

Two hours

Question ONE is COMPULSORY

**UNIVERSITY OF MANCHESTER  
SCHOOL OF COMPUTER SCIENCE**

Distributed Computing

Date: Friday 16th May 2014

Time: 14:00 - 16:00

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**Please answer Question ONE and also TWO other Questions  
from the remaining THREE Questions provided**

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This is a CLOSED book examination

The use of electronic calculators is NOT permitted

**[PTO]**

1. **Compulsory**

- a) Explain briefly why the lack of homogeneity is a challenge when developing distributed systems. (2 marks)
- b) Explain briefly why the assumption “latency is zero” is considered a common fallacy in distributed computing. (2 marks)
- c) Explain briefly what publish-subscribe messaging is. (2 marks)
- d) In a distributed system, what is the purpose of an IDL? (2 marks)
- e) In the context of RPC, what is copy-restore and what is it used for? (2 marks)
- f) What must a server do to provide at most once semantics to its clients? (2 marks)
- g) Explain briefly what failures are known as Byzantine failures. (2 marks)
- h) In the context of data replication, explain briefly what eventual consistency is. (2 marks)
- i) When using Java RMI, what is the purpose of the rmiregistry? (2 marks)
- j) In the context of lab exercise 2, what would you do to launch a *denial of service* attack against the server? (2 marks)

**Answer any two from Questions TWO, THREE and FOUR**

2. a) Explain briefly what the role of a client stub and a server stub is in RPC.  
(2 marks)
- b) Explain briefly what is meant by logical (Lamport) clocks and vector clocks. What property is captured by vector clocks that is not if Lamport clocks are used?  
(3 marks)
- c) Explain briefly what the four properties commonly denoted by the acronym ACID are when referring to transactions.  
(4 marks)
- d) (i) Describe in detail how a centralised coordinating process can provide a mutual exclusive access service in a distributed system.  
(3 marks)
- (ii) When the machine supporting such a process gets overloaded with other tasks it needs to find the least loaded machine in the network, and pass over the provision of the mutual exclusive access service to a process on that machine. Two algorithms are being considered for this. The first is to have the server ask each machine about its workload and then notify all the clients with the identity of the new server. The second is to use a ring-based election, initiated by the current server.
- Fully describe the latter, clearly stating any assumptions you make,  
(4 marks)
- and compare it with the former with respect to the number of messages passed.  
(4 marks)

[PTO]

3. a) Describe clearly all the operations that take place during a Remote Procedure Call (RPC). (4 marks)
- b) Two computers are used to provide a replicated service. Each computer has a mean time between failures of 12 days; a failure takes on average 12 hours to fix. What is the availability of the replicated service? (3 marks)
- c) Consider a client-server application, which consists of 100 services provided by some server. Ten of these services must be executed strictly one after the other, not in parallel with any other services. The remaining 90 services may be executed concurrently and in any order. Assume that each service takes the same time to execute. What is the maximum speedup that can be obtained for the application if multiple identical servers are used to provide the required services? (3 marks)
- d) Consider a simple server that carries out client requests without accessing other servers. Explain why it is generally not possible to set a limit on the time taken by such a server to respond to a client request. What would need to be done to make the server able to execute requests within a bounded time? (4 marks)
- e) The following two processes access the shared variables  $x$ ,  $y$ ,  $z$ . Each process accesses a different replica of the store used to hold these variables. Before any process starts executing, the value of all three variables,  $x$ ,  $y$ ,  $z$ , is 0 in all the replicas.

