15-440
Distributed Systems
Recitation 6

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Agenda

- Project 1 Recap
- Project 2 Objectives

Project 1: Recap

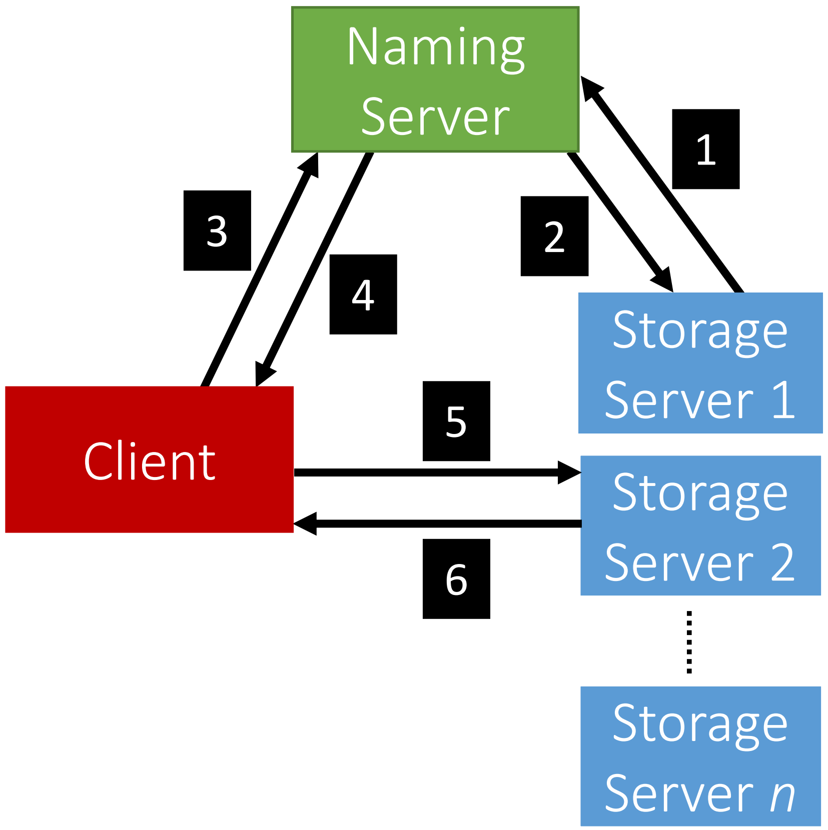
- Applied the knowledge of client-server communication and Remote Method Invocation (RMI) to build a Distributed File System denoted as FileStack

- Employed stubs and skeletons to mask communication, thereby transparently locating and manipulating files stored remotely at a cluster of machines

Entities & Architecture

- Storage Servers (SSs)
  - Each SS stores physically files to share in a directory (denoted as temporary directory) in its local file system
- Naming Server (NS)
  - Stores metadata about all shared files in the form of a mapping from filenames to storage servers (like DNS)
- Clients
  - Perform operations on files (e.g., write, read etc.)
- Architecture
  - Based on client-server architecture

Communication b/w Entities



Request–Reply
Communication Paradigm

1	**Registration**
2	**Duplicate Files**, **Create**, **Delete**
3	**CreateFile**, **CreateDirectory**, **IsDirectory**, **Delete**, **List**,
4	**GetStorage**
5	**Results**, **Storage Stub**
6	**Read**, **Write**, **Size**
	Results (*of Read, Write, Size*)

Agenda

- Project 1 Recap
- Project 2 Objectives

Project 2

- Involves *building on your Project 1 Distributed File System* (**DFS**): *FileStack*
- P2_StarterCode: Copy files into your P1 folder
- Release Date: **October 6th, 2019**
- Due date: **October 28th , 2019**

