ECE 8823a Take-Home Exam

Due Date: October 16, 2007; 3:00 PM

Instructions: This exam is to be completed on your own without discussing it with any one other than the Professor. You may use any reference materials you like in completing the exam but you must list the materials that you consulted below. It is not necessary to list class notes nor the papers distributed to the class nor the ARM books placed on reserve in the library as reference materials.

I, __________________, hereby state that I did not discuss this exam with any person other than Professor Blough and that I used only the following reference materials in preparing my solution:

__________________________________________  ____________________
(Signature)                                      (Date)
1) 25 points

Consider a wireless multi-hop network with the given topology:

![Network Diagram]

Assume that:
- channel bandwidth is 5 Mb/s and all transmissions take place on the same channel
- the distance between any 2 neighboring nodes is $d$ and the transmission range for every node is $1.5d$
- $S_1$ sends data to $D_1$ at 5 Mb/s along path $e_1$, $e_2$, $e_3$
- $S_2$ sends data to $D_2$ at 5 Mb/s along path $e_4$, $e_5$
- protocol overhead is zero, i.e. assume that 2 neighboring nodes can communicate data at the full channel bandwidth when no other communications are taking place

a) Calculate the maximum aggregate throughput attainable with the protocol interference model for random networks. Assume $\Delta = 0.1$.

b) Calculate the maximum aggregate throughput attainable with the physical interference model for random networks. Assume $\alpha = 3$, $\beta = 2$, and there is no noise.

2) 25 points

In the random waypoint model, the steady-state average velocity for nodes that are moving has been shown to be $(v_{\text{max}} - v_{\text{min}}) / \ln (v_{\text{max}} / v_{\text{min}})$, where $v_{\text{min}}$ and $v_{\text{max}}$ are the minimum and maximum velocities, respectively. For a pause time of $t_{\text{pause}}$ and a region of size $D \times D$, derive the expected fraction of nodes that are moving in the steady state. Evaluate your expression for $v_{\text{min}} = 1 \text{ m/s}$, $v_{\text{max}} = 10 \text{ m/s}$, $t_{\text{pause}} = 10 \text{ s}$, and $D = 50 \text{ m}$, and compare this to the fraction that you would expect near the beginning of a random waypoint simulation (say, 2 minutes into the simulation for the given parameters).
3) 25 points
a) Convert the following 16-bit Thumb instructions into their corresponding 32-bit ARM instructions:
   
   SUB R3, #15
   001 11 011 00001111
   
   BNE LOOP
   1101 0001 11101010
   
   ASR R6, R1
   010 000 0100 001 110

b) Write a program using the ARM instruction set to copy \( k \) words from one part of memory to another. Assume that the value of \( k \), the starting address to copy from, and the starting address to copy to are stored in 3 of the general-purpose registers. Use as few instructions as possible.

4) 25 points
Consider a system in which \( k \) jobs, \( J_1, J_2, \ldots, J_k \), are executed periodically every \( T \) seconds. Each job, \( J_i \), has an execution time \( t_i \), the time it takes to execute when the processor is at full speed, and a deadline \( d_i \), the time by which it must be completed (measured from the start of the current period). The earliest deadline first (EDF) scheduling algorithm schedules the jobs in order by increasing deadline. Now, consider a situation where the processor has dynamic voltage and frequency scaling (DVFS) capability. Assume that the maximum clock frequency is \( f \) and the processor can be set to one of \( m \) frequencies, \( f/m, 2f/m, \ldots, (m-1)f/m, f \).

a) Write pseudo-code for a modified EDF scheduling algorithm, which maintains the same job order as EDF and generates a schedule and frequency settings that produce the smallest possible time-averaged frequency while still allowing all jobs to complete by their deadlines. The output of your algorithm should be the start times and frequency settings for each job. The frequency can be changed only when switching from one job to another, i.e. a given job must execute at the same frequency during its entire execution. The time-averaged frequency is defined only over the non-idle times in the schedule. For example, if a schedule consists of \( J_3 \) executing for 10 msec at frequency \( f \), \( J_1 \) executing for 5 msec at frequency \( f/2 \), \( J_2 \) executing for 20 msec at frequency \( f/4 \), and idle time for 8 msec, the time-averaged frequency is: \((10f + 5f/2 + 20f/4)/35 = f/2\). Prove that your algorithm produces the lowest possible average frequency.

b) What is the time complexity of your scheduling algorithm from a) in terms of \( k \) and \( m \)? Do you think that there is a more efficient way to solve this problem while still producing the minimum average frequency? Why or why not?