

Part II

COMPUTING AND COMMUNICATIONS – On-line Assessment

Available Time [23 Hours]

Recommended Completion Time [3 Hours]

SCC.311 Distributed Systems

*Candidates are asked to answer **THREE** questions from **FOUR**; each question is worth a total of 25 marks.*

Question 1

1.a You are asked to build a cloud service that provides a tuple space. You need to design it for scalability as the service would be available to use by thousands of users or more at any point in time. You only need to provide the standard tuple interface. There is no need to record transactional data; i.e. access logs, modification history, etc.

i. Would this service be better designed as stateless or stateful? *(1 word)*

[1 mark]

ii. Justify your answer by focusing on only 2 reasons *(around 30-40 words)* and mentioning any assumptions you made *(around 20-30 words)*.

Please answer using bullet points.

[6 marks]

1.b Consider the following interface. Assume this is implemented on top of UDP.

```
public void executeOperation(int operationId, byte[] operationArguments);  
// The operation to be invoked and its arguments.
```

i What level of guarantee does this method provide? *(<10 words)*

[2 marks]

ii Rewrite the interface (in pseudocode or Java) in order to increase the level of guarantee, and name that level. *(<20 words)*

[3 marks]

1.c

i. Out of layering and tiering, which is more important to use when trying to optimise software maintenance; i.e. how to make it easier to update code in the future? *(1 word)*

[1 mark]

ii. Explain your choice. *(around 40-60 words)*

[6 marks]

1.d Briefly describe each of the concepts of access and location transparency, and explain the difference between them using a simple example. *(about 40-60 words)*

[6 marks]

[Total 25 marks]

Question 2

2.a Consider an Internet-based service composed of an application tier and a separate data tier which uses a database to store user data. Because the two tiers are loosely coupled, the application tier needs to check for crash, omission or timing faults when trying to communicate with the data tier. How would you implement the failure detector for this task? Clearly explain the assumptions that you are making about the system. *(4-5 sentences)*

[4 marks]

2.b Byzantine failures are those in which data is arbitrarily corrupted in transit – either by accident, or by a malicious actor. According to the seminal research on this topic by Lamport et al, how many computers are needed to detect failures in the presence of n misbehaving computers? Briefly outline why this is true, using an example. *(3-4 sentences)*

[6 marks]

2.c What are the two forms of replication for fault tolerance? Name and briefly describe the key properties of each form. *(4-5 sentences)*

[6 marks]

2.d What form of replication would you use for the data tier of an Internet banking system? Explain your answer. *(2-3 sentences)*

[3 marks]

Question 2 continues on next page...

Question 2 continued.

2.e

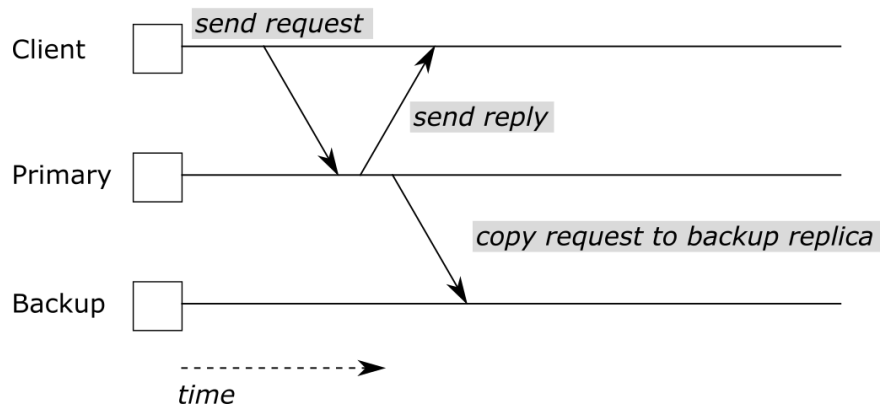
- i. Consider the following approach to implementing passive replication. Is this implementation correct? **[2 marks]**
- ii. Explain your answer. **[4 marks]** (2-3 sentences)

Data packet (client -> server)

MessageType	Message parameters
-------------	--------------------

Example request:

[add_to]	[record A, value_4]
----------	---------------------



[Total 25 marks]

Question 3

3.a In Paxos a consensus is reached when the majority of participants agree on a value by either accepting or rejecting it. Briefly explain why it would be a bad idea to use Paxos instead of two-phase commit to provide atomic distributed commit.

