UNIVERSITY OF DUBLIN

TRINITY COLLEGE

FACULTY OF ENGINEERING, MATHEMATICS & SCIENCE

SCHOOL OF ENGINEERING

Electronic & Electrical Engineering

Senior Sophister
Engineering
Annual Examinations

Hilary Term, 2015

WIRELESS COMMUNICATIONS (4C4)

Date: 6th January 2015 **Venue: LUCE UPPER** **Time: 9.30 – 11.30**

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Answer EIGHT questions.

Permitted Materials:

Calculator
Mathematical Tables
Lectures Slides

Q.1

(a) In the case of self-similar traffic, which of the following access schemes is the most suitable? (Motivate your answer)

(i) SDMA
(ii) TDMA
(iii) FDMA

[6.25 marks]

(b) Which of the following combinations of techniques can support the targeted downlink peak spectral efficiency of LTE-Advanced? (Motivate your answer)

(i) spatial multiplexing with a spatial rate of 8, 64-QAM, rate 0.625 code
(ii) spatial multiplexing with a spatial rate of 4, 64-QAM, rate 0.75 code
(iii)spatial multiplexing with a spatial rate of 8, 64-QAM, rate 0.75 code

[6.25 marks]

Q.2

(a) What value of the coherence bandwidth would you expect in an environment with severe multipath, such as an urban scenario with many scatterers between the transmitter and the receiver? (Motivate your answer)

(i) Low
(ii) High

[6.25 marks]

(b) What value of the coherence time would you expect in an environment where the transmitter is static and the receiver is moving slowly? (Motivate your answer)

(i) Low
(ii) High

[6.25 marks]

Q.3

(a) Which one of the following statements is incorrect at sub 1 GHz frequencies?

(i) Propagation characteristics are poor
(ii) Size of antennas gets bigger
(iii) Interference with TV systems might be an issue

[6.25 marks]

(b) Which of the following statements is incorrect at frequencies in the mm-wave range?

(i) Interference is not an issue
(ii) Signals are easily obstructed
(iii) It is difficult to have more than one antenna in devices

[6.25 marks]

Q.4

(a) Which of the following techniques can be useful for a battery limited sensor?

(i) Spatial diversity
(ii) Spatial multiplexing
(iii) High order modulation

[6.25 marks]

(b) Which of the following techniques are suitable for a communication link experiencing high SNR?

(i) Spatial diversity
(ii) Spatial multiplexing
(iii) Low order modulation

[6.25 marks]

Q.5
The following system components are available:

- multiple antenna schemes: spatial diversity mode with a spatial rate of 1, spatial multiplexing mode with a spatial rate of 4
- modulation schemes: QPSK, 16-QAM;
- channel coding: rate 1/2 code, rate 3/4 code;
- bandwidth: 50 MHz, 100 MHz, 200 MHz.

(a) One wants to achieve a throughput equal to 800 Mbps or higher. Design two systems obtaining such objective, using the system components listed above.

[5.5 marks]

(b) Now suppose an adaptive system can switch among the configurations A, B and C, where:

- A = {spatial rate = 1, QPSK modulation, 1/2 channel coding, 100 MHz bandwidth}, if SNR is below 5 dB;
- B = {spatial rate = 2, 16-QAM modulation, 3/4 channel coding, 100 MHz bandwidth}, if the SNR is greater or equal than 5 dB and is below 15 dB;
- C = {spatial rate = 4, 64-QAM modulation, 3/4 channel coding, 100 MHz bandwidth}, if the SNR is greater or equal than 15 dB.

Assume that the probability distribution for the three SNR regions is:

$$P(SNR < 5\,\text{dB}) = 0.5$$
$$P(5\,\text{dB} \le SNR < 15\,\text{dB}) = 0.3$$
$$P(SNR \ge 15\,\text{dB}) = 0.2$$

Calculate the average throughput of the adaptive system.

[7 marks]

Q.6

(a) Suppose we have a CDMA system and that a 1 is transmitted as a positive pulse $+L$ and 0 is transmitted as a negative pulse $-L$. A certain station "A" is assigned the code 111100 and another station "B" can choose among the codes 001111, 110011, and 001000 respectively. Which code should the station "B" use and why?

Note: use the chosen code when doing point (b) below.

