Google File System

CS 475: Concurrent & Distributed Systems (Fall 2021)

Lecture 5-2

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Some material taken/derived from:

- Princeton COS-418 materials created by Michael Freedman and Wyatt Lloyd.
- MIT 6.824 by Robert Morris, Frans Kaashoek, and Nickolai Zeldovich.

Review: MapReduce assumptions

- Commodity hardware
  - Economies of scale!
  - Commodity networking with less bisection bandwidth
  - Commodity storage (hard disks) is cheap
- Failures are common
- Replicated, distributed file system for data storage ← Today

Review: Fault tolerance

- If a task crashes:
  - Retry on another node
    - Why this is okay?
  - If the same task repeatedly fails, end the job

Review: Fault tolerance

- If a task crashes:
  - Retry on another node
    - Why this is okay?
  - If the same task repeatedly fails, end the job
- If a node crashes:
  - Relaunch its current tasks on another node
    - What about task inputs?

Google file system (GFS)

- Goal: a global (distributed) file system that stores data across many machines
  - Need to handle 100's TBs

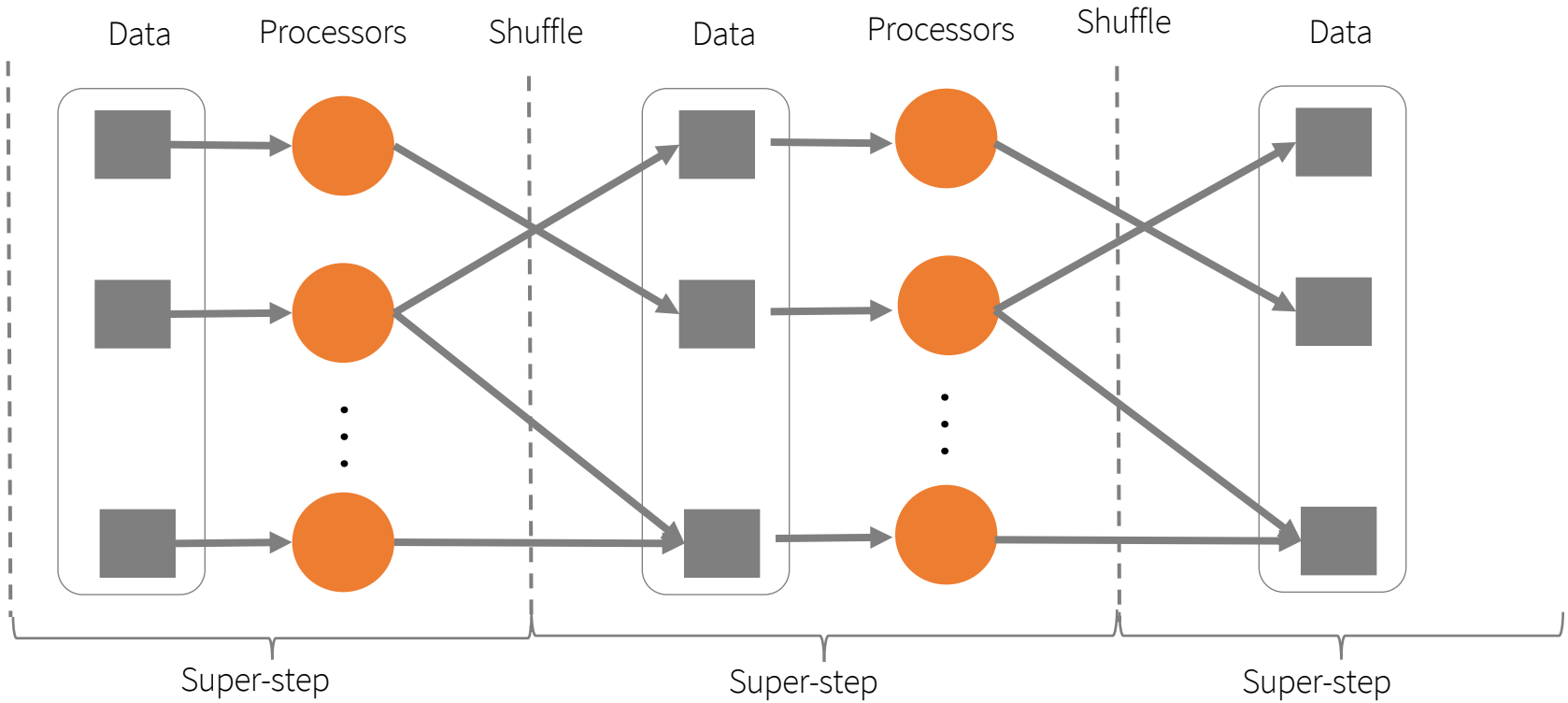
- Google published details in 2003

- Open source implementation:
  - Hadoop Distributed File System (HDFS)

