Operating Systems

Instructions:
For the **BREADTH** exam: Answer any 4 of questions 1-6.
For the **DEPTH** exam: Answer any 4 of questions 1-6 *and* 3 of questions 7-10. You are expected to spend about two hours on each half of the exam.

BREADTH QUESTIONS

Breadth 1. Disk Allocation:

Two common strategies for free space management on disks are *free lists* and *bit maps*.

(1a) One naive algorithm uses a simple linked list of free blocks. Each free block contains the disk address of the next block on the list. What's wrong with this strategy? How could you improve on it?

(1b) Why might you prefer to use a bit-map strategy rather than a free list? What are the tradeoffs between the two strategies?

Breadth 2. Synchronization:

When Dijkstra introduced semaphores, there was already a closely related synchronization primitive in use called an *event* variable. There are two operations on event variables: **await**(*e*) always blocks the caller, while **cause**(*e*) awakens the process that has been waiting the longest on event variable *e*. If no process is blocked on *e*, **cause**(*e*) has no effect.

(2a) Why are semaphores more convenient to use than event variables?

(2b) Event variables are very similar to *condition* variables in monitors. What is it about monitors that mitigates the problems discussed in part (a)?

(2c) Show how to implement semaphores using event variables, ordinary shared integer variables, and a test-and-set instruction.

Breadth 3. Medium-Term Scheduling

(3a) Medium-term scheduling is primarily concerned with the management of which physical resource?

(3b) A scheduler needs a *policy* to decide what to do, and a *mechanism* to do it with. What is the basic mechanism used by medium-term scheduling?

(c) Describe a reasonable policy for medium-term scheduling of very large jobs when lots of small jobs also exist.

Breadth 4. Security:

Securely accessing a service across the network involves (1) authenticating the parties involved, and (2) having a private communication between the parties.

(4a) Which of these two problems is addressed by the Needham and Schroeder protocol? Describe the protocol and how it solves the problem.

(4b) How can you solve the remaining problem?

Breadth 5. Message Passing:

Copying of buffers can be a major cost in sending messages, especially when sending remote messages (i.e., messages sent from a process on one host to a process on another host.

(5a) Where, in the course of sending a remote message, are messages copied?

(5b) How can you use the memory organization and memory mapping hardware to eliminate some of this copying?

Breadth 6. Memory Management:

The WSclock algorithm (in part) is an approximation to Working Set.

(6a) In what ways is the approximation more efficient to implement than pure Working Set?

(6b) Under what conditions will WSclock provide a good approximation of Working Set and what conditions will it provide a poor one?

DEPTH QUESTIONS

Depth 7. Networking:

Tanenbaum discusses two versions of sliding window protocols that he calls "go back *n*" and "selective repeat." However, he seems to be confusing two different dimensions in protocol design: receiver window size and ack semantics. The receiver window size is the amount of space the receiver has to buffer frames before passing them off to the higher layer; if the window size is 1, out-of-order frames are discarded. Ack semantics may be either *cumulative* or *individual*. A cumulative ack for frame *n* acknowledges all frames with sequence numbers less than or equal to *n*. An individual ack acknowledges only frame *n*.

Let r be the round-trip delay, t be the retransmission timeout ($t > r$), f be the frame size in bits, and ρ be the data rate in bits/sec. Assume one-way data flow, with "naked" acks of insignificant size. Calculate the total amount of channel capacity (in bits) wasted when a single frame is garbled in transmission under the following assumptions. (Assume the error rate is low enough that garbled frames are isolated events.) Justify your answers!

(7a) Receiver window size is 1.

(7b) Receiver window size is arbitrarily large and acks are cumulative. How big does the receiver window have to be to ensure maximum throughput and avoid dropping any frames other than the one that is garbled? Can the sender adjust its retransmission strategy to take advantage of the large receiver window if it knows about it?

(7c) Receiver window size is arbitrarily large and acks are individual.

Depth 8. Virtual Machine:

To implement a virtual machine, all operations that access hardware resources must be *virtualizable*. In user mode, the Motorola 68000 permitted read-only access to the status register, which contains the interrupt mask, the user/supervisor mode bit, and the trace bit, among other things. This was changed on the Motorola 68010 to deny all access to the status register during user mode. Attempting to access the status register in user mode causes a privilege violation exception (interrupt/trap).

(8a) Explain why the change was necessary to support virtual machines.

(8b) Describe how an OS running on a virtual machine would access the real status register. Include both hardware and virtual machine software operations.

Depth 9. File Servers

File servers can improve performance by caching file contents.

(9a) Files might be cached by blocks or by whole files. What are the advantages and disadvantages of each of these techniques.

(9b) Describe three places (in either the client or server) that these caches can be used. Also describe the advantages of each type of caching.

Depth 10. Process Migration

A process migrates from the *old* host to the *new* host.

(10a) In a message based operating system, after a process have migrated, messages sent to that process have to be sent to the new host. Describe two methods that processes who are currently communicating with the migrated process can use to find its new location. What are the advantages and disadvantages of these methods?

(10b) If the difference between the clocks on the old and new host is large, what problems could this cause? How can you get around this problem?