CS553 Spring 2018
Final Exam Study Guide

1. What are advantages of a non-blocking form of Send?
2. Name some advantages of distributed systems over centralized systems.
3. In many layered protocols, each layer has its own header. Surely it would be more efficient to have a single header at the front of each message with all of the control in it than to have so many separate headers. Why is this not done?
4. In this problem you are to compare reading a file using a single-threaded file server with a multi-threaded file server. It takes 16 msec to get a request for work, dispatch it, and do the rest of the necessary processing, assuming the data are in the block cache. If a disk operation is needed (assume a spinning disk drive with 1 head), as is the case one-fourth of the time, an additional 32 msec is required. What is the throughput (requests/sec) if a multi-threaded server is required with 4-cores and 4-threads, rounded to the nearest whole number?
5. Today's commodity processors have 1 to 32 cores, with some more exotic processors boasting 72-cores, and specialized GPUs having 5000+ CUDA-cores. About how many cores/threads are expected to be in future commodity processors in the next five years?
6. What is an advantage to blocking communication?
7. In what situation would non-blocking communication improve performance most?
8. What type of application should use an unbuffered communication approach?
9. What overheads are you limiting when using buffered communication?
10. Name a feature of the TCP communication protocol:
11. Name a technique that can be used to handle out of order packets efficiently?
12. Identify the function that cannot be used to implement a concurrent server.
13. Why is threading useful on a single-core processor?
14. Identify what a thread has of its own (not shared with other threads):
15. What is the advantage of OpenMP over PThreads?
16. Do more threads always mean better performance?
17. Is super-linear speedup possible?
18. Why would a layered protocol be preferred over a monolithic system?
19. What is an advantage to a connectionless oriented protocol compared to a connection-oriented protocol?
20. What form of a data stream is needed to handle archival video streaming?
21. What form of a data stream is needed to handle live 2-way audio streaming?
22. What is the purpose of the scheduler in a distributed system?
23. What are the advantages of centralized scheduling? What are the disadvantages of centralized scheduling?
24. Why do we need distributed scheduling?
25. You have a cluster with 1000 compute nodes. You have a centralized scheduler that can schedule 10 tasks per second. What is the smallest granularity of task lengths that your scheduler can support in order to achieve high system utilization?
26. You have a cluster with 1000 compute nodes. You have a distributed scheduler that has 1000 schedulers, and each scheduler can process 1 task per second. What is the smallest granularity of task lengths that your scheduler can support in order to achieve high system utilization?
27. Name a distributed system framework that implements a centralized scheduler?
28. A user is in front of a browser and types in www.google.com, and hits the enter key. Think of all the protocols that are used in retrieving and rendering the Google logo and the empty search box. Select all that could apply (partial credit will be given).
29. Outline an algorithm that is suitable for generating a unique name across a distributed system (hint: these operations would be done on each node, and do not involve any network communication)?
30. Why is time synchronization hard? What makes time synchronization inaccurate? Name a protocol used to synchronize time.
31. Why are locks needed in a multi-threaded program?
32. What are the advantages of centralized locks?
33. What makes distributed locks hard to implement?
34. How is replication different than caching?
35. Why do we need replication/caching?
36. Why did processors from the 1980s not need cache-coherent processors?
37. An alternative definition for a distributed system is that of a collection of independent computers providing the view of being a *single system*, that is, it is completely hidden from users that there even multiple computers. Give an example where this view would come in very handy.

38. In this problem you are to compare reading a .le using a single-threaded file server and a multithreaded server. It takes 15 msec to get a request for work, dispatch it, and do the rest of the necessary processing, assuming that the data needed are in a cache in main memory. If a disk operation is needed, as is the case one-third of the time, an additional 75 msec is required, during which time the thread sleeps. How many requests/sec can the server handle if it is single threaded? If it is multithreaded?
39. Would it make sense to limit the number of threads in a server process?
40. Constructing a concurrent server by spawning a process has some advantages and disadvantages compared to multithreaded servers. Mention a few.