Workload-driven design

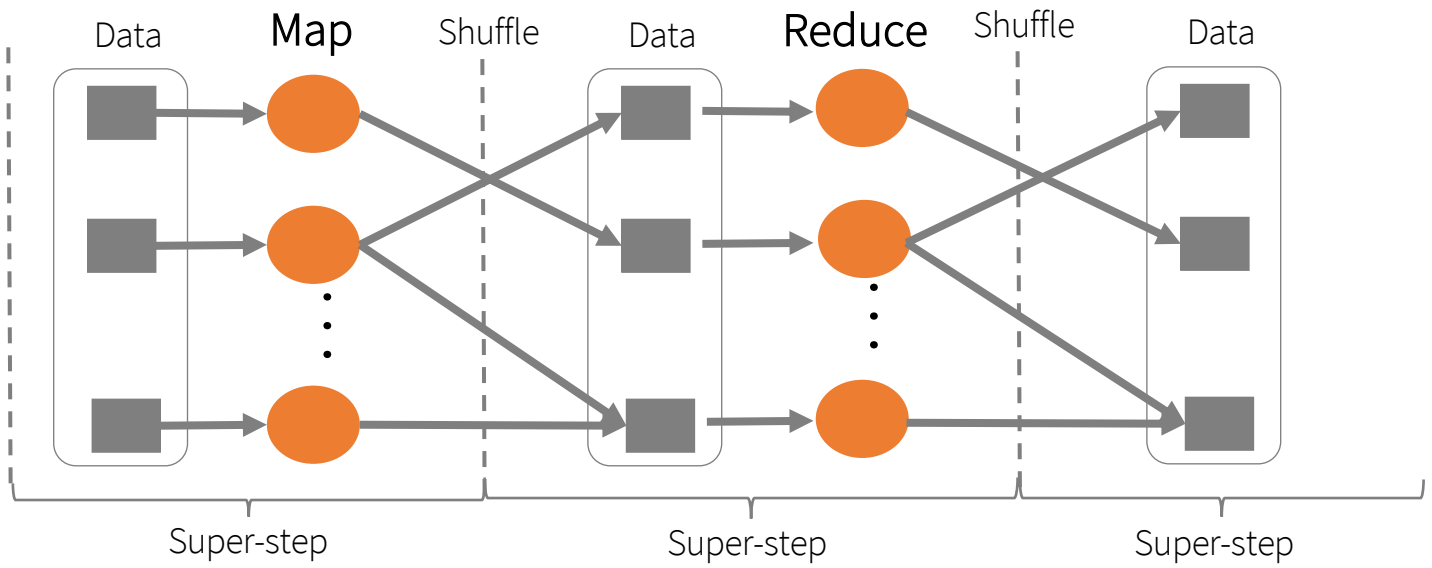
- MapReduce workload characteristics
  - Huge files (GBs)
  - Almost all writes are appends
  - Concurrent appends common
  - High throughput is valuable
  - Low latency is not

Example workloads: Bulk Synchronous Processing (BSP)



*Leslie G. Valiant, A bridging model for parallel computation, Communications of the ACM, Volume 33 Issue 8, Aug. 1990

MapReduce as a BSP system



- Read entire dataset, do computation over it
  - Batch processing

- Producer/consumer: many producers append work to file concurrently; one consumer reads and does work

