PhD Preliminary Written Test - Subjective

Instructions: Among sections B, C, D choose one and attempt questions only in that section. All questions carry equal weight.

Time: 1:30 hrs

Section B: Systems and Networks

Q1. Consider a deposit of Rs. 1000 and a withdrawal of Rs. 500 from account A. Initially, account A holds Rs. 10000. Assume the two operations are implemented by two threads (see below table), and assume that each instruction is atomic.

Thread 1	Thread 2
t1=A;	t2=A;
t1=t1+1000	t2=t2-500;
A=t1;	A=t2;

a) What are the possible outcomes of the above transfer? For each outcome give a possible execution of the threads leading to that outcome.

b) Assume Thread1 repeats the deposit operation 3 times and Thread2 executes the withdraw operation 2 times (i.e., there are three deposits of Rs. 1000 each, and 2 withdrawals of Rs. 500 each). What are the potential outcomes?

c) Give a simple solution to avoid incorrect outcomes.

Q2. Consider a broadcast channel with N nodes and a transmission rate of R bps. Suppose the broadcast channel uses polling (with an additional polling node) for multiple access. Suppose the amount of time from when a node completes transmission until the subsequent node is permitted to transmit (i.e., polling delay) is Dp. Suppose that within a polling round, a given node is allowed to transmit at most Q bits, what is the maximum throughput of the broadcast channel?

Q3. (a) Consider a subnet with prefix 101.101.101.64/26. Give an example of one IP address of form xxx.xxx.xxx.xxx (i.e., in Dotted Decimal Notation) that can be assigned to this network and also give the broadcast IP address of this network.

(b) Suppose an ISP owns the block of IP addresses of form 214.97.254/17. Suppose ISP wants to create six subnets (named as SubNets A,B,C,D,E,F) from that block of IP addresses with the following constraints: Subnet A should have enough addresses to support 250 interfaces (i.e., computers connected to that subnet); Subnets B and C should have enough addresses to support 120 interfaces EACH. Remaining three subnets (D,E,F) should EACH be able to support two interfaces. For each of six subnets, provide prefix assignments which should take the form a.b.c.d/x or a.b.c.d/x – e.f.g.h/y.

Q4. Consider sending a 1500-byte datagram into a link that has an MTU of 500 bytes. Suppose the original datagram is stamped with the identification number 179. Assume that IPv4 is used. The IPv4 header is 20 bytes long.

(a) Where does fragmentation happen? Where are the fragments reassembled?

(b) How many fragments are generated? Show them in frame formats highlighting values of relevant flags and fields.

(c) What is the size of last IP fragment (including 20-byte header)?

Q5. (a) Suppose that node A is competing with several other active nodes for access to a channel using slotted ALOHA. Each node attempts to transmit in each slot with probability p and uses the first slot which is successful. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

What is the probability that node A uses slot 4?

(b) Which of Pure ALOHA, Slotted ALOHA, Persistent ALOHA would you use when the channel load is heavy and why?

Section C: Theoretical computer science

Q1. Let $U = \{1, 2, \ldots, n\}$. Prove that $|\{(S, T) : S, T \subseteq U, S \cap T = \emptyset\}| = 3^n$.

Q2. Consider the language $L = \{0^m 1^n : \text{m+n is even}\}$. Prove or disprove: L is regular.

Q3. Give a $O(n)$ time algorithm to check whether an undirected graph G on n vertices has a cycle.

Q4. Describe a $O(n \log n)$ algorithm to solve the following problem: Given two sets S and T of integers of size n each and an integer x, check if there exists a pair (a, b) such that $a \in S$, $b \in T$ and $a + b = x$.

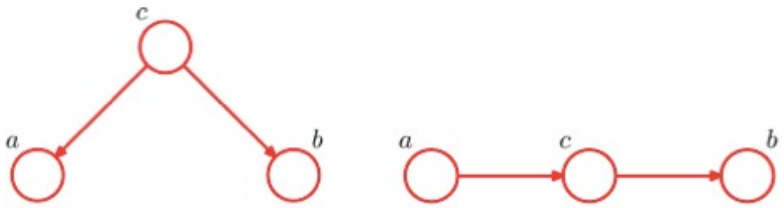
Q5. Let π be an unknown permutation of $1, 2, \ldots, 2n$. For any set $S \subseteq \{1, 2, \ldots, 2n\}$ such that $|S| = n$, one may ask for the order in which the elements of S appear in π. The goal is to determine π completely by asking a series of such questions for various sets S.

Suggest at least one method for doing this and analyse the number of questions that your solution requires.

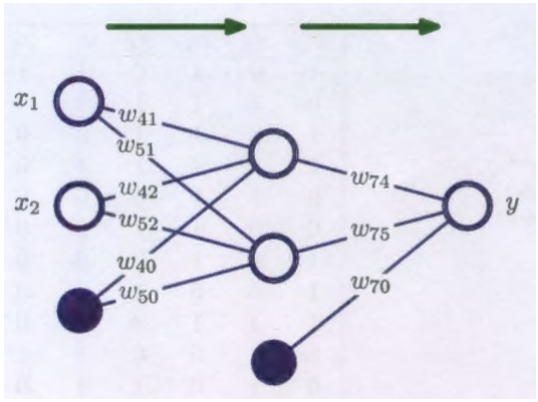
Section D: Machine Learning

1. Define the following terms (in 2-3 sentences at the maximum):
   (a) Categorical Data
   (b) Maximum-Margin Classifier

2. Consider the following two graphs. For each graph, discuss (in not more than 2-3 sentences per graph) whether a and b are *marginally* independent.



3. The figure below represents a 2-layer neural network with step activation functions.



Weights for the neural network are given below:

w_{21}	-1	w_{22}	-1	w_{23}	1
w_{11}	-1	w_{21}	-1	w_{13}	-1
w_{01}	1.5	w_{20}	0.5	w_{03}	-0.5

(a) What are the shaded nodes in this network, and what do the corresponding weights represent?
(b) Compute the output y of the network, for all four possible combinations of binary inputs x_1 and x_2. What logical function does this compute? Could we compute this

same function with a simpler network? (c) Can we automatically learn the weights that result in the desired output? If yes, how? If no, why not?

4. Consider an HMM with three states w_0, w_1, w_2 generating symbols v_0, v_1, v_2 with the following transition probabilities a_{ij} and symbol probabilities b_{jk} (Note that matrix indices begin at 0):

$$a_{ij} = \begin{pmatrix} 1 & 0 & 0 \\ 0.2 & 0.3 & 0.5 \\ 0.4 & 0.5 & 0.1 \end{pmatrix}$$

$$b_{jk} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0.7 & 0.3 \\ 0 & 0.4 & 0.6 \end{pmatrix}$$

(a) Give a graph representation of this Hidden Markov Model.

(b) Suppose the initial hidden state at t=0 is w_1. Starting from $t = 1$, what is the probability it generates the particular sequence $V^3 = \{v_2, v_1, v_0\}$?

(c) Given the above sequence V^3, what is the most probable sequence of hidden states?