41. How does the probability of failure of an entire distributed system (assuming all components are necessary to function properly) change as the number of independent components in the system grows?
42. What components in a computer system do we know how to make resilient, and what technique is used?
43. Which types of failures is easiest to detect?
44. Data resilience through forward error correcting codes is an example what type of recovery mechanism?
45. Data resilience through replication is an example what type of recovery mechanism?
46. RAID (redundant array of inexpensive disks) is an example what type of recovery mechanism?
47. What is the technique called that allows applications to restart and recover from an intermediary point after the start of the application?
48. Describe Moore's Law.
49. Describe Amdahl's Law.
50. Today's commodity processors have 1 to 32 cores, with some more exotic processors boasting 72 cores and 288 threads. About how many cores are expected to be in future processors by the end of the decade? How are these future processors going to look or be designed differently than today's processors? What are the big challenges they need to overcome?
51. Describe what a core and hardware thread is on a modern processor, and the difference between them? What type of workloads are hardware threads trying to improve performance for?
52. Describe what shared address space and message passing is, and the difference between them? In what environments would one be used over the other?
53. Describe what a process and a thread is, and the difference between them? Why are synchronization locks needed with threads? Why is this not the case with processes?
54. Define a cluster of computers. Define a supercomputer. What is the difference between clusters and supercomputers?
55. Define grid computing. Define cloud computing. What is the difference between grids and clouds?
56. Briefly characterize the following three cloud computing models: IaaS, PaaS, Saas
57. An increasing number of organizations in industry and business sectors adopt cloud systems. Answer the following questions on cloud computing. A. List and describe main characteristics of cloud computing systems. B. Discuss key enabling technologies in cloud computing systems. C. Discuss different ways for cloud service providers to maximize their revenue.
58. Multi-core and many-core processors have appeared in widespread use in both desktop computers and HPC systems. Answer the following questions in using advanced processors, memory devices, and system interconnects. A. What are differences between multi-core CPU and GPU in architecture and usages? B. Explain why it is hard for parallel programming to match the progress of processor technology. C. Suggest ideas and defend your argument by some plausible solutions to this mismatch problem between core scaling and effective programming and use of multicores. D. Explain why flash memory SSD can deliver better speedups in some HPC or HTC applications. E. Justify the prediction that InfiniBand and Ethernet will continue dominating the HPC market.
59. Discuss the major advantages and disadvantages using virtual machines and virtual clusters in cloud computing systems?
60. Briefly answer following questions on green information technology and energy efficiency in distributed systems. A. Why power consumption is critical to datacenter operations? B. What is *dynamic voltage frequency scaling* (DVFS) technique? C. If you were to build a large $1B data center, which would require $50M/year in power costs to run the data center and $50M/year in power costs to cool the data center with traditional A/C and fans. Name 2 things that the data center designer could do to significantly reduce the cost of cooling the data center? Is there any way to reduce the cost of cooling to virtually $0? Explain why or why not?
61. Compare GPU and CPU chips in terms of their strength and weakness. In particular, discuss the tradeoffs between power efficiency, programmability and performance.
62. There are three implementations of the MapReduce engine and its extensions: Google MapReduce, Apache Hadoop and Apache Spark. What is unique about each system that sets them apart?
63. Briefly characterize the following branches of distributed systems: HPC, HTC, MTC, P2P, Grid, Cluster, Cloud, Supercomputing
64. This problem refers to redundancy technique. Assume that when a node fails, it takes 10s to diagnose the fault and another 30s for the workload to be switched over: A. What is the availability of the cluster if planned downtime is ignored? B. What is the availability of the cluster if the cluster is taken down 1 hour per week for maintenance, but one node at a time?

65. Describe each of the following. Use examples to explain and contrast them in the context of cluster job management systems: A. Serial jobs versus parallel jobs; B. Batch jobs versus interactive jobs; C. Dedicated mode, space-sharing mode, and timesharing mode
66. Throughput can be used to measure processors, memory, disk, and networks. What are the basic units of measurement for each of these?