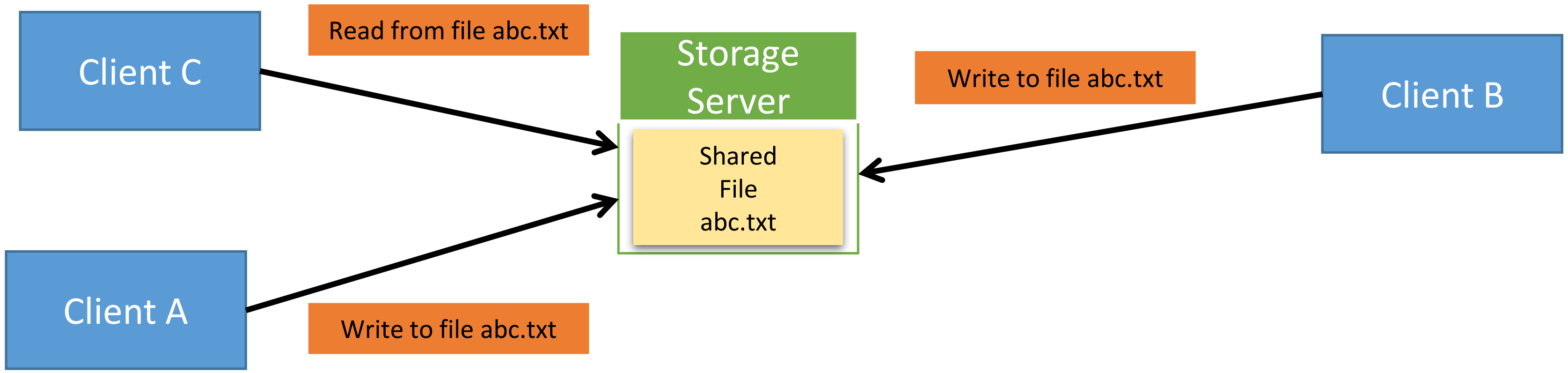
File Correctness & Consistency

- Did we allow multiple clients to write on a file?

  Yes!

- Did we allow a client to read a file under modification?

  Yes!



Project 2 Objectives

1. **Devise and apply a synchronization algorithm that:**
   - achieves *correctness* while sharing files
   - and ensures *fairness* to clients.

2. **Devise and apply a replication algorithm that:**
   - achieves load-balancing among storage servers
   - and ensures consistency of replicated files.

Project 2 Objectives

1. Logical Synchronization of Readers and Writers

2. **Devise and apply a replication algorithm that**:
   - achieves load-balancing among storage servers
   - and ensures consistency of replicated files.

Mutual Exclusion

1. **Reader**:
   - Reader is a Client who wishes to read a file at a SS
   - Reader first requests a **read/non–exclusive/shared lock**
2. **Writer**:
   - Writer is a Client who wishes to write to a file at a SS
   - Writer first requests a **write/exclusive lock**
3. **Order**:
   - Readers and writers are queued and served in the **FIFO** order

Read Locks

- Readers **request the NS for read locks** before reading files
- Readers **do not modify** contents of a file/directory
- **Multiple readers can acquire a read lock** simultaneously
- Readers **unlock files once done**

Write Locks

- Writers **request the NS for write locks** before reading/writing to files
- Writers **can modify contents** of files/directories
- Only **one writer can acquire a write lock** at a time
- Writers **unlock files once done**

Write Locks

- NS grants a write lock on a file if:
  - No reader is currently reading the file
  - No writer is currently writing to the file
- Assume a writer requests a write lock for project2.txt:

  /FileStack/users/student1/work/project2.txt

- NS applies read locks on all the directories in the path to prevent modifications
- NS then grants a write lock to the requestor of project2.txt

Service Interface

- **Two new operations** available to Clients:
  - LOCK(path, read/write)
  - UNLOCK(path, read/write)

Project 2 Objectives

1. **Devise and apply a synchronization algorithm that:**
   - achieves *correctness* while sharing files
   - and ensures *fairness* to clients.

2. Dynamic Replication of Files

Why Replicate?

- In our DFS, we'll have two kinds of Files:
  - Files that have a lot of requests
    - These are denoted as "***hot–files***"
  - Files that are very rarely accessed
    - These are denoted as "***cold–files***"
- To achieve load-balancing, we can replicate "***hot–files***" onto other SSs

How Many Replicas?

