Problem Set 2

15-440/15-640 Distributed Systems Spring 2016

Assigned: Tuesday February 16, 2016

Due: Tuesday February 23, 2016 (by the start of class)

Submission procedure:

- Create a .pdf of your answers and upload to Autolab**.**
- If you handwrite your answers, scan into .pdf before uploading. Use a proper scanner, not your smartphone camera. If you answers are illegible, you will receive a zero grade.

Question 1 (12 points)

Consider a LRU page cache that receives the following reference stream (the page number of each reference is shown):

27, 12, 15, 15, 15, 27, 34, 15, 12, 27, 34, 15, 15, 15, 12, 8

Suppose the cache size is 3 pages, and the cache is initially empty.

A. How many misses does the cache experience for this reference stream? Show your working to obtain this answer.

B. Which are the pages left in the cache after this reference stream? Ordering doesn't matter.

Question 2 (12 points)

Repeat Question 1 for the following reference pattern: 24, 25, 26, 27, 24, 25, 26, 27

A. How many misses will the cache experience? Show your working to obtain this answer.

B. How many misses would the optimal cache replacement policy (OPT) experience? Show your working to obtain this answer.

Question 3 (28 points)

You are the designer of a distributed system that does caches short video segments in their entirety from a server over the Internet. Video segments have an approximately normal size distribution, with a maximum observed size of 100 MB, a minimum observed size of 1 MB. The mean of the distribution is roughly 50 MB. Your server is located in Omaha, Nebraska which is roughly the center of the continental United States. Your clients are spread all over the continental United States (CONUS). Your deployment excludes Alaska and Hawaii. Akamai reports that the average end-to-end Internet bandwidth in the United States is about 15 Mbps in CONUS. About 95% of the accesses from users are for viewing a video, while 5% are for editing the videos after viewing it. Video playback typically consumes 0.5 MB of a video file per second. An edit session lasts at most 20 minutes, and the entire video segment is written back to the server at the end of the edit session.

A. Describe the design of a lease-based cache coherence protocol for this system that preserves one-copy semantics at the granularity of an entire video segment. You can make simplifying assumptions, but your protocol must provide one-copy semantics at the stated granularity. Be sure to clearly state and justify any assumptions you make. Ideally, you would like to avoid lease renewal for videos that are only viewed (i.e. not edited). Explain how to achieve this goal.

B. Suppose lease requests that cannot be honored immediately are FIFO-queued at the server. What is the worst case waiting time for a lease request if the queue length is zero on arrival?

C. How does your answer to B change, if the queue length is 5 on arrival?

D. What is the best case waiting time, if the queue length is 5 on arrival?

Question 4 (24 points)

Deciding to go retro like DropBox, you replace the caching mechanism described in Question 3 with full replication. Each client now needs to allocate sufficient local storage to contain all the video segments. Consider a point in time when there are one million video segments in the system.

A. Approximately how much storage will each client need to allocate for the video segments?

B. Suppose there are 10,000 continuously active users in the system who generate view and edit requests as stated in Question 3. Roughly how much update data will a client receive per second? You can make simplifying assumptions, but be sure to state them clearly.

C. Suppose user behavior changes so that 50% of the requests are now for edits. Recompute your answer to B. under these circumstances.

Question 5 (14 points)

Consider a server that hosts a read-only database. The database has 100,000 blocks, each 4KB in size. One of these blocks is a descriptor block; ten of the blocks are index blocks; the remaining blocks are data blocks. A client accesses this database using a cache of size of 1000 blocks, each 4KB in size. On a cache hit, accessing a block takes one ms. On a miss, it takes 100 ms. Suppose the client workload is as follows. Ten percent of the accesses are to the descriptor block. Another ten percent are uniformly distributed over the ten index blocks. The remaining 80% of the accesses are uniformly distributed over the rest of the database blocks. In steady state, what is the average time for a client operation? *(Hint: you may need to make simplifying assumptions. Be sure to state them clearly.)*

Question 6 (10 points)

Give an example of a failure-free scenario in which the NFS v3 caching protocol (i.e., “faith-based caching”) violates one-copy semantics. Your example should be detailed enough to clearly show step by step how the violation of one-copy semantics occurs.