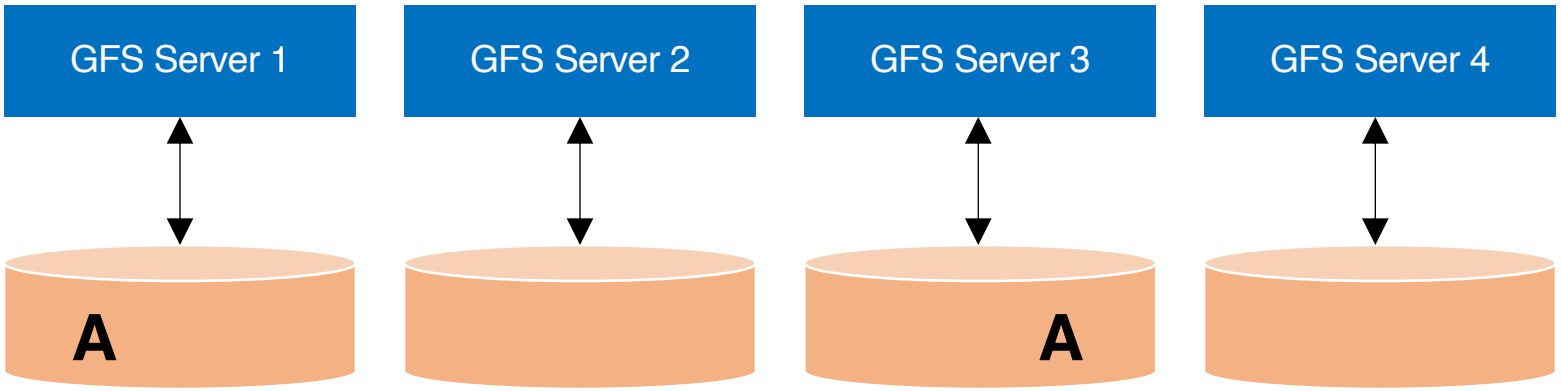
Workload-driven design

- Build a global (distributed) file system that incorporates all these application properties

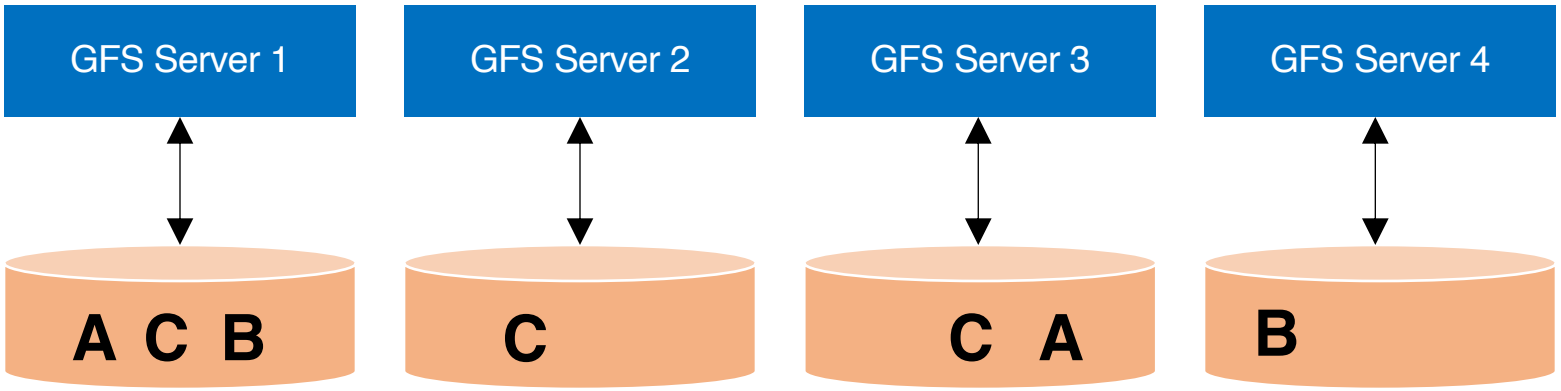
- Only supports features required by applications

