香 港 中 文 大 學
The Chinese University of Hong Kong

Course Examinations 2014-15 (1st term)

Course Code & Title : **CSCI4180 Introduction to Cloud Computing and Storage**

Time allowed : **2** **hours** **0** **minutes**

Student I.D. No. : .... **Seat No. :** ....

You have two hours to complete the exam. All questions are to be completed. The full score is **100 points**. This is an open-book, open-note exam. You are allowed to use an electronic calculator approved by the University. Other electronic equipments are prohibited. Write down your **student ID** and **seat number** in the answer book. Write **all** the answers in the answer book. Write **neatly**. Anything that is unreadable will receive zero point.

Questions

1. **(21%, 3% each) Short Questions.** Please keep your answers short (e.g., within 20 words) and precise.

   (a) What is the vendor lock-in problem in cloud computing?

   (b) Explain one disadvantage of private clouds compared to public clouds.

   (c) Explain briefly the purpose of using Chubby in BigTable.

   (d) By default, Amazon Dynamo configures $(N, R, W) = (3, 2, 2)$. Explain one advantage and one disadvantage of switching to $(N, R, W) = (6, 4, 4)$.

   (e) Suppose that for each photo in Facebook Haystack, we now keep eight versions of different sizes and six replicas. What would be the number of I/Os if we store a photo in Facebook Haystack? Explain your answers.

   (f) In the leader election implementation for Zookeeper, we choose the one with the smallest znode sequential number. Explain the reason.

   (g) Explain why paravirtualization generally has higher performance than full virtualization.

2. **(20%) Designs of MapReduce and HDFS.**

   Both MapReduce and HDFS (the latter follows Google's GFS) are carefully designed and configured to be scalable and reliable in the presence of big data. Please answer the following questions regarding the designs of MapReduce and HDFS. Keep your answers short and precise.

   (a) (4%) Compared to traditional file systems, explain two key design differences of HDFS that enable HDFS to achieve high performance when it manages big data.

   (b) (4%) The MapReduce split size is generally configured to be equal to the HDFS block size (64MB by default). Explain one disadvantage if the split size is set to be smaller than the HDFS block size.

   (c) (4%) MapReduce emphasizes locality. Explain what it means and why it is necessary.

   (d) (4%) HDFS uses a namenode to coordinate the read/write operations. Explain why it is *not* a bottleneck in read/write operations in general.

   (e) (4%) Instead of letting the HDFS client distribute replicas across DataNodes, HDFS uses a pipelined approach to distribute replicas. Explain the rationale behind.

3. **(10%) MapReduce Algorithm.**

   In notes Lecture 4, we discuss how we implement the computation of co-occurrence counts using MapReduce. We show both the pair approach and the stripe approach.

   - (6%) Using the stripe approach, revise and write down the pseudo-code of the Map function of co-occurrence counting in order to support in-mapper combining.
   - (4%) Explain in what situation in-mapper combining can improve the performance of the MapReduce algorithm for the co-occurrence counting problem.

4. **(18%) PageRank.**

Suppose that we have a web graph containing only five webpages denoted by n_1, n_2, n_3, n_4, and n_5. Our goal is to compute the PageRank of each page using MapReduce. The webpages contain URL links to other webpages, as defined below:

- n_1 contains links to n_2, n_3, and n_4;
- n_2 contains a link to n_3;
- n_3 contains links to n_2 and n_4;
- n_4 contains links to n_1 and n_3;
- n_5 contains links to n_1, n_2, n_3, and n_4.

(a) (12%) Show how you can solve for the PageRank values for all webpages using MapReduce. We assume that there is no random jump. In your answers, you need to show (i) how you initialize the PageRank values, (ii) the emitted outputs of the Map and Reduce functions of the *first two iterations*. Feel free to define the notation that is necessary.

(b) (2%) What is the final PageRank of n_5? Explain your answer.

(c) (4%) Suppose that we require every webpage to have PageRank value at least 0.01. If the PageRank of a webpage drops below 0.01, we redistribute the PageRank values among the webpages so that all webpages have PageRank values at least 0.01. Explain how the "redistribute" operation should be implemented. Your answers should specify precisely the actual values that need to be redistributed.

5. **(31%) Cloud Storage.**

In class, we learn that deduplication is a well-known technique that effectively removes storage redundancy. Rabin fingerprinting is often used as the chunking algorithm. It contains several configurable parameters for performance tuning.

(a) (6%) State two types of workloads for which deduplication is useful, and one type of workload for which deduplication is useless. Explain your answers.

(b) (4%) In general, the deduplication chunk size should not be set too small (e.g., 2 bytes) or too large (e.g., 20MB). Explain why.

(c) (4%) In Rabin fingerprinting, the modulo parameter q is always set to a power of two. Explain why. Please specify how we can leverage this property in the chunking operation.

(d) (4%) In Rabin fingerprinting, if we do not bound the maximum chunk size, explain a scenario where the chunk size can become unbounded.

(e) (4%) What is the trade-off of choosing between SHA-1 (which produces a 160-bit hash value) and SHA-256 (which produces a 256-bit hash value) to generate chunk fingerprints for deduplication? To answer this question, explain one advantage and one disadvantage of choosing one over the other.

(f) (4%) Suppose that we configure a 100MB Bloom filter for deduplication indexing. Let the chunk size be 4KB and the false positive rate be 0.001. Also, we use SHA-1 to generate 160-bit fingerprints. What is the minimum amount of storage capacity that can be represented? Also, state a reason why Extreme Binning and Sparse Indexing can use even less memory for deduplication indexing.

(g) (5%) Consider a cloud storage service that follows a tiered pricing model. For storage pricing, the service charges $0.30/month for the first 1TB and $0.25/month for the next 49TB. We assume that both transfer pricing and request pricing are free of charge. Suppose that we use the cloud storage service starting on January 1, 2014, and we generate 256GB of backup data per month. How much money do we have to pay on June 30, 2014? State your assumptions if needed.

Hope you have a fruitful winter break!

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