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Trinity College Dublin
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FACULTY OF ENGINEERING, MATHEMATICS & SCIENCE
SCHOOL OF Computer Science

MSc Computer Science **Semester 1, 2020 Annual Examinations**

CSU44031 NEXT GENERATION NETWORKS

January 2021 **BlackBoard** **2 hrs 30 mins**

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Instructions to Candidates:

- **Answer TWO questions from Part A, TWO questions from part B, FOUR question from part C and FOUR questions from part D.**
- **If you answer more than FOUR questions from part C and more than FOUR questions from part D, only the worst FOUR answers will be considered in the marks calculation.**

Materials Permitted for this Examination:

- **Calculator • Mathematical Tables**

PART A (36 Marks)

Q.1

Consider the following four schedulers: Round Robin, Maximum Carrier/Interference (Max C/I), Proportional Fair (PF), and Modified Proportional Fair (MPF). The MPF scheduling metric is:

$$n_{max} = \arg\max_n \left(\frac{d_n(t)^\alpha}{r_n(t)^\beta}\right) \qquad (1)$$

a) What scheduling metric does (1) turn into when □=□=□□ when □=□ and □=□□ and when
□=□ and □=□ ?

[6 marks]

b) Suppose you are given the following throughput traces for four users U_i, i=1,…,4, at times t-3, t-2, t-1, and the expected throughput at time t.

	$d_n(t-3)$	$d_n(t-2)$	$d_n(t-1)$	$d_n(t)$
U_1	6.71 Mbps	7.35 Mbps	8.50 Mbps	9.27 Mbps
U_2	4.76 Mbps	4.48 Mbps	2.33 Mbps	1.54 Mbps
U_3	7.54 Mbps	2.75 Mbps	9.93 Mbps	7.56 Mbps
U_4	1.11 Mbps	0.16 Mbps	0.42 Mbps	3.55 Mbps

Which users are going to be scheduled by RR, Max C/I, PF, MPF (with □=□□□□□ □=□□□□) at time t? What do you notice in terms of user scheduling for Max C/I and MPF, and why do you think that happens?

[12 marks]

Q.2

(a) Assume 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 101010 and another station B can choose among the codes 101110, 010101, and 111001 respectively. Which code should B use and why?

[6 marks]

(b) Suppose that A and B want to both send a 0 simultaneously. What is decoded at the receiver for A and B transmissions? Outline in detail the decoding procedure.

[6 marks]

(c) Now Suppose that simultaneously *A* wants to send a 1 and *B* wants to send a 0. What is decoded at the receiver for *A* and *B* transmissions? Outline in detail the decoding procedure.

[6 marks]

Q.3

The following system components are available:

- Multiple antenna schemes: spatial diversity-only mode with a spatial rate of 1, spatial multiplexing-only mode with a spatial rate of 2, spatial multiplexing-only mode with a spatial rate of 4;
- Modulation schemes: QPSK, 16-QAM, 64-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 1 Gbps or higher. Outline three systems to achieve this performance using the components above.

[5 marks]

(b) In the following equation:

$$C = m \cdot B \log_2 (1 + \frac{S}{N}) \qquad (1)$$

C represents the channel capacity [bps], B the system bandwidth [Hz], S the useful signal power [W], N the noise power [W], and $m = R_s \cdot O_m \cdot R_c$, where R_s is the multiple antenna spatial rate, O_m is the modulation order [bits / modulated symbol] and R_c is the channel coding rate. Assume that $\frac{S}{N} = 1$.

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

- A = {spatial rate = 1, BPSK modulation, 1/3 channel coding rate, 100 MHz bandwidth}, if SNR is below 5 dB;
- B = {spatial rate = 2, QPSK modulation, 1/2 channel coding rate, 100 MHz bandwidth}, if the SNR is greater or equal than 5 dB and below 15 dB;
- C = {spatial rate = 4, 8-PSK modulation, 2/3 channel coding rate, 100 MHz bandwidth}, if the SNR is greater or equal than 15 dB.

Assuming that the probability distribution for the three SNR regions is uniform, calculate the average capacity of the adaptive system.

[7 marks]

(c) In case you want to provide better coverage to users that are on the edge of a cell, what values (choosing between 'high' and 'low') of coding rate, modulation order and MIMO spatial rate should you choose (motivate your answer)? What will be the impact of the choice above on the system's spectral efficiency?

[6 marks]

PART B (36 Marks)

Q.4

With regards to fixed access network technologies:

a) Describe the reason why operators have moved progressively from solutions entirely based on twisted copper pair transmission to hybrid copper-fibre systems and finally to fibre to the home solutions. Provide your explanation making reference to the Shannon-Hartley theorem for network capacity.

[6 marks]

$$C = B \cdot log_2 (1 + \frac{S}{N})$$

b) Name at least one technology for each of the following architectures: full end-to-end twisted pair, fibre to the cabinet and fibre o the home. Then, for each of them, describe their main features (including bandwidth and data rate).

[6 marks]

c) Explain what is the main issue with using passive optical networks for providing fronthaul services to mobile stations (i.e. take split 7.2 or II_D as reference), and describe a possible solution, providing as much detail as possible and showing appropriate diagrams.

[6 marks]

Q.5

Quality of service is an important aspect of computer networks, enabling management of traffic flows with different priorities.

a) Describe the roles of the policer and the shaper tools, what action they carry out and describe how each of them can be implemented, using any required diagram.

[9 marks]

b) Provide a solution, using any appropriate quality of service tool, to the following problem. You need to process two traffic flows:
   - Flow 1 has a Committed Information Rate (CIR) of 5 Gb/s and Peak Information Rate (PIR) of 8 Gb/s. Flow 2 has CIR of 3Gb/s and PIR of 5 Gb/s.
   - After this you want to give strict priority to packets marked as green from Flow 1. All other packets get lower priority, but green packets from Flow 2 are served at double rate than yellow packets from Flow 1, which are served at three times the rate than yellow packets from flow 2.
   - Finally, the output port can support a maximum rate of 10Gb/s.

Show, using appropriate detailed diagrams and explanations, how you would use a chain of different QoS tools to implement your solution.

[9 marks]

Q.6

An optical signal has a bandwidth of 25GHz and requires 18 dB of OSNR in order to maintain a Bit Error Rate of 10^{-5}. The bit rate is 10Gb/s, the transmit power is 0 dBm and the fibre has a dispersion coefficient of 17ps/km/nm and a loss of 0.2 dB/km.

a) What is the minimum number of amplifiers required to cover a distance of 500 km and what is the span length? You can assume that each amplifier has a maximum gain of 25 dB and a noise figure of 8 dB. **[9 marks]**

b) In order to compensate for dispersion you will need to use dispersion compensating fibre (DCF). If you compensate the dispersion at each amplifier node and then at the receiver, what lengths of DCF do you need in each location, if the DFC has a dispersion coefficient of -150ps/km/nm? (Assume the following conversion ratio: 100 GHz = 0.8 nm). **[9 Marks]**

PART C (14 Marks)

For each question you pick, select only ONE answer out of the four available options. Please ONLY answer FOUR questions