- Avoid difficult local file system features, e.g.:
  - rename dir
  - links

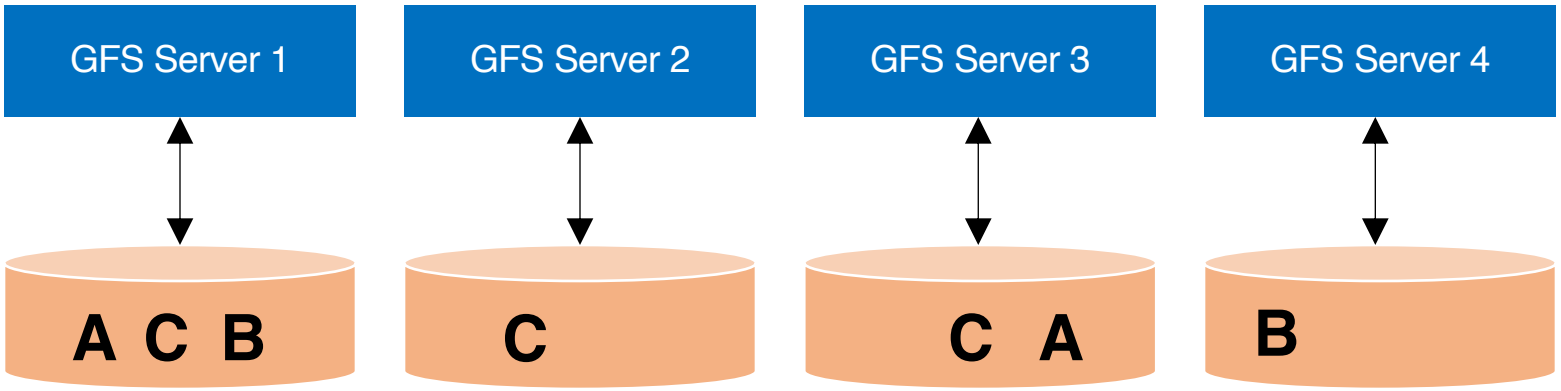
Replication



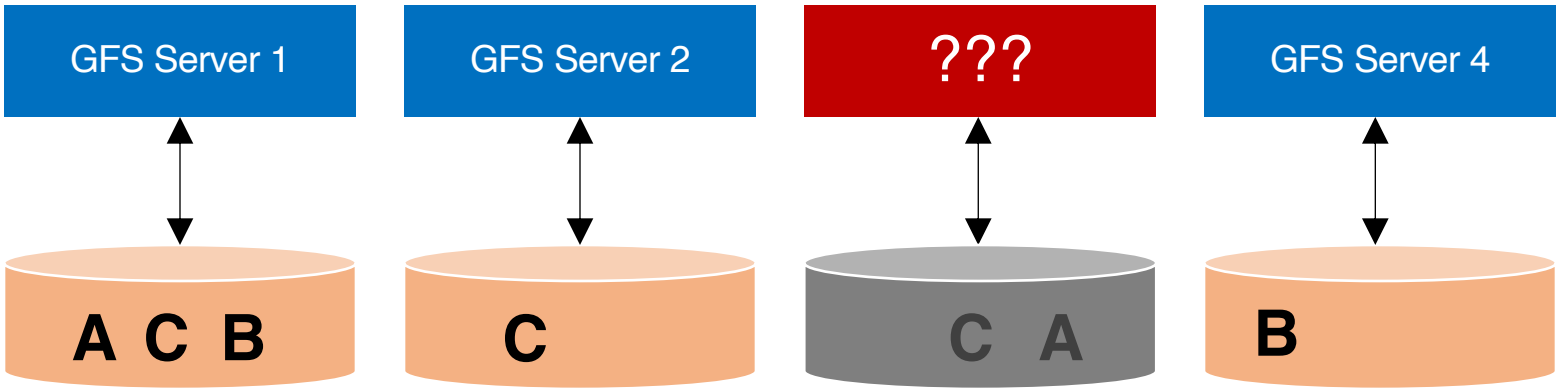
Replication



