Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 22 August 2015
TID: 14-18
PLATS: TER3
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 9th September 2015.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

A GPS navigation system in a car is a complex system interacting with the driver, the car power train subsystem and the road side information management units (or traffic notification systems). In its simplest form the navigation system consists of three processes as follows. (1) A location calculation process that determines the current position of the car based on earlier state and current input, (2) a map update process that redraws the relevant part of the map and the current position of the car, and (3) a driver input/output process which receives new commands by a driver (including start/stop), and outputs the nearest waypoint to be displayed in the map. Assume that the location calculation process has a period of 50 ms and runs with a worst case execution time (WCET) of 20 ms, and the map update process is run with a period of 200 ms and a WCET of 80 ms. Assume that the driver interaction process is a sporadic process with a way point update estimated at once every 10 seconds and a WCET of 500 ms.

a) To begin with consider the set of processes as independent. Compute the utilisation of the process set and determine whether the process set is schedulable using the exact analysis for EDF scheduling. (1 point)

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

(2 points)

c) Consider now that the above design is challenged since the third input/output process is restricting the driver interaction responsiveness (the driver may wish to change a command more often than every 10 seconds). The third process is now split into two processes, one for driver input and one for waypoint navigation output. The driver input process is assumed to have a minimum inter-arrival time of 1 second, and a WCET of 50ms, the navigation waypoint output process is run with the previous parameters for the input/output process in parts a) and b). Assume (for simplicity) that the fourth process (way point updates) is not subject to hard constraints any more. Determine whether the three process set (consisting of location calculation, map update and driver input) is schedulable using rate monotonic scheduling (RMS).

(3 points)

d) We now remove the independence assumption between the four processes in part c. The map update, the driver input, and the way point output processes share the same screen as a common resource. Assume that each process has a maximum access time to the screen equal to 10 ms. If all four processes are scheduled using RMS with immediate ceiling protocol as the resource sharing mechanism, what is the maximum blocking time for each of the four processes?

(4 points)

e) Discuss the problem of deadlocks in the context of cyclic CPU scheduling.

(1 point)

Q2: Dependability and predictability

a) On 28th July 2015 the National Transportation Safety Board (NTSB) released its report on the accident that caused the death of one pilot and injury of another pilot on the test flight of Virgin Galactic SpaceShipTwo in October 2014. According to NTSB the fatal breakup and crash of Virgin Galactic's first SpaceShipTwo space plane last year was caused by a co-pilot error, as well as the failure of the spacecraft's builders to anticipate such a catastrophic mistake, federal safety investigators say.
SpaceShipTwo's novel feather system rotates the craft's twin tail booms upward to help stabilize the craft during its re-entry into Earth's atmosphere at the end of a flight. During the boost phase, when the rocket motor is firing, it is locked into position to secure the tail booms during flight. When the co-pilot (Alsbury) unlocked the feathering system early, turbulence from SpaceShipTwo's transonic flight overpowered the tail booms' securing mechanism, leading to the vehicle's destruction. NTSB investigators said the accident occurred when Alsbury unlocked SpaceShipTwo's novel tail-boom "feather" system too early, while the craft was flying at Mach 0.8 and not at Mach 1.4 as the original flight plan required. (Mach 1.0 is the speed of sound.).

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 the difference between fault prevention and fault removal with the help of one example method for each.

(2 points)

c) The assurance of timing properties of a real-time system relies on computing the worst case execution time (WCET) for each running process. Describe how the WCET for a process can be computed.

(1 point)

Q3: Real-time Communication

a) The time-triggered architecture TTA supports redundancy in nodes and the transmission infrastructure as a means of achieving fault tolerance. Describe the hardware architecture of a system in one node, and explain which elements (forms of) redundancy are present in that node.

(3 points)

b) The following table presents 5 messages to be scheduled on a CAN bus (where "Tx time" stands for worst case transmission time of a message frame 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_2. 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	50	2
m_3	Medium	20	2
m_4	Low	10	5
m_5	Very Low	20	2

(3 points)

Q4: Application design & RTOS

a) Consider a mobile application intended to display which electric car charging stations are in the geographical area of an electric car and available for use. The system is to notify the driver if a selected charging station that was ready for use at the time of selection is taken by another vehicle arriving at that spot. Which of the following requirements are functional and which ones are non(extra)-functional properties for this system? Motivate your answer!

1. The server side of the system shall accept the current state of each charging station (ready/taken) every five minutes, and update the central availability map.
2. If two drivers attempt to select the same "ready" station on their respective maps but one request reaches the server first, the second driver is notified of the conflict.
3. The server should manage at least 2000 charge station updates and at least 10000 driver requests every X and Y seconds respectively.
4. A driver should be notified of a state change for a selected charging station within K minutes, so that a new charging station with reasonable distance can be selected by the driver.

(4 points)

b) Software engineering methods and processes are applied to both real-time and non-real-time systems for better quality assurance.
   1. Why is the discovery of design faults in real-time systems at an early stage harder than discovering them at a late development stage?
   2. What methods are available to find *design* inconsistencies in a real-time system at the pre-operation stages?

(2 points)

c) What is the difference between interrupt management in a real-time operating system and a non-real-time operating system?

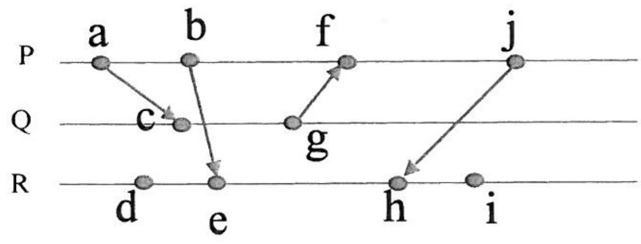
(2 points)

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) Voice communication is a real-time application with specific timeliness requirements.
2) Internal clock synchronization algorithms are preferable to external clock synchronization algorithms.
3) Vector clocks can be used to synchronise with a global real-time clock.

(3 points)

b) Consider the set of events shown in the following diagram, appearing on time lines of processes P-Q-R. Compute logical clocks for 3 of the 7 possible (non-initial) events.



(3 points)

c) Zhen Xiao et al. have suggested a method for managing overloads in physical machines at data centres by migrating virtual machines from overloaded ones to less overloaded ones. They use notions of hot, cold, skewness, etc with respect to the current load of a machine. Explain which measure of load they use when they refer to the *temperature of a machine* for reallocation decisions.

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

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

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

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

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