Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 22 April 2014
TID: 14-18
PLATS: TER4
ANSVARIG JOURLÄRARE: Simin Nadjm-Tehrani (013-282411, 0702 282412)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 5

Total no. of points: 40

Preliminary grade limits for grades: 3, 4 and 5

3:	20 - 26 p
4:	27 - 33 p
5:	34 - 40 p

INSTRUCTIONS:
Please write your anonymous ID on each sheet of paper that you hand in. Pages should only contain answer to **one question per page** (answers to sub-questions can be on the same page). You are asked to only write on one side of each paper. Please **sort** all the sheets that you hand in, in the order of question numbers.

Make sure that **all** answers are **motivated** and supported by **clear** explanations. Figures or charts can be used to provide a clearer explanation but should be accompanied by a **textual description**. Points will not be given to answers for which the reasoning cannot be followed or that cannot be read due to bad handwriting. Wrong answers/reasoning which is embedded in partially correct ones will lead to deduction of points. You may answer the questions in English (the course language) or Swedish.

Hints: Read the question carefully to find the focus of the question. Make sure your answer is to the point and relevant for the question asked. Take the opportunity of asking questions about unclear issues during the exam session. Otherwise, whenever in doubt about the question, write down your interpretation and assumptions, and answer the question based on the interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than 14th May 2014.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

a) A smart insulin pump has several processes for communicating, calculating suitable insulin values, and injecting insulin to diabetes patients during a daily life cycle. A simplified view of a modern pump (further developed since the early version devised in 1963) includes the following processes.

- A monitoring process that estimates the amount of insulin remaining in the blood since the last injection based on the value and timing
- A dose calculation process that computes the insulin dose to be injected based on the current state and the user input of amount of carbohydrates to be consumed
- A user interaction process that takes inputs from the user and displays acknowledgements or outputs
- An alarm process that monitors the user blood glucose test schedule and warns if the blood values have not been updated as required.

The Insulin estimator is a process running continuously, and provide a new estimate every minute based on available values. The dose calculator runs sporadically at user request (at a maximum interarrival rate of 12 times a day). The human interface also operates sporadically but accepts inputs or provides output once a minute. The blood test alarm process examines the predefined test schedule (and its updates) every hour, sending an alarm if it a prescheduled blood sugar test is missed.

Process	Ti (s)	WCET (s)
Insulin estimator	60	20
Dose calculator	7200	10
Human Interaction	60	10
Blood test alarm	3600	60

Construct a cyclic schedule for the above set of processes and present your minor and major cycle. (3 points)

b) Use the most relevant utilization based test to justify whether the above process set is schedulable with a rate-monotonic scheduling (RMS) approach.

(1 point)

c) Consider a new process, the Examination process, to be added to the above set and which is used by a specialist to visualise the operation of the insulin pump by sending the calculated and observed blood sugar levels to an external monitor. This process is a sporadic process that can be enabled with a minimum inter-arrival time of 5 minutes, and it will need 500ms to complete. Assume that this process has access to a dedicated channel for communicating the values. Would you consider implementing the fifth process on the same microprocessor? Motivate your answer!

(2 points)

d) Consider a new solution where the Examination process is granted access to use the same display as the one used by the insulin pump operational process (the Human interaction process in part a of the question). Combining the four processes with the fifth process (in part c above), means that a maximum blocking time has to be considered for accessing the shared display. Assume that the Examination process can access the display for max 250ms and the Human Interaction process can use it for max 1 s. Assume that RMS is combined with immediate ceiling protocol. What is the maximum blocking time for the two highest priority processes in the 5-task process set?

(3 points)

e) Explain the notion of domino effect in the context of earlier deadline first scheduling, and compare with the case of overrunning tasks leading to an overload in the rate-monotonic case.

(2 points)

Q2: Dependability and predictability

a) Give two methods for applying static and dynamic redundancy (one each) by including redundancy in hardware. For each method explain whether it is suitable to be used in presence of transient or permanent faults.

(4 points)

b) Explain how the use of exceptions in programs fits in the classification of fault treatment approaches according to IFIP 10.4 classifications. Describe how is the WCET analysis for an implemented software affected by the existence of exceptions. Consider both exceptions that are handled by a program and those handled by the runtime system.

