One and a half hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Fundamentals of Distributed Systems

Date: Monday 3rd June 2013
Time: 09:45 - 11:15

Please answer any TWO Questions from the THREE Questions provided.

Use a SEPARATE answerbook for EACH Question.

This is a CLOSED book examination

The use of electronic calculators is permitted provided they are not programmable and do not store text.
1. a) QWE is a music company. It is always in need of identifying unsigned artists and bands. Currently, it identifies leads (i.e., promising unsigned artists and bands) using a team of scouts that visit music venues and keep an eye for news of up and coming artists and bands. The process works well but is costly and time consuming. It’s also prone to an excess of ‘false positives’, i.e., artists and bands that look promising on paper but turn out, when seen and heard by one of the scouts, to be not so. This wastes a lot of the scouts’ time. QWE is considering investing on the development of a specialized search engine to harvest information from such sites as soundcloud.com and myspace.com. The idea is that this would simplify the task for the team of scouts by reducing the number of ‘false positives’ because QWE would tune the search engine to return artists and bands that fit QWE’s overall strategy and ignore those that don’t.

i) Explain whether QWE’s planned use of a distributed system is motivated by functional or non-functional reasons by appealing to what is meant, in this course unit, by these alternative notions?  
(2 marks)

ii) Use the information in the scenario above to justify your answer to the preceding item.  
(3 marks)

b) Explain why synchronization becomes a more significant problem when the components of a distributed system are very heterogeneous (i.e., have different capabilities in terms of software or hardware or both).  
(2 marks)

c) The next four items are about the Internet protocol stack architecture.

i) What is meant by the assertion that each protocol in the Internet protocol stack wraps the message it has received from the caller protocol one layer up before sending it to the protocol one layer down?  
(2 marks)

ii) Why is this approach seen as beneficial?  
(1 mark)

iii) What is meant by the claim that the Internet protocol stack is an example of an hourglass architecture?  
(1 mark)

iv) Give two examples of application layer protocols and two examples of devices that use different physical properties to gain a physical connection to the Internet.  
(2 marks)

d) The following two items are about the architectural paradigms for distributed sys-
tems discussed in this course unit. Assume that a component $C$ and a component $C'$ communicate through message exchange.

i) Explain the difference between direct message-exchange and mediated message-exchange by listing the communication steps needed to process a request from $C$ to $C'$ and the corresponding response from $C'$ to $C$. (By communication steps, we mean instances of primitive send and receive calls.)

(3 marks)

ii) Explain in what sense the use of mediated message-exchange facilitates making the interprocess communication between $C$ and $C'$ non-blocking and asynchronous.

(3 marks)

e) The following two items are about the use of massively-distributed systems for performance purposes, and about the Map-Reduce approach, in particular.

i) In the context of the Map-Reduce Model, explain how the barrier acts as a synchronization mechanism.

(1 mark)

ii) Explain why unbalanced workloads (i.e., partitions of uneven size being processed by machines of different capability) are a problem for approaches, such as the Map-Reduce Model, that use a barrier.

(3 marks)

f) In the context of so-called WS* service-oriented architectures, explain the meaning of the terms orchestration and choreography as introduced in this course unit.

(2 marks)
2. a) Explain, in terms of Internet routing, why an IP address is an address and a MAC address is not. (2 marks)

b) The next two items are about the contrast between stateful and stateless protocols. Assume the following sequence of events:

i. at time $t_1$, a client $C$ sends the message $M_1$ to a server $S$;
ii. at time $t_2 > t_1$, $S$ responds to the message $M_1$ from $C$ with the message $M_2$;
iii. at time $t_3 > t_2$, $C$ sends the message $M_3$ to $S$;
iv. at time $t_4 > t_3$, $S$ responds to the message $M_3$ from $C$ with the message $M_4$ if $M_1 \neq M_3$, otherwise it simply echoes $M_3$ back to $C$.

