Thursday, May 12, 2005
2.30p.m. - 4.15p.m.

University of Glasgow

DEGREES OF M.Sc and PG Dip in Adv CS, M.Sci, M.Eng., B.Eng., B.Sc., M.A. and M.A. (Social Sciences)

COMPUTING SCIENCE M:
REAL TIME AND EMBEDDED SYSTEMS

(Answer 3 out of 4 questions.)

1. **(a)** There are several different algorithms for scheduling periodic tasks on a uniprocessor system. Those algorithms fall into two broad categories: clock-driven and priority-driven. Discuss the relative advantages and disadvantages of the two categories of algorithm, explaining when it is appropriate to use a clock-driven scheduler and when one would expect to use a priority-driven scheduler.

[6]

(b) Consider a system of four independent preemptable periodic tasks:

$$T_1 = (5, 2),\ T_2 = (4, 1),\ T_3 = (10, 1), \text{ and } T_4 = (20, 3)$$

All jobs have phase equal to zero, and relative deadline equal to their period. Construct a cyclic schedule for these tasks, demonstrating that the system meets all deadlines.

[2]

(c) A number of aperiodic jobs are to be added to the system from part (b). Explain how those aperiodic jobs could be scheduled, and the limitations of this approach.

[2]

(d) The four independent preemptable periodic tasks described in part (b) are to be re-implemented on a system that supports priority scheduling. Which priority-scheduling algorithm would you prefer: rate monotonic or earliest deadline first? Justify your answer.

[5]

(e) A number of aperiodic jobs are to be added to the priority-scheduled system from part (d). There are several different mechanisms could be used to schedule those jobs. Which mechanism would you chose? Explain and justify your answer.

[5]

2. **(a)** Consider a system of three independent preemptable periodic tasks:

$$T_1 = (8, 1),\ T_2 = (4, 3),\ \text{and}\ T_3 = (12, 1)$$

All jobs have phase equal to zero, and relative deadline equal to their period. Can this system be scheduled using the earliest deadline first algorithm? Explain your answer.

[2]

(b) Can the system from part (a) be scheduled using the rate monotonic algorithm? Explain your answer.

[2]

(c) A sporadic job that requires three units of execution time with relative deadline of 10 times units is released into the system from part (a) at time 7. Both the periodic and sporadic jobs are scheduled using the earliest deadline first algorithm; the system implements an acceptance test for new sporadic jobs. Is this sporadic job schedulable? Justify your answer and explain how the acceptance test would work.

[8]

(d) Describe how you might support execution of sporadic jobs as part of a system of periodic tasks that are scheduled using the rate monotonic algorithm. Your answer should describe how the sporadic jobs are scheduled, and outline – at the conceptual level – the operation of the acceptance test.

[8]

3. You work for a company that is trying to deploy a real-time streaming audio application within an IP network. This application comprises a proprietary and closed-source server running on dedicated hardware, and a proprietary client running on a popular operating system. The server communicates with the clients using UDP/IP flows, one for each client. You are unable to change the clients or server, but have control over – and the ability to change – the network.

(a) During testing of the application, you observe that the audio playback is frequently disrupted, with gaps occurring in the output and variations in quality. On complaining to the vendor, you are told that the application works correctly, and that the problem is due to your network. Explain how and why the behaviour of the network might impact the application's performance.

[4]

(b) Some of the routers in your network support weighted fair queuing. Can this be used to help the performance of the application? How will it affect the other applications running on your network? Justify your answer.

[2]

(c) Explain the operation of the weighted fair queuing algorithm. Your answer should include a diagram showing the flow of packets through the router, and an explanation of how packets are queued and how the queues are serviced. You may need to refer to the "finish number" of packets, but you do not need to explain how the finish number is calculated. Highlight the features of the weighted fair queuing algorithm that are beneficial to the performance of the streaming audio application

[8]

(d) The remainder of your routers in your network support weighted round robin scheduling of network packets, but not weighted fair queuing. Can you use the weighted round robin scheduling to improve the performance of the streaming audio application? Justify your answer.

[2]

(e) Explain how the behaviour of the traffic flows traversing the network path using weighted round robin scheduling might differ from the performance of the traffic that traverses the path using weighted fair queuing. Explain how the load on the routers using weighted round robin might differ from the load on the routers using weighted fair queuing. Justify your answers.

[4]

4. You work for a company that builds "set-top boxes" which decode digital TV broadcasts. These run some periodic real-time tasks (the video decoder) and some aperiodic tasks reacting to user input (e.g. the programme guide). Although packaged as a consumer appliance, they are built using standard PC hardware and have much the same capabilities as an ordinary desktop computer. The company has decided to use Linux as the operating system for this product, since it provides a convenient development platform, runs a range of useful applications and libraries, and provides the POSIX 1003.1b extensions for real-time programming.

(a) Explain how this choice of operating system impacts the choice of possible scheduling algorithms that can be used for periodic tasks in the real-time parts of the system, and how it may impact the performance of those algorithms.

[4]

(b) You have been tasked with developing the programme guide, an aperiodic task that runs in response to user input and displays an on-screen listing of current TV shows. It is desired that the programme guide responds to commands from the user quickly, but there is no hard deadline on its response time. Given that the system must run on a general-purpose operating system with only the POSIX real-time extensions, which scheduling algorithm would you choose for the programme guide task? Explain why this is an appropriate choice.

[3]

(c) Your programme guide has been implemented on the Linux-based set-top box. In testing, it is found that the periodic video decoder task, running with real-time priority, sometimes misses its deadlines when your programme guide is active. Explain why this might occur.

[2]

(d) If you were implementing the programme guide on an operating system that could support any scheduler you desired, what scheduling algorithm would you choose? Justify your answer.

[3]

(e) After considering these issues, the company is considering moving the system to the RTLinux platform instead, since it implements a simple two-level scheduler abstraction and is claimed to provide better real-time performance. Describe the two-level scheduler abstraction, and explain how it works

[5]

(f) Explain why an operating system using a two-level scheduler to separate real-time and general-purpose tasks might offer better real-time performance than a general-purpose operating system with real-time extensions.

[3]