The University of Western Australia
Department of Electrical and Electronic Engineering

FIRST SEMESTER EXAMINATIONS **JUNE 2002**

REAL-TIME DISTRIBUTED SYSTEMS 408 **623.408**

ONLY PAPER

Time Allowed: Three Hours
Reading Time: 10 minutes

This papers contains: 12 questions; 7 pages.

Instructions to Candidates:
You are required to answer 10 questions. If you do more than 10 questions the highest marked 10 questions are used in the final mark. Each question carries equal marks and the mark associated with each part of a question is as shown.

QUESTION 1

a) Using a simple diagram, briefly describe the distinguishing features of *reactive systems* and *embedded systems* and how the terms relate to *real-time systems*. [3]

b) What is the difference between *distributed processing* and *parallel processing*? [2]

c) Describe the main characteristics and structural features of the Deadline-guaranteeing class of Real-Time Operating System. [5]

QUESTION 2

Using the Ada programming language, develop a code segment that shows the exchange of data between two tasks in rendezvous and the use of a conditional delayed entry call in one task and a selective wait with delay in the other. What the purpose of the delay is in both the selective wait and conditional entry calls? [10]

QUESTION 3

a) Describe the aim of the Portable Operating System Interface uniX (POSIX) IEEE 1003 standard and the definition and purpose of APIs and EEIs (include a simple diagram). [5]

b) In the Java programming language, describe the Remote Method Invocation (RMI) structure, and compare RMI with Java Sockets and Remote Procedure Call (RPC) mechanisms. [5]

QUESTION 4

a) An Object Request Broker is a common architectural design pattern in client/server distributed systems. Using a UML class diagram and a sequence diagram, illustrate the operation of this pattern between at least two example sub-systems. [5]

b) For the *Rhealstone* benchmark, distinguish with simple diagrams the difference between *task switch time* and *task preemption time*. [5]

QUESTION 5

a) Consider a distributed system operating a master-slave clock synchronisation algorithm. Suppose the slave clock returns the time $C_j(T)$ and the master clock returns the time $C_i(T)$. The interprocessor communication delays are u_i^j (master to slave) and u_j^i (slave to master). Develop an expression for the clock skew (assuming the slave clock error can be modelled as a zero-mean random noise process) that can be used to correct the slave clock $C_j(T)$? Briefly mention what can be done to improve the clock skew estimation accuracy for the scheme. [4]

b) As an example, suppose a master clock had a time of 00:00:00.378000. After a master to slave communication time of 4 msec, the slave clock reads 00:00:00.462000. At a slave time of 00:00:00.872000, a communication delay of 2 msec is incurred, after which the master clock reads 00:00:00.938000. What clock update is applied to the slave clock after <u>one</u> cycle of the synchronisation algorithm? [2]

c) Now consider a fully *distributed clock algorithm* (without a designated master), that uses a *minimize maximum error approach.* Determine what (if any) clock update is performed at node *j* given the following conditions:

<u>At node *i*</u>: Let the reset time be 00:00:00.000000, the time node *i* is queried is 00:00:00.067100, the estimated drift rate is 0.002 sec/sec, and the estimated residual error is 30 μsec.

<u>At node *j*</u>: Let the reset time be 00:00:00.000000, the time node *j* attempts to synchronize is 00:00:00.067000, the estimated drift rate is 0.003 sec/sec, and the estimated residual error is 60 μsec. The response delay from node *i* to node *j* is 20 μsec. [4]

QUESTION 6

a) In a real-time distributed system, where time constraints imposed at one node must propagate to another, suppose we have the time constraints TC_1 and TC_2:

TC_1 (*begin*): $3.2 \rightarrow 4.8$ TC_1 (*end*): $4.0 \rightarrow 5.2$ C_{id1}: $0.4 \rightarrow 1.2$

TC_2 (*begin*): $0.8 \rightarrow 5.0$ TC_2 (*end*): $3.6 \rightarrow 8.4$ C_{id2}: $2.2 \rightarrow 3.8$

Draw a diagram that shows both time constraint laxity windows, show TC_1 propagating onto TC_2, and then identify the regions where $TC_1 \sqcap TC_2 \neq \emptyset$ and $TC_1 \prec TC_2$. [6]

b) Suppose we have an incoming time constraint imposed by a remote object of TC_{in} and the constraint imposed on the remote object is TC_{out}, and we have a specification using temporal object relations of the form:

$$TC_{in} \prec TC_R \Uparrow \vee \prec TC_{out}$$

Show that the service to be invoked must succeed TC_{in} by more than γ time units, where $\|TC_R\| = \gamma$ by drawing inferences from the above relations. [4]

QUESTION 7

a) Identify the major components of the Common Object Request Broker (CORBA) standard, and specify the typical sequence of an applications development using CORBA (a simple diagram should be used to help illustrate). [5]

b) In the SAP R/3 business orientated client/server architecture, explain what business objects are and identify the main layers in the object (a simple diagram should be used to help illustrate)? [5]

QUESTION 8

Suppose we have an information system module that processes *two* channels of data concurrently. Each channel takes $T_2 = 4$ and $T_4 = 3$ time units respectively to input the data, and then takes $T_3 = 2$ and $T_5 = 2$ time units respectively to convert the data. After processing, the two channels are combined to produce a composite stream (taking $T_6 = 3$) which is passed through a moving average filter (taking $T_7 = 2$). The filter averages over several data points and eliminates older data points from the average (taking $T_8 = 1$). The input data on each channel is processed quite differently in other processes (taking $T_9 = 10$ and $T_{10} = 13$), and combined with the averaged data before recording. The recording process takes $T_{11} = 5$ time units. Input data is acquired synchronously by the system every $T_1 = 7$ time units.

