Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Distributed Computing

Date: Friday 23rd May 2008
Time: 14:00 – 16:00

Please answer Question ONE and any two from Questions TWO, THREE and FOUR

This is a CLOSED book examination

The use of electronic calculators is NOT permitted.
1. **Compulsory**

   a) Provide an example of a parallel application and an example of a distributed application. Use these examples to highlight the differences between parallel and distributed applications. (2 marks)

   b) Explain briefly what is meant by the term *middleware*. (2 marks)

   c) Describe one key difference between *client-server* and *peer-to-peer* applications. (2 marks)

   d) Explain briefly what the term *dependability* is concerned with in computing systems. (2 marks)

   e) Explain briefly what is the use of checkpoints to provide fault tolerance. (2 marks)

   f) In the context of RPC, what is meant by an *idempotent* operation? And why is this a useful property? (2 marks)

   g) Distinguish carefully between a *name server* and a *directory server*. (2 marks)

   h) In the Bully algorithm to elect a coordinator, why does a process which initiates the election need a timeout in waiting for the result of the election? I.e. explain the circumstances by which such a timeout could be triggered. (2 marks)

   i) AFS uses *callback promises*. Explain what this means. (2 marks)

   j) What is a *secure digest*? What is the purpose of including a secure digest in a digital signature? (2 marks)
2.   
   a)   Explain briefly what is wrong with the assumption “latency is zero” in the context of distributed computing. Why is it considered a common fallacy?  
   (3 marks)  
   
   b)   Explain briefly what are the four properties commonly denoted by the acronym ACID when referring to transactions. 
   (3 marks)  
   
   c)   Briefly describe the two-phase commit protocol.  
   (3 marks)  
   
   d)   For the needs of a certain semi-scientific experiment, five data collection instruments are deployed to five different locations of a country, one instrument at each location. We call the five different locations A, B, C, D, E. These instruments collect data on a continuous basis; once every hour, they transmit a batch of data to a server for further processing. In this experiment, there are three identical servers (each one connected to the Internet) which are placed on three of the five different locations; the three servers keep running a certain program that performs several computations on the batch of data sent by a data collection instrument. The processing done by a server calculates an integer value for each batch of data received by a data collection instrument. This value is between 1 and 200 and, once computed, the server needs to update an object held in a remote data store, available through the Internet, that holds the number of times each of the values between 1 and 200 has been calculated throughout the experiment.
   
   i)   Assume that when placing the three servers the objective is to minimise the time needed to transmit the data from an instrument to a server. Assume also that the time needed to transfer a data unit from a data instrument in one location to a server in every other location is given by the table:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>9</td>
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<tr>
<td>C</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>8</td>
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<tr>
<td>D</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>E</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Describe a strategy to choose the three sites that are going to host a server. What are the three sites your strategy would choose?  
(3 marks)  

(Question 2 continues on the following page)
(Question 2 continues from the previous page)

ii) Assume that the network links connecting every data instrument with every server are not particularly reliable and may fail with a probability of $0.5 \left(2^{t/2}\right)$, where $t$ is the time needed to transfer a data unit from a data instrument to a server (for example, as given by the table above). If you are not supposed to make any changes to the infrastructure used in this experiment nor the location of the servers, suggest two different approaches to transmit data from the instruments that minimise the probability that a batch of data is never processed by a server. Discuss the advantages and disadvantages of each approach.  (5 marks)

iii) Indicate some of the problems that may arise when servers update the remote data store. Suggest a way to avoid these problems. (3 marks)

3. a) Why is it difficult for processors in a distributed system to achieve synchronized real-time clocks? (4 marks)

b) Explain what is meant by the terms logical time and vector clocks. What property is accurately represented by vector clocks that is not if logical time is used? (6 marks)

c) In a particular distributed system, providing a single service to a number of clients, the server is replicated a number of times for reliability. Each client request is sent in a message to each server. On receiving a request message from a client, each server sends an acknowledgement back to the client, and this acknowledgment message is also sent to each of the other servers. A server stores the requests in order of logical time of sending (using the processor identity of the source to resolve ties), and acts on them in this order. But no server acts on a request until it has seen the acknowledgements for that message from all other servers. What useful result is achieved by this, in a system in which no messages are lost and messages between the same two computers do not overtake? (5 marks)

d) How does it behave if some messages are lost? (2 marks)

e) Show why the assumption about overtaking is necessary. (3 marks)
4. a) Give a definition of an ontology as used in computer science and very briefly give an example of how ontologies might be useful in solving problems caused by the need to link together heterogeneous resources. Explain the difference between a resource ontology created by matching terms and one created by the reconciliation of terms at a higher level of abstraction. (4 marks)

b) What is the difference between "implicit" and "explicit" semantics? Explain why the need to make implicit semantics explicit and discoverable arises from the need to make different Grid systems interoperate. Write a brief description of the difference between the representation of resource requestor and resource provider space and relate this to the implicit semantics in these different spaces. (4 marks)

c) What does REpresentational State Transfer (REST) refer to and how might it be of importance in solving problems of distributed computing? What are the three principles of REST and for each of them describe its relevance in distributed computing. (4 marks)

```
<MathsOperation>
  <Operation name ="ADD">  
    <Arg>5</Arg>
    <Arg>10</Arg>
    <Arg>3</Arg>
  </Operation>
</MathsOperation>

int add( int value1, int value2 )
```

```
<body>
  <add>
    <value1 xsd:type="int">10</value1>
    <value2 xsd:type="int">5</value2>
  </add>
</body>
```

d) Write down explicitly the mathematical operation defined in each of the XML fragments shown in the diagram above. What style of distributed computing does each fragment represent and for each style give one advantage and one disadvantage in terms of using each style to invoke a Web Service. (4 marks)

e) What is a Web Service? What does it mean to say that Web Services are “stateless”? Give an example of showing how state could be important in Grid Computing. How does the Web Services Resource Framework (WSRF) represent the state of the resources that provide the Web Service? (4 marks)

END OF EXAMINATION