67. We can build 100 PFlop/s systems today. Why cannot we simply build systems that are 10 times larger to make a 1 EFlop/s system today?
68. Name two network technologies you would use in building a large scale computing system? One network should be used to optimize cost, while the other should be used to optimize performance. Give cost/performance details for each network type.
69. Name two network topologies you would use in building a large scale computing system? One of these network topologies is destined to be used in most future supercomputers due to some desirable properties at large scale. What are these properties?
70. If you have a system with 99.9999% availability, how much downtime a year can you have?
71. What is live migration of virtual machines? Describe the steps needed to complete for live migration to occur.
72. Name some open source cloud IaaS middleware systems. What is the common theme across all of these systems? Which system seems to have gained the most traction?
73. What is the difference between a NOSQL and SQL database? Give some examples of each.
74. What is an elastic block device (EBS) in Amazon's infrastructure? Why is it a useful system?
75. Name some advantages of distributed systems over centralized systems.
76. Since the early 2000s, commodity processors with an x86 architecture have had more than 1 computing core per processor. How many cores/threads are expected to be in future commodity processors within the next decade?
77. What does it mean for a system to be scalable?
78. Why is threading useful on a single-core processor?
79. Do more threads always mean better performance?
80. Is super-linear speedup possible?
81. Why did processors from the 1980s not need cache-coherent processors?
82. Under what conditions would live migration not work? Assume the VM is running off a network disk.
83. What is 1 advantage of full virtualization compared to para-virtualization?
84. Why do we not have processors running at 100GHz today (as would have been predicted in 2000)?
85. What is an advantage of a modular data center shipping container resource over traditional racks with machines?
86. What technique is used to secure data in a storage system with the least performance penalty?
87. What technique is used to secure data in a computer system?
88. What is the local loopback network interface?
89. Describe the difference between strong scaling and weak scaling experiments.
90. Why does Cloud Computing claim to offer infinite capacity? Why is it not the case for Supercomputing?
91. Assume that you have a x86 processor that has the following characteristics: 100 cores, 10 hardware threads per core, 1GHz speed for AVX640 instructions (vector of 640 bits) with 5 Fused Multiply-Add (FMA) per vector, FMA throughput of 2 instructions per cycle, 10GHz speed for all other instructions with 1 FMA and 2 instructions per cycle, 1MB L1 cache, 10MB L2 cache, and 100MB L3 cache, with a power envelope of 100 watts. What is the theoretical double precision (DP) TeraFlops per second?
92. Assume you have virtual machines with 1-core, 10MB caches, 10GB memory, 100GB disk, and a 10Gb/sec network. Assume the 100GB disk resides on a network volume. Estimate the downtime the VM would have as it migrated from one physical machine to another. The downtime should measure from when the application on node 1 stops until it is running again on node 2. Measure downtime in milliseconds, and round to the nearest millisecond.
93. Assume that you have a private cloud that has 100 physical nodes which has a decentralized storage system to manage its VM images. Assume the storage system can sustain up to 10GB/sec I/O rates, and assume the 100 nodes running VMs are equipped with 10Gb/sec network interfaces. Assume that a single user wants to launch 100 VMs on the 100 physical machines. Assume that the cloud scheduler can initiate 10 VM launch requests per second. Assuming image sizes of 1GB each and that the OS takes 10 seconds to boot, estimate how long (in milliseconds; round to nearest millisecond) it would take for a single user to launch 100 VMs on the 100 nodes?
94. If you have a system with 99.999% availability, how much downtime a year can you have (round to nearest second)?

95. Assume you have a cluster with 30 nodes. You have 1 network card per node with 1Gb/sec Ethernet Full Duplex, and have access to 6-port switches (also 1Gb/sec Ethernet Full Duplex) in order to build a Fat Tree network architecture. Draw a picture of the Fat Tree topology for your 30-node cluster (clearly show the switches, cables, and nodes). How many switches in total do you need? What is the bi-section bandwidth of your network? What is the bi-section bandwidth of your network in Gb/sec (round to nearest Gb/sec)? Assuming each switch incurs a 100-microsecond forwarding delay, and networking stack requires 40-microseconds to process network messages (e.g. TCP/IP) on each side (e.g. sender and receiver), what is the best-case and worst-case latency you can expect from this network topology?
