15-440
Distributed Systems
Recitation 6

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Adopted from: Previous TAs

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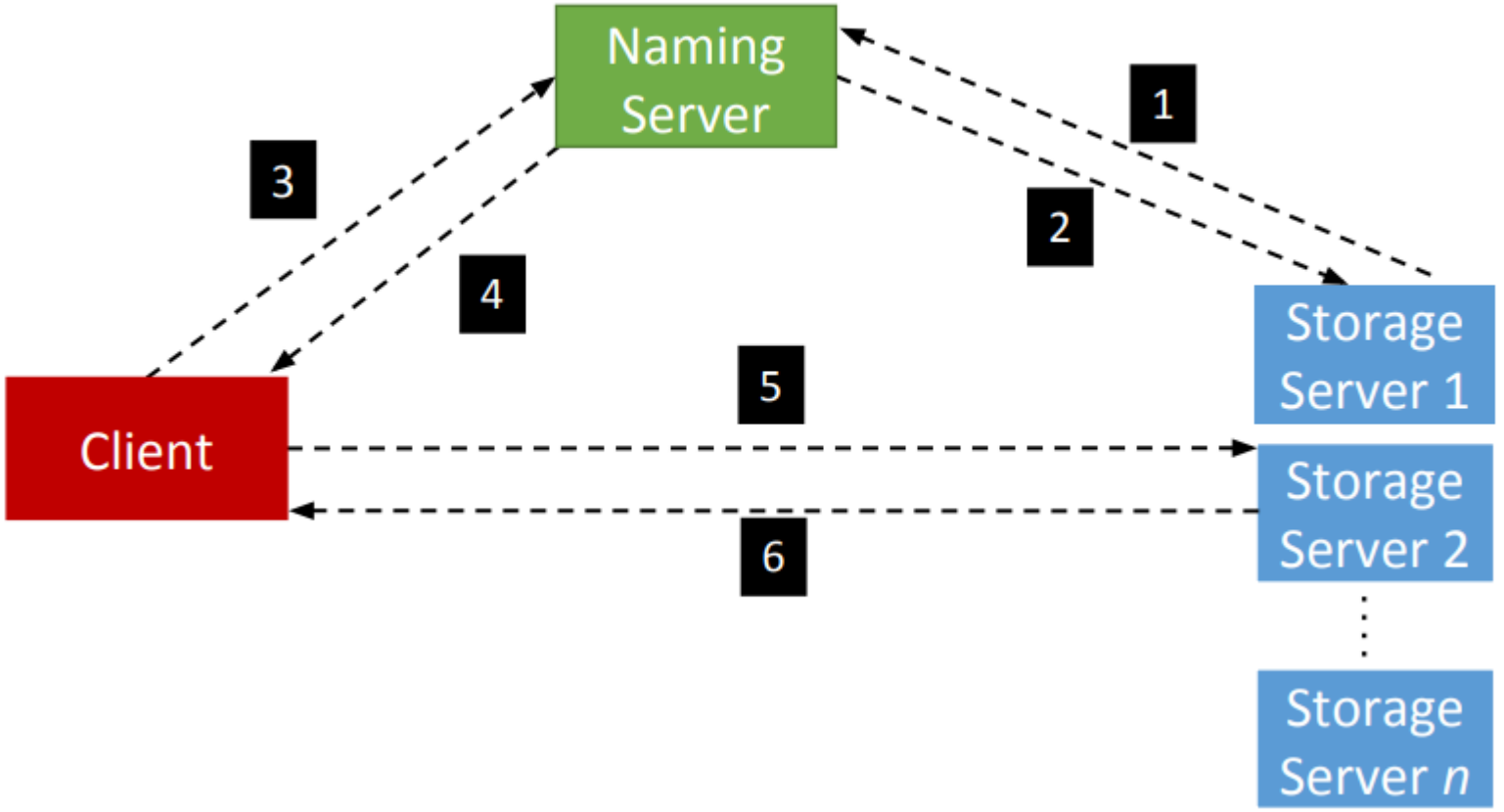
Logistics

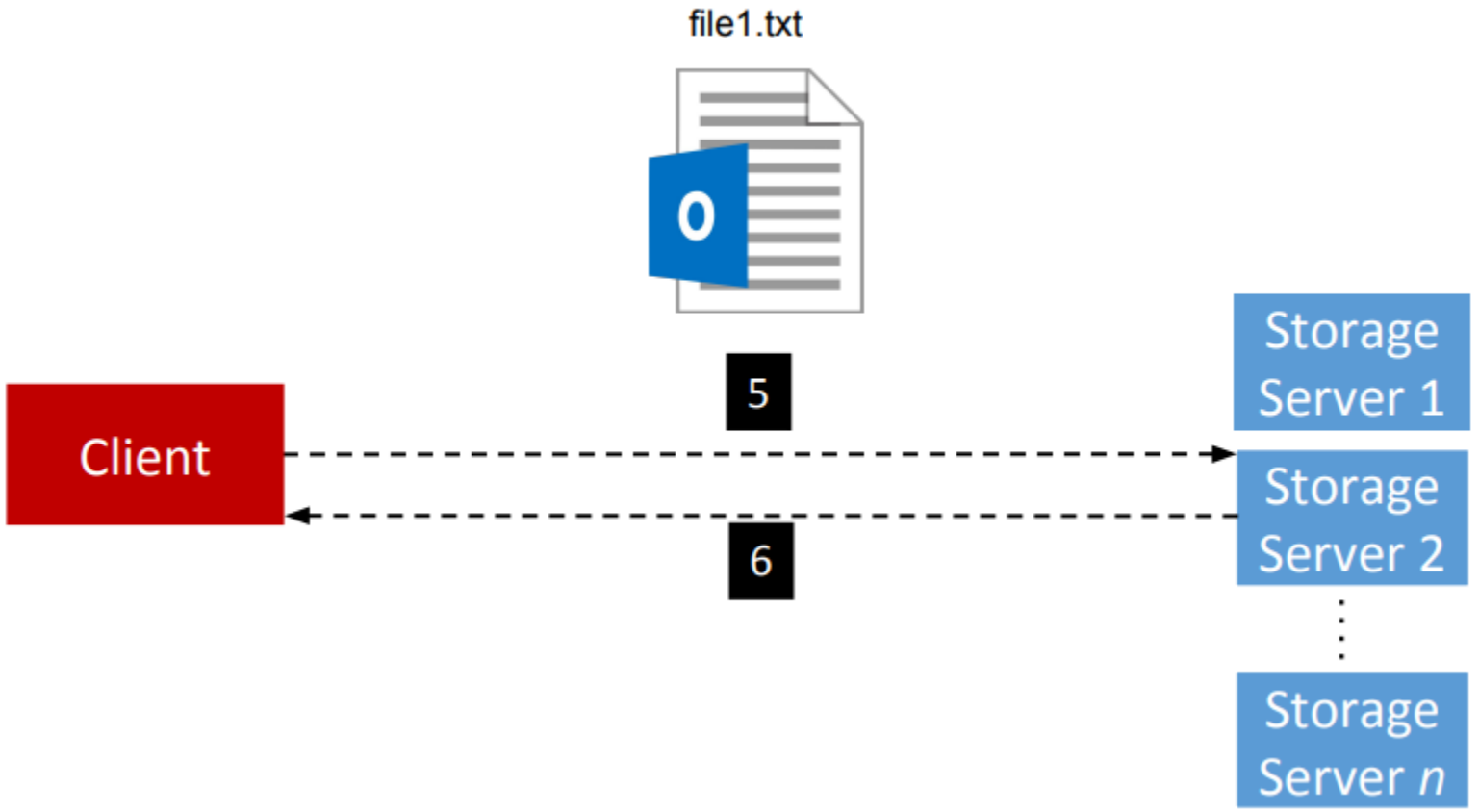
- P1 Done!
- P2 Out (due October 4)
- Midterm (September 25)
- PS3 (due September 29)

