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. Does the `NameNode` component represent a bottleneck for reading and writing data to HDFS? Explain, briefly, by outlining the anatomy of a read and a write operation.

2. Explain why, with HDFS, it is preferable to store a small number of very large files, as opposed to storing a very large number of small files.

Problem 2 (2 points) [MapReduce]

1. What is the impact of skew in the distribution of the output keys of Mappers? As an illustrative example, to better understand the question, consider the classic `WordCount` program: what is the consequence of counting the occurrences of words – using MapReduce – when some words are largely more frequent than others?

2. Explain the role of `Combiners` in a MapReduce program, and the implication of their utilization on cluster resources (CPU, I/O, ...)

Problem 3 (4 points) [Hadoop Mapreduce]

1. What is the role of the `JobTracker`? List at least one important operation executed by the `JobTacker` and explain in a few sentences how that operation works. For example, a possible answer would be:

   The `JobTracker` collects `heartbeats` from `TaskTrackers`, and this mechanism is used to ...

2. Describe in a few sentences what is the **speculative execution** mechanism, and explain why is it useful.

3. Explain why, in Hadoop, it is possible to configure the fraction of `Map` task that need to complete before `Reduce` tasks can be scheduled.

4. Explain why, with Hadoop MapReduce, *iterative* algorithms have severe performance problems. In answering the question, consider that an iterative algorithm involves several `Map`/`Reduce` phases, one for each iteration, until convergence. Your goal is to indicate what constitutes a bottleneck in the execution of this kind of algorithms.

Problem 4 (2 points) [PigLatin and Hadoop Pig]

1. Given a PigLatin script, indicate at least one operator that is used by the Pig system to decide which part of the code is executed in the `Map` phase, and which is executed in the `Reduce` phase. For example, consider the following simple script:

   ```
   DATA = LOAD ‘‘input-file.txt’’ AS (a1:chararray ; a2:int);
   A = FILTER DATA BY a2 IS NOT NULL;
   ```

```
B = GROUP A BY a1 PARALLEL 30;
C = FOREACH B GENERATE group, SUM(A);
DUMP C;
```

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

1. Explain data partitioning used in Amazon Dynamo and Apache Cassandra. [1 points]
2. Explain what are virtual nodes and how they affect load balancing in Amazon Dynamo and Apache Cassandra. [1 point]
3. Explain replica placement schemes in Apache Cassandra. Explain how fault-tolerance considerations affect replica placement. [1 point]
4. What are Bloom filters and how are they used in Apache Cassandra? [1 points]
5. Give and explain various consistency models in Apache Cassandra and exemplify them with values for R, W and N. How often can consistency be changed in Apache Cassandra?

Problem 6 (4 points) [Apache Zookeeper]

1. Explain the concept of watches in Zookeeper. Name different variants of watches. Which operations can set a watch in Zookeeper? Which operations can set a watch on a non-existing znode? [1 point]
2. What are ephemeral znodes? What are sequential znodes? [0.5 points]
3. Are reads in Zookeeper linearizable? If yes, explain how is this linearizability achieved internally in Zookeeper. If not, explain why and suggest a way to achieve linearizable reads in Zookeeper. [1 points]
4. Give pseudocode of a Zookeeper implementation of Total Order Broadcast. [1.5 points]
   - **Request**: $toBroadcast(m)$ by process p_i.
   - **Indication**: $toDeliver(p_i, m)$, where p_i is the broadcaster of message m.

Problem 7 (1 point) [Cloud Computing]

Name cloud delivery and deployment models. For each delivery model, name one public cloud service you know of that belongs to this delivery model.