

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 minute) (Max: 1 pts)		
1	(5 minutes) (Max: 8 pts)		
2	(5 minutes) (Max: 10 pts)		
3	(5 minutes) (Max: 9 pts)		
4	(5 minutes) (Max: 10 pts)		
5	(8 minutes) (Max: 10 pts)		
6	(3 minutes) (Max: 6 pts)		
7	(10 minutes) (Max: 16 pts)		
8	(10 minutes) (Max: 18 pts)		
9	(10 minutes) (Max: 12 pts)		
Total (61 minutes) (Max: 100 pts)			

0. (1 point, 0 minute) (you get 1 point regardless of your answer)

This test format:

- (a) increases my anxiety for test taking
- (b) reduces my anxiety for test taking
- (c) allows me to learn the material much better
- (d) makes me procrastinate getting ready for the test

Lesson 5: Distributed Systems

1. (8 points, 5 minutes) (Lamport's logical clock)

A student has implemented a distributed algorithm using Lamport's happened-before relationship to timestamp the events. She is in the middle of debugging the program. She observes the following events for each processor. Each event is tagged with the local timestamp recorded for the event on that processor following Lamport's logical clock.

P1's activities	P2's activities	P3's activities
1: msg-send (to ???)		1: local event
	2: msg-receive (from ??)	2: msg-send (to ??)
	3: msg-receive (from ??)	3: local event
	4: msg-send (to ??)	4: local event
5: msg-receipt(from ???)	5: msg-send (to ??)	
		6: msg-receive (from ??)

Please help her by identifying who is the sender/receiver for each message (namely, the sender, receiver, and the logical timestamp associated with that event).

In answering the question use the following format:

<processor-number>: <local-time>: msg-<send/receive> (<from>/<to>)

(e.g., P1: 20: msg-receive(P3) would mean P1 received a message from P3 at local time 20)

2. (10 points, 5 minutes) (Lamport's M.E. Algorithm)

3. (9 points, 5 mins) (Latency Reduction in RPC) [HIDDEN]

Lesson 6: Distributed Objects and Middleware

4. (10 points, 5 minutes) (Spring OS)

You are managing a subset of nodes in a cluster. You have chosen to use Spring as the network OS for the cluster. You must host the following services:

1. A PostGRES database server which is replicated on 3 nodes
2. A Web server on 3 nodes
3. A Web-server-load-balancer that does ensures equitable CPU utilization on all the servers for the client requests.
4. A PostGRES-load-balancer that does round-robin allocation of the servers for the client requests.

Each of the above servers and the load balancers are hosted on distinct nodes on the LAN. The clients are all on the same LAN and are expected to make requests to both the POSTGRES and Web service.

- (i) (6 points) For the above deployment to work as envisioned above,
- (a) list the subcontracts needed on the client machines.
 - (b) list the subcontracts needed on the Web-server-load-balancer
 - (c) list the subcontracts needed on the PostGRES-load-balancer

(ii) (2 points) You decide to beef up your web server with 2 more nodes. What changes will you need to make to ensure that the client requests can utilize the two new nodes?

(iii) (2 points) You now need to access the PostGRES database from the web service. What changes do you need to make to the system?

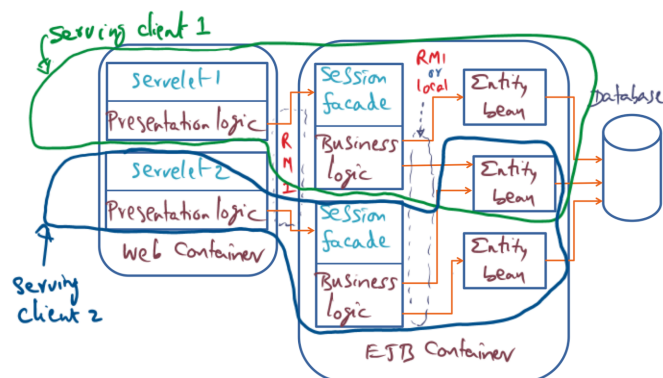
5. (10 points, 8 minutes) (EJB)

It is circa 2002. Yelp and Google Reviews don't exist yet. You're a developer and a foodie. You decide to build a restaurant review website that has the following functionalities:

1. Accept a restaurant name or a cuisine as input and display a list of restaurants with their ratings.
2. If a user clicks on a restaurant, they will be shown the reviews for the restaurant.
3. The user should be able to sort restaurants by distance from their location, and average review score.
4. Allow a user to post a review about a restaurant and store it in the database, along with some keywords (e.g., cuisine, ambience, etc.), which may or may not explicitly be provided by the user.

Now you realize that restaurant searches are hyper-local, so you only need to show the user the restaurants which are within a 15-mile radius. So, you decide to use the user's GPS location to filter results.

