School of Engineering and Applied Science (SEAS), Ahmedabad University
End Semester Examination (Winter 2025)

Subject Code: CSE533
Subject Name: Social Network Analysis
Total Marks: 60

Date: May 01, 2025 (Thursday)
Time: 05:00 PM – 08:00 PM
Final Grade Weight: 30%

Instructions (Please read them carefully):

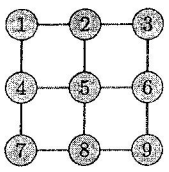
- **All questions are compulsory.** The marks are mentioned with each question.
- Explicitly mention all necessary assumptions for the completeness of the answers. All acronyms and symbols (if any) carry their usual meaning.
- There will be a **PENALTY** for unnecessary or verbose explanations, calculation mistakes, and unlabeled answers (e.g., not explicitly mentioning the question number).
- Write the **serial number** (as mentioned on the left side of your name in the attendance signature page) at the top left corner of the first page of your answer sheet.

All the best!

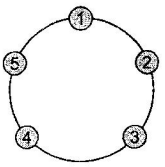
Q1 **(A) [(3 + 4) marks]** For an unweighted (3×3) grid network (as shown in Figure 1(a)), estimate the following: (i) normalized degree centrality and (ii) normalized closeness centrality.

(B) [3 marks] Estimate 1-hop, 2-hop, and 3-hop conflict graphs from the network graph as shown in Figure 1(b).

(C) [2 marks] What are the asymptotic average path lengths for an N-node random network, small-world network, and scale-free network.



(a) Figure for Problem 1(A).



(b) Figure for Problem 1(B).

Figure 1: Figures for Question 1.

Q2 **(A) [6 marks]** Scale-free networks exhibit power-law distributions. The scaling exponent can be analytically estimated by calculating the probability density function. Now, assume that a network exhibits power-law degree distribution in the form of $P(f) = Cf^{-\alpha}$ where $P(f)$ measures the probability of how many nodes have degree f, C is the normalized constant, and α is the scaling exponent. Also, note that all network nodes have positive real degree values with the minimum degree of f_{min}. Prove that the degree distribution of the network can be represented as $P(f) = (\alpha - 1) f_{min}^{\alpha-1} f^{-\alpha}$.

(B) [6 marks] Consider an N-node network with exponential distribution that can be presented as $P(f) = Ce^{-\alpha f}$ where $P(f)$ estimates the probability of the presence of nodes with degree f, C is the normalized constant, and α is the scaling exponent. If f_{min} is the minimum degree of a node in the network and f_{max} is the largest possible degree of a hub node, then show that $f_{max} = f_{min} + \frac{\ln N}{\alpha}$.

Q3 **(A) [(2 + 2) marks]** Describe the procedure that you will adopt to identify a popular node. Is popularity a key property for transforming a random network to scale-free? Provide reasons for your answer.

(B) [(2 + 2 + 2 + 2) marks] Define similarity when a network is concerned. Why is the similarity score important in a real-world network? What can be inferred if the similarity scores of two network nodes are comparable? Can similarity alone transform a random network into a scale-free network? Discuss in detail.

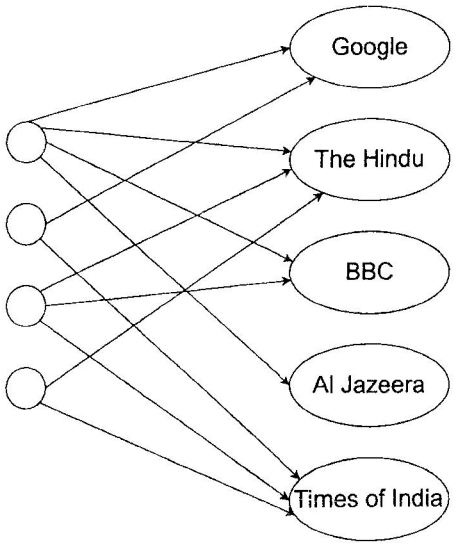
Q4 **(A) [3 marks]** Compare and contrast between any one deterministic and a random long-ranged link (LL) addition strategies (assume you have to add k LLs) in terms of time complexity and overall network performance.

(B) [(2 + 2) marks] What are the implications, in the context of average network flow capacity (ANFC), when a set of LLs are added to the pendant nodes in a weighted network? Is there a difference in executing maximum capacity (MaxCap)-based LL addition strategy when considering an unweighted network? Justify.

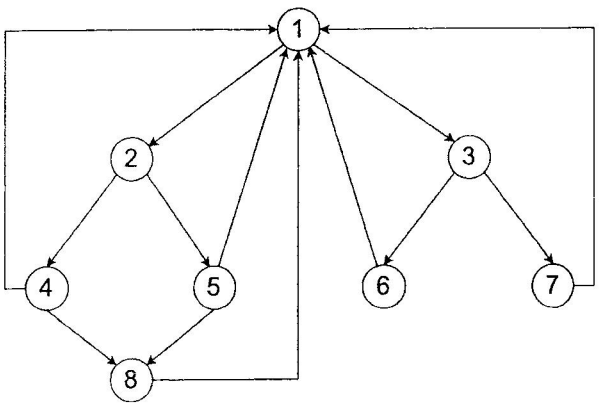
(C) [(4 + 1) marks] Write an algorithm to realize the following: Three LLs to be added in an existing random network (unweighted) of 100 nodes based on the MaxCap strategy. Also, mention the time complexity of your designed algorithm.

Q5 **(A) [(1 + 1 + 4) marks]** Figure 2(a) shows a hub-authority model for accessing the online version of newspapers through a web search. In this model, which entities act as hubs, and which act as authorities? Which one will be updated first, a hub node or an authority node? Apply voting in-link and repeated improvement *two times* on Figure 2(a), then normalize the authority scores. Comment on your observations after the normalization.

(B) [6 marks] Mention the PageRank for all nodes of Figure 2(b) before applying the repeated improvement and then apply the repeated improvement three times and calculate PageRank at each step. Comment on the static/changed PageRank values after each repeated improvement.



(a) Figure for Problem 5(A).



(b) Figure for Problem 5(B).

Figure 2: Figures for Question 5.