राष्ट्रीय प्रौद्योगिकी संस्थान पटना

National Institute of Technology Patna

End Semester Examination (Jul-Dec'22)

Session: 2022-23 Autumn'22 Semester

Department: Computer Science and Engineering

Programme: B.Tech.-CSE

Semester: 7th

Course Code: CS7479

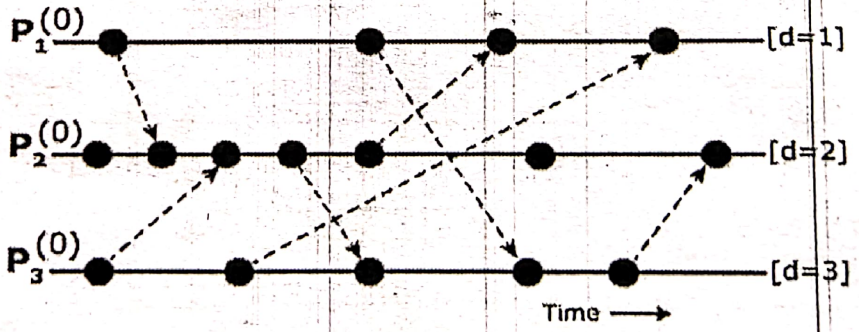
Course: Distributed Systems

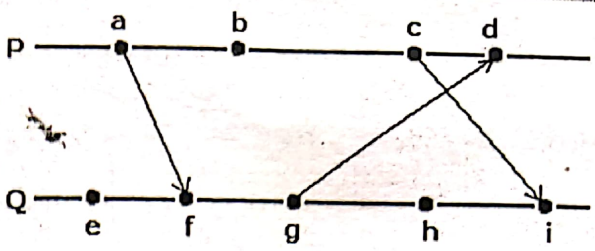
Full Marks: 60

Duration: 3 hours

[Attempt all questions; Answer concisely only in blue/black ink; Use pencil for artwork; Assume missing data; No mobile phones]

[Marks, Course Outcome and Bloom's Level are mentioned on right-hand side of each question]

Sl.		Question body	CO	BL
1.		Consider three processes P1, P2 and P3 in a distributed system performing read (i.e. R) and write (i.e. W) operations on data item x. Different versions of x produced in course of execution are identified as x_1, x_2, x_3 etc. Notation ';' indicates continuity between preceding and succeeding versions of x, while '|' (pipe) indicates no such continuity. Consider the order of operations given in the adjoining figure. Prove or disprove that the client-centric consistency models — monotonic read, monotonic write, read-your-writes and writes-follow-reads, are individually fulfilled in the given distributed system. **(15)** L_1: $W_{P1}(x_1)$ $R_{P1}(x_1)$ L_2: $W_{P2}(x_1 \mid x_2)$ $W_{P3}(x_2; x_3)$ $W_{P1}(x_3; x_4)$ $R_{P3}(x_4)$ Time ⟶ [Course outcome(s) evaluated: CO-5(Analyse/Determine)]	CO-5	Level-4
2.	a.	Consider a distributed system of 3 processes following Lamport's logical clock, with initial clock values = 0 and clock increments (i.e. value of d) to be 1, 2 and 3 respectively. Their events are shown as black circles in the adjoining figure. At the end of all events (as per the given figure), what are their respective clock values of the 3 processes? **(6)**  [Course outcome(s) evaluated: CO-4(Apply/Solve)]	CO-4	Level-3
	b.	Consider a distributed system comprising of r concurrently-executing processes racing for mutually-exclusive access of shared resource R. Write down the mandatory conditions that any of the m processes are required to fulfill for accessing R within their respective critical sections in each of the following cases: (i) Lamport's mutual exclusion algorithm;	CO-1	Level-1