You decide to implement the system with the state of the art, i.e., EJB entity beans as shown below:



(i) (6 points) For the functionality that you need on the website, describe concisely what components go into the presentation logic, business logic and the entity beans.

(ii) (2 points) How would you optimize for latency for concurrent requests from users in the same location?

(iii) (2 points) You decide to open shop in India, where there are 22 official languages. You realize that restricting yourself to English might be a problem. Where in this framework would you add the functionality to render content in different languages? Justify your answer (No points without justification).

6. (6 points, 3 minutes) (Java RMI)

(i) (4 points)

Java RMI evolved from the Spring Subcontract mechanism. Name one similarity and one difference in the implementation of the two systems.

(ii) (2 points)

Java allows object references to be passed as parameters during object invocation. What is the difference in parameter passing (when a local object reference is passed as a parameter) while invoking a remote object using Java RMI?

Lesson 7: Distributed Subsystems

7. (16 points, 10 minutes) (GMS)

(i) (2 points)

Upon a page fault, GMS converts the VPN to a UID. The UID includes the IP-ADDR of an NFS server. Why?

(ii) (2 points)

Your friend suggests that the UID could be generated by simply prefixing the faulting VPN with the IP-ADDR of the source node and the PID of the faulting process. Will that work? Credit only if there is justification for your answer.

(iii) (2 points) (Answer True/False with justification)

For the geriatrics algorithm, it is straightforward to record the time of access to the virtual pages visited by a process during its execution.

(iv) (6 points)

Assume that there is a designated node (which never fails) in charge of additions/churns of the nodes participating in GMS. A new node joins the GMS.

(a) List the actions that ensue.

(b) What data structures of GMS will get modified as a result? Why?

(c) What data structures of GMS will not get modified as a result? Why?

(v) (4 points)

Your friend suggests implementing GMS with a replicated table in each node that gives the mapping UID -> <nodeid, pframe>.

(a) What work would need to be done on each page fault?

(b) What work would need to be done on each page eviction from a node.

8. (18 points, 10 minutes) (DSM)

(i) (2 points) (Answer True/False with justification)

For correctness of a multiprocess application using DSM running on a LAN cluster, a given virtual page should be mapped to the same physical frame number in each node.

(ii) (2 points) (Answer True/False with justification)

For correctness of a multiprocess application using DSM running on a LAN cluster, the size of physical memory on each node of the cluster should be the same.

(iii) (2 points)

Consider a DSM application that has no data races. It properly uses synchronization with mutual exclusion locks to safeguard access to shared data structures. The underlying DSM uses SC memory model with page level granularity for coherence. The application experiences poor performance. Explain why.

(iv) (4 points)

The data structures protected by a lock is in the purview of the application and the DSM system has no knowledge of this association. LRC ensures the coherence maintenance of the data structures protected by a lock to the point of lock acquisition. How is coherence maintenance achieved in LRC?

(v) (8 points)

In Treadmarks DSM system the following critical section is executed at a node N1:

```
Lock(L1);  
  
    Write to Page X;  
  
    // Assume that the page is not present at this node;  
  
    // Assume that there are three diff files for page X  
    // named,  $X_d^2$ ,  $X_d^3$ , and  $X_d^4$  in nodes N2, N3, and N4,  
    // respectively.  
  
    // Assume the sync causality for the lock L1 is  
    // N3 -> N2 -> N1 (i.e, this is the order of lock acquisition).  
  
Unlock (L1);
```

a) (2 points)

What actions would be carried out by Treadmarks at Node 1 before the critical section above is executed by N1?

b) (2 points)

Upon exiting the critical section what action would be carried out by Treadmarks at Node N1?

A little while later, Node N1 executes the following critical section. Assume that no other node acquired the lock L1 in the interim.

```
Lock(L1);
```

```
    Read page X;
```

```
    do some computation without changes to any pages;
```

```
Unlock(L1);
```

(c) (2 points)

What would be the action carried out by Treadmarks at Node 1 before the critical section above is executed by N1?

d) (2 points)

Upon exiting the critical section what would be the action by Treadmarks at Node N1?

9. (12 points, 10 minutes) (DFS)

Inspired by xFS, you and your classmate decide to implement a true distributed FS. In your implementation similar to xFS, the location of the files on the disks remain fixed (i.e., they are never migrated). However, you periodically assess the meta-data server activity on each node and redistribute the meta-data management to balance the load in the entire cluster. In your implementation you are using the same data structures as in the original xFS.

(i) (4 points)

You observe that there is a load imbalance in the system. You carry out a load re-distribution.

List the steps in your meta-data load re-distribution algorithm.

(ii) (4 points)

What data structures change as a result of the load re-distribution algorithm? Why?

(iii) (4 points)

What data structures do not change as a result of the load re-distribution algorithm? Why?