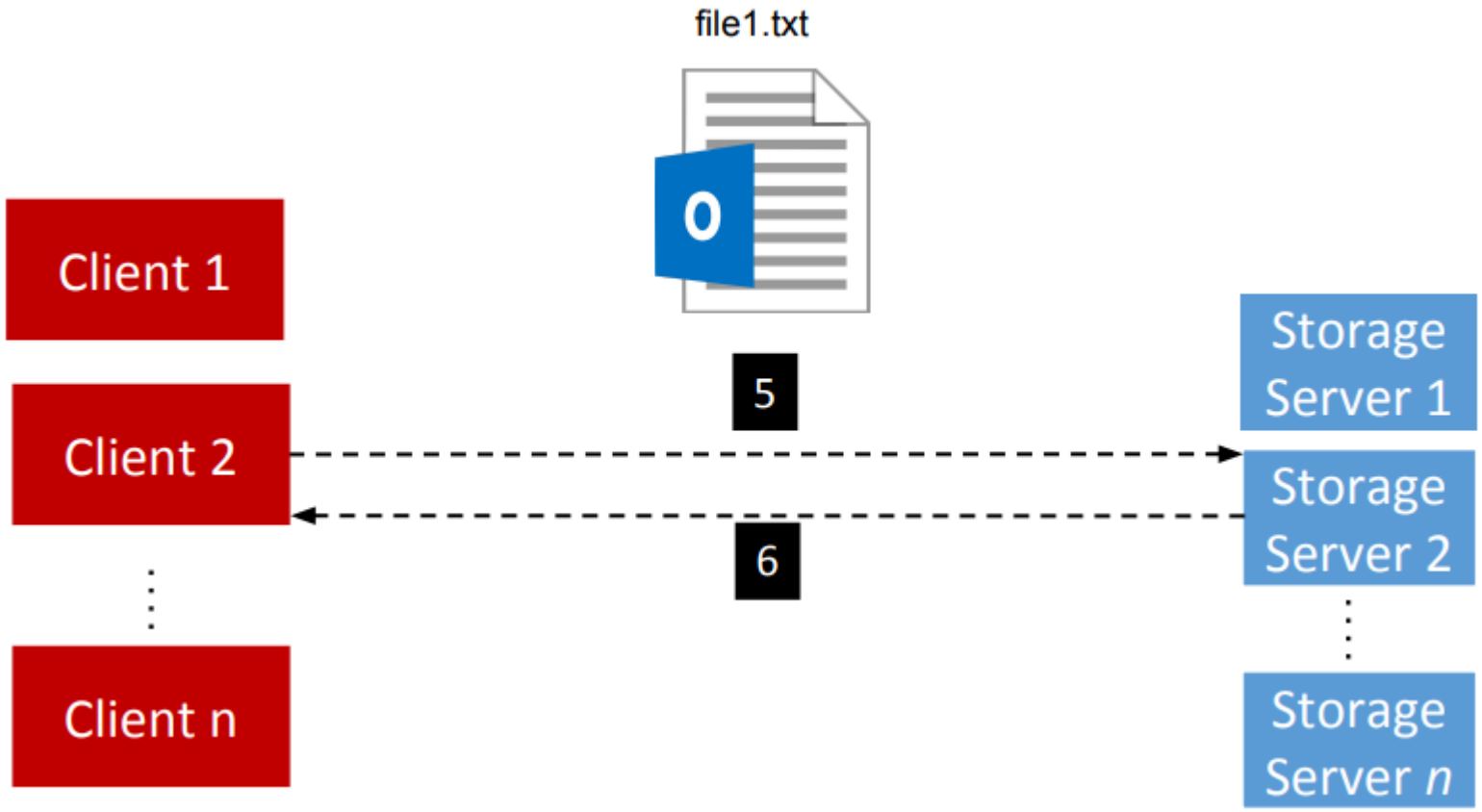
Project 2

- Involves *building on your Project 1 Distributed File System* (**DFS**): *FileStack*
- P2_StarterCode: Copy files into your P1 folder
- Release Date: **September 15th**
- Due date: **October 4th**

FileStack Architecture




file1.txt
Client
5
6
Storage Server 1
Storage Server 2
Storage Server n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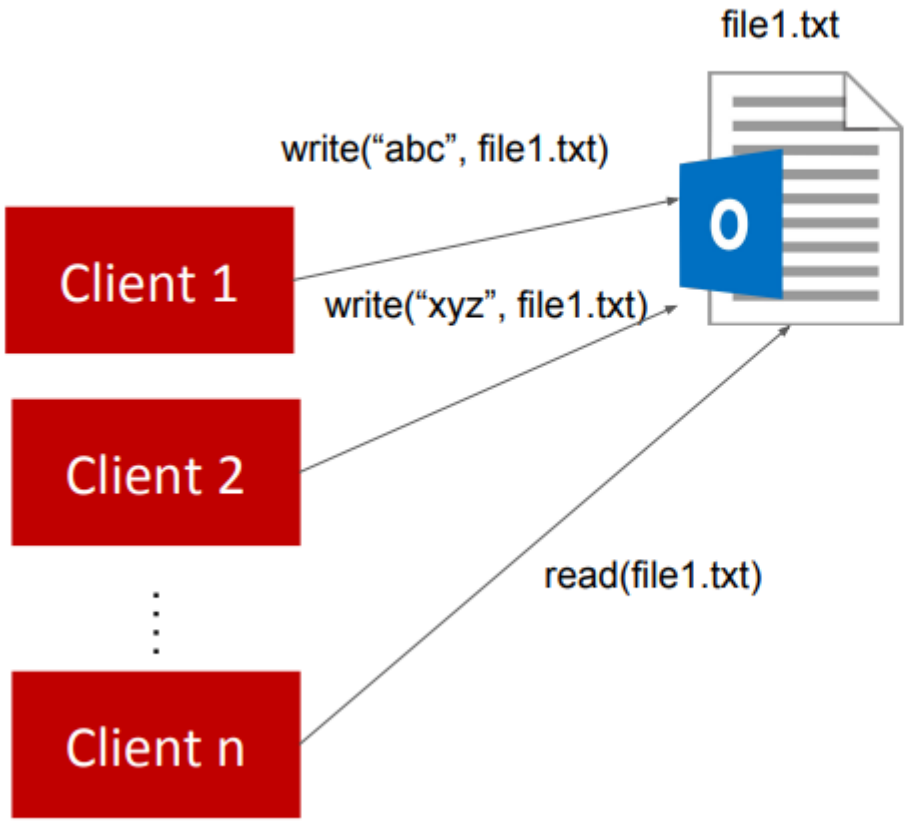

What might go wrong?

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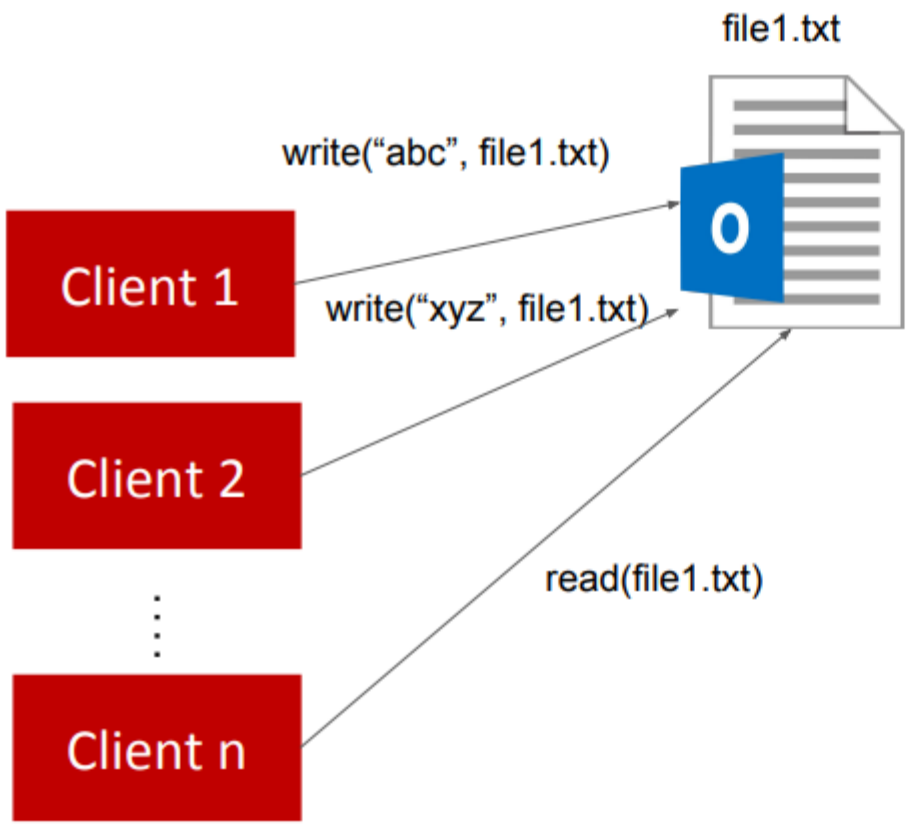
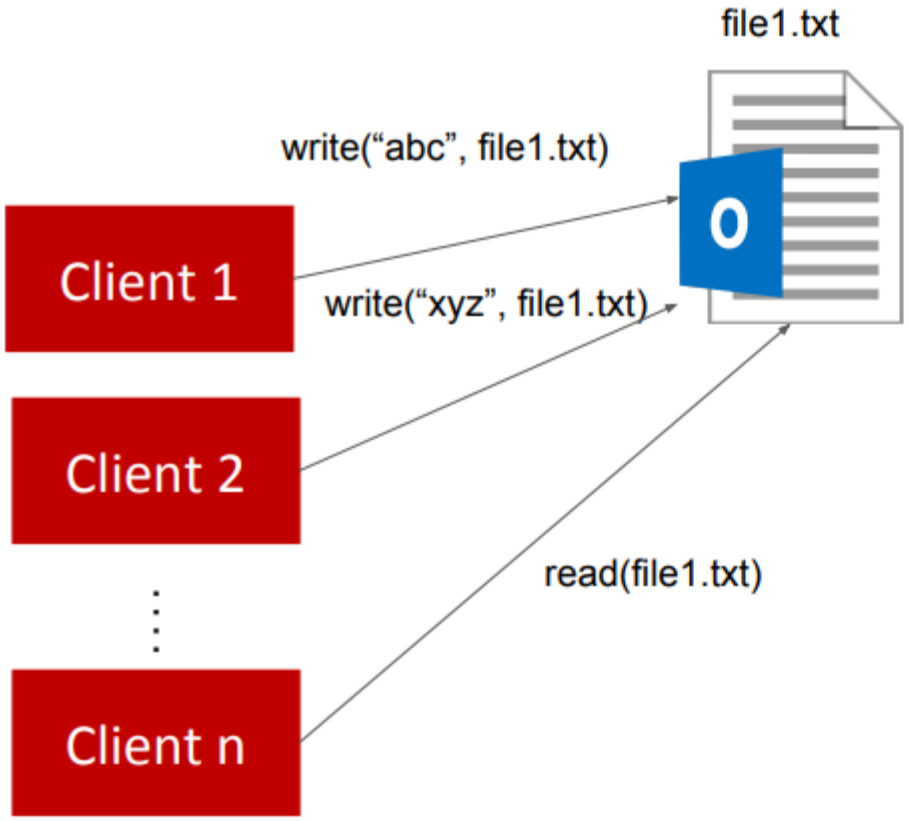