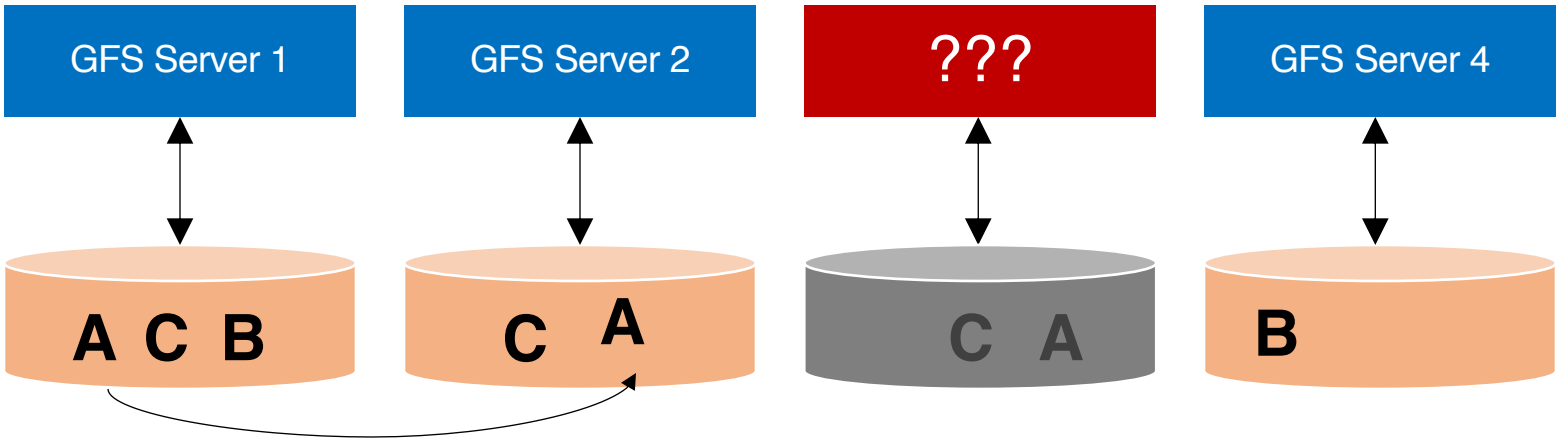
Resilience against failures



Resilience against failures

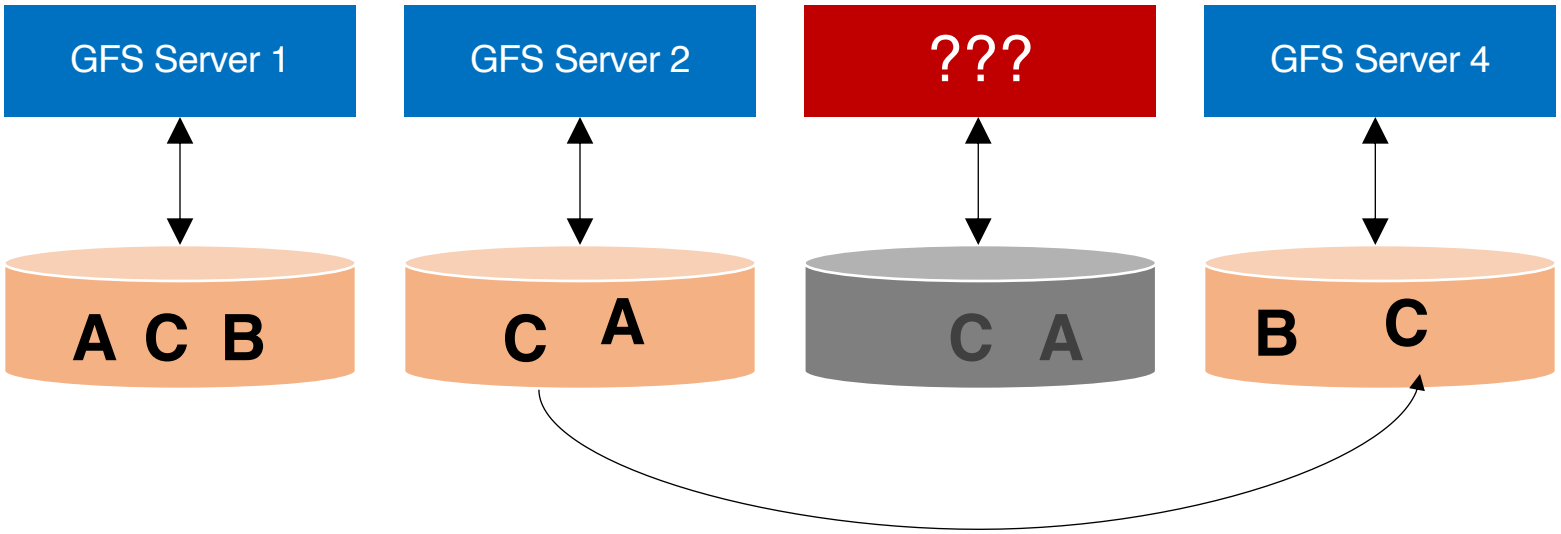


Data recovery



