**NATIONAL UNIVERSITY OF SINGAPORE**

# CS4226 – INTERNET ARCHITECTURE

(Semester 1: AY2015/16)

Time Allowed : 2 Hours

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**INSTRUCTIONS TO STUDENTS**

1. Please write your Student Number only. Do not write your name.
2. This assessment paper contains **FIVE (5)** questions and comprises **NINE (9)** printed pages.
3. Students are required to answer **ALL** questions.
4. All questions must be answered in the space provided in the answer sheet; no extra sheets will be accepted as answers.
5. This is a CLOSED BOOK assessment.
6. You are allowed to bring one A4 cheat sheet. No book is allowed.
7. Electronic calculators are not allowed.

**STUDENT NO:** _____

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This portion is for examiner's use only

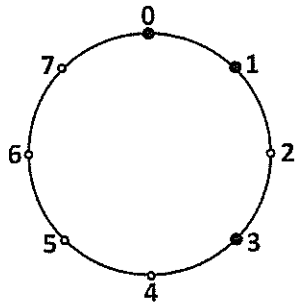
| Question | Marks | Remarks |
|---|---|---|
| Q1 | | |
| Q2 | | |
| Q3 | | |
| Q4 | | |
| Q5 | | |
| Total | | |

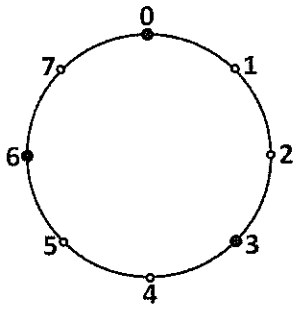
## Question 1: Software-Defined Networking [14 marks]

**A.** Provide some motivations of the software-defined networking approach. In other words, why do we need such a new networking approach in the first place? [7 marks]

**B.** Discuss the principles of software-defined networking. In other words, what are the special features that define SDN? [7 marks]

## Question 2: Peer-to-Peer Networks [18 marks]




**A.** Consider a Chord network with namespace $[0, 7]$. Suppose three nodes 0, 1 and 3 are active as shown in the above left figure, please construct the finger tables for the three active nodes. [9 marks]

| finger table of node 0 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

| finger table of node 1 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

| finger table of node 3 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

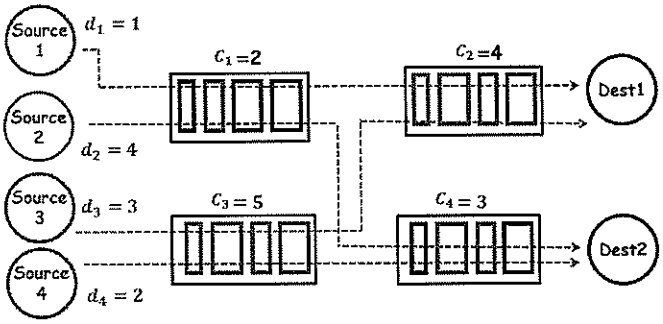
**B.** Suppose after node 6 joins and node 1 leaves the network, three nodes 0, 3 and 6 are active as shown in the above right figure. Please construct the finger tables for the three active nodes. [9 marks]

| finger table of node 0 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

| finger table of node 3 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

| finger table of node 6 | | |
|---|---|---|
| start | interval | successor |
| | | |
| | | |
| | | |

## Question 3: Fairness [16 marks]

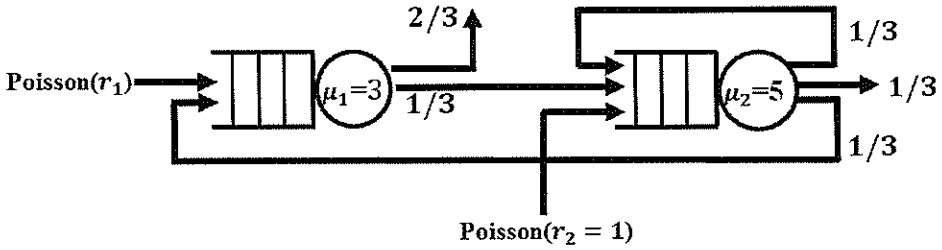



Consider the above system with four flows and four links. The demand for the four flows are 1, 4, 3 and 2 (Mbps) and the capacity of the four links are 2, 4, 5 and 3 (Mbps), respectively.

**A.** Calculate the weighted max-min fair allocation $\mathbf{x} = (x_1, x_2, x_3, x_4)$ to the four flows when the weights are $\phi = (\phi_1, \phi_2, \phi_3, \phi_4) = (2, 3, 4, 5)$. [8 marks]

**B.** Repeat part A when $d_1$ changes from 1 to 3 (Mbps) and $C_3$ changes from 5 to 2 (Mbps). [8 marks]

## Question 4: Jackson Network [28 marks]




A packet-switched Jackson network routes packets among two routers according to the routing probabilities shown above. Notice that there are two points at which packets enter the network and two points at which they can depart.