(3 points)

Q3: Real-time Communication

a) What is the purpose of membership protocol in a TTP bus architecture, and which part of the architecture does it run in?

(3 points)

b) The Scania Truck company uses a 3-colour scheme for scheduling messages sent on the CAN bus segments, generated by its 1000 functions operating in its trucks. Assume that the following table presents 4 messages to be scheduled on one CAN bus segment (where "Tx time" stands for worst case transmission time of a message on the bus). Assume that deadline is equal to period for each of the messages. Assume further that time to transmit one bit is less than 1ms. Compute the maximum response time for message m_3. Motivate the choices that you have made in the analysis, including your additional assumptions.

Message	Priority	Period (ms)	Tx time (ms)
m_1	Very High	5	1
m_2	High	10	2
m_3	Medium	20	2
m_4	Low	50	5

(3 points)

Q4: Application design & RTOS

a) Computing the worst case execution time (WCET) for an application that has hard real-time constraints is dependent on a number of characteristics of the hardware and software involved. Explain two such aspects that affect WCET.

(2 points)

b) UML diagrams are a popular notation for describing software systems designs. Give an example of a shortcoming of standard UML for modelling real-time systems designs and propose an alternative that resolves it.

(2 points)

c) What is memory locking and why is it required in POSIX compliant real-time operating systems?

(2 points)

d) What is an exact test in the context of scheduling in real-time systems, and how can it be used by the designer of a system?

(2 points)

Q5: Distributed systems, Quality of Service (QoS)

a) Take a stand on the following statements, motivating your answer by referring to the relevant terminology discussed in the course literature:
1) Live video broadcast and video streaming applications both belong to the same class of applications with respect to QoS classifications.
2) Intserv creates large overheads when running interactive applications.

(2 points)

b) What is the benefit using leaky bucket as a concept for modelling flows in Internet based applications? (2 points)

c) What is meant by a consensus service, and how is the implementation of it related to timing models in distributed systems?

(3 points)

d) Explain why the idea of logical clocks is useful.

(1 point)

Notation for Processes

C = Worst-case execution time
B = Worst-case blocking time
D = Relative deadline
n = Number of processes
T = Period
R = Worst-case response time
J = Release jitter

Schedulability test for Rate Monotonic:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq n(2^{1/n}-1)$$

Schedulability test Earliest Deadline First:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq 1$$

RMS Response time analysis

$$w_i = C_i + B_i + \sum_{\forall P_j \in hp(P_i)} \left\lceil \frac{w_i + J_j}{T_j} \right\rceil C_j$$

$$R_i = w_i + J_i$$

$hp(P_i)$ is the set of processes with a higher priority than process P_i.

Timing Analysis of CSMA/CR

B = blocking time
C = transmission time of entire frame
T = period
τ_{bit} = transmission time of one bit
w = response time for the first bit of a frame to be sent
R = total response time
J = Jitter
t = Longest busy interval
$lp(m)$ = set of frames with lower priority than m.
$hp(m)$ = set of frames with higher priority than m.
$hep(m)$ = set of frames with higher or equal priority than m.
n = number of bytes in message (data field)

$$R_m = \max_{q=0..Q_m-1}(R_m(q))$$

$$R_m(q) = J_m + w_m(q) - q \cdot T_m + C_m$$

$$w_m(q) = B_m + q \cdot C_m + \sum_{\forall j \in hp(m)} \left\lceil \frac{w_m(q) + J_j + \tau_{bit}}{T_j} \right\rceil \cdot C_j$$

(with $w_m{}^0(q) = B_m + C_m q$)

$$Q_m = \left\lceil \frac{t_m + J_m}{T_m} \right\rceil$$

$$t_m = B_m + \sum_{j \in hep(m)} \left\lceil \frac{t_m + J_j}{T_j} \right\rceil \cdot C_j \qquad (\text{with } t_m{}^0 = C_m)$$

$$C_m = \left(8n + 47 + \left\lfloor \frac{34 + 8n - 1}{4} \right\rfloor \right) \tau_{bit}$$

$$B_m = \max_{j \in lp(m)}(C_j)$$