15440/15640 Distributed Systems Homework 3

Q1. RAID (15 Points)

As a TA for 15-440, Eunice wants to build a DFS to store all relevant files for the course. She bought 20 used hard drives, each with 100GB capacity and an MTTF of 4 years. The read and write throughput for each disk is 100MB/s. She wants to apply the fault tolerance concepts she learned in class and build a RAID array with her disks.

Q1.1 (5 Points)

Eunice starts out by building a RAID-0 array with the disks she bought.

A. What is the effective capacity and MTTF of the RAID-0 array she built? (2 point)

B. What is the read throughput and write throughput of this RAID-0 array? (1 Point)

C. Eunice notices that her disks are unreliable, so every time one disk fails, part of her entire filesystem is lost. What can she change about her system to reduce the loss of data? Explain why your solution helps. (2 Points)

Q1.2 (5 Points)

Eunice is talking to Henry about the reliability issues with her RAID-0 array, and he recommends that she build a RAID-1 array instead. She decides to use her disks to build a RAID-1 array instead of a RAID-0 array.

A. What is the new effective capacity and MTTF of this RAID-1 array? (2 points)

B. What is the read throughput and write throughput of this RAID-1 array? (1 point)

C. Eunice notices that two of her disks have potential hardware issues. Can her current setup tolerate these two disk failures? Why or why not? (2 points)

Q1.3 (5 Points)

Eunice has decided that in addition to storing all the course files, she also wants to store every student submission. Her storage overhead has increased dramatically and is now quite expensive, since she needs to store a lot of files but has limited capacity.

A. Is RAID-1 still the best choice for her DFS? Why or why not? (2 points)

B. Eunice wants to use a new scheme (i.e. different RAID level) to decrease storage overhead, while still maintaining a reliability of at least 1. What scheme do you recommend, and what would be the new read and write throughput of this new system? (3 points)

Q2. Mock Interview on Distributed ML (18 Points)

You are about to interview with a company that specializes in distributed ML. Crystal offers to do a mock interview with you so that you can review all concepts. Can you answer all her questions?

Q2.1 (6 Points)

As a warm-up activity, tell Crystal which framework you would prefer for the following scenarios (Spark or MapReduce) with a one-sentence explanation. (3 points each, 1 for the framework, 2 for the explanation)

A. Cluster has a high rate of node failures.

B. Perform iterative data analytics.

Q2.2 (6 Points)

MapReduce Challenges:

A. If the MapReduce framework randomly assigns map tasks to nodes, how would such random assignment impact the execution of a MapReduce job on a cluster? (2 points)

B. MapReduce has a simple failure model. Briefly explain how MapReduce addresses node failure on a map task execution and explain why such failure handling is safe. (4 points)

Q2.3 (6 Points)

Spark Challenges:

A. One big term that people use when talking about Spark is “lineage”. What is lineage information used for? (2 points)

B. “In-memory” is another keyword that people know about Spark. Can you tell Crystal why Spark is considered "in-memory"? How is this different from what MapReduce uses? (4 points, 2 for each framework)

Q3. GFS (24 Points)

Nirav is building a datacenter, and wants to equip it with the latest and greatest in distributed storage technology. He hears about Google File System (GFS), the cluster file system design pioneered by Google. He also knows about Andrew FS (AFS) from his time at CMU. Despite forgetting his Kerberos password every week, he remembers an interesting detail about AFS: it uses whole file caching (with callbacks) so reads/writes can be buffered locally and then flushed on close.

Q3.1 (6 Points)

For each of the following cases, help Nirav evaluate whether GFS or AFS would be a better fit for his datacenter. For the purpose of this question, assume that the server failure rate is 0% unless specified otherwise. Give a **one-line** explanation for your answer (2 points each).

A. Multiple (several hundred) clients concurrently appending entries to the same file, with the expectation that all writes should persist.

B. Tolerating high rate of failure of the file server (*i.e.* chunkservers for GFS).

C. Repeated read accesses to the same file.

Q3.2 (11 Points)

After carefully considering the alternatives, Nirav decides to implement his datacenter's file storage atop GFS. Recall that, in GFS, the master server is the central repository of chunk metadata, while the chunkservers store chunks of files. Help Nirav configure his GFS implementation so he can keep up with his fiercest competitor, nozamA!

A. By default, GFS implements *migration*, or periodic relocation of data chunks from a live chunkserver to another. A clever engineer suggests that disabling migration might help improve performance. Give one reason in support of the engineer's argument, and one reason against. [4 points]

B. Nirav observes that the master server's RAM utilization is consistently at 100%, and metadata for a large number of chunks is being swapped to disk, hurting performance. How might Nirav fix this bottleneck without adding any new hardware? [3 points]

C. Nirav observes a peculiar trend of correlated failures: for some unknown reason, the likelihood of a Top-of-Rack (ToR) switch failing is several orders of magnitude higher than any other type of failure. Without increasing his operational costs or storage capacity requirements, what change should Nirav make to the default GFS configuration in order to improve chunk availability? Give one downside of this change. [4 points].

Q3.3 (7 Points)

Having crowdsourced design decisions from the brilliant students in 15-440/640, Nirav finally deploys his GFS-based datacenter. His deployment consists of a single master server and three chunkservers.

