University of California, Berkeley
College of Engineering
Computer Science Division — EECS

Fall 2005 John Kubiatowicz

Midterm II

December 5th, 2005

CS162: Operating Systems and Systems Programming

Your Name:	
SID Number:	
Circle the letters of CS162 Login	First: a b c d e f g h I j k l m n o p q r s t u v w x y z Second: a b c d e f g h I j k l m n o p q r s t u v w x y z
Discussion Section:	

General Information:
This is a **closed book** exam. You are allowed 1 page of **hand-written** notes (both sides). You have 3 hours to complete as much of the exam as possible. Make sure to read all of the questions first, as some of the questions are substantially more time consuming.

Write all of your answers directly on this paper. *Make your answers as concise as possible.* On programming questions, we will be looking for performance as well as correctness, so think through your answers carefully. If there is something about the questions that you believe is open to interpretation, please ask us about it!

Problem	**Possible**	**Score**
1	20	
2	20	
3	20	
4	20	
5	20	
Total		

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3.14159265358979323846264338327950288419716939937510582097494 4

Problem 1: True/False

In the following, it is important that you *EXPLAIN* your answer in TWO SENTENCES OR LESS (Answers longer than this may not get credit!). Also, answers without an explanation *GET NO CREDIT*.

Problem 1a[2pts]: In a modern operating system using memory protection through virtual memory, the hardware registers of a memory-mapped I/O device can only be accessed by the kernel.

True / False
Explain:

Problem 1b[2pts]: Using the TCP/IP protocol over an unreliable network, the receiver can receive the same IP packet multiple times.

True / False
Explain:

Problem 1c[2pts]: With the NFS distributed file system, it is possible for one client to write a value into a file that is not seen by another client when reading that file.

True / False
Explain:

Problem 1d[2pts]: The fastest way to send a large document securely to a third party that you have not interacted with yet is to encrypt it with their public key. Assume you know everyone's public key.

True / False
Explain:

Problem 1e[2pts]: The IP-v4 standard permits 2^{32} different hosts to talk directly with one another without requiring any network address translation.

True / False
Explain:

Problem 1f[2pts]: A "broadcast network" is one which uses radio-frequency transmissions to send data from one party to another.

True / False
Explain:

Problem 1g[2pts]: The best way to correct virtual memory thrashing is to increase the overlap between I/O and computation, namely by increasing the number of runnable threads.

True / False
Explain:

Problem 1h[2pts]: A Remote Procedure Call (RPC) can be used to call a procedure in another process on the same machine.

True / False
Explain:

Problem 1i[2pts]: The complexity of handling software TLB faults increases when exceptions are imprecise.

True / False
Explain:

Problem 1j[2pts]: TCP/IP must wait for a timeout in order to start retransmitting lost data, since it has insufficient information about which packets are lost before then.

True / False
Explain:

Problem 2: Paging and Virtual Memory

Suppose that we have a 64-bit virtual address split as follows:

6 Bits [Segment ID]	11 Bits [Table ID]	11 Bits [Table ID]	11 Bits [Table ID]	11 Bits [Page ID]	14 Bits [Offset]

Problem 2a[2pts]: How big is a page in this system? Explain in one sentence.

Problem 2b[2pts]: How many segments are in this system? Explain in one sentence.

Problem 2c[2pts]: Assume that the page tables are divided into page-sized chunks (so that they can be paged to disk). How much space have we allowed for a PTE in this system? Explain in one sentence.

Problem 2d[2pts]: Show the format of a page table entry, complete with bits required to support the clock algorithm and copy-on-write optimizations.

Problem 2e[2pts]: Assume that a particular user is given a maximum-sized segment full of data. How much space is taken up by the page tables for this segment? Explain. *Note: you should leave this number as sums and products of powers of 2!*

Problem 2f[4pts]: Suppose the system has 16 Gigabytes of DRAM and that we use an inverted page table instead of a forward page table. Also, assume a 14-bit process ID. If we use a *minimum-sized* page table for this system, how many entries are there in this table? **Explain.** What does a page-table entry look like? (round to nearest byte, but support clock algorithm and copy on write).

Problem 2g[2pts]: As mentioned in one of the lectures on distributed security, a common attack point for Internet worms is to exploit a buffer-overrun bug to execute code on the stack of the victim program. What can we add to the PTE to prevent this problem and how should we use it (use no more than two sentences)?