[5.5 marks]

(b) Now suppose both stations of point (a) above want to send a 1 simultaneously. What is decoded at the receiver for the two transmissions? Outline in detail the decoding procedure.

[7 marks]

Q.7

Calls arrive to a call-center according to a Poisson process with intensity of 3 calls per minute. The call holding times are exponentially distributed with an average of 1/4 minutes. Calls that find all operators busy are blocked.

(a) Give the Kendall notation of the system (motivate your choice).

[5 marks]

(b) How many operators are necessary to keep the blocking probability below 10%?

[7.5 marks]

Q.8

In a single server - finite buffer system, arrivals can be modelled as a Poisson process with rate 1.5 s^{-1} and the service times are exponentially distributed with mean 0.01 s.

(a) Give the Kendall's notation (motivate your choice).

[4 marks]

(b) Calculate the average number of customers in the system, assuming the maximum capacity of the system is 3 customers.

[3.5 marks]

(c) Calculate the blocking probability.

[2.5 marks]

(d) Calculate the rate of rejected customers.

[2 marks]

Q.9

A system has a Markovian input, an arbitrary service-time distribution function and one server.

(a) Give the Kendall's notation (motivate your choice).

[5 marks]

(b) The arrival rate is $\lambda = 1/10$ sec^{-1} and the average service time is $E(X) = 8$ sec.

(i) Calculate the utilisation of the system.

(ii) Is the system well dimensioned to properly serve its users and why?

(iii) Calculate the expected number of customers in the queue, assuming that $E(X^2) = a$ sec^2.

[7.5 marks]

Q.10

We have a stochastic process modelling the connection arrivals at a mobile phone. Such arrivals occur continuously and are independent and identically distributed, with no traffic source dominating. The arrivals are described by the rate:

$$\lambda(t) = 1 + \sin(3t)$$

(a) Calculate the probability of having five arrivals between t=1.5 sec and t=4.5 sec.

[6.5 marks]

Suppose we measure the sample mean of the number of connections arrivals in a large number of independent time intervals. We run this experiment six times, and the sample means of the number of connection arrivals in the six experiments is given by {2.5, 5, 1.8, 2.2, 1.9, 4.3}.

(b) Calculate the 99% confidence interval.

[6 marks]

Q.11

In a certain system the arrivals, which can be modelled as a Poisson process, occur at a rate of one every 250 ms, and the service times are exponentially distributed with mean 0.2 s. Also, there is no limit in the number of servers available.

(a) Give the Kendall's notation (motivate your choice).

[5 marks]

(b) Calculate the average number of customers in the system.

[3.5 marks]

(c) Calculate the average delay per customer.

[2 marks]

(d) Calculate the queuing delay.

[2 marks]

Q.12

A scheduler is a system component in charge of allocating over time the radio resources needed to transmit to the wireless users.

A Round Robin (RR) schedules users in a round-robin fashion, i.e., cyclically. Another feature of RR, is that it schedules users independently of their channel conditions.

A Maximum Carrier/Interference (Max C/I) schedules at time *t* the user n_{max} such that

$$n_{\max} = \arg\max_{n}\{d_n(t)\}$$

where $d_n(t)$ is the expected throughput of user *n* at time *t*, if scheduled.

A Proportional Fair (PF) schedules at time *t* the user n_{max} such that

$$n_{\max} = \arg\max_{n}\{d_n(t)/r_n(t)\}$$

where $d_n(t)$ is the expected throughput of user *n* at time *t*, if scheduled, and $r_n(t)$ the average past throughput of user *n*, i.e.

$$r_n(t) = \overline{d_n(t')} \quad , \quad t < t'$$

Suppose we are given the following throughput traces for three users U_1, U_2, U_3 at times *t-2*, *t-1*, and the expected throughput at time *t*:

	$d_n(t-2)$ [Mbps]	$d_n(t-1)$ [Mbps]	$d_n(t)$ [Mbps]
U_1	0.9	1.54	0.9
U_2	1.5	1.6	1.8
U_3	6	4.2	1.9

(a) Which user is going to be scheduled by an RR scheduler at time *t* ?

[3.5 marks]

(b) Which user is going to be scheduled by a Max C/I scheduler at time *t* ?

[4 marks]

(c) Which user is going to be scheduled by a PF scheduler at time *t* ?

[5 marks]