NATIONAL UNIVERSITY OF SINGAPORE

CS4226 – INTERNET ARCHITECTURE

(Semester 1: AY2018/19)

Time Allowed : 2 Hours

INSTRUCTIONS TO STUDENTS

1. Please write your Student Number only. Do not write your name.
2. This assessment paper contains **SIX (6)** questions and comprises **TEN (10)** 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 help sheet. No book is allowed.

STUDENT NO: _____

This portion is for examiner's use only

Question	Marks	Remarks
Q1		
Q2		
Q3		
Q4		
Q5		
Q6		
Total		

Question 1: M/M/1 Link Model [10 marks]

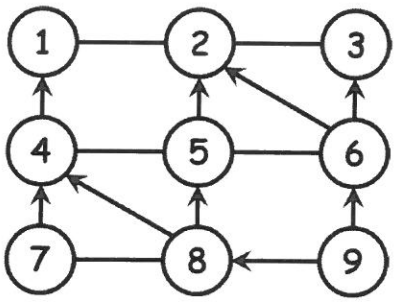
Consider a link modeled as an $M/M/1$ system. Suppose we know that the mean sojourn time of the packets is $\mathbf{E}[W] = 3$ seconds and 80% of time that the server is busy.

A. What is the packet flow's arrival rate to the link? [5 marks]

B. What is the minimal arrival rate of the packet flow that is going to make the system unstable? [5 marks]

Question 2: BGP and Inter-Domain Routing [20 marks]

Two common ISP peering relationships are (1) provider-customer and (2) peer-peer relationships. In each case, the bilateral business agreements will disallow certain paths. In the following figure, each node represents an ISP, each directed edge represents a provider-customer relationship (arrow side is the customer, for example, ISP 4 is a customer of ISP 1), and each undirected edge represents a peer-peer relationship.

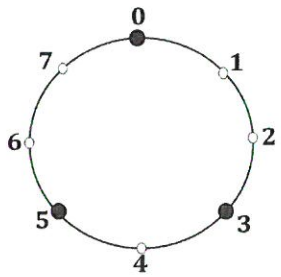


A. For each of the following paths, indicate whether it is valid based on the ISPs' business relationships. [12 marks]

path	is it valid?	path	is it valid?
$4 \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 6$		$9 \rightarrow 8 \rightarrow 5 \rightarrow 2 \rightarrow 6$	
$4 \rightarrow 1 \rightarrow 2 \rightarrow 5 \rightarrow 8$		$1 \rightarrow 4 \rightarrow 7 \rightarrow 8$	
$7 \rightarrow 4 \rightarrow 5 \rightarrow 8$		$3 \rightarrow 2 \rightarrow 5 \rightarrow 8 \rightarrow 9$	

B. Describe the differences between iBGP and eBGP in terms of their functionalities. [8 marks]

Question 3: Peer-to-Peer Networks [20 marks]



Consider a Chord network with namespace $[0,7]$ and three nodes 0, 3 and 5 being active.

A. Please construct the finger tables for node 0 and node 3. [10 marks]

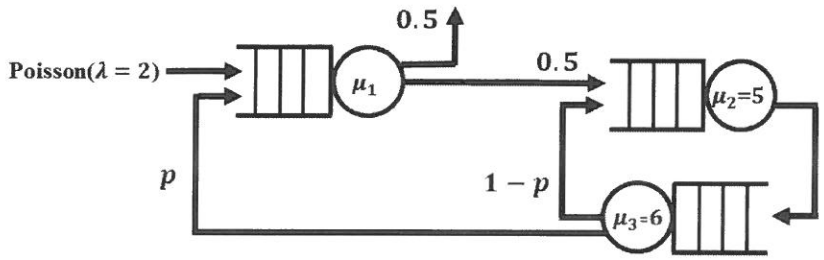
finger table of node 0		
start	interval	successor

finger table of node 3		
start	interval	successor

B. Suppose some content with a hash key value of 0 is queried at node 3. Show the sequence of nodes visited until the content is retrieved. [5 marks]

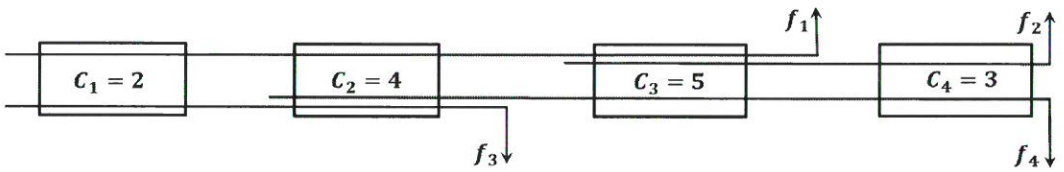
C. Suppose some content with a hash key value of 2 is queried at node 5. Show the sequence of nodes visited until the content is retrieved. [5 marks]

Question 4: Jackson Network [10 marks]



In the above Jackson network, the service rates of the right two servers are $\mu_2 = 5$ (packets/second) and $\mu_3 = 6$ (packets/second). The arrival rate is $\lambda = 2$ (packets/second). To guarantee the stability of the system, what are the conditions we need for the routing probability p and the server capacity μ_1? [10 marks]

Question 5: Fair Resource Allocation and Scheduling [20 marks]



Consider a network path with four links $1,2,3$ and 4 that have capacities $C_1 = 2$, $C_2 = 4$, $C_2 = 5$ and $C_4 = 3$ (Mbps), respectively. There are four traffic flows: flow f_1 traverses links $1,2$ and 3; flow f_2 traverses links 3 and 4; flow f_3 traverses links 1 and 2; flow f_4 traverses links $2,3$ and 4. Suppose the demand of the four flows are $d_1 = 2$, $d_2 = 4$, $d_3 = 1$ and $d_4 = 3$ (Mbps), respectively.

A. Calculate the weighted max-min fair allocation $\mathbf{x} = (x_1, x_2, x_3, x_4)$ to the three flows when the weights are $\phi = (\phi_1, \phi_2, \phi_3, \phi_4) = (1,2,3,4)$. [10 marks]

B. Identify the bottleneck link(s) for each traffic flow under the above weighted max-min allocation. [10 marks]

Question 6: Weighted Fair Queueing (WFQ) [20 marks]

Consider a single switch serving two packet flows a and b. The switch has a processing capacity of 80 bytes/second. Before (clock) time $t = 0$, the switch is empty. The first two packets from flow a arrive at time $t_a^1 = 0$ (seconds), $t_a^2 = 3$ (seconds) with length $l_a^1 = l_a^2 = 120$ (bytes). The first two packets from flow b arrive at time $t_b^1 = 1$ (seconds) and $t_b^2 = 2$ (seconds) with length $l_b^1 = 60$ (bytes) and $l_b^2 = 180$ (bytes). No other packets arrive afterwards.

A. If the two flows have the weights $3\phi_a = \phi_b = 3$, 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. [5 marks]

B. If the two flows have the weights $3\phi_a = \phi_b = 3$, calculate the virtual finishing time F_a^1, F_a^2, F_b^1 and F_b^2 for each packet under WFQ. [10 marks]

C. If the two flows have the weights $3\phi_a = \phi_b = 3$, 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. [5 marks]

Scratch Paper

— END OF PAPER —