Problem 2h[4pts]: What is the FIFO page replacement algorithm? Explain *in one or two sentences* why this is a bad algorithm for page replacement. Explain what makes the clock algorithm different from a FIFO page replacement algorithm (even though pages are examined for replacement in order) and how it is superior to FIFO.

Problem 3: Disk Subsystem

Suppose that we build a disk subsystem to handle a high rate of I/O by coupling many disks together. Properties of this system are as follows:

- Uses 10GB disks that rotate at 10,000 RPM, have a data transfer rate of 10 MBytes/s (for each disk), and have an 8 ms average seek time, 32 KByte block size
- Has a SCSI interface with a 2ms controller command time.
- Is limited only by the disks (assume that no other factors affect performance).
- Has a total of 20 disks

Each disk can handle only one request at a time, but each disk in the system can be handling a different request. The data is not striped (all I/O for each request has to go to one disk).

Problem 3a[4pts]: What is the average *service time* to retrieve a single disk block from a random location on a single disk, assuming no queuing time (i.e. the unloaded request time)? *Hint: there are four terms in this service time!*

Problem 3b[3pts]: Assume that the OS is not particularly clever about disk scheduling and passes requests to the disk in the same order that it receives them from the application (FIFO). If the application requests are randomly distributed over a single disk, what is the bandwidth (bytes/sec) that can be achieved?

Problem 3c[2pts]: Suppose that the application has requests outstanding for all disks (but they are still randomly distributed, handed FIFO to disks), what is the maximum number of I/Os per second (IOPS) for the whole disk subsystem (an "I/O" here is a block request)?

Problem 3d[4pts]: Assume that the application cannot alter the random nature of its disk requests. Explain how the operating system could use scheduling to increase the IOPS. What does the application have to do in order to allow this type of optimization?

Problem 3e[2pts]: Taking this idea of (3d) to its limit, what is the absolute maximum number of IOPS that we could ever hope to get (this will be an upper bound, not really reachable)

Problem 3f[5pts]: Treat the entire system as an M/M/m queue (that is, a system with m servers rather than one), where each disk is a server. All requests are in a single queue. Assume that the system receives an average of 800 I/O requests per second. For simplicity, assume that any disk can service any request. Assuming FIFO scheduling by the OS again, what is the mean response time of the system? You might find the following equation for an M/M/m queue useful:

$$\text{Server Utilization } (\zeta) = \frac{\lambda}{\frac{1}{\text{Time}_{\text{server}} / m}} = \lambda \times \frac{\text{Time}_{\text{server}}}{m}$$

$$\text{Time}_{\text{queue}} = \text{Time}_{\text{server}} \times \left[\frac{\zeta}{m(1-\zeta)} \right]$$

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Problem 4: Potpourri

Please keep your answers short (one or two sentences per question-mark). *We may not give credit for long answers.*

Problem 4a[2pts]: Under what circumstances would you use Byzantine Agreement instead of two-phase commit?

Problem 4b[4pts]: Assume that you have a RAID-5 system with five disks. One of the disks fails. Explain how the operating system can continue to satisfy block reads for that disk. Can the system deal with two failures? Why or why not?

Problem 4c[3pts]: Given the RAID system of (4b), suppose that the bad disk is replaced by a new disk. What must be done to get the system back to the way it was before the disk went bad?

Problem 4d[3pts]: How can you use public key encryption to securely distribute a secret key (for symmetric key encryption) between two parties?

Problem 4e[4pts]: The UNIX BSD 4.1 inode structure is intended to support both small files (e.g. a couple of KB) and large files (e.g. up to some number of GB). Briefly describe the mechanism employed to achieve this. Are small files or large files handled more efficiently?

Problem 4f[4pts]: Suppose that the primary access pattern for files is sequential, large file access. If the primary goal is to access these files at the highest possible rate, explain (1) how files should be constructed from blocks and (2) how blocks of the file should be laid out on the disk.