What might go wrong?

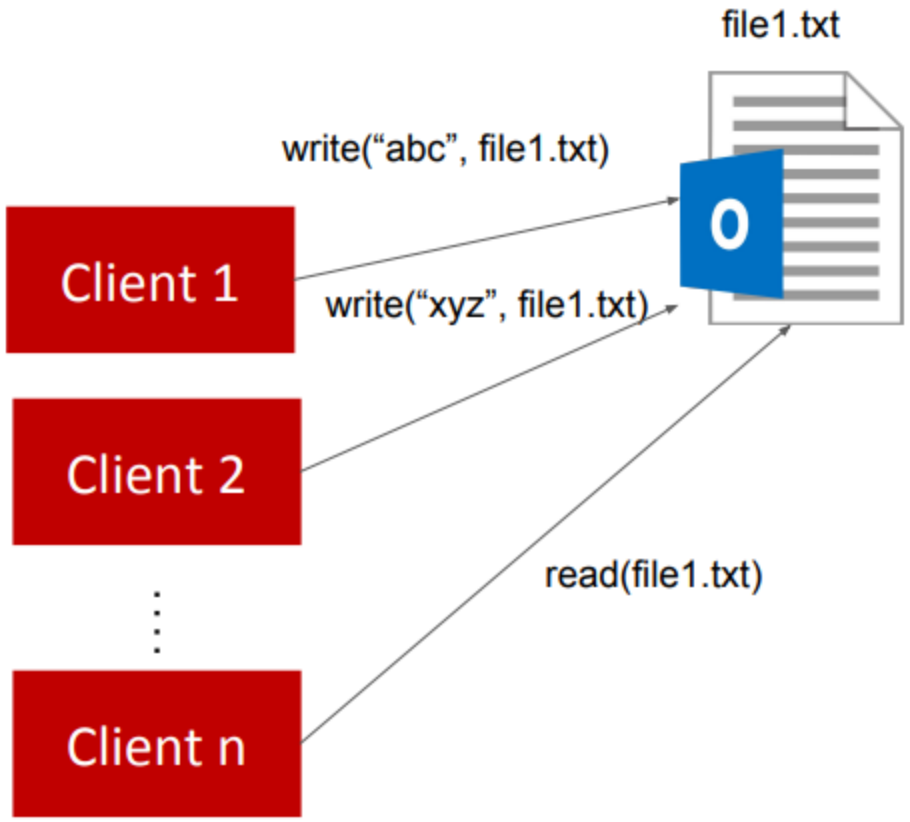
- Synchronization



What might go wrong?

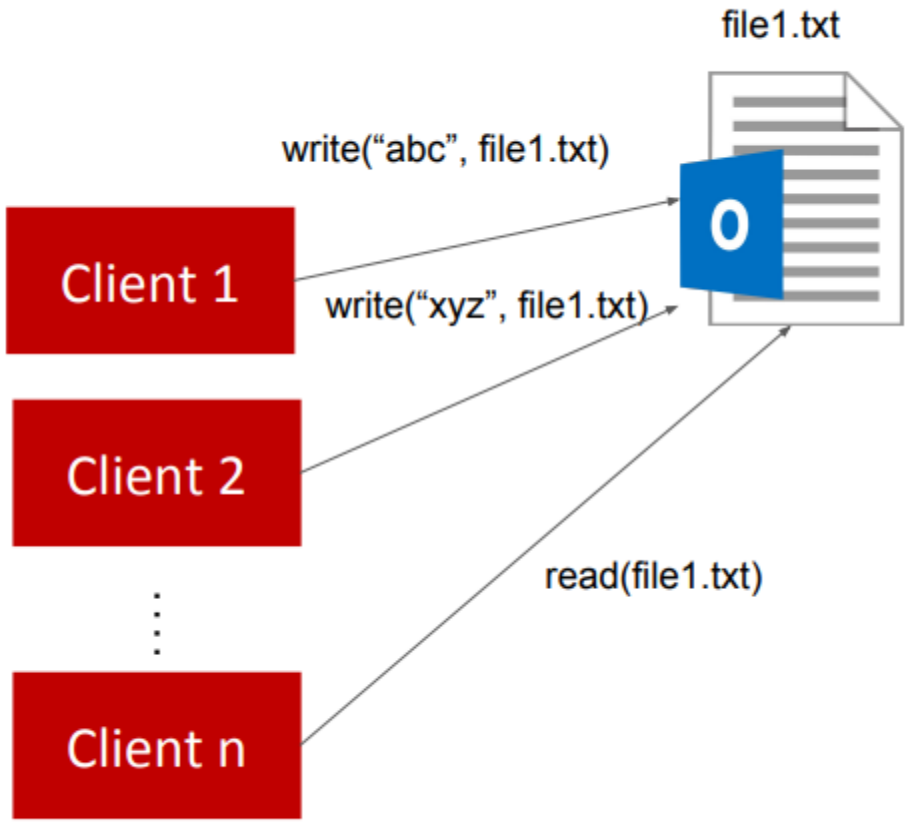
- Synchronization

file1.txt is hosted on SS9, and it's gets 5000 reqs/ sec. As opposed to file2.txt which gets 1000 reqs / month on SS3



What might go wrong?

- Synchronization
- Load-balancing



What might go wrong?

- Synchronization
- Load-balancing

Replicate file1.txt on multiple Storage Servers

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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:**
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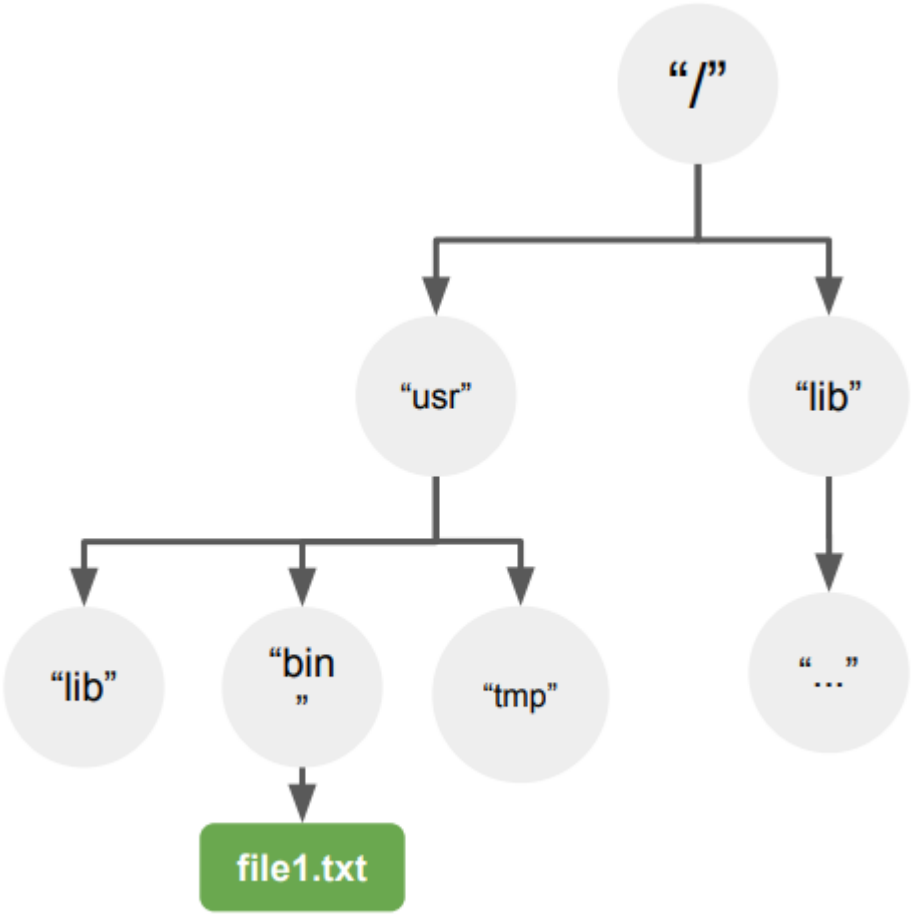
Synchronization



