CARLETON UNIVERSITY

Department of Systems and Computer Engineering

SYSC5608 – Wireless Communications Systems Engineering – Fall 2014

Term Exam I

08 October 2014 – Prof. H. Yanikomeroglu

Closed-book. One-page aid-sheet is permitted. No smart phones.

Instructions: 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. A blank page is provided after the last question.

Name:
Carleton or uOttawa?:
Student Number:

E-mail:

Question	Mark	out of
1a		35
1b		10
1c		15
1d		20
1e		15
1f		15
1 Total		110
2		60
TOTAL		170

Question 1 – Short Questions [110 points]

a) **[35 pts]** In this question use the Shannon-Hartley-Nyquist limit for the spectral efficiency: SE $=\log_2(1+SNR)$ bits/sec/Hz.

- Sketch SE as a function of SNR_{dB} (SNR_{dB}: SNR represented in the dB form; for instance, SNR=2 → SNR_{dB} = 3 dB). In your sketch, use the following values in the horizontal axis, SNR_{dB} = -5 dB, 0 dB, 5 dB, 10 dB, 15 dB, 20 dB, 25 dB).

- Starting from the SE$=\log_2(1+SNR)$ expression, find a tight approximation for SE as a function of SNR_{dB}, when SNR is high. Is your answer consistent with the sketched values?

- Assume SE is high. In order to increase SE by 1 bits/sec/Hz, how much should SNR_{dB} be increased?

b) **[10 pts]** In a receiver, noise power is given as P_N = -99 dBm. If N_0 = -174 dBm/Hz, and the noise figure as 8 dB. Find the signal BW.

c) **[15 pts]** The main goal of 4G is to enable fast internet browsing (including video streaming) by smart phones, tablets, and laptops. How is 5G envisioned to be different? In other words, what else is 5G expected to offer?

d) **[20 pts]** The impulse response of a two-path wireless channel is given as $h_{ch}(t) = \alpha\,\delta(t) - \alpha\,\delta(t-t_d)$. The distance between the direct path and the reflected path is denoted as d, and the corresponding time difference in arrival times is denoted by t_d. This system uses binary signalling with a bit-duration of T seconds.

- We have two applications with transmission rates R = 100 Kbps (VoIP) and 10 Mbps (high definition video streaming). For each application, for what d value, we will have $t_d = T$. For each case, comment whether this situation (i.e., $t_d = T$) will occur in indoors or outdoors.

- In the class, we computed the P_e (probability of error) value for the case when $h_{ch}(t) = \alpha\,\delta(t) + \alpha\,\delta(t-T)$. Compute P_e when $h_{ch}(t) = \alpha\,\delta(t) - \alpha\,\delta(t-T)$.

e) [15 pts] Suppose that you are involved in the design of a next-generation WLAN standard, say 802.11hy, that operates in the millimeter wave. The target downlink peak rate is 100 Gbps. Choose some appropriate

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

values for this network.

f) [15 pts] 4G promises rates up to 1 Gbps. On the other hand, the rates wireless users experiences are substantially less. Describe the two main reasons for this situation.

Question 2 [60 marks] – Adaptive Modulation in Wireless Communications

In a WLAN system, the adaptive modulation scheme operates based on the following look-up table:

		SNR	<	0 dB	→ SE = 0
0 dB	≤	SNR	<	4.77 dB	→ SE = 1 bits/sec/Hz
4.77 dB	≤	SNR	<	8.45 dB	→ SE = 2 bits/sec/Hz
8.45 dB	≤	SNR	<	11.76 dB	→ SE = 3 bits/sec/Hz
11.76 dB	≤	SNR	<	14.91 dB	→ SE = 4 bits/sec/Hz
14.91 dB	≤	SNR			→ SE = 5 bits/sec/Hz

The distance-dependent SNR between an access point and a user which is d meters away is given as SNR = 81.16 – 36 log(d) + X_σ, where X_σ: G(μ=0 dB; σ=8 dB) captures the shadow fading.

- If the user is 100 m away from the AP, what is the likelihood that the spectral efficiency is 3?

- If the user is 500 m away from the AP, what is the likelihood that it will still have the connection?

Help: If u: G(μ, σ) → 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

[for Q2]