COMPUTER SCIENCE TRIPOS Part IB

Wednesday 2 June 2010 1.30 to 4.30

COMPUTER SCIENCE Paper 5

*Answer **five** questions.*

*Submit the answers in five **separate** bundles, each with its own cover sheet. On each cover sheet, write the numbers of **all** attempted questions, and circle the number of the question attached.*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

STATIONERY REQUIREMENTS
Script paper
Blue cover sheets
Tags

SPECIAL REQUIREMENTS
Approved calculator permitted

1 Computer Design

(*a*) Given a positive reset signal, how is an asynchronous reset described in Verilog? [2 marks]

(*b*) For each of the following six `always` blocks, what sequence or error will be produced? You should assume that registers are reset to zero at the start (as they are for FPGAs) and that `clk` is a clock. [3 marks each]

```
reg [2:0] counterA, counterB, counterC, counterD, counterE, counterF;

always @(posedge clk)
  begin
    counterA <= counterA+1;
    if(counterA==5) counterA <= 1;
  end

always @(posedge clk)
  begin
    if(counterB==5) counterB <= 1;
    counterB <= counterB+1;
  end

always @(posedge clk)
  begin
    if(counterC==5) counterC = 1;
    counterC = counterC+1;
  end

always @(*) counterD <= counterE+1;

always @(posedge clk)
  counterE <= (counterD==5) ? 1 : counterD;

always @(*)
  begin
    if(counterF==5) counterF <= 1;
    counterF <= counterF+1;
  end
```

2 Computer Design

Gordon Moore's "law" was originally an observation about transistor density improving exponentially and the implications for the semiconductor industry.

(*a*) Does Moore's law still apply to transistor density? Justify your answer. [4 marks]

(*b*) Can Moore's law be applied to processor performance? Justify your answer. [4 marks]

(*c*) Communication to peripherals, including disks, now uses serial rather than parallel communication techniques.

(*i*) What are the electrical reasons for this change? [4 marks]

(*ii*) What are the economic reasons for this change? [4 marks]

(*d*) Why did EDSAC perform calculations in a bit-serial manner and yet modern processors compute bit-parallel? [4 marks]

3 Computer Design

(*a*) Pipelining is used to improve processor performance and yet it increases instruction execution latency. How does pipelining improve performance? [4 marks]

(*b*) Is the pipelining technique scalable to ever more pipeline stages? Justify your answer. [6 marks]

(*c*) Flynn's original taxonomy of parallel architectures identifies four classes of parallelism: SISD, SIMD, MISD, MIMD. What do these acronyms mean? [4 marks]

(*d*) Today's commercial desktop processors are often said to be "many-core". How would you classify them using Flynn's taxonomy? Do they exhibit other forms of parallelism? [6 marks]

4 Concurrent and Distributed Systems

In an application, processes may be identified as "readers" or "writers" of a certain data object. Multiple-reader, single-writer access to this object must be implemented, with priority for writers over readers. Readers execute procedures *startread* and *endread* before and after reading. Writers execute procedures *startwrite* and *endwrite* before and after writing one-at-a-time.

The following variables are used in an implementation of the algorithm:

ar	is the count of active readers
rr	is the count of reading readers
aw	is the count of active writers
ww	is the count of writing writers (who write one-at-a-time)

(*a*) In a semaphore implementation:

For mutual exclusion:
SemCountGuard is a semaphore under which the above counts are read and written.
SemWrite is for writers to wait on, in order to write one-at-a-time.
For condition synchronisation:
SemOKtoRead is for readers to wait until all writers have finished.
SemOKtoWrite is for writers to wait until currently reading readers have finished.

Discuss the following pseudocode for an attempted implementation of *startread*:

```
procedure startread ( )
wait(SemCountGuard);
ar := ar + 1;
if aw > 0 then wait(SemOKtoRead);
rr := rr + 1;
signal(SemCountGuard)
return
```

[6 marks]

(*b*) Using the above example, comment on the ease of monitor programming and implementation, compared with semaphore programming. Assume a monitor *ReadersWriters* defines condition variables *OKtoRead* and *OKtoWrite*. [6 marks]

(*c*) Describe and comment on the Java approach to supporting mutual exclusion and condition synchronisation. [4 marks]

(*d*) Explain how active objects and guarded commands avoid some of the issues arising in the above programs. [4 marks]

5 Concurrent and Distributed Systems

For a transaction model based on objects and object operation time-stamps:

(*a*) (*i*) Define how conflict may be specified in terms of object operation semantics.

(*ii*) Give an example of conflicting operations.

(*iii*) Give an example of non-conflicting operations that would be defined as conflicting under read–write semantics.

[3 marks]

(*b*) Define the necessary and sufficient condition for two transactions to be serialisable. Give an example of a non-serialisable execution of a pair of transactions. [3 marks]

(*c*) Define the necessary and sufficient condition for *any* number of transactions to be serialisable. [1 mark]

(*d*) Discuss how the following methods of providing concurrency control in database systems enforce the properties defined above.