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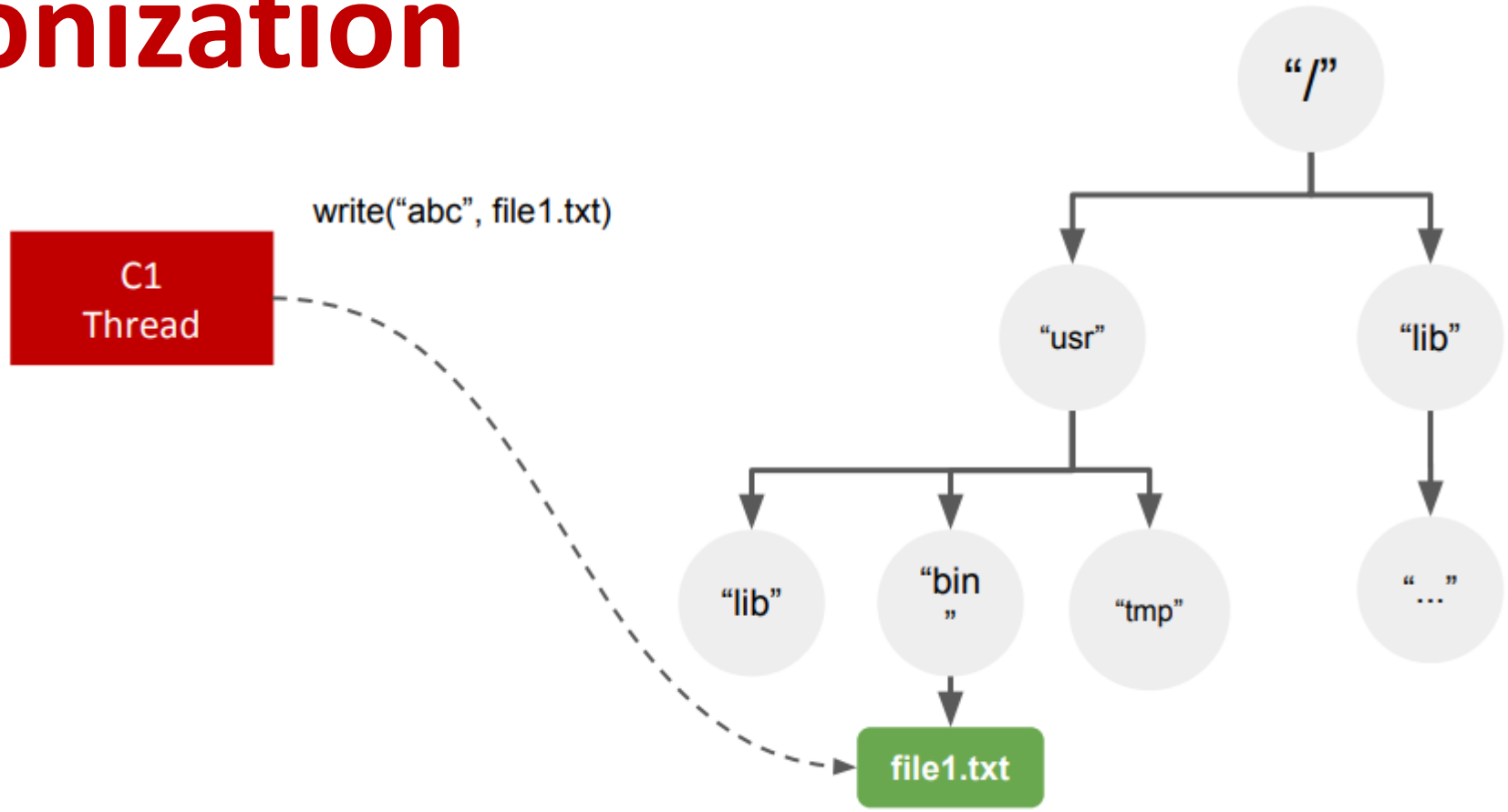

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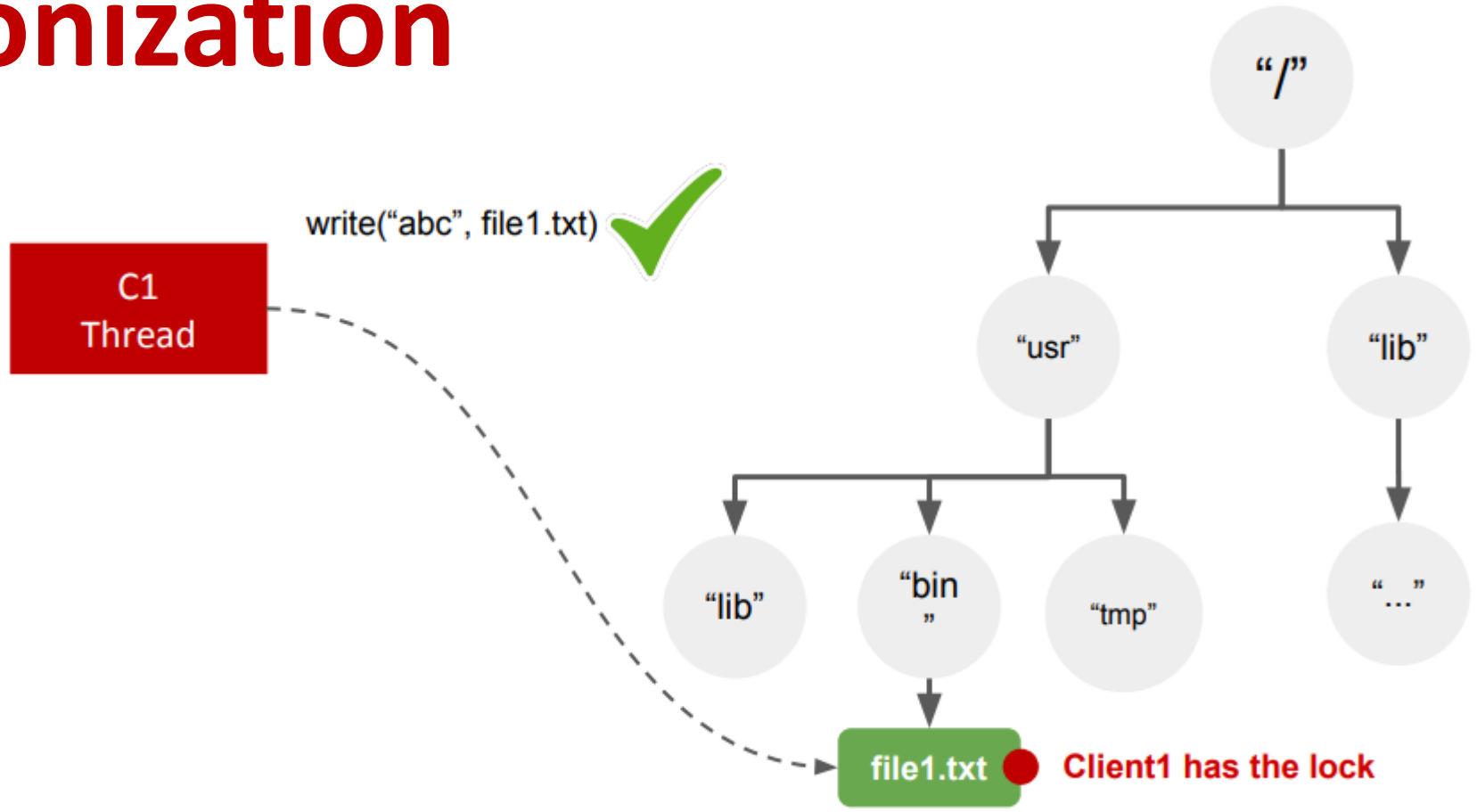

