Strathmore
UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF COMPUTER NETWORKS AND CYBER SECURITY
END OF SEMESTER EXAMINATION

CNS 2204: COMPUTATIONAL MODELLING

DATE: 4th December, 2024 **Time: 13:00-15:00 Hours**

Instructions
1. This examination consists of **FIVE** questions.
2. Answer **Question ONE (COMPULSORY)** and any other **TWO** questions.

QUESTION ONE **(Total:30 Marks)**

a. List and discuss 3 applications of Computation Modelling in Computer Networks and Cyber security. (3 Marks)

b. Develop an adjacency matrix to represent the graph in figure 1. (2 Marks)

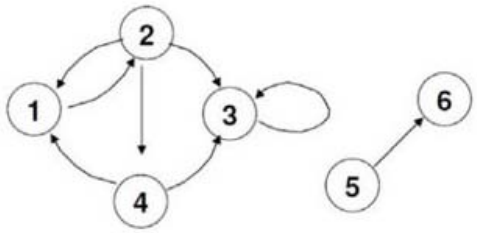

Figure 1

c. In a network router, data packets arrive according to a Poisson process at an average rate of 10 packets per second.
   i. What is the probability that no packet will arrive in a 0.2-second interval? (3 Marks)
   ii. What is the expected number of packets to arrive in 2 seconds? (2 Marks)

d. Consider a Markov chain with three states representing network congestion levels: Low (L), Medium (M), and High (H). The transition matrix is given by:

$$P = \begin{pmatrix} 0.6 & 0.3 & 0.1 \\ 0.2 & 0.5 & 0.3 \\ 0.1 & 0.4 & 0.5 \end{pmatrix}$$

   i. If the network is currently in the Low congestion state, what is the probability that it will be in the Medium state after three transitions? (4 Marks)
   ii. How would this Markov chain help predict network congestion trends? (2 Marks)

e. An Intrusion Detection System (IDS) monitors network traffic and uses agglomerative clustering to identify patterns of Distributed Denial of Service (DDoS) attacks. Explain how agglomerative clustering could help detect a DDoS attack and how you would set up such a system. (4 Marks)

f. You are tasked with clustering a network of 1000 nodes. Describe how you would determine the optimal number of clusters in k-means clustering. (2 Marks)

g. For a specific network, the probability that user X is sending packets at a given time is 80%, the probability that user Y is sending the packets at a given time is 65%, while the probability that they are both sending the packets at the same time is 60%. If user X is sending the packets, what is the probability that user Y is also sending the packets at the same time? (4 Marks)

h. As a network administrator responsible for managing data packet flow in online gaming environments, you are tasked with evaluating two distinct queue management systems: a Single Queue System that operates on a first-come, first-served (FCFS) basis, and a Multiple Queue System integrated with a load balancer. Justify your recommendation by comparing the two advantages and disadvantages of each system within the context of online gaming performance and user experience. (4 Marks)

QUESTION TWO (Total: 15 Marks)

a. A queuing system consists of five basic components. Discuss them briefly and show them in a diagram. (5 Marks)

b. You are a network administrator analyzing the number of network packets and data bytes processed by different devices during a potential Distributed Denial of Service (DDoS) attack. You want to group devices based on their traffic patterns to understand which devices may be targeted by the attack. Use hierarchical agglomerative clustering to group these devices in table 1 based on their traffic patterns and develop a dendrogram with 2 clusters given a threshold of 100. (10 Marks)

Table 1

Device ID	1	2	3	4	5
Bytes Transferred	300	280	500	450	350

QUESTION THREE (Total: 15 Marks)

a. Describe the technique used in measuring similarity between two objects. (2 Marks)

b. A given network load balancing system uses two servers to balance the traffic load in that network. The system has been structured in a way that the default setting load capacity of server A is 80% of the total load while server B handles the remaining 20%. An algorithm has been developed that allows load balancing (1 round) based on the probabilities in table 2.

Table 2

	Server B	Server B
Server A	0.75	0.25
Server A	0.55	0.45

i. What will be the probability of the load in server A & B after another two rounds of balancing the load? *Show all the steps* (4 Marks)

ii. Assuming that in the long-run, the load balancing system reaches an equilibrium $[x_1, x_2]$ where $[x_1, x_2] = [x_2, x_1]P$ and $x_1 + x_2 = 1$, determine the optimal balanced load probabilities for server A & B. (5 Marks)

c. A packet transmission system sends data in fixed-size packets at a constant rate. The number of packets transmitted over a given period follows a discrete random variable, while the time between successive packet arrivals is modeled by a continuous random variable.

i. What distinguishes a discrete random variable from a continuous random variable in this context? Discuss (2 Marks)

ii. Give an example of each in computer networks. (2 Marks)

QUESTION FOUR (Total: 15 Marks)

a. Describe the four key elements in game theory. (4 Marks)

b. Explain how game theory can be applied in wireless network access control, where multiple devices are competing for limited bandwidth and how concepts like dominant strategy and Nash equilibrium can help design more efficient access control systems. (3 Marks)

c. In a simplified zero-sum game, a hacker and a network administrator are involved in a conflict. The hacker has two strategies: Attack or Stay Idle. The network administrator can either Deploy Extra Security or Do Nothing. The payoff matrix is shown in table 3.

Table 3

		Network Admin	
		Deploy Extra Security	Do Nothing
Hacker	Attack	(-2, 2)	(3, -3)
	Stay Idle	(1, -1)	(0, 0)

Explain the meaning of table 2 and determine the optimal strategy for both the hacker and the network administrator using game theory principles. (8 Marks)

QUESTION FIVE (Total: 15 Marks)

a. How can the shortest path algorithm be applied to minimize latency in a network used by a cybersecurity monitoring system? (2 Marks)

b. For the design of a backbone network, figure 2 below shows six nodes and seven links with the associated link costs. If host 6, connected to node D originates a packet to be delivered to hosts {3,4,5,7}, show with arrows and appropriate labels how the packet travels through the network and provide link costs based on Dijkstra's algorithm. (7 Marks)

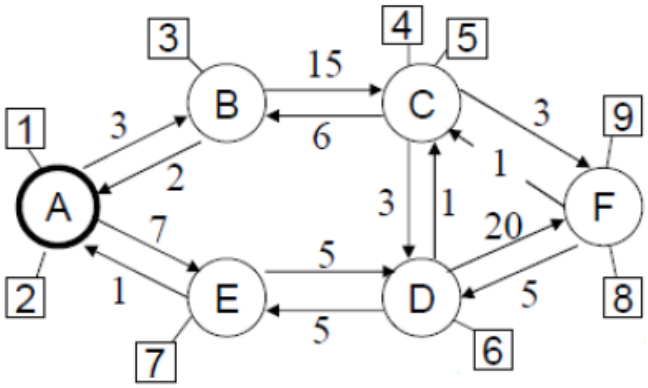

Figure 2

c. Consider a network router where data packets arrive following a Poisson process at an average rate of 6 packets per second. The router can process packets at an average rate of 10 packets per second. Assuming an M/M/1 queue, calculate:

i. The utilization of the system. (2 Marks)

ii. The average number of packets in the system (both in the queue and being processed). (2 Marks)

iii. The average time a packet spends in the system. (2 Marks)