BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI (RAJ.)
First Semester 2022-23
CS G623
Advanced Operating Systems
COMPREHENSIVE EXAMINATION

Date: 21st December 2022 Weightage: 35 % Max. Marks: 70 Duration: Total 180 minutes

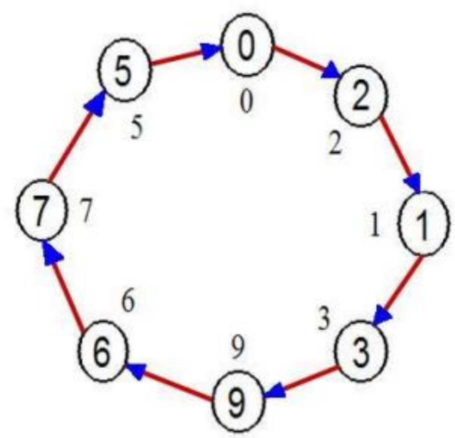
Part A [35 marks]

Important Instructions:

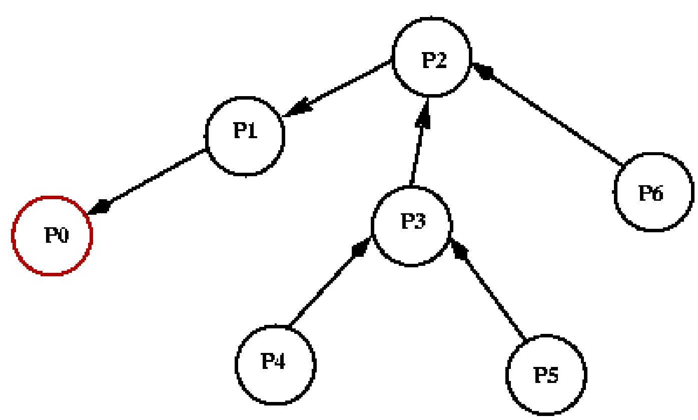
Question paper consists of two parts – A and B, of 35 marks each. This is Part A, which is CLOSED BOOK, while Part B is OPEN BOOK. Answer them on <u>separate</u> answer sheets. On the top-right corner of each answer sheet, clearly mention Part A or B. There is no individual time limit for each part. **You can collect Part B after submitting Part A.**

1. Briefly discuss the primary difference between the Oral Message (OM) protocol by Lamport-Shostak-Pease for the Byzantine Generals Problem and the protocol Paxos. Briefly describe the three kind of entities in Paxos and their respective roles. [6]

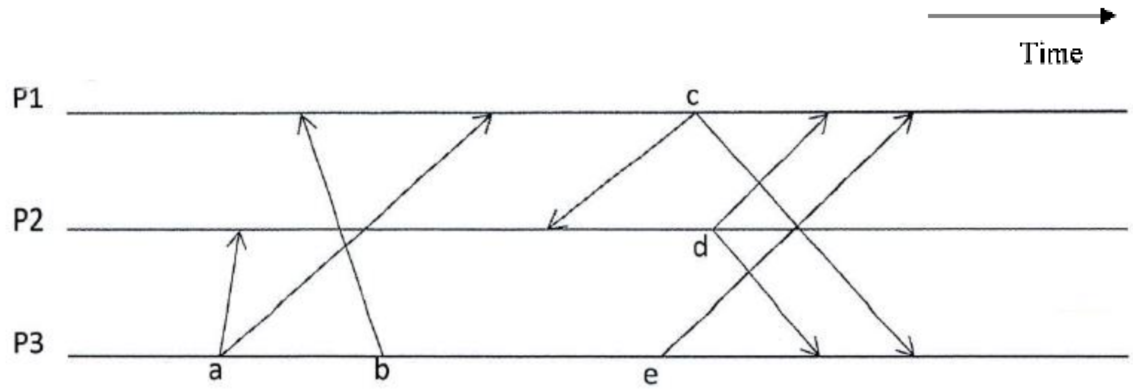
2. The Figure on the right shows an eight node unidirectional ring topology. The numbers in the circles present the node IDs and the numbers outside of the circles show the virtual ID tags. Use the Peterson's leader election algorithm to compute the leader. You need to show all computations along with the ring at the end of each round. Assume that lower ID implies higher priority. [9]



3. Consider the following tree-like topology in a distributed system. Raymond's algorithm is used to provide distributed mutual exclusion. **Node P0** currently holds the privilege (token), as shown. Show all steps (as well as corresponding changes in the topology) if P3 requests for the token. Further, as P3's request reaches P0, P2 also wants to obtain the token. You should answer in terms of the data structures and routines used by this algorithm, and show all steps involved until both P3 and P2 complete the execution of the critical section. [10]



4. Consider the time- space diagram in the figure below. Apply (a) BSS and (b) SES algorithms to verify if there is any causal order violation. Give the clock values and conditions for saying Yes or No to causal order violation. You are free to make any suitable assumptions and also make any changes to the algorithms, as necessary. However, any such assumptions/changes must be clearly mentioned and justified. [10]



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Part B [35 marks]

Important Instructions: These questions are designed to make you ***think***. Kindly read and re-read the questions and then take out time to *think* before you write. A thoughtful and to-the-point answer will fetch marks as compared to vague, long, pointless stories.

1. Consider an n × n grid-like graph consisting of n^2 nodes, where each node (i, j), $0 \leq i, j \leq n - 1$, is connected to nodes (i − 1, j), (i + 1, j), (i, j − 1), and (i, j + 1), where all computation is done modulo n. Note that these values wrap around *modulo n,* so (0, 0) has neighbors (0, n − 1), (1, 0), (0, 1), and (n − 1, 0). Consider a distributed message-passing system with bi-directional communication in the form of the n × n graph as above. Assume that each node has a unique identifier (a large integer) but doesn't know the value of n. Give an algorithm for leader election in this model with the best message complexity you can come up with. **Hint**: Think in terms of algorithms already taught in the class and try to reuse/repurpose them. [11]

2. This course has taught you many approaches for a distributed system, such as Distributed Mutual Exclusion, Distributed Deadlock Detection, etc. Let's build a new distributed approach now. Assume we want to build a hypothetical Distributed Stop Service - let's call it DSS! The basic idea is that we want to issue a stop order to nodes in the system, so that they will not send any further messages to any node. You need define the DSS mechanism ***as a modification to an existing protocol*** already taught to you in the class, in which any node can issue a stop order that *eventually causes* all processes to stop sending messages. We would like such a DSS mechanism to satisfy the termination property, i.e., if some node issues a stop order at time t, no node sends a message at time t + Δ or later, for some finite bound Δ that may depend on the structure of the network. Show how to implement DSS ***as a modification to an existing protocol*** (first of all you must clearly identify which protocol you have chosen for modification). Demonstrate the termination property of DSS and provide the upper bound on Δ as a function of the structure of the network. [12]

3. Consider a synchronous system with n processes, each of which is provided a label: east, west, north, south. The processes have unique IDs that are known to all the other processes, and all processes know which processes have which label. An adversary can turn any number processes into Byzantine (malicious), provided that all the processes corrupted by the adversary are of the ***same label***.
   Is it possible to solve Byzantine agreement in this system for any number of processes $n \geq 4$ using any assignment of labels that gives at least one process of each label? If yes, show how the conditions of agreement, validity and termination are met (assuming a non-faulty source). If no, demonstrate why. [12]