NATIONAL UNIVERSITY OF SINGAPORE

CS4226 – INTERNET ARCHITECTURE

(Semester 1: AY2016/17)

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 **TWELVE (12)** 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.
7. Electronic calculators are not allowed.

STUDENT NO: ______________________________

This portion is for examiner's use only

Question	Marks	Remarks
Q1		
Q2		
Q3		
Q4		
Q5		
Q6		
Total		

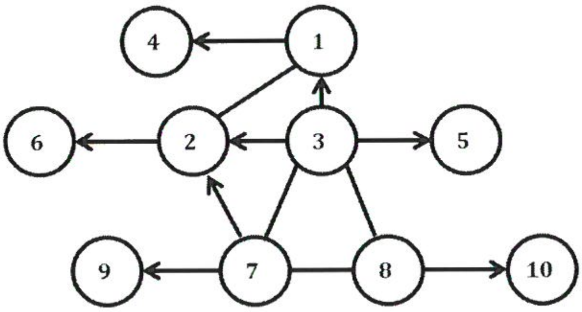
Question 1: Exponential Distribution and M/M/1 System [15 marks]

A. Suppose you want to download n files. The download time for each file is independent and exponentially distributed with rate λ. Suppose you start downloading all of them simultaneously, and let T denote the time until you get all these files. What is your expected waiting time $\mathbf{E}[T]$? [5 marks]

B. Consider an $M/M/1$ system with arrival rate λ and service rate μ. If you start to observe the system at a random time, what is the expected waiting time until you see the next event? Notice that an event could be either an arrival or a departure. Explain your derivation. [10 marks]

Question 2: ISP Peering Relationship [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.

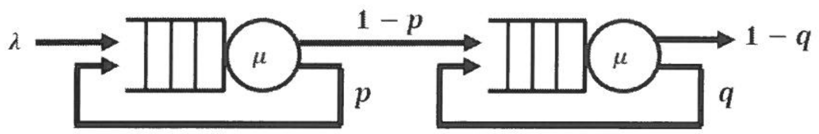


A. For each of the following paths, indicate whether it is valid based on the ISPs' business relationships. [12 marks]

path	is it valid?	path	is it valid?
$4 \to 1 \to 2 \to 7 \to 9$		$10 \to 8 \to 7 \to 2 \to 1 \to 4$	
$4 \to 1 \to 2 \to 6$		$1 \to 3 \to 7 \to 8 \to 10$	
$9 \to 7 \to 3 \to 8 \to 10$		$5 \to 3 \to 2 \to 7 \to 9$	

B. BGP policy routing can be used to control traffic. Give examples of how an ISP could use BGP attributes to control its incoming and outgoing traffic. Please state what you are trying to achieve, and how that is achieved by using the specific BGP attribute. [8 marks]

Question 3: Jackson Network [15 marks]

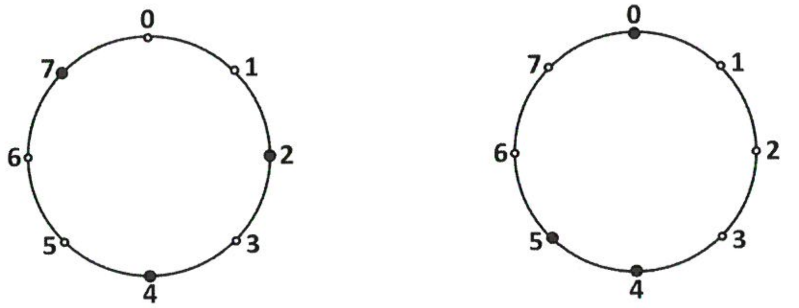


In the above Jackson network, we assume $0 < p < q < 1$ and the arrival rate λ is chosen so as to not overload the network.

A. Determine the average sojourn time of jobs $\mathbf{E}[W]$ as a function of λ, μ, p and q. [10 marks]

B. If we interchange the order of the queues (that is p and q are flipped), does $\mathbf{E}[W]$ increase, decrease, or stay the same? Please justify your answers. [5 marks]

Question 4: Peer-to-Peer Networks [18 marks]



A. Consider a Chord network with namespace $[0, 7]$. Suppose three nodes 2, 4 and 7 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 2		
start	interval	successor

finger table of node 4		
start	interval	successor

finger table of node 7		
start	interval	successor

B. Suppose after nodes 0 and 5 join and nodes 2 and 7 leave the network, three nodes 0, 4 and 5 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 4		
start	interval	successor

finger table of node 5		
start	interval	successor

Question 5: Fair Resource Allocation [16 marks]

Consider a network with four links 1, 2, 3 and 4 that have capacities $C_1 = 1$, $C_2 = 3$, $C_3 = 4$ and $C_4 = 2$ (Mbps), respectively. There are four traffic flows: flow 1 traverses links 1 and 2; flow 2 traverses links 2 and 3; flow 3 traverses links 3 and 4; and flow 4 traverses links 4 and 1. Suppose the demand of the four flows are $d_1 = 2$, $d_2 = 3$, $d_3 = 4$ and $d_4 = 1$ (Mbps), respectively.

A. Calculate the max-min fair allocation $\mathbf{x} = (x_1, x_2, x_3, x_4)$ to the four flows. [4 marks]

B. Identify the bottleneck link(s) for each traffic flow under the max-min allocation. [4 marks]

C. 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 $\phi = (\phi_1, \phi_2, \phi_3, \phi_4) = (1, 2, 3, 4)$. [4 marks]

D. Identify the bottleneck link(s) for each traffic flow under the weighted max-min allocation of Part C. [4 marks]

Question 6: Scheduling [16 marks]

Consider a single router with two packet flows A and B. The router has a processing capacity of 50 bytes/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 $t_a^2 = 2$ (seconds) with length $l_a^1 = l_a^2 = 35$ (bytes). The first two packets from flow B arrive at time $t_b^1 = 0$ (seconds) and $t_b^2 = 3$ (seconds) with length $l_b^1 = l_b^2 = 90$ (bytes). No other packets arrive afterwards.

A. If the two flows have the weights $4\phi_A = \phi_B = 4$, 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 $4\phi_A = \phi_B = 4$, calculate the virtual finishing time F_a^1, F_a^2, F_b^1 and F_b^2 for each packet under WFQ. [6 marks]

C. If the two flows have the weights $4\phi_A = \phi_B = 4$, 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 —