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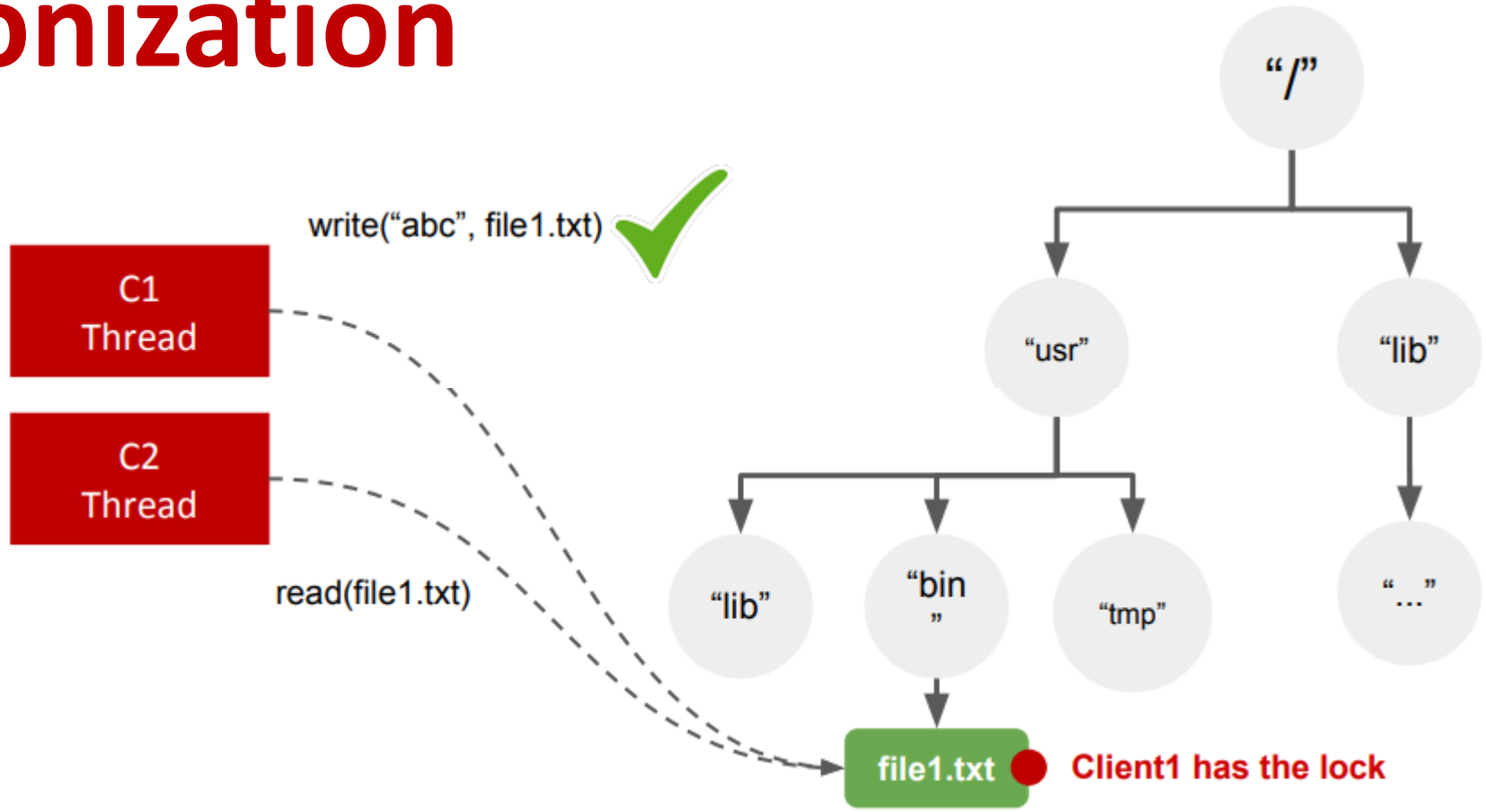

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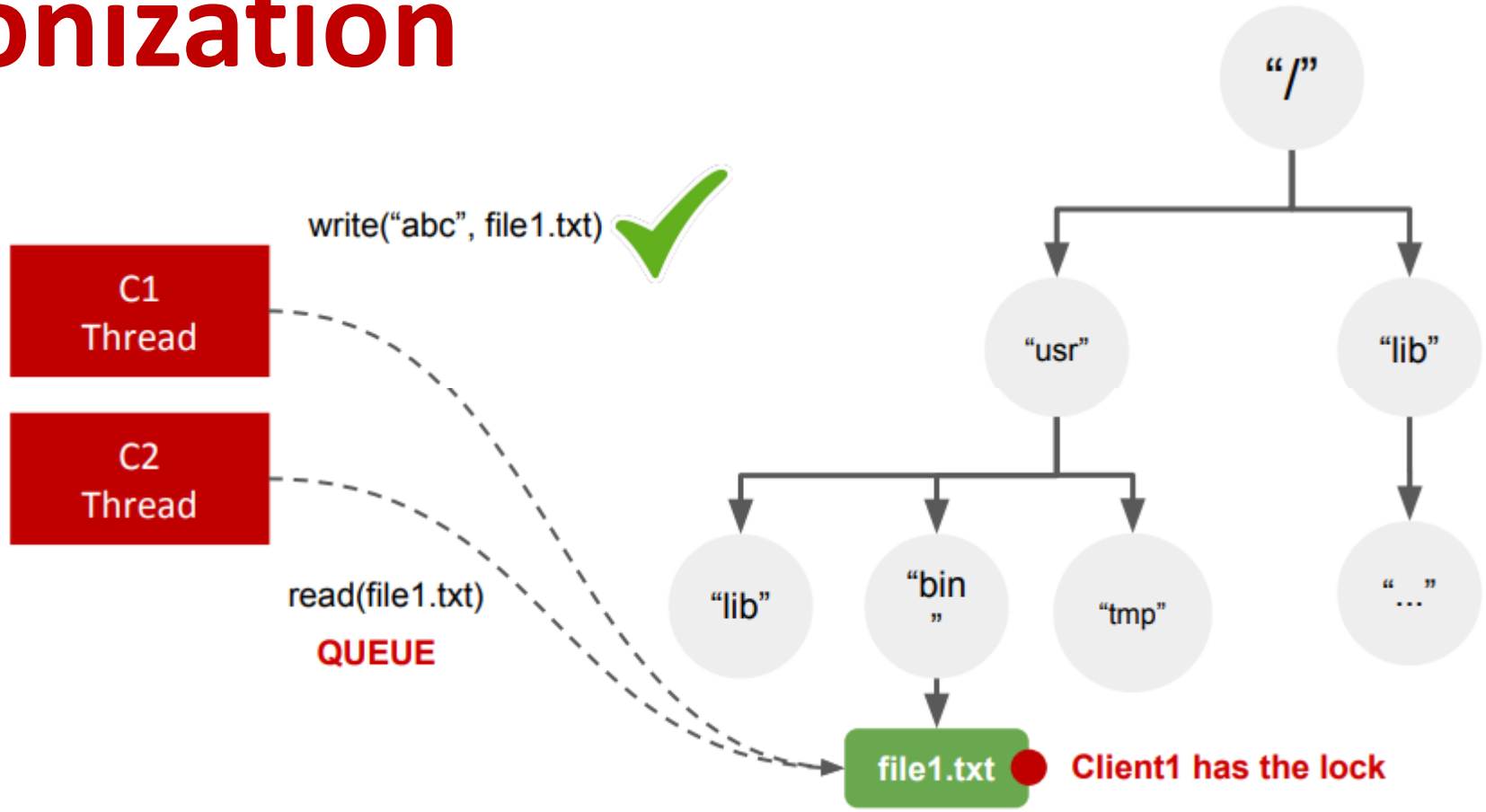

