TENTAMEN TDDD07 Real-time Systems

DATE:21 August 2010
TIME: 14-18
LOCATION: TER3
RESPONSIBLE TEACHER: Simin Nadjm-Tehrani (Tel: 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. Further, 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 the question number**.

Make sure your answers are relevant to the question being asked and supported by clear explanations. Figures or charts 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. You may answer in Swedish or English as you prefer.

Hints: Try to dispose of your time on each question in proportion of the assignment points. In any case where you are in doubt about the question, write down your interpretation and assumptions, and answer the question based on the interpretation. A correct answer that is embedded in errors may give reduction in points, so make sure your answers are to the point.

Results are reported no later than September 7th.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling, QoS

a) Future "smart homes" will include a range of embedded devices where temperature and ventilation control, security surveillance, light management, energy optimisation and other services are integrated using several sensors and distributed actuator devices. Consider a home network in which the same CPU is to be used for hosting three control processes, some with hard real-time deadlines as follows:

- A sensor fusion process used for detection of intruders. It combines movement sensor signals and other indicators to issue an alarm if an anomaly is noted. This process needs to run periodically twice per second and takes a maximum of 100 ms to run.
- A sporadic process that checks for indications of accidents like fire or gas leaks using smoke detectors and gas leak detectors. This process can be activated with a minimum inter-arrival time of 1 second and takes 200 ms to validate and send an alarm as an output.
- A smart meter that collects data so that the current electricity usage can be optimised based on the real-time market price of electricity and currently powered devices in the home. This process is to be run periodically every 750ms and has a maximum computation time of 250 ms.

Assume that the communication time between the sensors/actuators and the computation processes is deterministic in time, and the time taken for communication is already included in the above maximal computation times.

1. Is the above set of processes schedulable on the CPU using the Cyclic scheduling policy? Construct a cyclic schedule and give the minor and major cycles respectively. You may assume that all processes can be subjected to output jitter equal to max 50% of process period.

   (5 points)
2. Is the set of processes schedulable using the rate-monotonic policy? Motivate your answer, and state two assumptions (in addition to the given assumptions) that are needed for your analysis to be valid.

   (4 points)
3. If the smart metering data collection would be run as an aperiodic process, i.e. only activated when the electricity market price changes, would it affect your reasoning under point 2 above? Why, or why not?

   (2 points)

b) Throughput is a basic form in which QoS can be expressed. How is throughput measured? Give two traffic models for data for adherence to a given throughput requirement.

(3 points)

Q2: Dependability

a) Explain the notion of graceful degradation and give one example of it in a real application setting.

(2 points)

b) Take a stand on the following propositions (true or false), and motivate your answer:
   1) Redundancy in hardware through triple modular redundancy does not increase the response time of an application compared to a non-replicated solution.

2) TCP employs redundancy in data when a message is retransmitted to achieve reliable communication.
3) TCP employs redundancy in time when a message is retransmitted to achieve reliable communication.

(3 points)

c) Identify the causal chain in the following phenomena in terms of faults, errors and failures.
   1) The recent oil spill in the Gulf of Mexico has apparently been preceded by a disconnected alarm. A Transocean employee says "...that the system [on the Deepwater Horizon drilling rig] that automatically sounded a general alarm had been disabled because rig managers did not want people woken up at 3 a.m. with false alarms".
   2) In Java 1.6.0_21, the company field was changed from 'Sun Microsystems, Inc' to 'Oracle.' Some applications depend on that field to identify the virtual machine. For example, all Eclipse versions since 3.3 including the recent Helios release (2010) have been reported to crash with an OutOfMemoryError due to this change.
   3) When new software was uploaded to fix a bug in a Prius car, the existing data was not backed up. Later the contact list in the owner's cell phone was removed due to an automatic pairing with the car phone through Blue Tooth.

(3 points)

Q3: Design

a) Give an example technique that helps to discover early design faults in embedded real-time systems.

(2 points)

b) What is meant by platform independence, and why is it a good property in modelling languages for real-time systems?

(2 points)

Q4: Real-Time Communication

a) Consider a set of messages to be scheduled on a CAN bus with the following priorities and parameters. Assume the deadline for a message is equal to its period, and that all messages have a maximum transmission time of 1 ms. Assume further that transmission time for i bit is less than 1 ms.

Message	period (ms)	Jitter
m1 (high priority)	30	5
m2 (middle priority)	15	0
m3 (low priority)	5	0

Compute the worst case response time for the message with the lowest priority.

(4 points)

b) TTA is a bus architecture in which the messages are transmitted on the bus using a time-triggered schedule. Explain whether the architecture requires a particular scheduling for the tasks that run on the node CPUs and produce the messages on the bus.

(2 points)

Q5: Distributed systems, QoS

a) Give an example of a distributed real-time system with hard deadlines, and another example with soft deadlines.

(2 points)

b) In a networked system jitter can be defined as the difference between the inter-departure times and inter-arrival times of the i^{th} and $(i+1)^{th}$ data unit. Give an example application in which minimization of jitter is important. Motivate your answer!

(2 points)

c) Consider vector clocks that record the local events in 4 different processes. Describe how concurrent events can be identified using such clocks. Give an example of a pair of concurrent events using VC vector notation.

(4 points)

Formula sheet

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

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 messages with lower priority than m.
$hp(m)$ = set of messages with higher priority than m.

$hep(m)$ = set of messages with higher or equal priority compared to 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 $w_m^{\,0}(q) = B_m + C_m q$)

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

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

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

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