Clouds — Final Exam

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Please do not forget to put your name at the bottom of this page!

The test is a **closed book** one, no course notes, no electronic devices, cheat sheets, etc. Scratch paper will be provided upon request.

Duration: 2h.

Good luck!

Student name

Problem 1 (2 points) [HDFS]

1. Explain whether you think the Hadoop Distributed File System (HDFS) can be used as a regular POSIX compliant file system, which provides data durability (thanks to replication).

`HINT:` *You need to assume a scenario such as: user A writes a MS Word document in HDFS, user B reads the same Word document* ***at a later time****, modifies it and writes it back to HDFS.*

Problem 2 (2 points) [MapReduce]

- What is the main performance bottleneck in MapReduce?
- Which kind of algorithms would you define embarrassingly parallel? Precisely, which kind of computations (or mathematical operations) are easily amenable to a MapReduce implementation?

Problem 3 (2 points) [MapReduce + HDFS]

Assume we have an Hadoop cluster in which HDFS is configured to have a `Block Size` of 64 MB. Now, we write in HDFS a single file to be later analyzed with MapReduce: this file is of size 1TB, and it contains a single line of text.

1. Assume you read the file using `TextInputFormat`. How many Map tasks will be launched by Hadoop?
2. What is the problem in this scenario?

Problem 4 (4 points) [HBase]

Assume you have the following schema design:

- 1000 rows
- 3 Column families, each containing 3 columns
- cell i, identified by `[ROWKEY]:[COLKEY]:[TimeStamp]`, is 1 KB in size

1. What is the `[COLKEY]`, that is the *column key*?
2. How many `HFiles` will be materialized on disk?
3. Now, assume each cell i is 1MB in size, and you have 10^6 rows. How many `RegionServers` will be used?
    - What information are you missing to answer this question?
    - Select an arbitrary value for that missing information and answer the question

Problem 5 (4 points) [Amazon Dynamo and Apache Cassandra]

1. Explain both data partitioning (consistent hashing) and replica placement schemes used in Apache Cassandra. [2 points]
2. What are Bloom filters and how are they used in Apache Cassandra? [1 points]
3. What are Merkle trees and how are they used in Amazon Dynamo? Assuming a node stores n key-value pairs give the complexity of updating a binary Merkle tree after a single key-value pair has been updated (using big O notation). [1 points]

Problem 6 (3 points) [Apache Zookeeper]

1. State the consistency properties guaranteed by Apache Zookeeper. Sketch a Zookeeper execution which violates linearizability. [1.5 points]
2. Give pseudocode of a Zookeeper implementation of read/write locks without the herd effect where concurrent reads are mutually non-blocking. [1.5 points].

Problem 7 (1 point) [Statistical Multiplexing]

Assume a cloud provider multiplexes n independent demands each with variance $\sigma^2 = 4$ and mean $\mu = 10$.

- What is the minimal number n such that the coefficient of variation of aggregate demand is 10% of the coefficient of variation of any individual demand? [0.5 points]
- What is the value of aggregate coefficient of variation for such minimal n? [0.5 points]

Problem 8 (2 points) [CAP Theorem]

1. State the CAP theorem. [1 point]
2. Classify the following systems/protocols as per where they belong in the CAP space: Paxos, ZAB, Amazon Dynamo, Apache Cassandra (with consistency level ONE) [1 point]