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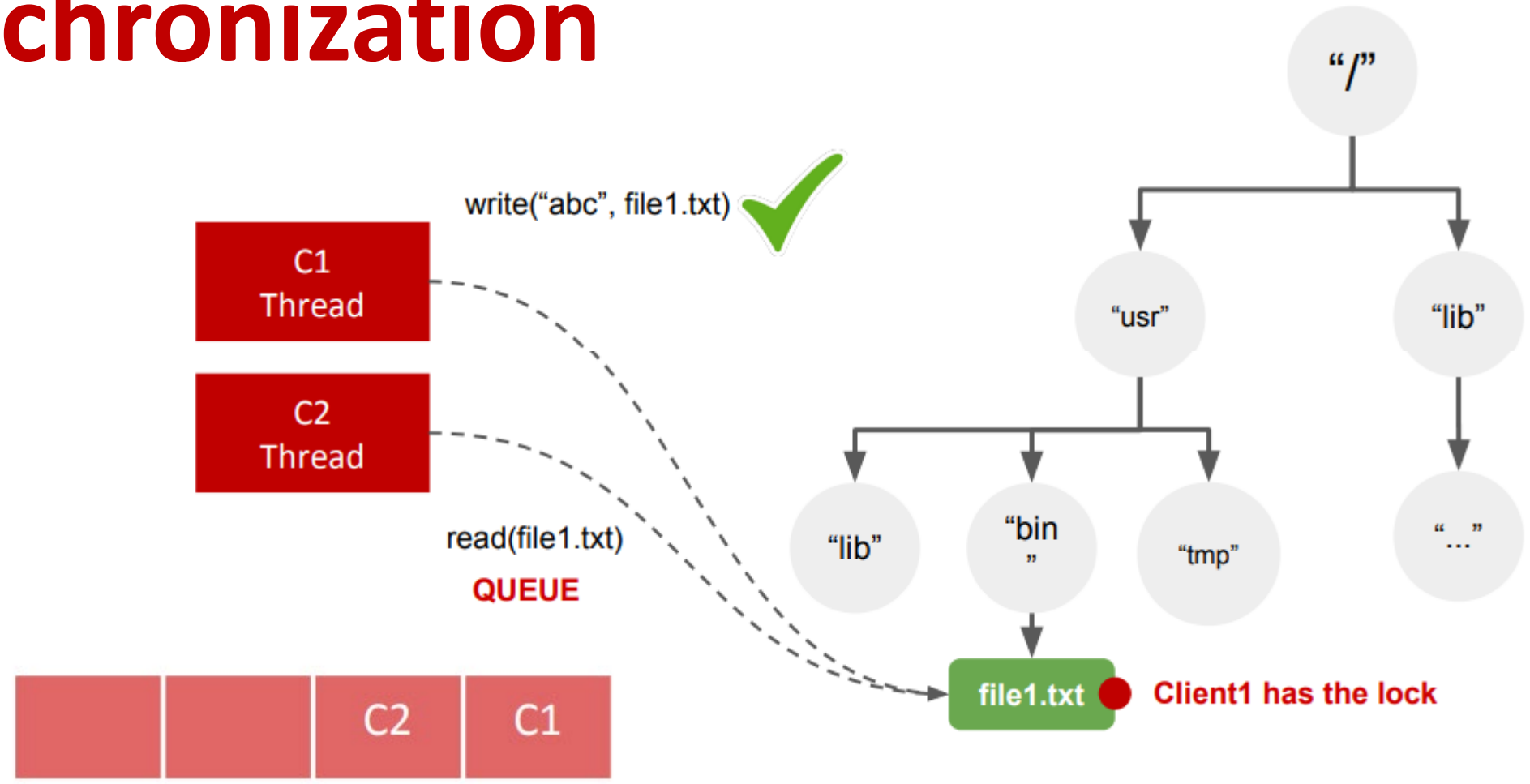

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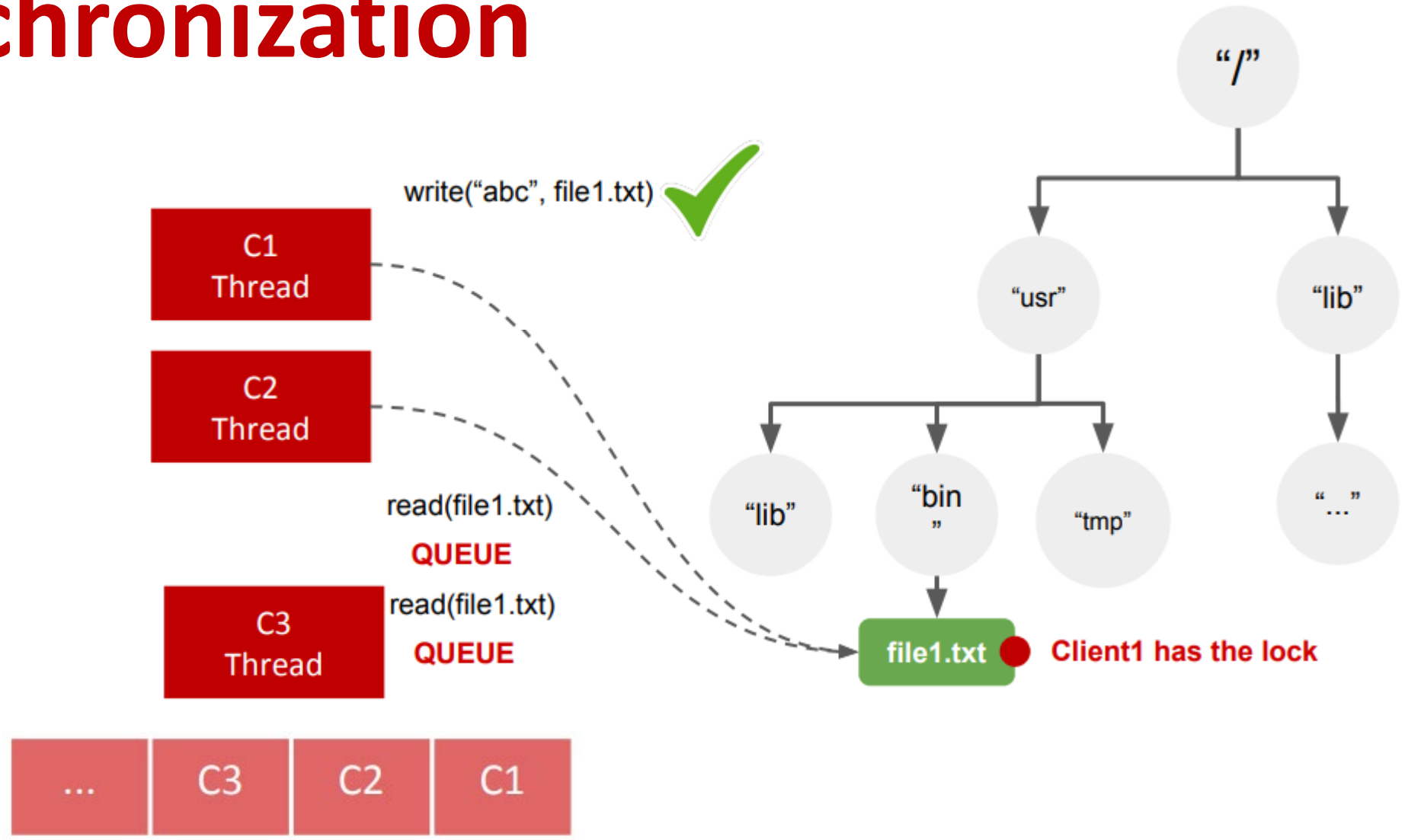

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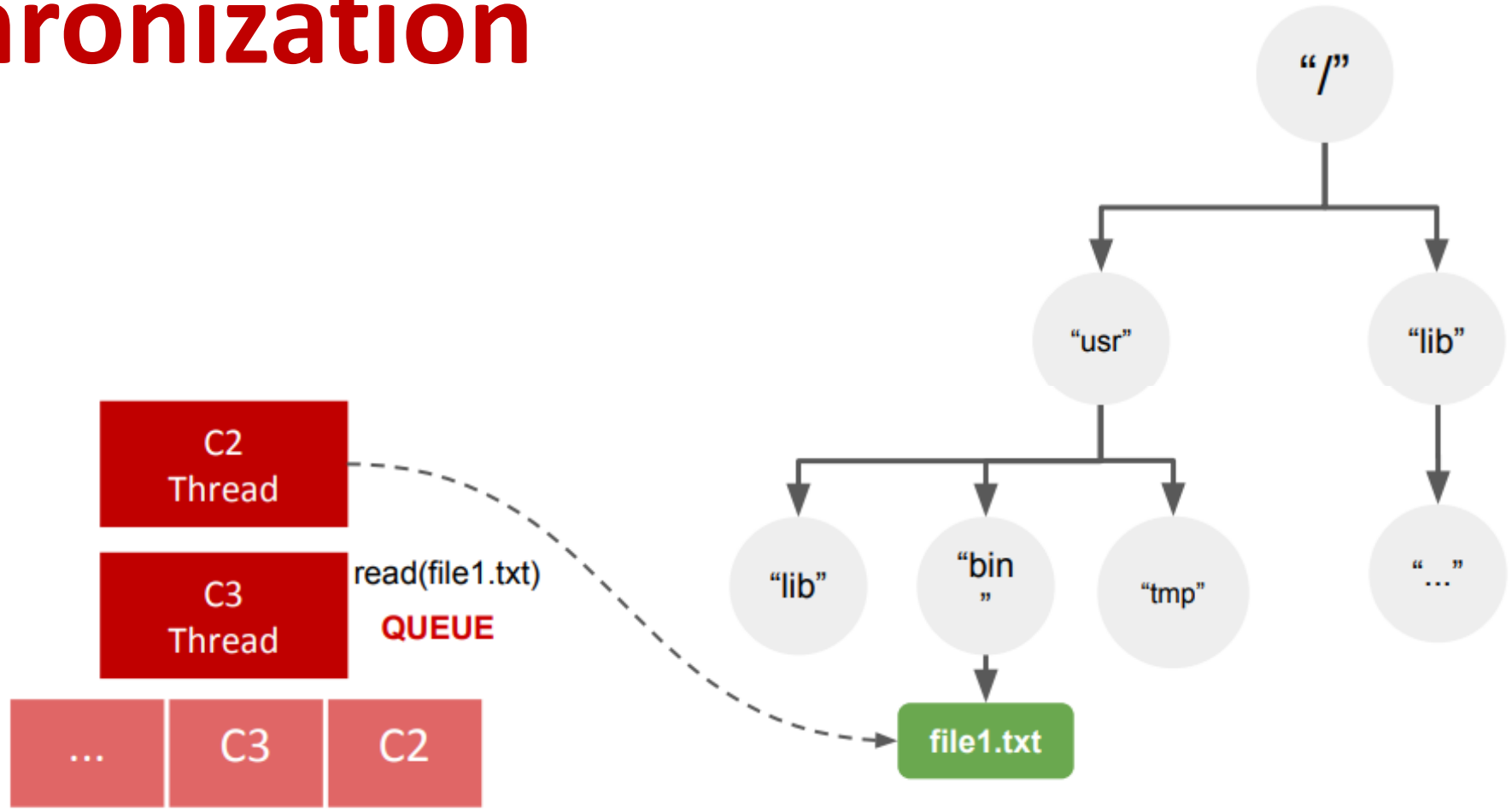