Sl.		Question body	CO	BL
		(ii) Ricart-Agrawala mutual exclusion algorithm. Your answer must clarify every notation used. **(3+2)** [Course outcome(s) evaluated: CO-1(Remember/Recall)]	CO-1	Level-1
	c.	In the adjacent figure, where P and Q are the two processes maintaining Lamport's clock, explain which of the following options correctly capture the nature of causality or concurrency between the pair of events (c,f) and (d,f)? Assume initial clock values = 0 and clock increments (i.e. value of d) to be 1 for both the processes. **(4)**  (i) $c \rightarrow f;\ d \parallel f.$ (ii) $f \parallel c;\ f \rightarrow d.$ (iii) $c \rightarrow f;\ f \rightarrow d.$ (iv) $c \parallel f;\ d \parallel f.$ [Course outcome(s) evaluated: CO-3(Understand/Explain)]	CO-3	Level-2
3.	a.	Define replication system, and draw its generic architecture showing all constituents. **(2)** [Course outcome(s) evaluated: CO-1(Remember/Recall)]	CO-1	Level-1
	b.	Explain whether sequential consistency model is achieved in active replication architecture of any distributed systems of n Replica-Managers. **(3)** [Course outcome(s) evaluated: CO-3(Understand/Explain)]	CO-3	Level-2
	c.	A cab management company (which provides hospitality service) manages its fleet of cabs through replication system, where a conit is defined as set $\{d, g, p\}$, replicated across two servers — Replica A and Replica B. Here, g = amount of fuel refilled in cab, p = price of fuel g, d = total distance covered since last time fuel refilled. The status of both Replica A and Replica B at vector time (11,5) and (0,8) respectively are shown in the adjacent figure. Find out the numerical deviation and ordering deviation of the conit at both Replica A and Replica B. **(8)** [Course outcome(s) evaluated: CO-4(Apply/Solve)] Replica A Conit: d = 558 // distance; g = 95 // gas; p = 78 // price Operation / Result: <5, B> g ← g + 45 [g = 45]; <8, A> g ← g + 50 [g = 95]; <9, A> p ← p + 78 [p = 78]; <10, A> d ← d + 558 [d = 558] Replica B Conit: d = 412 // distance; g = 45 // gas; p = 70 // price Operation / Result: <5, B> g ← g + 45 [g = 45]; <6, B> p ← p + 70 [p = 70]; <7, B> d ← d + 412 [d = 412]	CO-4	Level-3
	d.	Define availability and reliability of dependable distributed system in time interval $[0, t)$. **(2)** [Course outcome(s) evaluated: CO-1(Remember/Recall)]	CO-1	Level-1

Sl.		Question body	CO	BL
4.	a.	Consider that Dropbox has discovered the secrets to perfect computers and networks. The secrets are --- (i) none of its servers crash and its network is never get partitioned; (ii) it somehow achieves 'instantaneous' message transmission through its SPECIAL network. Such network includes its servers and all client devices. The promises are --- (i) all file changes to be immediately visible to each connected user; and (ii) any user to be allowed access (either READ or WRITE) of any file on any of its devices at any time. Assuming the breakthrough of Dropbox through its SPECIAL network is real, can it deliver these promises? Explain your answer with reference to the CAP theorem. **(4)** [Course outcome(s) evaluated: CO-3(Understand/Explain)]	CO-3	Level-2
	b.	Write down the steps of two-phase checkpointing algorithm, stating the required assumptions, in the blocking coordinated checkpoint-based rollback recovery. **(11)** [Course outcome(s) evaluated: CO-1(Remember/Recall)]	CO-1	Level-1

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List of Course Outcomes of "Distributed Systems": After completing this course, a student should be able to —

CO-1. *recall* distributed system terminologies, as well as fundamental concepts, operational principles and methods of its communication, synchronization, consistency, replication and failure recovery functionalities; [Bloom level: *Remember*; Mapped to: PO-1]

CO-2. *recognise* communication paradigms and architectural patterns in functioning of given distributed systems; [Bloom level: *Remember*; Mapped to: PO-1]

CO-3. *explain* concepts and techniques in functioning of middleware platforms of distributed systems, and functional/nonfunctional characteristics of architectural elements and patterns in architectural models of distributed systems; [Bloom level: *Understand*; Mapped to: PO-1, PO-2]

CO-4. *solve* problems on principles of multithreading, communication, naming, synchronization, conit, replication, checkpointing and performance measurements in given distributed systems; [Bloom level: *Apply*; Mapped to: PO-1, PO-2, PO-3]

CO-5. *determine* nature of identification/access, synchronization, coordination, consistency, consensus, availability, and their correctness, that are supported in given distributed systems; [Bloom level: *Analyze*; Mapped to: PO-1, PO-2, PO-3]

CO-6. *evaluate* protocols of communication, agreement, commit, consensus, allocation and recovery in given distributed systems. [Bloom level: *Evaluate*; Mapped to: PO-1, PO-2, PO-4, PO-5]