Calculators may be used in this examination provided they are not capable of being used to store alphabetical information other than hexadecimal numbers

UNIVERSITY OF BIRMINGHAM

School of Computer Science

LH Dependable and Distributed Systems

Main Summer Examinations 2024

Time allowed: 2 hours

[Answer all questions]

Note

Answer ALL questions. Each question will be marked out of 20. The paper will be marked out of 60, which will be rescaled to a mark out of 100.

Question 1

N-version programming (NVP), recovery blocks and reliability modelling are mechanisms for the development of fault tolerant software.

(a) Distinguish between NVP and recovery blocks. **[4 marks]**

(b) Identify challenges for the implementation of NVP with majority voting. **[4 marks]**

(c) A software system S comprising five modules (M_{1-5}) and operating in three stages (*Stage 1-3*) is shown in Figure 1. S will be operational if at least one module in each stage is operational.

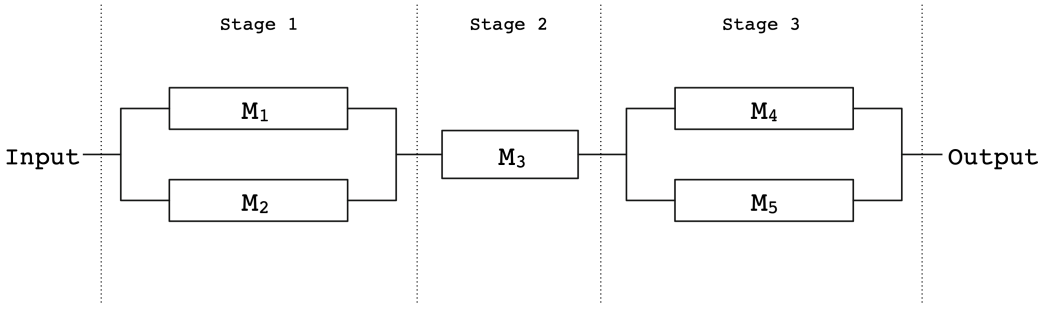

Figure 1: Software system S comprising five modules and operating in three stages.

(i) Enumerate the minimal tie sets of S. **[4 marks]**

(ii) It is stated that the union of two minimal tie sets is a tie set. Using S as your example, explain whether you agree with this statement. **[4 marks]**

(iii) Derive an expression for the reliability of S. State any assumptions. **[4 marks]**

Question 2

Assume a connected, bidirectional ring network with N nodes.

(a) Define the leader election problem. **[4 marks]**

(b) Develop an algorithm that solves leader election in a synchronous bidirectional ring network. State any assumptions. **[4 marks]**

(c) Analyse the time complexity of your algorithm. **[4 marks]**

(d) Analyse the communication complexity of your algorithm. **[4 marks]**

(e) It is stated that the communication complexity of leader election algorithms that do not permit the modification of process identifiers is bounded by $\Omega(n \log n)$. Explain whether you agree with this statement. Identify any implications for your algorithm. **[4 marks]**

Question 3

Clocks provide a means for sequencing and synchronising events in computer systems.

(a) Explain the concept of *drift rate*. You should identify the implications of the concept and provide a labelled diagram to support your explanation. **[4 marks]**

(b) Explain what it means for a set of clocks to be *well-synchronised*. **[4 marks]**

(c) Outline the role convergence functions play in clock synchronisation. **[4 marks]**

(d) Motivate the use of logical clocks in distributed systems. **[4 marks]**

(e) Develop a scheme for the implementation of logical clocks. You should state all relevant properties that must hold for your scheme to operate. **[4 marks]**

End of Paper

Do not complete the attendance slip, fill in the front of the answer book or turn over the question paper until you are told to do so

Important Reminders

- Coats/outwear should be placed in the designated area.
- Unauthorised materials (e.g. notes or Tippex) must be placed in the designated area.
- Check that you do not have any unauthorised materials with you (e.g. in your pockets, pencil case).
- Mobile phones and smart watches **must** be switched off and placed in the designated area or under your desk. They must not be left on your person or in your pockets.
- You are not permitted to use a mobile phone as a clock. If you have difficulty seeing a clock, please alert an Invigilator.
- You are not permitted to have writing on your hand, arm or other body part.
- Check that you do not have writing on your hand, arm or other body part – if you do, you must inform an Invigilator immediately
- Alert an Invigilator immediately if you find any unauthorised item upon you during the examination.

Any students found with non-permitted items upon their person during the examination, or who fail to comply with Examination rules may be subject to Student Conduct procedures.