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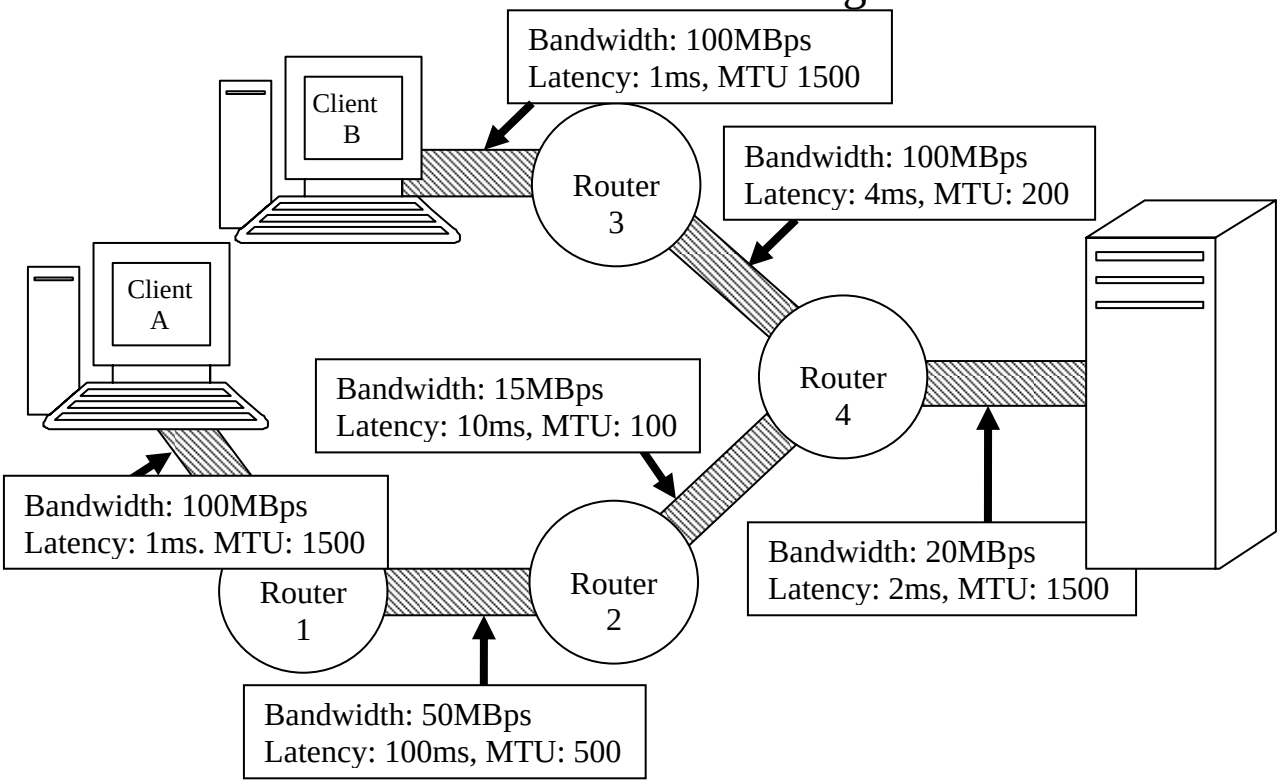
Problem 5: Networking



The above figure illustrates a network in which two clients (Client A and Client B) route packets through the network to the server. Each link is characterized by its Bandwidth, one-way Latency, and Maximum Transfer Unit (MTU). All links are full-duplex (can handle traffic in both directions at full bandwidth).

Problem 5a[4pts]: Under ideal circumstances, what is the maximum bandwidth that Client A can send data to the server without causing packets to be dropped (Assuming that the headers are of zero length)? How about Client B? Explain.

Problem 5b[4pts]: Keeping in mind that TCP/IP involves a total header size of 40 bytes (for TCP + IP), what is the maximum *data* bandwidth that Client A could send to the server through TCP/IP? Explain.

Problem 5c[4pts]: Assume that Client A sends a continuous stream of packets to the server (and no other clients are talking to the server). How big should the send window be so that the TCP/IP algorithm will achieve maximum bandwidth without dropping packets? Explain. *Hint: don't forget to account for the 40 bytes of header.*

Problem 5d[4pts]: Assume that Clients A and B both send a continuous stream of packets to the server simultaneously. Assume that Bandwidth is shared equally on shared links. What must the sizes of their send windows be so that packets are not dropped? Explain.

Problem 5e[4pts]: Consider the situation of (5d). If the server is sending data back to Clients A and B at full rate, do the acknowledgements for data headed to the clients decrease the bandwidth in the forward direction (clients→server)? State your assumptions and explain your answer.

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