i) Explain whether the behaviour revealed by the above sequence of events is indicative of a stateless or a stateful interaction. (3 marks)

ii) Using the assumption that there may be thousands of clients (such as $C$) concurrently sending messages to a server (such as $S$), explain why statelessness is desirable, all other things being equal. (3 marks)

c) The next two items are about the use of caching, with particular reference to the Internet Message Access Protocol (IMAP).

i) Explain what feature of the IMAP protocol (in contrast the Post Office Protocol POP3) leads to the conclusion that the email held by a client is best understood as a local cache. (1 mark)

ii) Explain why the client-side caching aspect of IMAP makes it easy and clean for a user to have multiple inboxes (say, in the various devices she uses to read her email). (2 marks)

d) The next three items are about the Coffman conditions for deadlock between processes to occur.

i) The inability to pre-empt is one of the Coffman conditions for a deadlock to occur. Briefly describe what is meant by ‘inability to pre-empt’. (1 mark)

ii) Assume three processes $A$, $B$ and $C$. Assume that $A$ is waiting on $B$ and $B$ is waiting on $C$. Explain whether these two assumptions imply that all the Coffman conditions are satisfied. If not, rearrange the waiting dependencies in such a way that at least one Coffman condition is satisfied. (3 marks)

iii) Assume that a process $A$ currently holds control of a resource $R$ and that $B$ is locked out from gaining control of $R$ because of mutual exclusion. Is this sufficient for deadlock to occur? (1 mark)

e) The next two items are about Lamport (or logical) clocks.
i) Suppose we are using logical clocks to establish a partial order of events over a system comprising two processes, \( P \) and \( P' \). We denote the logical clocks of \( P \) and \( P' \) by \( L \) and \( L' \), respectively. Now, assume the following events:

A. when \( L = 5 \), \( P \) sends a message \( M \) to \( P' \);
B. when \( L' = 4 \), \( P' \) receives the message \( M \) sent by \( P \).

Explain what is the value of \( L' \) after \( P' \) receives the message \( M \) sent by \( P \) making sure that you explain how that value is related to the value of \( L \) and how the definition of logical clocks by Lamport enables this behaviour.

(4 marks)

ii) Recall that, in the context of Lamport clocks, \( x \rightarrow y \) denotes that \( x \) happened before \( y \), where \( x \) denotes the sending event of a message \( M \) by a process and \( y \) denotes the receipt event of \( M \) by another process. Assuming that logical clocks are being used and that the following two facts hold: \( a \rightarrow b \) and \( b \rightarrow c \), state what holds between \( a \) and \( c \).

(2 marks)

f) Based on the notion of distributed causality, briefly explain why clock synchronization is essential to distributed multi-player games and give an example of what might go wrong if clock synchronization is not achieved.

(3 marks)
3. a) What is narrow-band telephone quality speech, and how is it commonly digitised? (2 marks)

b) Why is it appropriate for the Session Initialisation Protocol (SIP) to use a client-server arrangement with TCP to set up VoIP calls and a peer-to-peer arrangement with real time transfer protocol (RTP) for the voice connections? (3 marks)

c) Explain why the sound cards or equivalent on-board circuitry on personal computers require the use of buffers when implementing, concurrently with the CPU, the A-to-D and D-to-A conversion processes required by VoIP telephony. In giving your answer, refer to the leaky bucket analogy. (6 marks)

d) Explain what problems may occur when the crystal controlled clocks that determine the speech sampling rates at two interacting VoIP hosts cause them to have slightly different speech sampling rates, 7999 Hz and 8001 Hz. Suggest a solution to these problems assuming that the VoIP hosts are communicating 20 ms (G711) voice packets over an IP network. (6 marks)

e) Explain why VoIP application software must have a jitter-buffer when receiving VoIP telephony packets over computer networks? Explain how a VoIP’s receiver’s jitter-buffer affects the VoIP conversation and how increasing the jitter-buffer size would change this effect. What limits the size of jitter-buffer that may be employed? (4 marks)

f) Explain why lost packets occur when VoIP for telephony is conveyed by wired computer networks. Explain how the occurrence of lost packets can be identified at the receiver. (4 marks)