Name: _____ Email: _____ 3-digit ID: _____

Systems Breadth Exam

September 13, 2006

Please read the following instructions carefully before answering the questions.

This is a closed-book, closed-notes, written examination. You must answer all questions in the "core" section and the questions in the other two sections you have selected. The total time of the examination is three hours. Write your name and email address on this paper. Also choose a 3-digit ID and fill in the space provided. Write your answers on the blank sheets provided. Use only one side of each sheet and start each section with a new sheet. Write the 3-digit ID you have chosen on the top of each answer sheet.

1 Core

1. Data representation

   (a) One's complement representation of integers has two representations for the number 0. True or false?

   (b) One can always convert a 32-bit integer into a 32-bit floating-point number without loss of precision. True or false?

   (c) Express the number whose octal representation is `325542704` in binary.

2. Data structures

   (a) It is possible to code a recursive routine such as tree traversal or Quicksort without using recursive procedures. True or false?

   (b) When people talk about storing information *on the heap*, they are talking about one data structure. When they talk about storing information *in a heap* they are talking about another data structure. What are these two data structures?

3. Boolean algebra

   Consider this truth table:

A	B	C	output
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

   (a) Write the function represented by this truth table as a Boolean combination of A, B, and C. Make your function as simple as you can.

   (b) Draw a circuit using only **AND**, **OR**, and **NOT** gates to implement this truth table.

4. Operating Systems

   (a) In a computer that uses paging, virtual address are considered to have two parts, the page number and the offset within the page. Is the page number part composed of the high-order or the low-order bits of the virtual address?

   (b) What would be the effect of designing paging hardware that made the opposite choice to your answer in the previous question?

   (c) The ABCXYZ computer has main memory that takes 100 ns to access. There is an on-board L2 cache that takes 20 ns to access. There is also an on-chip L1 cache that takes 5 ns to access. If 90% of all accesses are satisfied by the L1 cache, 6% by the L2 cache, and the rest by the main memory, what is the effective memory-access time?

   (d) An operating-system kernel designed for a multiprocessor certainly needs to worry about critical sections. But why does a kernel designed for a uniprocessor also need to worry about them?

2 Distributed/Advanced Operating Systems

1. Show by means of an example why the existence of a cycle in the resource allocation graph is not sufficient for the existence of deadlock. Present a simple algorithm for preventing deadlocks in a distributed system. Discuss the advantages and disadvantages of your algorithm.

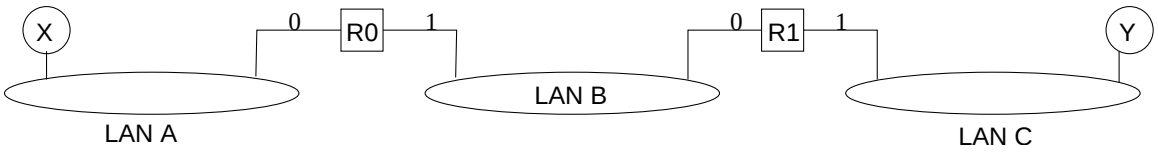
2. Describe the Lamport's "happened before" relation between events in a distributed system. Does Lamport's timestamp help in capturing the "happened before" relation? Justify your answer. If your answer is "no", what other mechanism can be used to capture Lamport's "happened before" relation. Explain in detail why that mechanism will work.

3. If you were to design and implement a replicated file system, what are the issues you need to consider. Enumerate and explain the issues. Present a method for implementing a replicated file system which addresses all these issues.

3 Networks

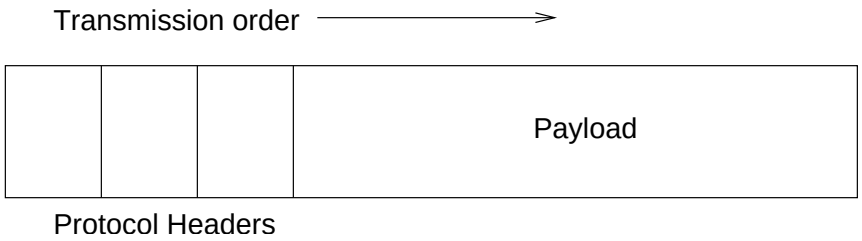
1. The figure below shows a portion of an Internetwork. The IP addresses and MAC addresses of the hosts and routers are shown below.

Interface	IP Address	MAC Address
Host X	130.207.8.101	0:1:2:3:4:5
Router 0 interface 0	130.207.8.1	1:2:3:4:5:6
Router 0 interface 1	128.163.200.44	7:6:5:4:3:2
Router 1 interface 0	128.163.202.55	6:5:4:3:2:1
Router 1 interface 1	20.21.22.1	3:3:3:3:3:3
Host Y	20.21.22.100	4:4:4:4:4:4



Suppose Host X opens a TCP connection to Host Y.

(a) Draw a diagram, similar to the box below, of the packet when it is first transmitted by Host X over LAN A. Label **all** protocol headers with the name of the protocol. The left side of the box corresponds to the first byte transmitted on the wire. For each header, indicate as well any **address information** that would appear in the header.



(b) Now draw the same kind of diagram, with the same information, only this time depict the packet as it travels across LAN C, i.e. when transmitted by Router R1.

2. This problem deals with Medium Access Control Protocols.

(a) Explain why Ethernet has a minimum frame size, and why it is 512 bits for 10-Mbps Ethernet.

(b) Explain why Ethernets have a maximum size, while Token Ring networks have a minimum size.

(c) Suppose the Ethernet transmission rate is increased by a factor of 10 (to 100 Mbps). What other parameters of the protocol have to change, and how?

3. Suppose nodes A and F have the forwarding tables below, in a network with six nodes (A–F) where all links have unit cost.

A's Table

Dest	Cost	NextHop
B	1	B
C	1	C
D	2	B
E	3	C
F	2	C

F's Table

Dest	Cost	NextHop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

(a) Draw a diagram of the *smallest* (fewest edges) network consistent with these values.

(b) Suppose the link between F and C goes down in this network. Assuming a distance-vector routing protocol is in use, describe what happens after that.

(c) Suppose a link-state protocol is in use, and the same link goes down. Describe what happens after that.

4. Throughput is the rate at which bytes can be transmitted through a channel, while latency is the delay experienced by any individual byte in passing through the channel. It is sometimes said that throughput and latency are independent. However, this is not true in all cases.

   (a) At the data link level (i.e., over a single hop), explain how increasing throughput will generally decrease latency.

   (b) At the Transport level, specifically in TCP, increasing latency will decrease throughput, in general. Explain why.

4 Compilers

1. In numerous programming languages one name can refer to different objects such as variables or functions. Explain how this ambiguity is resolved by a compiler and run-time storage organization.

2. Consider the following grammar G:

```
Expr --> - Expr
Expr --> (Expr)
Expr --> V ExprT
ExprT --> - Expr
ExprT --> empty
V --> x VarT
VarT --> (Expr)
VarT --> empty
```

   (a) Is `x - x((x))` a sentence in L(G)? Prove your answer.

   (b) Is this grammar redundant in the sense that one or more productions can be removed without changing the language?

   (c) Show FIRST(ExprT) and FOLLOW(ExprT).

   (d) Construct LL(1) table for G or give pseudocode for a set of functions implementing a recursive descent parser for G.