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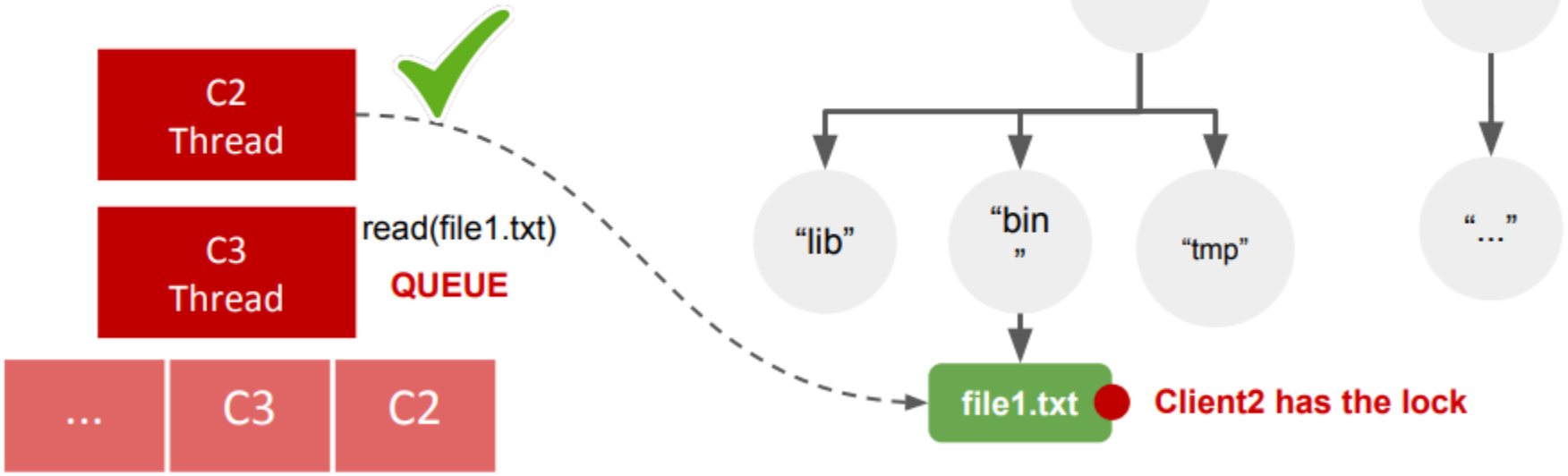
Synchronization

Is this good enough?



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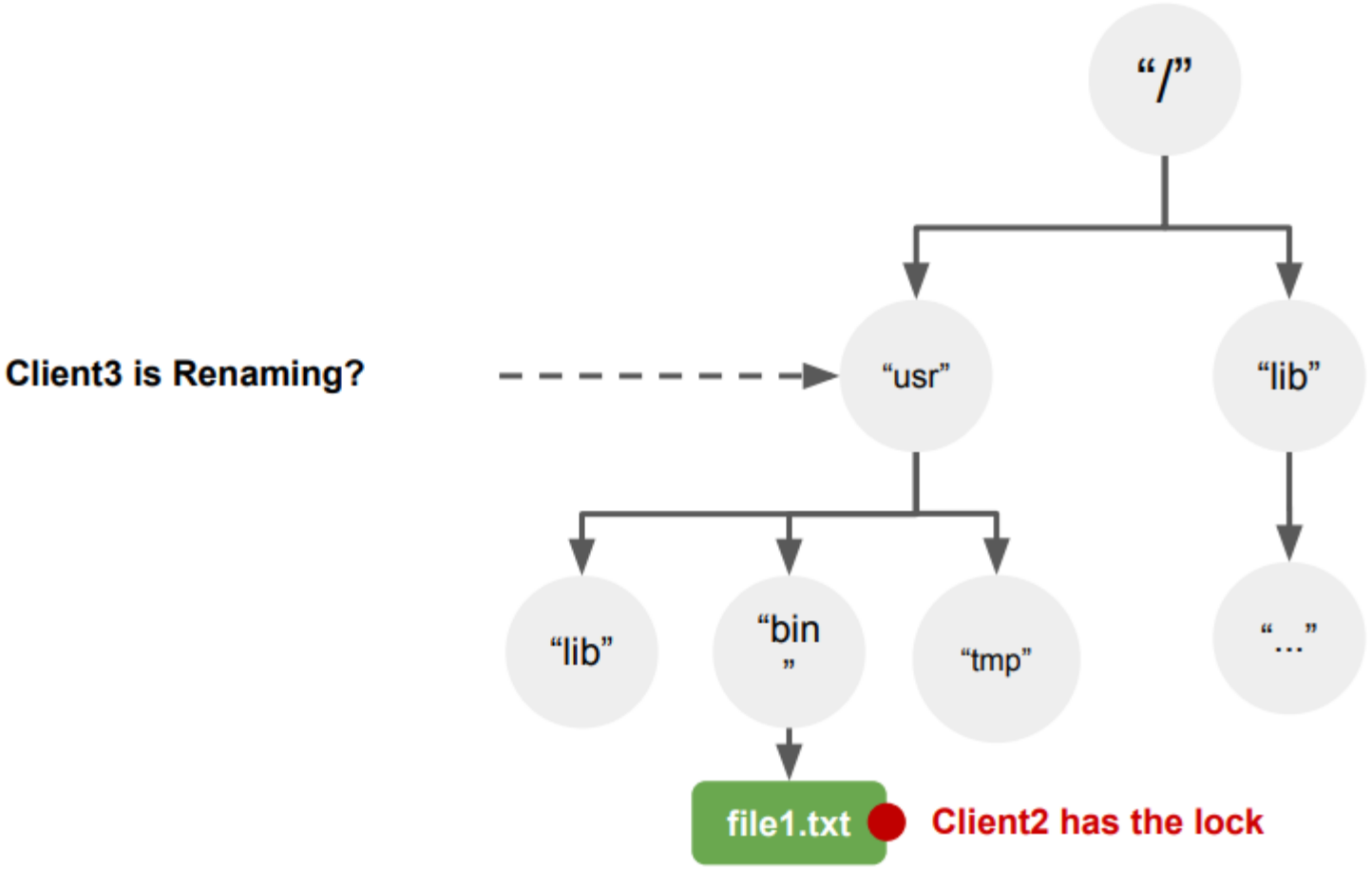

