Försättsblad till skriftlig tentamen vid Linköpings universitet

(fylls i av ansvarig)

Datum för tentamen	2014-08-23
Sal	TER4
Tid	14-18
Kurskod	TDDD07
Provkod	TEN1
Kursnamn/benämning	Realtidssystem, Real-time Systems
Institution	*IDA*
Antal uppgifter som ingår i tentamen	5
Antal sidor på tentamen (inkl. försättsbladet)	7
Jour/Kursansvarig	Simin Nadjm-Tehrani
Telefon under skrivtid	0702 282412
Besöker salen ca kl.	15.15
Kursadministratör (namn + tfnnr + mailadress)	Åsa Kärrman, 013-285760, asa.karrman@liu.se
Tillåtna hjälpmedel	miniräknare, lexikon
Övrigt (exempel när resultat kan ses på webben, betygsgränser, visning, övriga salar tentan går i m.m.)	
Vilken typ av papper ska användas, rutigt eller linjerat	Rutigt
Antal exemplar i påsen	

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 23 August 2014
TID: 14-18
PLATS: TER4
ANSVARIG JOURLÄRARE: Simin Nadjm-Tehrani (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 10th September 2014.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

A smart detector device is a valuable instrument to be placed in strategic areas in a forest to create an early detection and continuous monitoring of a potential forest fire with huge health and economic consequences. A prototype for such a device has at least three processes essential for detection, evaluation, and transmission of real-time data to a remote command and control server. Assume that all three processes run on the same processing unit. A sensor that combines detecting heat, particles and smoke is polled by a polling process every 10ms and has a worst case computation time of 2ms. A second process computes seasonal averages and normalises the collected values before evaluation by a outlier detection algorithm. This process has a WCET of 25ms and is run every 50ms. A third process is in charge of alarm communication, and uses signalling via GSM to relay a set of relevant signals (normal or identified hazards) every 10ms. It takes maximally 1ms to run on the processor.

a) What is simplest schedulability test you could apply to check whether the process set is schedulable by rate-monotonic scheduling (RMS)? You are not required to take a stand on this set's schedulability.

(1 point)

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

(3 points)

c) Consider a new process, a battery level monitoring process that needs to warn the command and control server when the battery level for the device is too low (alternatively ensure that a solar power is operating correctly). Assume that the checkup/reporting takes 2ms to perform. What is the maximum frequency at which this process can be run if RMS is deployed? For this part of the problem ignore the communication medium that is used for reporting the battery level. State any other assumption that you make.

(2 points)

d) Now consider the case that the energy monitoring process (in part c above) is sharing the same GSM channel that is used for transmitting the alarm data (described above part a), and we use immediate ceiling protocol for resource allocation. Assume further that it has a periodic transmission interval of 10ms, and uses the GSM channel for max 1ms for every transmission. Assume that the fire alarm transmission process requires to use the GSM channel maximally 1ms for every transmission. Compute the maximum blocking time for each of the 4 processes, stating clearly any assumptions that you have made. What is the maximum response time for the alarm reporting process when combined with RMS in this case?

(3 points)

e) Explain the mathematical notion of optimality for the Earliest Deadline First scheduling algorithm compared to other algorithms.

(2 points)

Q2: Dependability and predictability

a) The newspaper NyTeknik on 5:th Maj 2014 reported the results of investigations after the train accident on "Saltsjöbanan" in Stockholm in January 2013:

"The only thing that the cleaning lady did was to close the train door. Then the train started to move and it ended in the crashing accident in the nearby apartment at Saltsjöbaden last winter.

The report by the accident investigation committee indicates that the manoeuvre of closing the door was connected to the motors starting to run. Since the train brakes were not engaged, and the rail's brake mechanism was out of order, the train started rolling on the track.

The cleaner did not know how the driver knobs and control handles worked and had no chance in stopping the train. Finally she sought protection by hiding behind a seat behind the train driver room. She was found there badly injured by the rescue workers after the crash."

Use the terminology of IFIP Working Group 10.4 (from the course literature) to associate the chain of events with the fault-error-failure causal chain in this scenario, and classify the fault as permanent or intermittent.

(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 function of MEDL in a TTP bus architecture, and which part of the architecture is it stored 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 the red 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_4. 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) Consider a server that stores and distributes the latest messages delivered by satellite communication from a nuclear reactor disaster area. The clients that are outside the area are thereby connected to the clients in the area and informed of the local situation via the server. Decide which of the following properties is a functional property and which is an extra-functional property that relates to quality of service. Motivate your answer!

1. An actor outside the area can ask for the messages received in the past 30 minutes to be dispatched at one go by the server.
2. The messages can be sorted in length and the actor outside the area may ask for the shorter messages to be delivered by the server if there are bandwidth limitations.
3. The system should provide a throughput of at least 2kb/s between any two clients connected with the lowest bandwidth.
4. To avoid a single point of failure the server should be replicated with a primary-backup failover mechanism.

(2 points)

b) When designing a complex system, diving it into subsystems and assuring that each subsystem in itself satisfies its requirements is denoted by modular (compositional) design. Why is modular design of hard real-time system difficult?

(2 points)

c) Describe static and dynamic memory management mechanisms deployed in a real-time operating system.

(4 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 have different jitter requirements in terms of QoS.
2) Intserv creates large overheads when running interactive applications.
3) Vector clocks define concurrent events in a different way compared to logical clocks.
4) Packet scheduling with QoS constraints cannot be fair.

(4 points)

b) Explain the need for the concept of fault model in distributed systems, and give two examples of fault models that apply to:
1) Nodes in a distributed system
2) Communication channels between nodes
(one example for each).

(4 points)

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:

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

Schedulability test Earliest Deadline First:

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

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

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

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

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

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