CS 6210 Fall 2020 Test 2

Name:_____GT Number:

Note:

1. **Write your name and GT number on each page.**
2. The test is **CLOSED BOOK** and **NOTES.**
3. Please provide the answers in the space provided. You can use scratch paper (provided by us) to figure things out (if needed) but you get credit **only** for what you put down in the space provided for each answer.
4. For conceptual questions, **concise bullets** (**not wordy sentences**) are preferred.
5. While it is NOT REQUIRED, where appropriate use figures to convey your points (a figure is worth a thousand words!)
6. **Illegible answers are wrong answers.**
7. **DON'T GET STUCK ON ANY SINGLE QUESTION…FIRST PASS: ANSWER QUESTIONS YOU CAN WITHOUT MUCH THINK TIME; SECOND PASS: DO THE REST.**

Good luck!

Question number	Points earned	Running total
0 (0 minutes) (Max: 2 pts)		
1 (10 minutes) (Max: 10 pts)		
2 (5 minutes) (Max: 5 pts)		
3 (5 minutes) (Max: 5 pts)		
4 (5 minutes) (Max: 5 pts)		
5 (5 minutes) (Max: 5 pts)		
6 (10 minutes) (Max: 10 pts)		
7 (10 minutes) (Max: 10 pts)		
8 (10 minutes) (Max: 10 pts)		
Total (60 minutes) (Max: 62 pts)		

0. **(0 min, 2 points)** (you get 2 points regardless of your answer)

Pre-exam quiz using Gradescope:
(a) I took it
(b) I procrastinated taking it (Kishore has said this is a good practice!)

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Lesson 5: Distributed Systems

1. **(10 min, 10 points) (Lamport's M.E. Algorithm)**

In a distributed system with N nodes, the communication among the nodes is constrained to use a ring topology. That is, node P_i sends messages ONLY to node $P_{(i+1) \bmod N}$. Assume that there are no loss of messages and the messages go in-order between any two nodes. The nodes use Lamport's logical clock to order the communication events.

Your co-worker is implementing Lamport's M.E algorithm in this system. Her goal is to minimize the amount of communication. She uses three types of messages in her implementation: LOCK, ACK, UNLOCK.

Answer the following questions:

(a) What should be the action at a node upon receiving a LOCK message?

(b) What should be the action at a node upon a receiving an ACK message?

(c) What should be the action at a node upon receiving an UNLOCK message?

(d) When does a node know that it has successfully acquired the LOCK?

(e) How many ACKS will a node receive before it knows that it has successfully acquired the LOCK? (No credit without justification)

2. **(5 min, 5 points) (Latency Reduction in RPC)**

Given the following:

- It takes 10 ms to perform a context switch at a node (i.e., switch from one process to another one)
- It takes 20 ms to communicate between the client and the server (includes all the OS protocol processing overheads at both ends and the network communication)
- It takes anywhere from 1 ms to 30 ms for the server procedure to execute

Your buddy is designing an RPC package. His goal is two-fold: (a) reduce the end-to-end latency for the RPC, (b) ensure that the processing resource at both the client and the server are fully utilized. What tips would you give him to accomplish both these objectives?

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3. **(5 min, 5 points) (Active Networks)**
You are the designer of the "capsule" mechanism in Active Network. You make the following design decision:

- upon receiving a capsule which the node has not seen before, the node requests the code for processing the capsule from the "prev" node contained in the capsule

What should be the action at a node if the "prev" node says it does not have the code? Justify your answer.

Lesson 6: Distributed Objects and Middleware

4. **(5 min, 5 points) (Spring Kernel)**
You are the implementor of the "subcontract" subsystem in the Spring kernel. On the client side, you have the following API calls available to the Client-side stub: Invoke; Marshall: Unmarshall

You want to optimize the "Marshall" call to exploit the location of the server. If the server is on the same machine as the client, how would you optimize marshalling the arguments of the call?

5. **(5 min, 5 points) (EJB)**
You have a startup to implement a portal for airline reservations. The clients come to you over an insecure wide-area network. These are the objectives which are your "secret sauce" for the startup:

- You want to exploit parallelism across independent client requests
- You want to exploit parallelism within each client request
- You want to protect your business logic from being exposed to the wide-area Internet

You are planning to use EJB for meeting these objectives. Your N-tier solution has a Web container, an EJB container, and a Database server. To meet the design objectives:
(a) What functionalities would you put into the Web container (that interfaces with the client browsers)?