Process A

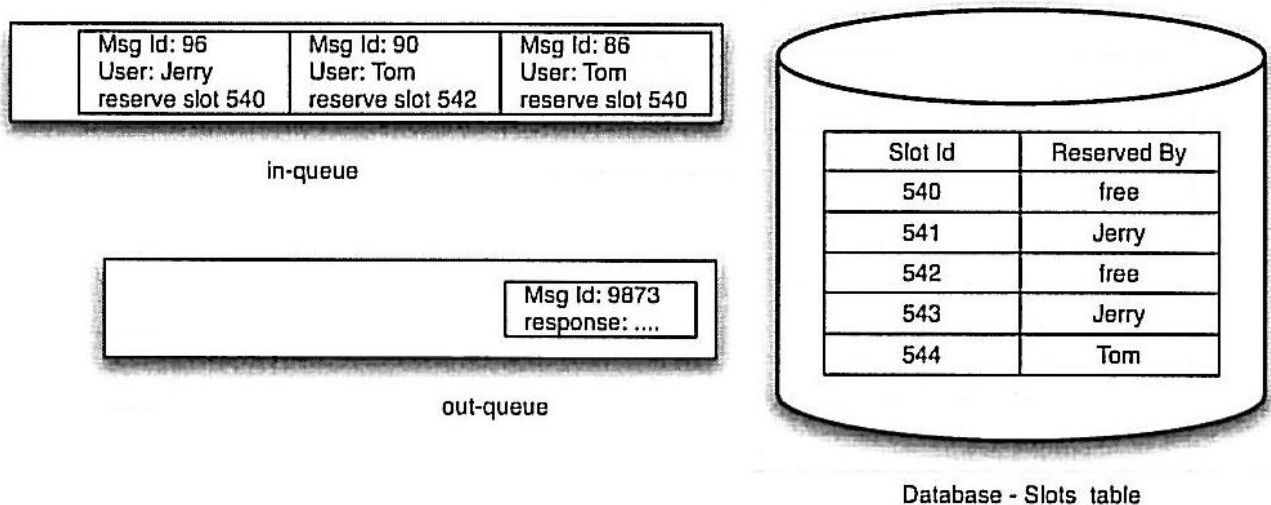
$x = I;$   
 $if (y == 0) z++;$

Process B

$y = I;$   
 $if (x == 0) z++;$

- (i) When both processes have completed executing the statements given, what are the possible values of  $z$ , if the replication uses the sequential consistency model? Justify your answer. (3 marks)
- (ii) When both processes have completed executing the statements given, what are the possible values of  $z$ , if the replication uses the causal consistency model? Justify your answer. (3 marks)

4. This question concerns transactions and distributed transactions in the context of lab exercise 2. The server that processes all requests (reservation, cancellation, availability and bookings retrieval) hosts a database for storing reservations and some message-oriented middleware, which provides an in-queue (to queue requests) and an out-queue (to queue responses to messages). Suppose there are three messages in the in-queue: two from Tom and one from Jerry. Suppose also that Tom already holds a reservation for slot 544 and Jerry holds a reservation for slots 541 and 543 (assume a total of 1000 slots). The state of the database and queues is shown below.



The pseudo-code that processes a reservation request is shown below. It assumes that all messages are delivered exactly once by the underlying messaging infrastructure. Also, assume that the maximum permitted number of reservations a client (user) can hold at any one time is two per slots table, that is, `max_res=2`.

```
begin_tx;    // this is an ACID transaction to reserve a slot
    dequeue a request from the in-queue

    if requested slot is 'free' and
        number of reservations by student < max_res then
        reserve slot for the student;
        send 'slot reserved' response message;
    else if number of reservations by student >= max_res then
        send 'fail: too many reservations' response message;
    else if slot is not 'free' then
        send 'fail: slot is not free' response message;
    endif
commit;    // transaction commits
```

(Question 4 continues on the following page)

(Question 4 continues from the previous page)

- a) Show via an execution sequence (an order in which statements are executed), how Tom can hold more than the maximum permitted number of reservations if two threads are concurrently processing messages from the in-queue and if the pseudo-code that processes a reservation request is not enclosed in an ACID transaction. (4 marks)
- b) After which statements in the pseudo-code for processing a reservation request can the server crash? Describe the state of the database, in-queue, and out-queue after the crash and recovery. (4 marks)
- c) When and why is the two-phase commit protocol used by the server? What happens when the middleware or the database fail during a two-phase commit? (4 marks)
- d) Suppose that two threads, running on different CPUs, are concurrently processing messages from the in-queue. Every incoming message requires processing time of 50 milliseconds and, on average, there are about 7200 messages per hour sent to the server. How long do you expect to have messages waiting in the in-queue before their processing starts? State any assumptions you make. (4 marks)
- e) The following pseudo-code describes a client strategy to reserve the earliest common slot for two different slot tables: band and hotel. Explain why this strategy may not always achieve the desired result. State any assumptions you make. (4 marks)

```
// assume 1 sec delays and all requests are correctly implemented
retrieve and cancel all current bookings;
repeat
    get availability for band;
    get availability for hotel;
    find earliest_common_slot;
    reserve earliest_common_slot for hotel;
    reserve earliest_common_slot for band;
until both hotel and band reservation successful;
print "reserved:" earliest_common_slot;
```

**END OF EXAMINATION**