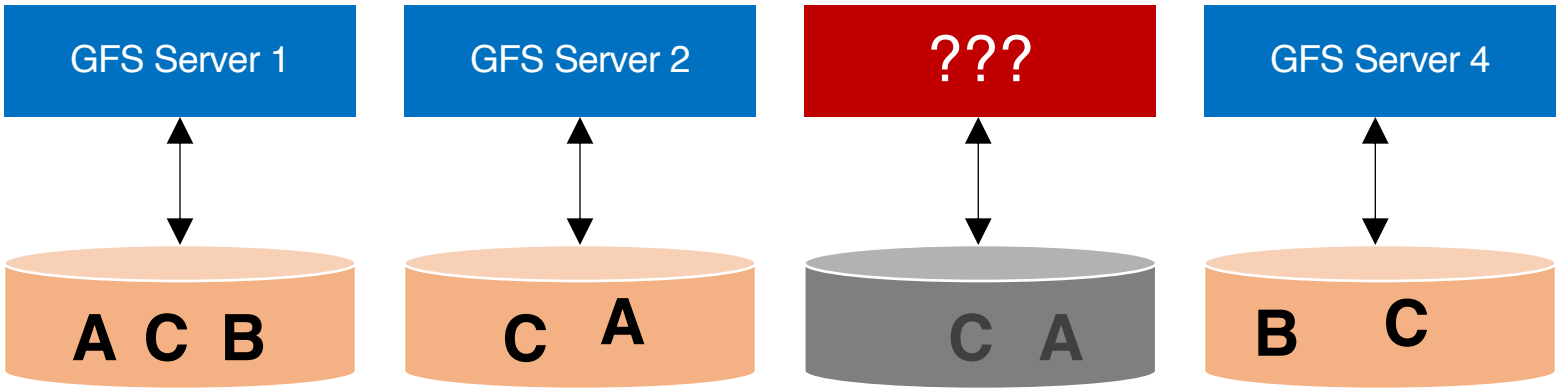
Replicating A to maintain a replication factor of 2

Data recovery



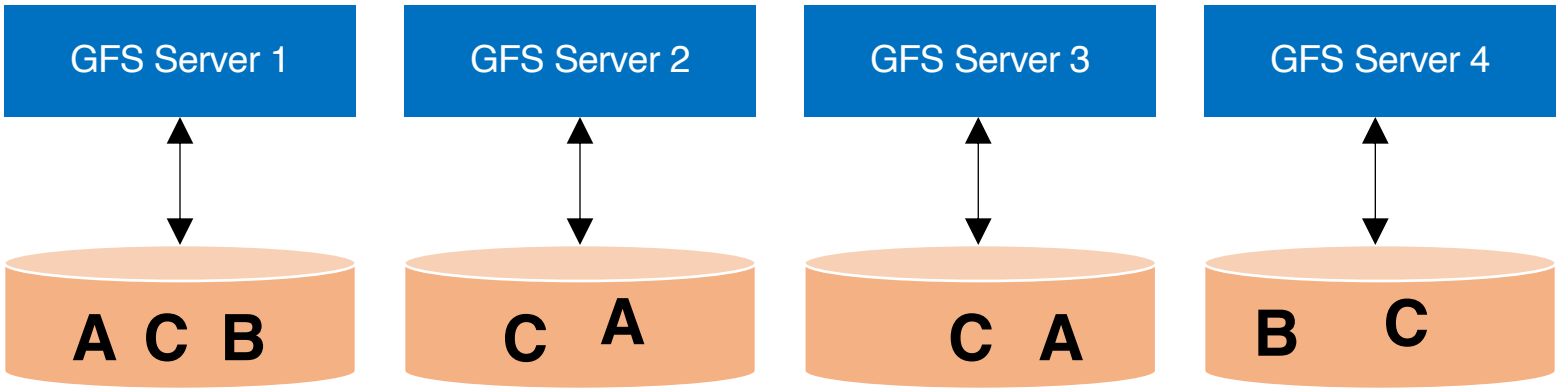
Replicating C to maintain a replication factor of 3