(b) What functionalities would you put into the EJB container?

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Lesson 7: Distributed Subsystems

6. **(10 min, 10 points) (GMS)**
You are implementing the idea of paging to peer memories from GMS in a datacenter environment. There are 100,000 nodes in the datacenter. The datacenter has a scalable global file system which is available to all the nodes to use as a paging device. The implementation objectives you set for yourself are as follows:

- You want page fault service to take as little time as possible
- You want to be space efficient in the data structures to support your GMS implementation
- You want to be communication efficient in your GMS implementation
- You want to be resilient to failures of peer nodes

(a) One co-worker suggests using a replicated data structure at each node (functionally equivalent to a page table for managing virtual memory) that informs the faulting node which peer node has the page that it is looking for. What is the downside of this design choice with respect to the above implementation objectives?

(b) Another co-worker suggests broadcasting the faulting page details to all the peer nodes to quickly discover which node is currently hosting that page. What is the downside of this design choice with respect to the above implementation objectives?

(c) Disk writes are several orders of magnitude more expensive compared to writing the page to peer memory. A co-worker suggests skipping writes to the disk altogether at the time of page eviction from a node since the page is anyway being stored in a peer memory. What is the downside of this design choice with respect to the above implementation objectives?

(d) For page eviction using LRU, each node must know the "age" of each page in its local DRAM. A co-worker suggests intercepting each memory access from the CPU to collect this age information. What is the downside of this design choice with respect to the above implementation objectives?

(e) You decide that at the time of page fault, to make room for the incoming page, you will immediately send the evicted page to some peer memory as part of the page fault processing. What is the downside of this design choice with respect to the above implementation objectives?

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7. **(10 min, 10 points) (DSM)**
You are helping a friend implement an efficient page-based software DSM library in a local area network wherein the nodes are connected by 100 Gbps network links. The CPU architecture of the system uses a page size of 8KB. She is interested in achieving the following implementation objectives:

- Avoid false sharing
- Optimize consistency maintenance by overlapping computation with communication
- Increase the opportunity for concurrent execution of an application's threads when they are not needing mutual exclusion for shared memory access.
- Reduce the amount of data transferred between the nodes

You offer the following helpful suggestions to her:
(a) To keep the implementation simple, you suggest using sequential consistency as the memory model. What is the downside of this suggestion with respect to the above objectives?

(b) Another suggestion you make to simplify the implementation is to use the "page" as the unit of coherence maintenance. What is the downside of this suggestion with respect to the above objectives?

(c) You change your mind and suggest that she use "eager" release consistency memory model. What is the downside of this suggestion with respect to the above objectives?

(d) You change your mind yet again and suggest using "lazy" release consistency memory model. What is upside of this suggestion with respect to the above objectives?

(e) You suggest creating "diffs" of the pages a node modifies in a critical section and associate this information with the specific lock that a thread uses to make these modifications. What is upside of this suggestion with respect to the above objectives?

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8. **(10 min, 10 points) (DFS)**
You are implementing a disk-based distributed file system for the College of Computing. The environment is a LAN interconnected by 100 Gbps network links. You are given the following marching orders in terms of design objectives:

- Implement standard NFS stateless-server semantics
- Ensure ease of system administration (i.e., allow for churn in the user community)
- Ensure that no file server becomes a hotspot
- Reduce disk accesses as much as possible
- Use the available physical memory of the clients and servers to the fullest to enhance performance
- Assume no server failures

(a) You decide to host the files of the user community into distinct and disjoint partitions in different servers. How does this implementation decision relate to the design objectives?

(b) You decide to implement a file cache in DRAM. How does this implementation decision relate to the design objectives?

(c) For simplicity, you decide to keep the meta-data for the files at the server that hosts the files on its local disk. What are the downsides of this implementation decision?

(d) You change your mind and decouple the server location of the metadata for a file from the server that hosts the files on its local disk. How does this implementation decision relate to the design objectives?

(e) You decide to keep state information at the server on open files as to which client(s) have them in their respective DRAMs. How does this implementation decision relate to the design objectives?