

CARLETON UNIVERSITY
Department of Systems and Computer Engineering
SYSC5608 – Wireless Communications Systems Engineering – Fall 2012
Term Exam
29 October 2012 – Prof. H. Yanikomeroglu

Instructions: Closed-book. One-page aid-sheet is permitted. Write answers in the spaces provided on the question sheet. If necessary, use both sides of a page. Write legibly, and state any assumptions that you make.

Name:

Student Number:

E-mail:

Question	Mark	out of
1.a		10
1.b		10
1.c		10
1.d		10
1.e		10
1.f		15
1.g		10
1.h		15
1.i		10
1.j		10
1.k		10
1.l		10
1.m		15
1.n		10
1.o		15
1 Total		170
2		75
Total		245

Question 1 – Short Questions [140 points]

a) [10 pts] Suppose that you are involved in the design of a next-generation cellular network which targets to deliver an aggregate peak rate of 10 Gbps per base station in the downlink. Choose some appropriate

- bandwidth,
- spectral efficiency, and
- number of antennas (for MIMO gain)

values for this network.

b) [10 pts] In the context of cellular communications, what is the relation between the documents that ITU-T issues regarding the next-generation cellular networks, such as IMT-2000 and IMT-Advanced, and the standards developed by the standardization platforms such as 3GPP?

c) [10 pts] What are the aggregate (per cell) peak rate requirements specified in the IMT-Advanced document for the 4G wireless networks for

- nomadic applications, and
- mobile applications?

d) [10 pts] A wireless user will experience only a small fraction of the 4G peak rates specified in the previous question. Describe the two main reasons for this situation.

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e) [10 pts] What is the data rate for voice telephony commonly used in current wireless cellular networks?

f) [15 pts] In a WLAN, the path-loss is given as $PL \text{ [dB]} = 37 + 36\log_{10}(d)$ where d is the distance between the access point (AP) and a user in meters. The AP transmits at the same power level to all users. If the distance between the AP and user X is 8 times the distance between the AP and user Y, how many dB less power does user X receive in comparison to user Y?

g) [10 pts] Find the maximum spectral efficiency using Shannon's channel capacity formulation when $SNR = 18 \text{ dB}$.

h) [15 pts] A wireless system is characterized by the following parameters:

Path loss = 133 dB, $P_{TX} = 2$ dBW, $G_{TX} = 5$ dB, $G_{RX} = 2$ dB, $N_0 = -174$ dBm/Hz.

If the transmission bandwidth is 1 MHz, compute the SNR at the receiver.

i) [10 pts] If a mobile terminal antenna array has 4 antennas, how many nulls can be generated towards interferers in addition to the main lobe towards the BS?

j) [10 pts] The following acronyms refer to various generations of cellular technologies: UMTS, LTE, HSPA, GSM, EDGE, AMPS. Order these six technologies from the oldest to the most recent.

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k) [10 pts] Write the following acronyms in open form

- RRM:
- RAN:
- PHY:
- LTE:
- TDMA:
- ICIC:

l) [10 pts] Briefly explain the following concepts:

- HetNet

- CoMP (coordinated multipoint)

m) [15 pts] The antenna pattern of a directional antenna is given as follows:

$$P_r = \begin{cases} 0dB, & |\theta| \leq \pi/6 \\ -6dB, & \pi/6 \leq |\theta| \leq \pi/3 \\ -12dB, & \pi/3 \leq |\theta| \leq \pi \end{cases}$$

Sketch the antenna pattern in radial plane.

n) [10 pts] In a wireless system the path loss expression is given as $PL = 128 + 31 \log(d)$, where d is given in km. Rewrite the path loss expression when d is expressed in meters.

o) [15 pts] Consider a cellular network with 100 BSs. There are two design options with different cluster sizes (N):

Design I: $N_I = 4$

Design II: $N_{II} = 1$.

Due to different interference dynamics, the experienced average SINR levels are different in the two designs; as a result, the corresponding average spectral efficiencies (η), calculated using $\log_2(1+\text{SINR})$, are also different.

If the network capacity is the same for both designs, and the average spectral efficiency for Design I is 14 dB, find the average spectral efficiency for Design II.

Question 2 [75 points] – Handoff in Cellular Communications

Consider two base stations, BS_A and BS_B , located on a highway which can be modeled as a straight line. There is a wireless user moving from BS_A towards BS_B ; the user's position is denoted as point C. The distance between the two BSs is $d_{AB} = d_{AC} + d_{CB} = 5,000$ m.

The following propagation model relates the received power to the transmit power in the

given environment: $P_{RX} = P_{TX} G_{TX} G_{RX} F_1 F_2 \left(\frac{\lambda}{4\pi d_0} \right)^2 \left(\frac{d_0}{d} \right)^{3.5} X$. In this expression,

F_1 : correction factor for the terrain type,

F_2 : correction factor for the transmit and receive antenna heights,

X [when expressed in dB domain]: Gaussian random variable, $X: G(0; \sigma_x = 6 \text{ dB})$, modeling the shadowing.

The transmit power levels and all the other propagation parameters (P_{TX} , G_{TX} , G_{RX} , d_0 , F_1 , F_2) as well as the statistics of the Gaussian RV X are the same for both links, i.e., the link between BS_A and the user, and that between BS_B and the user.

The handoff rule is rather simple: The user is connected to the BS from which it receives more power.

- Find the probability that the user is connected to BS_A when $d_{AC} = 2,500$ m; $d_{AC} = 3,000$ m; $d_{AC} = 4,000$ m; $d_{AC} = 4,500$ m.
- Explain the effects of the propagation exponent and the shadowing standard deviation. That is, if the propagation exponent is higher, will the above calculated probabilities be higher or lower? Likewise, if the shadowing standard deviation is higher, will the above calculated probabilities be higher or lower?

Help 1: If $X_i : G(\mu_i; \sigma_i)$, for $i=1, \dots, n$, then $\sum_{i=1}^n a_i X_i : G\left(\sum_{i=1}^n a_i \mu_i; \sqrt{\sum_{i=1}^n (a_i \sigma_i)^2}\right)$.

Help 2: If $u: G(\mu, \sigma) \rightarrow \text{Prob}(u \geq z) = Q\left(\frac{z - \mu}{\sigma}\right)$. Also, $Q(t) = 1 - Q(-t)$.

t	$Q(t)$	t	$Q(t)$	t	$Q(t)$	t	$Q(t)$
0.0	0.50000	1.0	0.15866	2.0	0.02275	3.0	0.00135
0.1	0.46017	1.1	0.13567	2.1	0.01786	3.1	0.00097
0.2	0.42074	1.2	0.11507	2.2	0.01390	3.2	0.00069
0.3	0.38209	1.3	0.09680	2.3	0.01072	3.3	0.00048
0.4	0.34458	1.4	0.08076	2.4	0.00820	3.4	0.00034
0.5	0.30854	1.5	0.06681	2.5	0.00621	3.5	0.00023
0.6	0.27425	1.6	0.05480	2.6	0.00466	3.6	0.00016
0.7	0.24196	1.7	0.04457	2.7	0.00347	3.7	0.00011
0.8	0.21186	1.8	0.03593	2.8	0.00256	3.8	0.00007
0.9	0.18406	1.9	0.02872	2.9	0.00187	3.9	0.00005

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