A38622

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

Third Year Undergraduate

06-38963

LH Dependable and Distributed Systems

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions.

Question 1

(a) Outline the relationship between faults, errors, and failures. **[4 marks]**

(b) Using a labelled diagram, explain the operation of recovery blocks. **[4 marks]**

(c) N-version programming (NVP) is often implemented with majority voting.

(i) Justify the use of NVP with only two versions. Your answer should provide an example of a situation where using NVP with only two versions would be effective. **[4 marks]**

(ii) Propose how masking fault tolerance could be provided using NVP where the number of versions is two. **[4 marks]**

(iii) Discuss the challenges faced when when implementing majority voting between versions in NVP. **[4 marks]**

(d) A Triple Modular Redundancy (TMR) system is developed with three processors P_1, P_2, and P_3. The output of each processor is fed into a voter V.

(i) Explain the concept of a minimal cut set. **[4 marks]**

(ii) Enumerate the minimal cut sets of the TMR system. **[4 marks]**

(iii) It is stated that the union of two minimal cut sets is a minimal cut set. Explain whether you agree with this statement. **[4 marks]**

(iv) Processors P_1, P_2, and P_3 are known to have failure rates of λ_1, λ_2, and λ_3 respectively. Assuming the exponential failure law, derive an expression for the reliability of the TMR system. **[8 marks]**

Question 2

Assume a complete, undirected network with N nodes. The network must be capable of tolerating stop failures.

(a) Develop an algorithm that solves the distributed consensus problem in a synchronous network. State any assumptions. **[5 marks]**

(b) Define the properties that must be satisfied to solve distributed consensus in a partially synchronous network. **[5 marks]**

(c) Explain why the properties that must be satisfied to solve distributed consensus differ between partially synchronous and synchronous networks. **[5 marks]**

(d) The Byzantine generals problem can be solved in a synchronous network.

(i) Prove that, in a synchronous network with authenticated channels, the Byzantine generals problem can only be solved for m failed processes when there are more than 3m processes. **[10 marks]**

(ii) Develop an algorithm that solves the Byzantine generals problem based on the use of oral messages. State the communication complexity of your algorithm. **[5 marks]**

Question 3

Broadcast abstractions can be developed on the basis of reliable links and failure detectors.

(a) Compare the communication guarantees provided by reliable broadcast and uniform reliable broadcast. **[5 marks]**

(b) Explain the operation of reliable broadcast when a sender is faulty. **[5 marks]**

(c) Analyse the communication complexity of reliable broadcast. **[5 marks]**

(d) Develop a uniform reliable broadcast algorithm. **[5 marks]**

(e) Explain the properties of reliable links. **[5 marks]**

(f) For each reliable link property, explain why it is a safety property or liveness property. **[5 marks]**

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.