = 3.2\,[\log_{10}(11.75\,h_m)]^2 - 5.0 \qquad 200\,\text{MHz} \leq f \leq 1500\,\text{MHz} \tag{11}$$

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

$$a_2(h_m) = 0.8 + \left[1.1\,\log_{10}(f\,[\text{MHz}]) - 0.7\right] h_m - 1.56\log_{10}(f\,[\text{MHz}]) \tag{12}$$

Sub-urban area (i.e., $i = 3$):

$$a_3(h_m) = a_2(h_m) + 2\left[\log_{10}\left(\frac{f\,[\text{MHz}]}{28}\right)\right]^2 + 5.4 \tag{13}$$

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

$$a_4(h_m) = a_2(h_m) + 4.78\,[\log_{10}(f\,[\text{MHz}])]^2 - 18.3\log_{10}(f\,[\text{MHz}]) + 40.9 \tag{14}$$

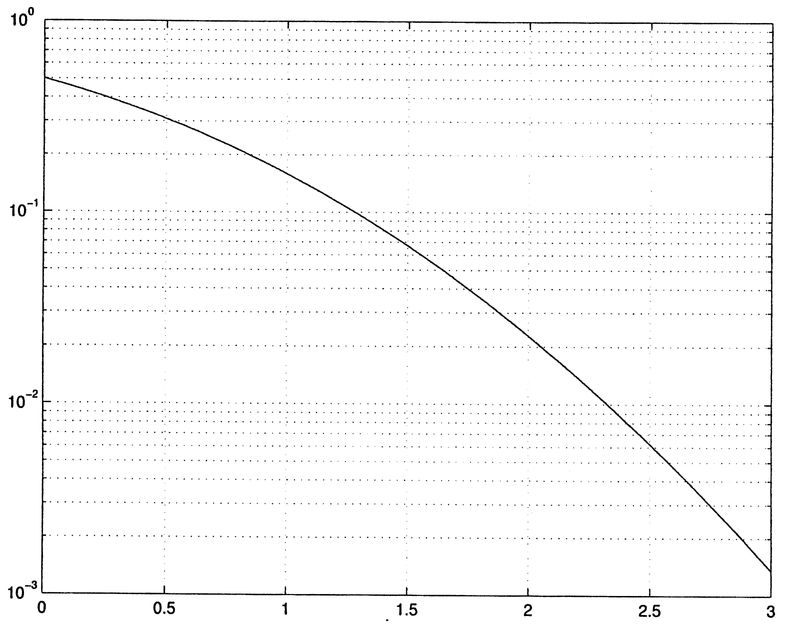

Figure 2: Plot for the Marcum Q-function.