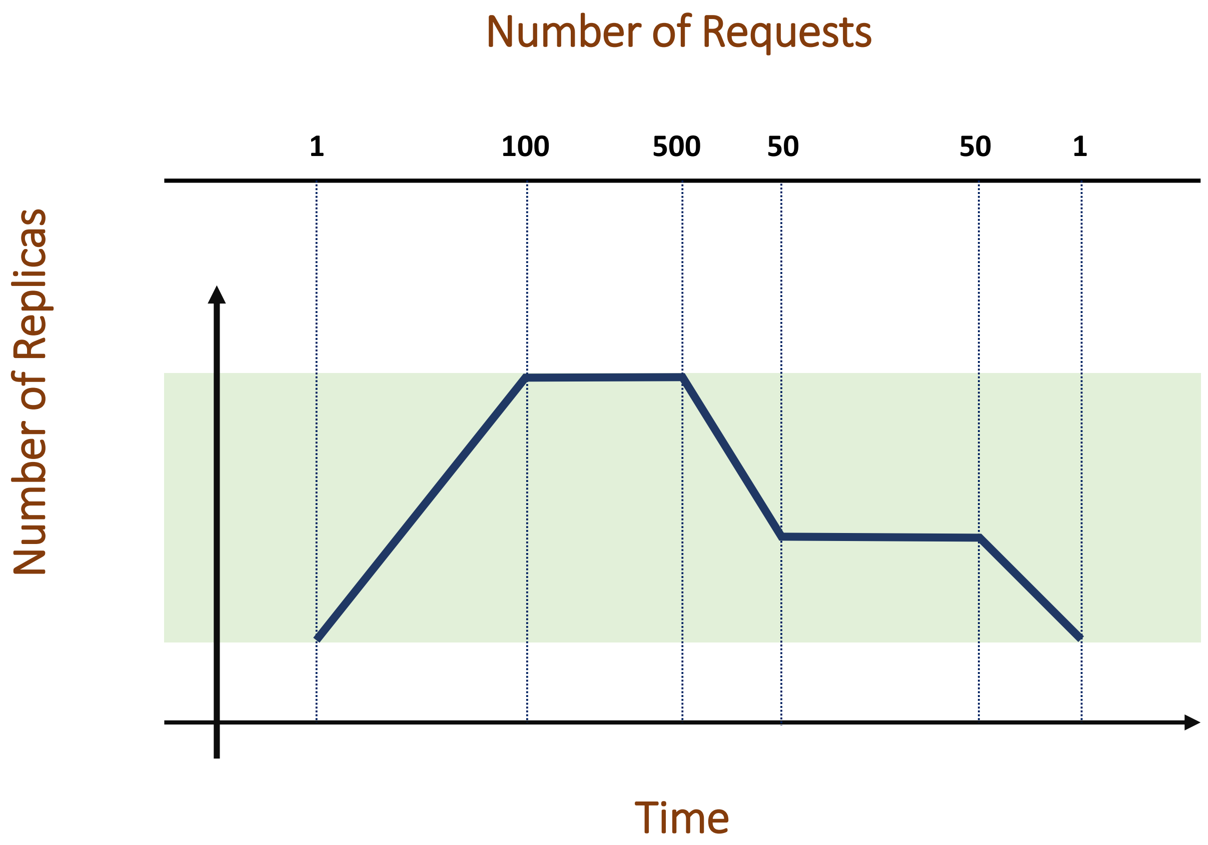
- To measure how "hot" a file is, the NS can keep track of the number of requests to a file:
  - ***num_requests***: number of read requests to a file

- *To scale replicas linearly with the increase of* ***num_requests***:
  - $num\_replicas = \alpha * num\_requests$

How Many Replicas?

- However, we need to limit the number of replicas:
  - ***num_replicas* = *min*(α * *num_ requests*, *upper_bound*)**
- This is still too sensitive/fine-grained:
  - ***num_requests_coarse*: *num_ requests* rounded to the nearest multiple of 20**
  - ***num_replicas* = *min*(α * *num_requests_coarse*, *upper_bound*)**

How Many Replicas?



When to Replicate?

- NS would want to store ***num_requests*** as file metadata
- However, how can we determine and in turn update ***num_requests*** over time?
  - We know that Clients invoke read operations on storage servers
  - Therefore, every "read" lock request from a client is deemed as a read operation
  - Afterward, NS increments ***num_requests***
  - Reavaluate **num_replicas**

How can we Replicate?

- NS first elects one or many SSs to store the replicas
- NS commands each elected SS to copy the file from the original SS
- Therefore, the metadata of a file now includes ***a set of SSs*** instead of a single SS

How to Update Replicas

- **When a Client requests a write lock on a file**:
  - It causes the NS to *invalidate* all the replicas except the locked one

- Invalidation is achieved by **commanding those SSs hosting replicas to delete the file**

- When the Client unlocks the file, the NS commands SSs to copy the modified file

The Command Interface

- **One new operation** available to the NS:
  - COPY (path P, StorageStub S)

    copies file with path P from StorageStub S

Implementation Tips: Synchronization

- Consider a **Lock** object that:
  - Stores a list of "**Request**s" (represents a read/write Request)
  - Is assigned to each **Node** in your tree
- In the new LOCK/UNLOCK method:
  - Traverse your tree
  - Obtain/Release locks as necessary

Implementation Tips: Replication

- Keep track of the number of reads for files:
  - You need to modify your Tree data structure
- Create a formula for calculating the number of replicas given the number of reads
  - Similar to the one shown earlier
- After each read/write:
  - Update the number of replicas