For the system as described, produce a time-augmented Petri net graph to model the processes, and derive the constraints imposed on the process times using the notion of *safeness in the presence of time*. Can the module achieve the specified time constraints?

[10]

QUESTION 9

You are given that the distributed control software for a Flexible Manufacturing System (FMS) consists of three assembly control cyclic processes and a shared common resource process. A Stochastic Petri net (SPN) model for this system has been devised with the following transition rates:

$\lambda_1 = 3$ (after process 1 waiting)	$\lambda_4 = 6$ (after process 1 active)
$\lambda_2 = 4$ (after process 2 waiting)	$\lambda_5 = 8$ (after process 2 active)
$\lambda_3 = 5$ (after process 3 waiting)	$\lambda_6 = 10$ (after process 3 active)

Draw the SPN model, evaluate all marking probabilities and determine which assembly process has the *worst* cycle time. [10]

QUESTION 10

Consider the case of three periodic tasks (with context switch times included):

Task 1: C_1 = 20 ms; T_1 = 100 ms

Task 2: C_2 = 50 ms; T_2 = 200 ms

Task 3: C_3 = 60 ms; T_3 = 300 ms

a) Apply the *Utilization Bound Theorem* from Real-Time Scheduling Theory to determine if these tasks are schedulable using rate monotonic scheduling. [2]

b) Suppose the computation time for task 1 increases to 50 ms. Now determine if the tasks are guaranteed to be schedulable, and then apply the less conservative *Completion Time Theorem* if required. [4]

c) Suppose an additional interrupt driven aperiodic task is added to the first task set in a) above: Task A: C_A = 15 ms; T_A = 150 ms
Assuming that all the other tasks are likely to share access to common data at some time, use the *Generalized Utilization Bound Theorem* to determine if the new task set is guaranteed to be schedulable. [4]

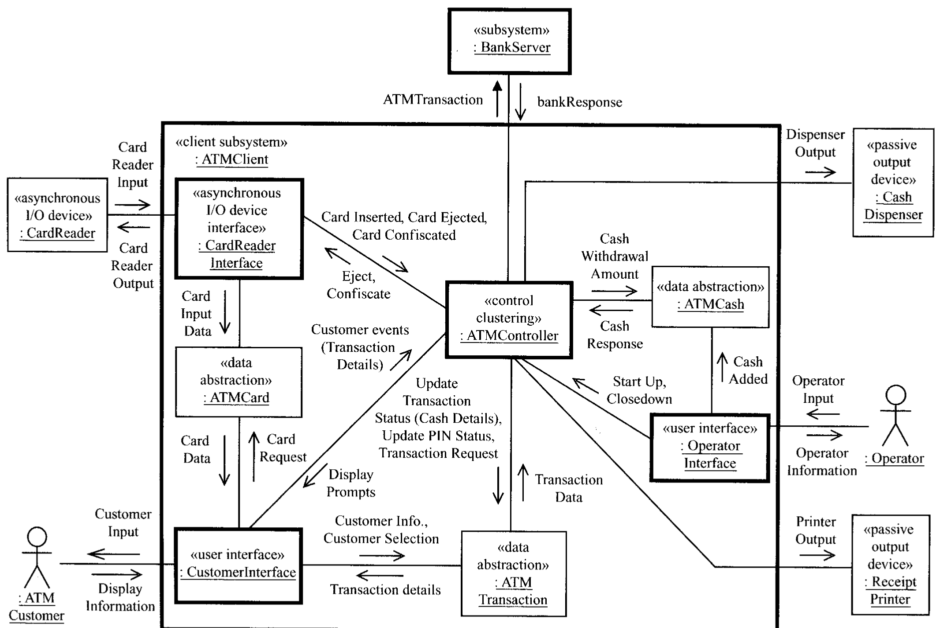
QUESTION 11

a) In a formal specification for a real-time system software component, suppose some CONTROL action must be completed within 38 time units of an INTERRUPT event. A DRIVER module is activated by an INTERRUPT event. The result of DRIVER (which has a computation lower bound of 24 time units) is conveyed to the CONTROL module (which has a computation lower bound of 15 time units). Show how these time constraints could be represented as Real-Time Logic expressions, produce a constraint graph and reduce it to show if this specification is satisfiable. [5]

QUESTION 11 continued over page

QUESTION 11 continued

b) Use any segment of the following task architecture diagram for an ATM client application to discuss the purpose of *event sequence analysis* in real-time performance modelling:



(Gomaa, 2000)

[5]

QUESTION 12

a) In the context of the COMET design approach for real-time distributed systems, what is *dynamic analysis* and how is it used? Illustrate the key concept in this form of analysis with an example from any application (e.g. Cruise Control). [5]

b) The *three-tier client-server model* is commonly applied in Internet web services. How is an *n-tier model* created in the same framework and what part can the Simple Object Access Protocol (SOAP) play in this? [5]