[5 marks]

3.b.i Fill in the blank: One reason it is difficult to scale symmetric cryptosystems is that a shared secret is difficult to _____. (1 word)

[1 mark]

3.b.ii Explain your answer (around 20-30 words).

[2 marks]

3.c Which of the following statements describe middleware? (identify multiple letters)

[2 marks]

- A. Software that functions solely to distribute authentication keys.
- B. Software that provides services beyond those provided by an operation system.
- C. Software that restricts the operating system from accessing shared resources.
- D. Software that enables distributed components to communicate and manage data.

3.d.

i. Choose the correct phrase to complete this sentence: (identify 1 letter)

Saltzer's end-to-end principle advocates that application-specific features be placed _____.

- X. in networking elements such as gateways and routers
- Y. closer to the end-user application
- Z. in the cloud

[1 mark]

ii. Give one reason that explains your choice. (around 40-60 words)

[2 marks]

3.e Explain the concept of a one-way function. (around 20-30 words)

[2 marks]

3.f Consider the classic client-server model in the context of an HTTP web server.

i. What is the call semantic / guarantee level typically followed in this model? (<5 words)

[2 marks]

ii. Illustrate this semantic using a diagram.

[2 marks]

iii. Under this semantic, what happens when a response is lost? (<10 words)

[1 mark]

Question 3 continues on next page...

Question 3 continued.

- iv.** How does the server know that its previous response was delivered? *(10-20 words)*

[2 marks]

3.g Consider authenticating with a server using a private key. A well-known vulnerability is the reflection attack, which is commonly mitigated by keeping track of authentication sessions. Name and describe the system property that is lost when this mitigation approach is followed. *(around 40-60 words)*

[3 marks]

[Total 25 marks]

Question 4

4.a. For each of the following scenarios, which kind of multicast would you choose to implement? For each scenario you should identify the kind of multicast and explain the rationale for your answer. (*aim for an answer of 2-3 sentences per part*)

- i. Consider an application in which we need to send regular space weather updates, every 10 minutes, from a ground-based control centre to a collection of spacecrafts. We can assume that it is sufficient for the spacecraft to receive a weather update once every two hours, the network channel is at least 70% reliable, and sending messages is relatively expensive.

[3 marks]

- ii. Consider a group text chat service for use on the Internet, in which any member of a group can send a message and all other members of the group will receive that message. The chat service should use UDP messages at the network level, and should try to display the messages in the correct time order.

[3 marks]

- iii. Consider an Internet-based shopping service, on which users can purchase a range of items for delivery. For reliability, the service uses a set of replicated servers to record the current stock levels and user transactions. Whenever a user makes a purchase, the request is multicast to all servers in the replicated set.

[3 marks]

4.b.

- i. Atomic multicast is a useful paradigm when we need to support crash failures. Imagine that we have a system with three replicas of a server, in which clients send a single message to one of those replicas. When a server receives a client message, it uses atomic multicast to send the message to the other servers (with TCP as the point-to-point network protocol). The protocol is designed so that servers do nothing on receiving a message they have already seen, but no other optimisations have been made to the atomic multicast protocol. If we assume that no servers crash, and no messages are lost, what is the maximum number of messages that may be sent among the server group? Explain your answer. (*2-3 sentences*)

[4 marks]

- ii. Describe a simple optimisation you could make to the above atomic multicast protocol. What is the maximum number of messages that would be sent among the server group now? (*2-3 sentences*)

[4 marks]

4.c. Message ordering is an important part of many group communication systems, with a range of different possible ordering schemes available.

- i. What are the possible consequences of not using an appropriate ordering scheme? (*aim for 2 sentences*)

[2 marks]

Question 4 continues on next page...

Question 4 continued.

- ii. Why is FIFO ordering easier to implement than global time ordering? (2-3 sentences)

[4 marks]

- iii. What is the benefit of using causal ordering instead of total ordering? (2-3 sentences)

[2 marks]

[Total 25 marks]

--- End of Paper ---