**A.** What is the maximum allowable rate $r_1$ that the network can tolerate? [8 marks]

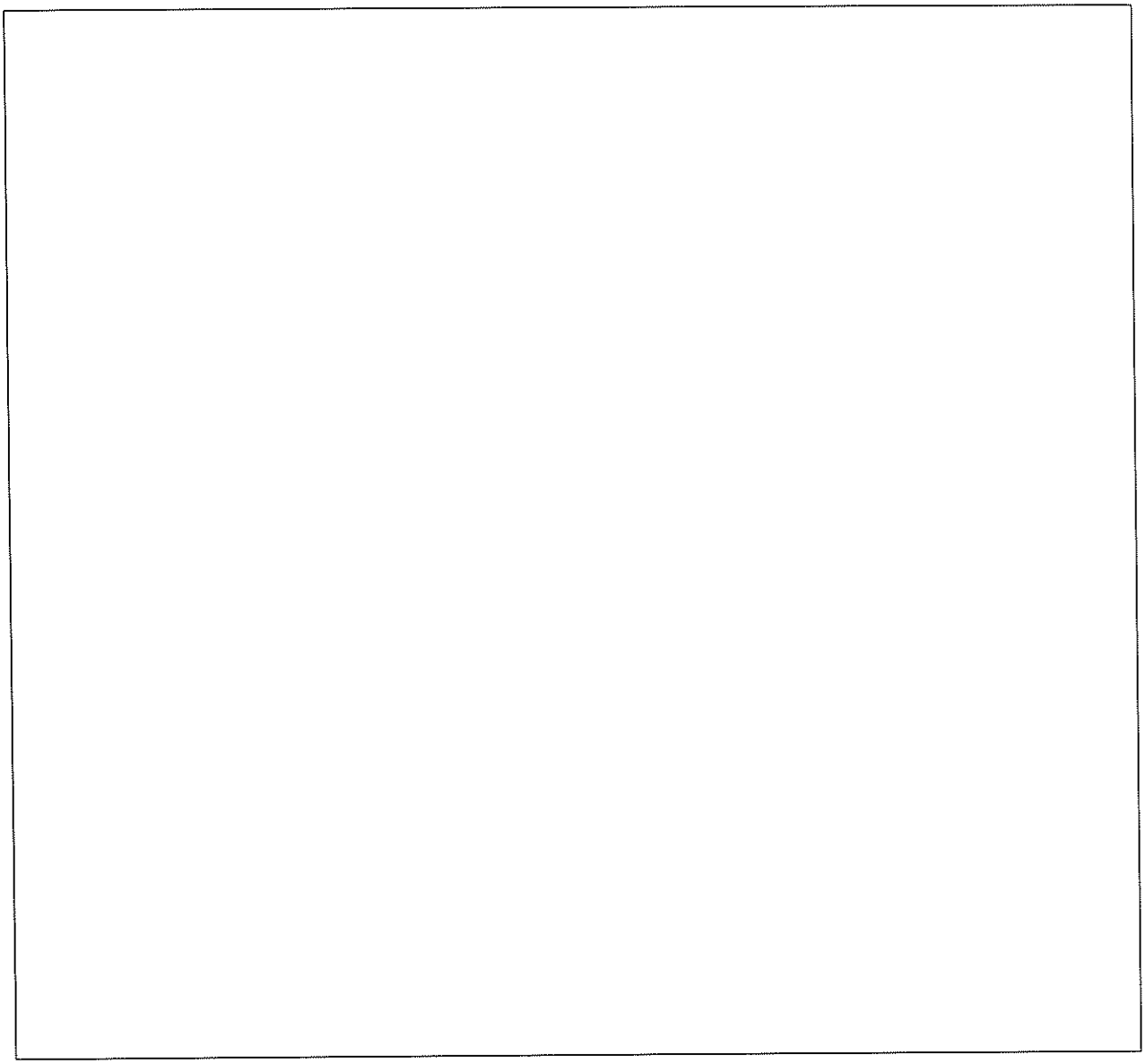
**B.** Suppose $r_1 = 1/3$. Let $E[T_i]$ be the expected time spent for a single visit to sub-system $i$ (server $i$ and its queue). What are the values of $E[T_1]$ and $E[T_2]$? [8 marks]

**C.** Suppose $r_1 = 1/3$. Let $E[T^i]$ be the expected total time spent in the network by a packet arriving at sub-system $i$ (arriving at sever $i$ first). What are the values of $E[T^1]$ and $E[T^2]$? [12 marks]

## Question 5: Scheduling [24 marks]

Consider a single router with two packet flows $A$ and $B$. The router has a processing capacity of 100 bits/second. Before (clock) time $t = 0$, the router is empty. The first two packets from flow $A$ arrive at time $t_a^1 = 1$ (seconds) and $t_a^2 = 3$ (seconds) with length $l_a^1 = 200$ (bits) and $l_a^2 = 100$ (bits). The first two packets from flow $B$ arrive at time $t_b^1 = 0$ (seconds) and $t_b^2 = 2$ (seconds) with length $l_b^1 = 200$ (bits) and $l_b^2 = 300$ (bits). No other packets arrive afterwards.

**A.** If the two flows have the weights $2\phi_A = \phi_B = 2$, calculate the real (or wall clock) finishing time $f_a^1, f_a^2, f_b^1$ and $f_b^2$ for each packet under GPS. [8 marks]



**B.** If the two flows have the weights $2\phi_A = \phi_B = 2$, calculate the virtual finishing time $F_a^1, F_a^2, F_b^1$ and $F_b^2$ for each packet under WFQ. [8 marks]

**C.** If the two flows have the weights $2\phi_A = \phi_B = 2$, calculate the real (or wall clock) finishing time $\hat{F}_a^1, \hat{F}_a^2, \hat{F}_b^1$ and $\hat{F}_b^2$ for each packet under WFQ. If two packets have the same virtual finishing time, we use FIFO to break the tie. [8 marks]

Scratch Paper

— END OF PAPER —