96. A MapReduce Job consists of many tasks that are distributed among TaskTrackers for execution. Sometimes, even when the machines and the tasks are identical, a few of the tasks will take much longer to complete than the others. But, a map or reduce stage cannot complete until its constituent tasks all complete. Describe a technique used by both Google's MapReduce and Hadoop MapReduce to mitigate this problem. Explain why it is safe and effective.
97. While using the Amazon AWS or a similar cloud services, imagine running an application that could have access to a Hadoop Distributed File System (HDFS), an Elastic Block Service (EBS), Simple Storage Service (S3), and DynamoDB. A. (4 points): Which of the four storage options would you expect to be the easiest for a traditional enterprise application to be modified to use, and why? B. (3 points): Which of the four storage options is the most likely to provide the highest total data bandwidth for processing large data volumes, and what design feature is most likely to provide this performance advantage? C. (3 points): Assuming that the you are aiming to deliver interactive usage of small (e.g. 100 byte) data objects, which storage option would best suit this use case, and why?
98. In your Program Assignment #2 part A, you had to sort large amounts of data. Write the pseudo code of your external sort you implemented in your PA2a (make sure your psuedo code utilize multi-core architectures and solid-state memory).
99. More questions about sort: A. (2 points): What is the difference between in-memory sort and external sort? B. (2 points): For in-memory sort, how many times do you have to read and write your data between disk and memory? C. (2 points): For external sort, what is the lower bound of how many times you have to read and write your data between disk and memory? D. (4 points): Based on your own implementation of sort in PA2, what (e.g. processor, memory, disk) do you believe was the bottleneck in your implementation? Please explain.
100. You are hired by a startup company who is considering to use cloud computing instead of building its own infrastructure. There is consensus that a cloud computing software stack at the layer of IaaS will be used, but its not clear whether the computing resources should be rented from a public cloud on-demand, or whether a private cloud should be purchased. You are tasked to find the cost breakdown of a private cloud, and compare that to what Amazon would charge. The goal is to support 10K users, where each user requires a virtual machine with 2-cores, 8GB of RAM, 1Gb/sec network, and 100GB of network storage. On Amazon AWS, the m4.large instance type fits, and EBS storage works. M4.large instances cost $0.10 per instance per hour, and EBS volumes costs $0.10 per GB per month. For your private cloud, assume that you can purchase 64-core servers with 256GB of RAM and 40Gb/sec network for $10K a server; for the distributed network storage, assume that it can be built with 10TB drives that cost $500 a drive, and that data would be replicated for resilience (hint: replication gives a storage efficiency of 50%, so you need twice as much raw storage than usable storage for the end user). Assume you can buy storage servers that can hold 50 disk drives each, at a cost of $5000 each server. Assume that you can buy 50-port 40Gb/sec switches for $10K (including all cables), and that the network is organized as a Fat Tree topology. Assume each server in your private cloud consumes 500 watts of power, and each switch consumes 100 watts of power. Assume the cost of power is $0.10 per Killowatt-hour. Assume you need a system administrator for every 100 servers, at a cost of $100K a year per administrator. Assume a 5-year amortization for the private cloud. Hint: Use the next blank page for scratch paper to solve the problems below. A. What is the cost of the public cloud over a 5-year period? B. How many servers are sufficient in the private cloud? C. How many switches are needed in the private cloud? D. How much does the hardware cost for the private cloud? E. How much power does the private cloud consume? How much does the power cost over a 5-year period? F. How many system administrators does the private cloud require? How much does the system administration cost for the over a 5-year period? G. What is the total cost of the private cloud over a 5-year period? H. Explain in words if it is better to rent (public cloud) or buy (private cloud). If it is better to buy, what utilization must you maintain over the 5-year lifetime of the private cloud in order to break even on the investment?