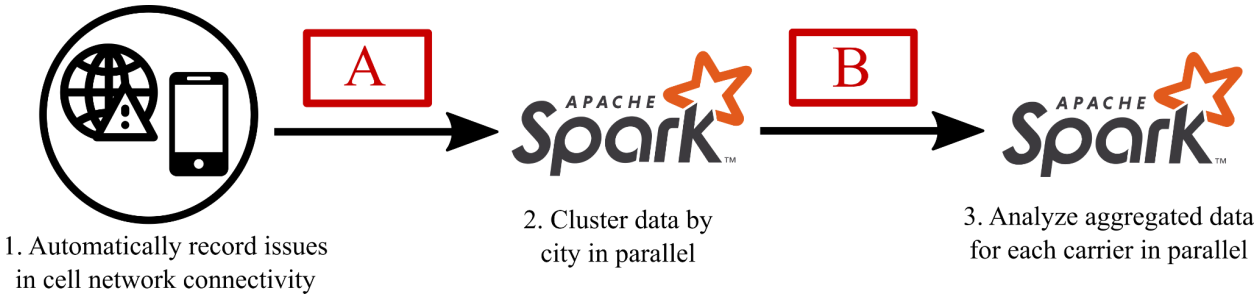
A. Nirav is drafting a document describing the guarantees provided by his datacenter's storage system. State whether the following statements he has written about GFS are true or false, and provide a *one-sentence* justification of your answer. For the moment, assume no failures. [4 points].
   i. *"During a WRITE operation, chunk data is transferred along a daisy-chain comprising the nearest secondary replica, the master replica, and finally the furthest secondary replica, in that order."*

   ii. *"If two users, Alice and Bob, concurrently perform APPEND to the same chunk, it is possible that Alice's data gets overwritten by Bob's."*

B. Now imagine one of the chunkservers in the deployment fails. **Name** the mechanism used to detect this failure, and state the next steps performed by the master once it has detected the failure. [3 points].

Q4. PubSub (6 Points)

A new startup, WeLoveNetworkCarriersSoMuch, is pitching an analytics dashboard to allow network carriers to quickly identify and triage city-wide connectivity issues in real time. They achieve this using a smartphone application that records cell phone connectivity events (*e.g.* dropped calls). Their application records and periodically sends data about its location, carrier, and any recent connectivity issue to WLNCSM's central servers. They have data-centers that they want to dedicate to two different tasks: clustering location data by city, and analyzing the data for each carrier. The system pipeline is depicted in the figure below.



Q4.1 (2 Points)

Uber considers using RPCs to communicate between the application and its computing servers. Is this a good idea? Give a one-sentence justification for your answer. [2 pts].

Q4.2 (2 Points)

What framework(s) would we apply in this situation instead? Name the frameworks that you would use at A and B, and give a one-sentence justification for your answer. [2 pts].

Q4.3 (2 Points)

A and B will probably require some sort of data grouping. In one sentence each, describe the best way to group data for both A and B. Please frame your answer in the context of the framework being used. [2 pts].

Q5. Let's buy her a gift! (16 Points)

For this question, please upload a PDF file as your final answer. You are responsible for uploading the correct document to this question. The course staff will not help upload your solution after the hw deadline.

Link for template file:
https://docs.google.com/document/d/1ehC2p-FRYCHkRNiU4DXTrJipktrM94GOZ7cQ-M4Jc2k/edit?usp=sharing

Eunice's birthday is approaching, and Emma wants to buy her a gift. She decides to look on gifts.emmazon.com, her own proprietary online gift store, for a suitable gift. To direct her to the website, her local DNS server performs an iterative lookup. The diagram below shows some of the DNS records contained in each DNS server. Note that DNS responses are cached in the local DNS server.

localdns.cmu.edu (S1)

Record Number	Name	Value	Type	TTL
R1	c.root.net	190.40.4.8	A	24 hours
R2	.	c.root.net	NS	24 hours

c.root.net (S2)

Record Number	Name	Value	Type	TTL
R3	b.gltd.net	190.31.1.9	A	12 hours
R4	.	c.root.net	NS	12 hours

b.gltd.net (S3)

Record Number	Name	Value	Type	TTL
R5	emmazon.com	ns-9.emmazon.com	NS	4 hours
R6	ns-9.emmazon.com	83.102.188.3	A	4 hours

ns-9.emmazon.com (S4)

Record Number	Name	Value	Type	TTL
R7	gifts.emmazon.com	83.102.188.4	A	30 minutes
R8	gyfts.emmazon.com	83.102.188.5	A	30 minutes

R9	gifts.ammazon.com	83.102.188.6	A	30 minutes
R10	gefts.amazon.com	83.102.188.7	A	30 minutes

Q5.1 (4 Points)

Fill in the following table to indicate the sequence of queries and responses exchanged among the servers.

	Sender	Receiver	Type (Query/Response)	Data
1	Emma's PC	S1	Query	gifts.emmazon.com
2				
3				
4				
5				
6				
7				
8				

Q5.2 (4 Points)

Fill in any new DNS records in the local DNS server right after the sequence of queries and responses in (a). Label the new records with record numbers starting at R10.

Record Number	Name	Value	Type	TTL
R1	c.root.net	190.40.4.8	A	24 hours
R2	.	c.root.net	NS	24 hours
R10				
R11				

Q5.3 (4 Points)

Emma takes a break from browsing to hold office hours. After 4 hours, Emma is done, and looks at gifts.emmazon.com again, to see if there are any updates of super cool gifts on the site. Fill in the DNS records in the local DNS server right before any queries and responses are performed for her second request.

Record Number	Name	Value	Type	TTL

Q5.4 (4 Points)

Once again, fill in the following table to indicate the sequence of queries and responses exchanged among the servers for Emma's second request.

	Sender	Receiver	Type (Query/Response)	Data
1	Emma's PC	S1	Query	gifts.emmazon.com
2				
3				
4				
5				
6				