

UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2004

MSci Honours Degree in Mathematics and Computer Science Part IV
MEng Honours Degrees in Computing Part IV
for Internal Students of the Imperial College of Science, Technology and Medicine

*This paper is also taken for the relevant examinations for the
Associateship of the City and Guilds of London Institute
This paper is also taken for the relevant examinations for the
Associateship of the Royal College of Science*

PAPER C437

DISTRIBUTED ALGORITHMS

Tuesday 11 May 2004, 14:30
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators not required

- 1a What are the three assumptions that characterise a synchronous network model?
- b The *SyncBFS* algorithm computes a breadth-first spanning tree in a general synchronous network.
 - i) Give an informal description of the algorithm stating what assumptions are made about the network.
 - ii) Using the state machine notation, give a formal specification of *SyncBFS*.
 - iii) Give the communication and time complexity of the algorithm.
- c The initiating process of a *SyncBFS* does not know when the spanning tree construction is complete. Describe informally an extension to *SyncBFS* which detects *termination*.
- d Describe informally an algorithm that uses terminating *SyncBFS* to elect a leader in a general synchronous network. Give precise measures of the time and communication complexity of this algorithm in a network which is in fact a ring with N nodes. Give a brief explanation of how you arrived at these measures.

The four parts carry, respectively, 15%, 30%, 20%, 35% of the marks.

- 2a Give the specification for Atomic Commitment and include the conditions for both Strong and Weak Atomic Commitment.
- b Sketch an informal proof that Strong Atomic Commitment is impossible in a synchronous connected network with no process failures but in which link failures may occur.
- c Give an informal description of the Three-Phase Commit termination protocol which is invoked when the coordinator crashes.
- d Consider a synchronous system where communication link failures may occur. In such a system, describe an execution (scenario) of the Three-Phase Commit Algorithm where the *Agreement* property is violated.
- e Assume that a maximum of 2 processes fail while Three-Phase Commit is executed in a group of 7 processes. What is the worst possible *number of messages* (upper bound) required for the termination of 3PC in this environment? Describe the scenario in which this worst case occurs.

The five parts carry, respectively, 20%, 20%, 20%, 20%, 20% of the marks.

- 3 An asynchronous system consists of a fixed number of distributed processes P_i each of which needs exclusive access to a particular resource at various times.
- a Lamport's algorithm for mutual exclusion uses three types of message with logical timestamps: request **req**, release **rel** and acknowledgement **ack**. Each process P_i maintains a local request queue Q_i . Assuming that the queues are initially empty, outline the following:
- i) the actions of P_i on receipt of a timestamped message m from P_j ,
 - ii) the conditions required for granting of the resource at P_i ,

What is the communications overhead in order for a process to gain exclusive access?

- b Lamport's algorithm (part (a)) requires that there be no overtaking of messages between sites. Show a scenario where, if two processes P_0 and P_1 both send request messages, and overtaking of an acknowledgement message is possible, it can lead to a violation of mutual exclusion. Indicate the state of the local queues Q_0 and Q_1 in each process at each stage.
- c Ricart and Agrawala's algorithm does not require that there be no overtaking of messages between sites. Give an outline description for this algorithm, including the types of message used and the information that is stored at each site. Briefly justify why this algorithm is not sensitive to message overtaking.

What is the communications overhead in order for a process to gain exclusive access?

The three parts carry, respectively, 30%, 30%, 40% of the marks.

- 4a Define the Validity, Agreement and Integrity properties required of a reliable broadcast algorithm in an asynchronous distributed system. Define the additional property that must be satisfied by a reliable broadcast algorithm that provides FIFO delivery order.
- b Explain the difference between Causal and FIFO broadcast. Outline a simple algorithm which uses FIFO broadcast to implement Causal Broadcast.
- c Describe briefly how the ISIS CBCAST protocol is implemented and comment on why it is more efficient than the protocol you described in part b.
- d Andrew, Bob and Cameron (A, B & C) all subscribe to an Internet mailing list on interesting car registration plates. Andrew broadcasts a request for plates beginning with m and Bob responds with his latest sightings s . However, when Cameron reads his email, he sees Bob's response (s) before Andrew's request (m) arrives. Using message diagrams, explain the operation of the protocols you described in each of parts b & c in resolving this situation.

The four parts carry respectively 20%, 30%, 30%, 20% of the marks.