Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.826 Principles of Computer Systems

PROBLEM SET 4

Assigned: March 6, 2006 Due: March 8, 2006

Problem 1: Bounding Mean Execution Time (20 points)

In this problem, you are to specify a service which guarantees a bounded mean execution time for long-enough executions. In particular, your spec should admit the set of executions of `TimedP` which either have fewer than `N` executions or have a mean execution time of at most `T`.

```
VAR now : Time
    ...

THREAD Clock() = ...

PROC TimedP() = ...
```

As in the block of code from page 3 of Handout 10, the advance of real time should be modeled as being under the control of the system.

Problem 2: Reliable FIFO Buffer (15 points)

Consider the following specification for a reliable FIFO buffer:

```
MODULE Buffer[M] EXPORT put, get = % M = message
    TYPE Q = SEQ M

    VAR q := {}

    APROC put(m) = << q := q + {m} >>
    APROC get() -> M = << VAR m | m = q.head => q := q.tail; RET m>>
END Buffer
```

Assume that `M` is four bytes in size.

(a) (10 points) Write a specification for this buffer that enforces *upper* bounds of 10ms and 250MB/s, respectively, on the buffer latency and throughput.

(b) (5 points) Give an abstraction function from your specification to `Buffer`.

To give specifications that talk about real time, you should use the `TimedP` code from page 3 of Handout 10 and equate clock ticks to some unit of real time.

Problem 3: Widgets (15 points)

Ben Bitdiddle has quit MIT and started a .com selling widgets like it's 1999. His webserver is a 1200 MIPS machine, with a hard disk bandwidth of 50MB/s and latency of 6ms. Each widget transaction requires 200K instructions, and writes a total of 4KB of data to disk.

(a) (5 points) Ben wishes to balance the speed of the processor with the speed of the disks. How many disks should Ben use to accomplish this if the load on the disks is perfectly balanced?

His e-business online and thriving (I said it was like 1999!), Ben modifies his server to batch the transactions' disk I/O in groups of 10. Batched transactions are read and written sequentially to disk.

(b) (5 points) Now how many disks does Ben require to balance the speed of the processor with the speed of the disks?

(c) (5 points) At what rate can Ben's modified web server handle widget transactions in the steady state, using just a single disk?

Problem 4: Resource Allocation (20 points)

Consider a task which first uses CPU, then uses the disk. This task is evaluated on a set of 10 benchmarks, each of which is normalized to run for the same time t_0. We evaluate the system by taking the mean performance over the 10 benchmarks. Upgrading the CPU reduces the running time of benchmarks 1-5 to $(1-x)t_0$ where $0 < x < 1$, and does not affect the running time of benchmarks 6-10; on the other hand, upgrading the disk reduces the running time of benchmarks 7-9 to $(1-y)t_0$ where $0 < y < 1$, and doesn't affect any other running times. Your budget allows you to upgrade either the CPU or the disk, but not both.

(a) (10 points) For what values of x and y is upgrading the CPU better than upgrading the disk; for what values is upgrading the disk better; and for what values do we get identical results?

(b) (10 points) Is there a value of x that guarantees that upgrading the disk can never be better than upgrading the CPU? Is there a value of y that guarantees that upgrading the CPU can never be better than upgrading the disk? If so, what are these values?