TENTAMEN TDDD07 Realtidssystem

DATUM: 11 January 2016
TID: 8-12
PLATS: TER4
ANSVARIG JOURLÄRARE: Mikael Asplund (0700895827)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 6

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.

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 that interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than 27 January 2016.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

A search and rescue mission typically requires situational awareness and an overview of a large geographical area with tight real-time requirements. A prototype for a drone is being developed that takes pictures at regular intervals and uploads to a remote server whenever it flies close to a sink node (a receiving node like a base station) with a dedicated radio. It consists of several concurrent processes running on the same CPU, and has three functions for altitude control and navigation, moving the drone in the three-dimensional space (x, y, and z). These collectively take a maximum of 30 ms to compute and run once every 100 ms. The drone also has a process for activating a camera, and storing the picture at a local database once a second; this process has a maximum execution time of 100ms. There is a third process that polls availability of a sink node with a period of every 2 seconds. If a sink is available a protocol to establish a connection (or reconfirm it) is run that has a WCET of 100 ms.

a) Consider the three processes above and determine whether the process set is schedulable with rate-monotonic scheduling if we require that a 30% utilization is allowed for running the operating system related processes.

(1 point)

b) In general, how is the application developer expected to estimate the RTOS scheduler's overhead in a system so that analyzing schedulability can be applied with a margin for the overhead? Use the example to clarify the answer if you need.

(2 points)

c) Consider now that a fourth process is to be added to take care of the actual picture uploading, and assures transmission of real-time data to a remote command and control server. Assume that this process takes a maximum of 500ms and it will run with a period of once every 4 seconds. Discuss whether a cyclic schedule for running the set of processes consisting of the three processes under part a) and the fourth process for uploading is a good idea or not, and motivate your answer. You need not construct a full schedule here, and may ignore the scheduler overhead.

(3 points)

d) Assume now that the navigation and control functions are realized on a dedicated chip and we are only concerned with running the application specific processes (camera/storage, connection management towards a sink, uploading) that will be run on one CPU. The engineer in charge of the prototype proposes that a cyclic schedule to be constructed in order to avoid the need for mutual exclusion of access to two common resources. These are: 1) the shared database of stored picture to which both the camera and upload processes have access, and 2) the radio channel that both the connection manager and uploading process need to access. Construct a cyclic schedule and discuss whether your solution confirms her statement about the shared resources.

(2 points)

e) A WCET estimate is a function of inputs provided to the function for which the WCET is being estimated. Describe two approaches for generating valid and relevant inputs to an application.

(2 points)

f) Describe the notion of priority inversion and explain how priority inheritance reduces its effects.

(3 points)

Q2: Dependability and predictability

a) Boston Globe reported on December 10th 2015: "The Red Line train out of Braintree Station had already blown through three stops when the lights flickered out and the wheels slowly rolled to a stop. Yet not a word of explanation had come from the conductor — for a very good reason. When passengers looking for answers forced open the door to the operator's cabin, nobody was there.

Pulling out of Braintree around 6:08 a.m., the runaway train carrying about 50 people passed without stopping through the Quincy Adams, Quincy Center, and Wollaston stations on a 9-minute and more than 5-mile trip, before MBTA officials managed to stop it past North Quincy Station by cutting power to the third rail.

Officials explained Thursday that while the train was parked in Braintree, the driver reported a signal problem and requested permission to put his train into "bypass mode," which allows the train to move even if it has not received the right signal. Trains occasionally operate in this mode, Pollack said, saying that it is safe under the proper procedures.

To enter bypass mode, the driver had to leave the train to throw a toggle switch, said Jeff Gonneville, the MBTA's chief operating officer. That was when the train left without him. Gonneville said MBTA procedures require operators to set two brakes before leaving the train. Pollack would not say whether the brakes were set, saying that was a matter for the ongoing investigations."

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 purpose of MEDL in a TTP bus architecture, and which part of the hardware architecture is it stored in?

(2 points)

b) Consider a set of four messages to be transmitted on a CAN bus (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	10	1
m_2	High	5	2
m_3	Medium	30	1
m_4	Low	50	4

(3 points)

c) Consider an application in which the main fault model is the presence of faults arising in the manufacturing process of the (cheap) hardware circuits. Which fault tolerance method would you consider as a means of mitigating a potential error?

(2 points)

Q4: Application design & RTOS

a) When designing a complex system, dividing 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 systems difficult?

(2 points)

b) Describe how a real-time operating system can support the functions for static and dynamic memory management used by a real-time application.

(4 points)

Q5: Distributed systems, Quality of Service (QoS)

a) Take a stand on the following statement, motivating your answer by referring to the relevant terminology discussed in the course literature:
   - Packet loss and link reliability are two QoS indicators for achieving the *same* QoS requirement.

(2 points)

b) Describe the notion of skewness as defined mathematically in the context of adaptive load sharing in the paper by Xiao et al 2013.

(3 points)

c) Compare the benefits of external and internal clock synchronization algorithms to explain why you would choose one approach as opposed to the other.

(2 points)

Q6: Bonus points

a) In this question you state if you have any bonus points allocated to your attempts at bonus exercises 1, 2, and 3 during the course. Please sum up all three (if any) of your attempted exercises and write the total attained points here.

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

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

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

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

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