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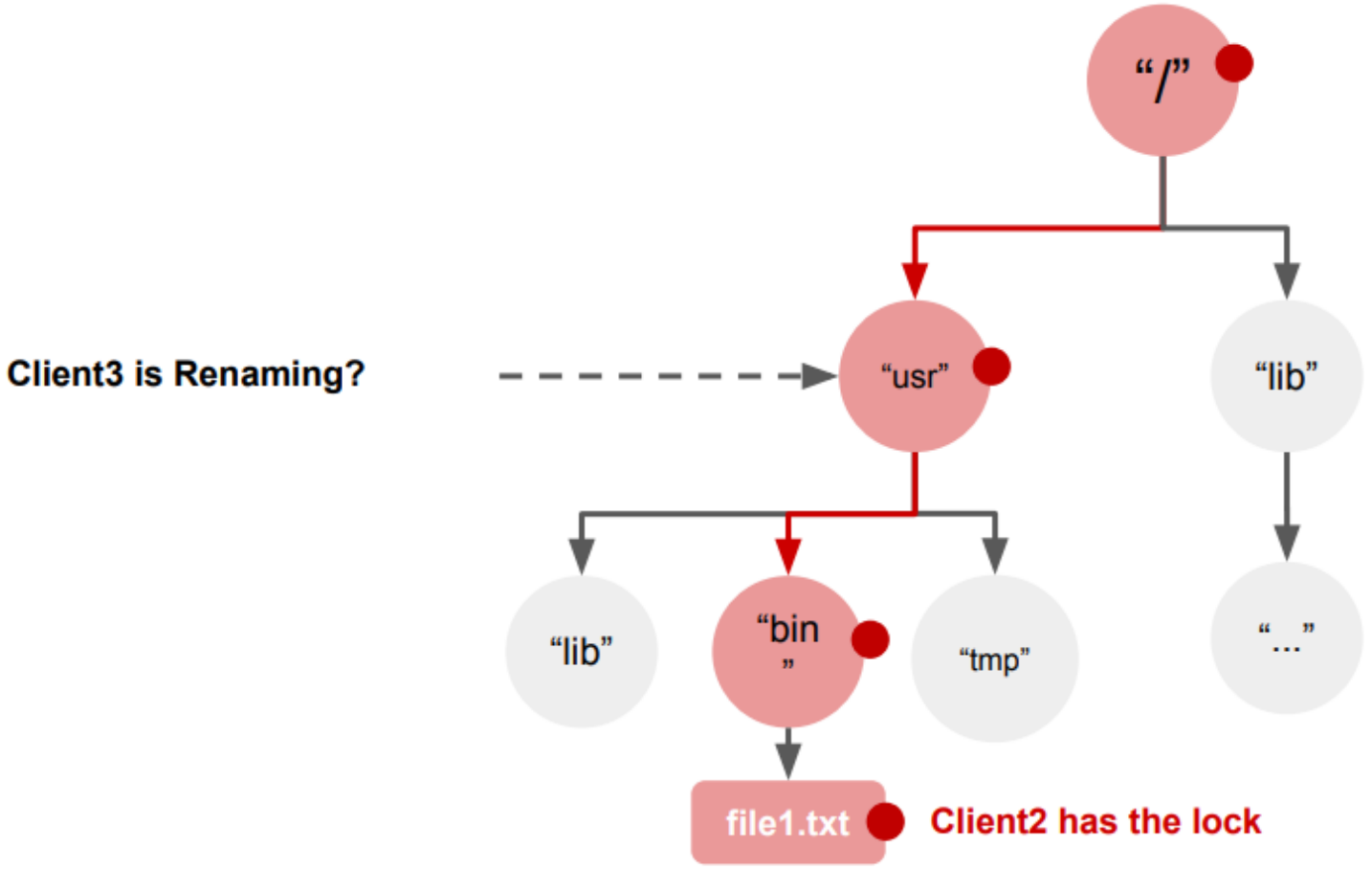

Mutual Exclusion Recap

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

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Service Interface

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

Project 2 Objectives

1. Logical Synchronization of Readers and Writers

2. **Devise and apply a replication algorithm that:**
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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

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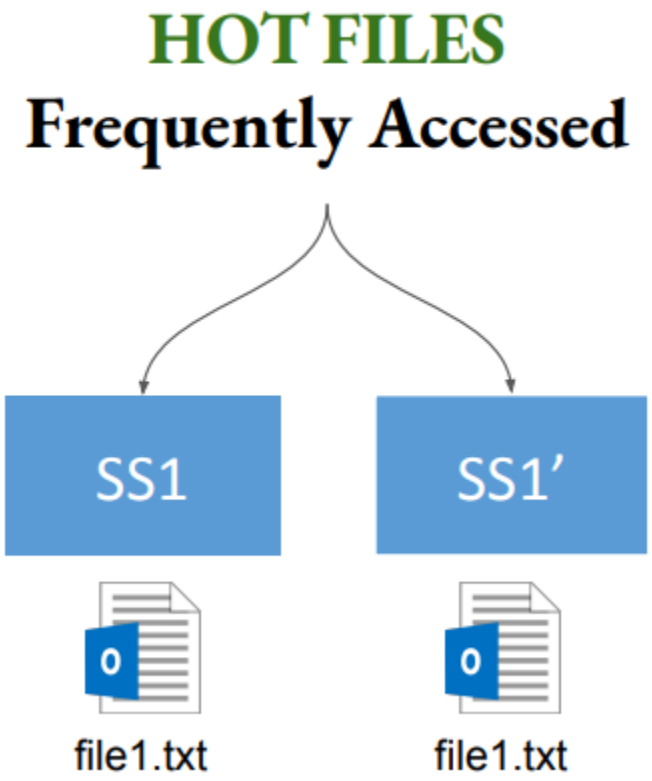
How many replicas?



num_replicas = ALPHA * num_requesters

num_replicas = min (ALPHA * num_requesters , REPLICA_UPPER_BOUND)

num_requesters_coarse = {N | N >= num_requesters & a m ul ti pl e o f 20}

num_replicas = min (ALPHA * num_requesters_coarse , REPLICA_UPPER_BOUND)

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**

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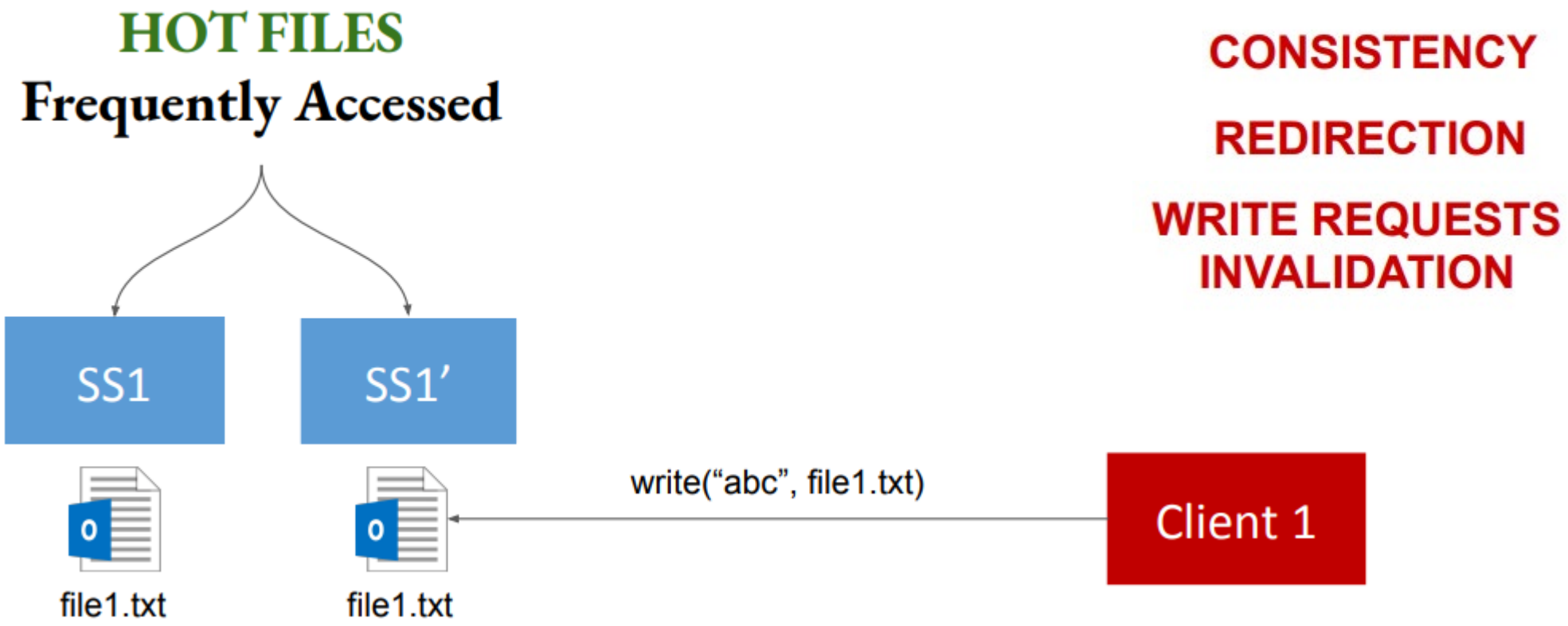
How can we Replicate?

- 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

Load Balancing

What are the challenges?



CONSISTENCY

REDIRECTION

WRITE REQUESTS INVALIDATION

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