(*i*) Strict two-phase locking. [4 marks]

(*ii*) Strict timestamp ordering. [4 marks]

(*iii*) Optimistic concurrency control. [5 marks]

6 Concurrent and Distributed Systems

(*a*) When distributed systems are designed and engineered, certain fundamental characteristics have to be taken into account, including:

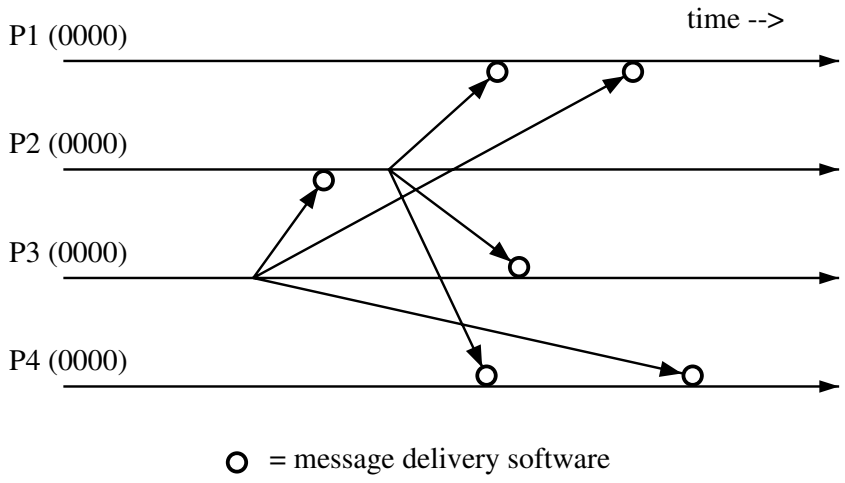
1. Concurrent execution of components.
2. Independent failure modes.
3. Communication delay.
4. No global time.

In the light of these characteristics, discuss the monitoring of a widely distributed industrial process with the following properties:

Distributed monitoring computers analyse regions of the process. Each region contains a number of sensors at identified locations and with the ability to generate timestamps. Some sensors monitor temperature, others monitor pressure.

If both temperature and pressure are found by a monitoring computer to be above their defined thresholds in a given locality within its region it sends an alarm signal to the process control centre, indicating the time and place of the occurrence. The control centre initiates action to bring the values under control. [10 marks]

(*b*) The diagram below represents a process group that communicates by means of multicast messages.



At each process-hosting node, message delivery software decides whether an incoming message should be delivered to the process or buffered for later delivery. This is achieved by the use of vector clocks.

With reference to the example shown in the diagram, describe the vector clock algorithm for delivery of messages in causal order. [10 marks]

7 Digital Communication I

When Skype establishes an audio channel for telephony calls, it can do so in three ways:

- Direct connection, using UDP.
- Indirect connection, using UDP relayed via a Supernode.
- Indirect connection, using TCP to reach a Supernode, then UDP from there to the destination.

(*a*) Why does Skype provide these three modes? [2 + 2 + 2 marks]

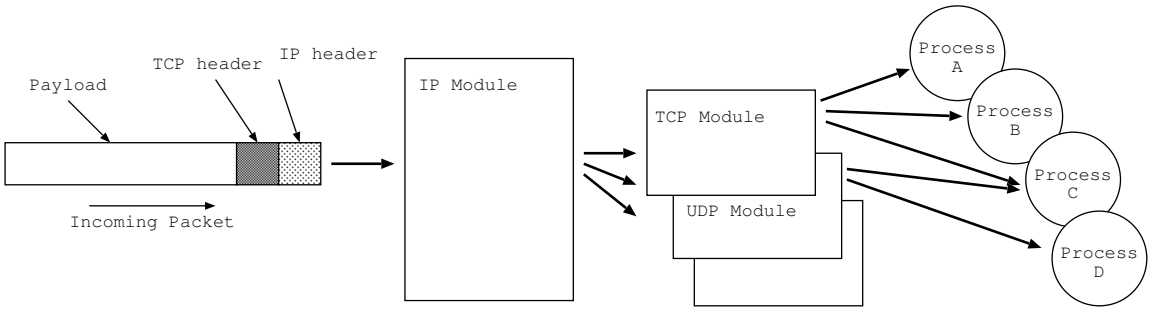
(*b*) Describe the different audio problems you might encounter when the first and last modes are used. [8 marks]

(*c*) Which mode will normally provide the best audio experience? Why? [2 marks]

(*d*) Suggest **two** further techniques that an Internet telephony application such as Skype can use to minimise the effects of packet loss. Discuss their relative merits. [2 + 2 marks]

8 Digital Communication I

(*a*) The diagram below shows an abstraction of the modules involved in processing an incoming packet on an Internet host.



Explain how these modules process the header fields in the incoming packet so that the data is delivered to the correct process. [6 marks]

(*b*) The Transmission Control Protocol (TCP) utilises a *3-way handshake* at the start of a connection. Explain, with reference to sequence numbers, how this operates and the purpose of the third packet in this exchange. [8 marks]

(*c*) What is meant by a *TCP port*? Make reference to how ports are used at client and server when a web browser opens a TCP connection of a web server. [6 marks]

9 Further Java

Consider the following client program extract:

```
1  Socket s = new Socket("localhost",10000);
2  ObjectInputStream ois = new ObjectInputStream(s.getInputStream());
3  Object o = ois.readObject();
4  Class c = o.getClass();
5  for(Field f :  c.getDeclaredFields())
6    System.out.println(f.get(o));
7  c.getMethod("run").invoke(o);
```

(*a*) Describe the execution of this extract, assuming that no exceptions are thrown. [5 marks]

(*b*) Identify **five** distinct exceptions that may occur during execution of the client program extract. Your answers should include the line number at which the exception would be thrown and a brief description of the problem which would cause it. General virtual machine errors such as OutOfMemoryError or StackOverflowError should not be included in your answer. [2 marks each]

(*c*) Write a server program extract that is capable of communicating successfully with the client extract shown above. You should assume the existence of an Object variable called **sendMe** which contains the object to be sent to the client. You do not need to write any error handling code. [5 marks]

END OF PAPER