One and a half hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Fundamentals of Distributed Systems

Date: Monday 2nd June 2014
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) In most distributed applications, message exchange is a means to an end. For example, messages between the client and an e-commerce server carry information that allows a transaction to be completed (or not) but the content is not the main purpose of that exchange: the main purpose is (typically) to buy a product or a service. Give two examples of kinds of application (e.g., that run in smartphones) in which message exchange is the main purpose. (2 marks)

b) Draw three diagrams whose purpose is to illustrate the essential difference between threaded, parallel and distributed computations. Consider carefully whether your notation and the symbols used have a clear interpretation and, if in doubt, provide additional textual explanation. (6 marks)

c) Assume a modern desktop computer (for example, with a multicore processor) running a modern operating system (for example, Linux). Assume the single user currently logged in to this computer launches in quick sequence such graphical user interface-based applications as a word processor (to open an existing document) and a presentation program (to create a new presentation from scratch).

   i) Explain whether or not, as stated, the given scenario is likely to involve concurrent computing. (2 marks)
   ii) Explain whether or not, as stated, the given scenario is likely to involve parallel computing. (2 marks)
   iii) Explain whether or not, as stated, the given scenario is likely to involve distributed computing. (2 marks)

d) The `ping` command (issued from, for example, a Linux shell) measures the time it takes for a message to do a round-trip to a given remote machine. Assume you are on a machine in Manchester and you issue the command `ping www.google.co.uk` (i.e., a machine likely to be in the UK) and then the command `ping www.baidu.cn` (i.e., a machine likely to be in China). Describe what you expect to be the difference between the measurements resulting from the first and the second commands in terms of the axioms of distributed systems as studied in this course unit. (1 mark)

e) The `host` command (issued from, for example, a Linux shell) performs a domain name system lookup.

   i) Explain what result you expect such a lookup to return if the command you issue is `host www.facebook.co.uk`. (2 marks)
   ii) The `host` command may return multiple results. Explain how this relates to one of the transparency goals studied in this course unit. (2 marks)
f) The traceroute command (issued from, for example, a Linux shell) displays the route (path) from the issuing machine to the destination machine. For example, if you issue the command `traceroute www.facebook.com` from a machine in Manchester, the command will show the route taken for a particular kind of packet to reach the Facebook web server(s).

i) If you issue the command `traceroute www.facebook.com` from a machine in Manchester twice should you expect the output to be the same or not? Explain your answer. (2 marks)

ii) Which axiom amongst those studied in the course best relates to the behaviour you have described in your answer to Item 1(f)i. (1 mark)

iii) Explain whether your answers to Items 1(f)i and 1(f)ii suggest that an attempt at hardwiring optimal paths inside code is likely to be a sound design decision. (1 mark)

iv) Given your answer to Item 1(f)iii, explain whether code that runs in a bespoke interconnect, such as in a data centre (of the kind engineered by, for example, Google) might be an exception or not. (2 marks)
2. a) In the context of the architectural paradigms for distributed systems studied in this course unit:

i) Draw two diagrams whose purpose is to illustrate the essential difference between direct and mediated message exchange. Consider carefully whether your notation and the symbols used have a clear interpretation and, if in doubt, provide additional textual explanation.

ii) Explain in what sense it could be argued that Twitter acts like a message-oriented middleware component.

b) Using the diagrammatic notation introduced in this course unit, draw a diagram that describes the relevant elements and events in a non-blocking, asynchronous send.

c) Let BETTR be a company that promises to take a user’s photos and apply a collection of independent filters to each photo so as to improve its quality (according to some proprietary model of quality, e.g., one that prefers sharper, brighter, warmer-toned photos). Assume that the estimated demand for this service is very large (e.g., millions of photos per hour).

i) Assume you have just been hired by BETTR and in your first technical meeting, your boss asks you whether you think it is a good idea to use a master-workers parallelization pattern to process this workload and why. What answer would you give her?

ii) Your boss then says that someone told her that replication is an important strategy for improved availability. She asks you to explain what is meant by this and whether there are drawbacks to using replication in the case of BETTR’s photo processing pipeline. What answer would you give her?

d) In the map-reduce model:

i) Explain what element in the output of a mapper is designed to enable the reducers to run in parallel.

ii) In the original Google implementation of the map-reduce model, many instances of a mapper using the same input partition were started in parallel at the same time in different machines as a race-to-the-finish, i.e., only the results of the first instance to complete were kept, the other instances were killed off. Classify this computation in terms of Flynn’s taxonomy.
e) Let ODD be a web-of-data (WOD) start-up company you work for. A prospective
customer has asked for a technical meeting, and you’re attending it. In this meeting,
one member of the customer’s technical team asked you whether in the WOD
context, HTTP is also merely a transport mechanism as in the WS-* context. Explain
the difference, if any, between how HTTP is used in the WOD and in the WS-*
context. (3 marks)

f) Give two reasons why a WS-* service-oriented architecture might be chosen by a
business-to-business company to integrate its suppliers and customers rather than a
RESTful resource-oriented one. (4 marks)
3. a) Explain in what sense we can say that DNS servers use a caching strategy.
(2 marks)

b) From the viewpoint of state management, explain what is the purpose of cookies.
(2 marks)

c) Email communication is asynchronous, i.e., sending and reading are decoupled in time. Bearing this in mind, take the viewpoint of state management and explain why email requires two distinct protocols to be implemented.
(3 marks)

d) By appeal to one or more of the Coffman conditions for deadlock, argue that if the only resource (for example, a file) shared by two processes \( P \) and \( P' \) is only ever read (as opposed to updated) by them, then deadlock between \( P \) and \( P' \) is preventable.
(3 marks)

e) Consider the Two Generals problem. Use one of the eight axioms studied in this course unit to argue that it is impossible to design an algorithm that is guaranteed to lead to a coordinated solution.
(4 marks)

f) Assume that, when using a logical clock system, we have the following relationships between events \( A, B, C \) and \( D \) in a distributed system:

\[
\begin{align*}
A & \rightarrow B \\
A & \rightarrow C \\
C & \rightarrow D \\
D & \rightarrow B
\end{align*}
\]

Draw a diagram that shows that this is (or is not) a consistent set of assertions. Consider carefully whether your notation and the symbols used have a clear interpretation and, if in doubt, provide additional textual explanation.
(4 marks)

g) Define what is meant by a critical section of code and use it to argue whether the statement ‘A critical section of code is one that must complete in a prescribed amount of time’ is true or false.
(2 marks)

h) Explain what is meant by a tit-for-tat policy in the context of BitTorrent and then use this to explain why it is desirable for a peer to prefer downloading chunks that few other peers have.
(4 marks)

i) Consider the main sub-systems inside a typical games engine. Which one is mostly concerned with the kinds of challenges discussed in this course unit?
(1 mark)