Data recovery



Machine may be dead forever, or it may come back

Data recovery



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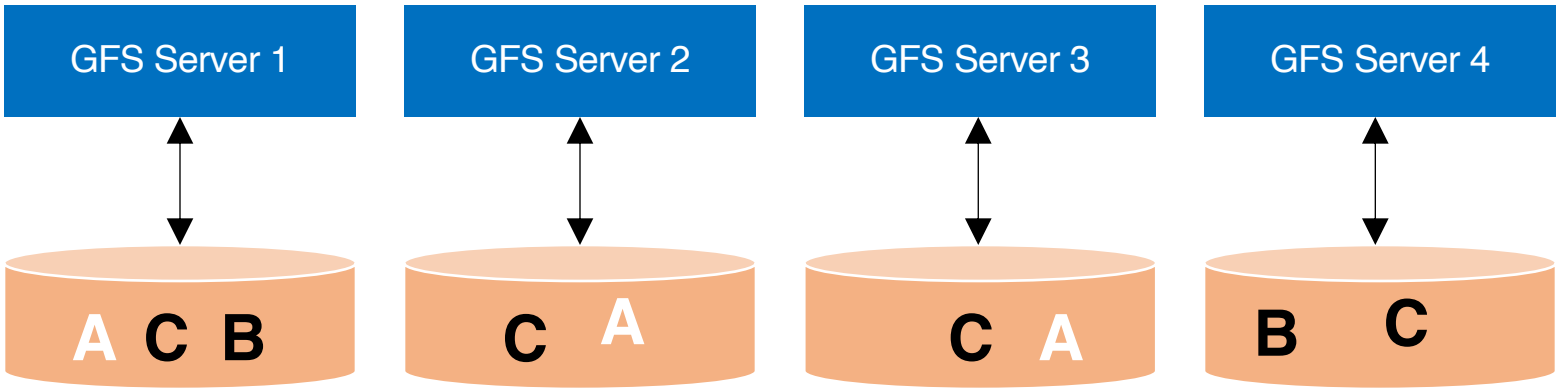
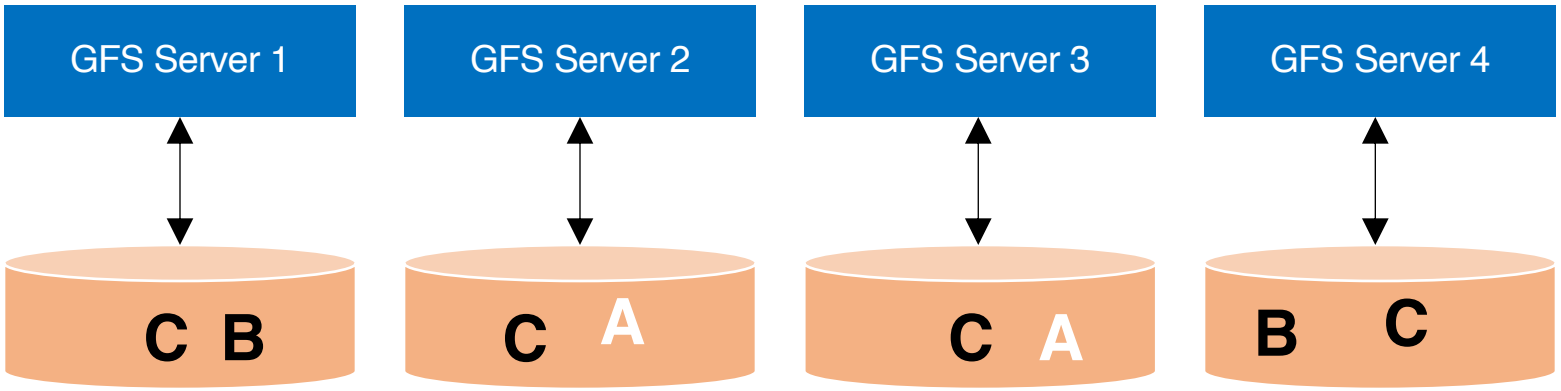


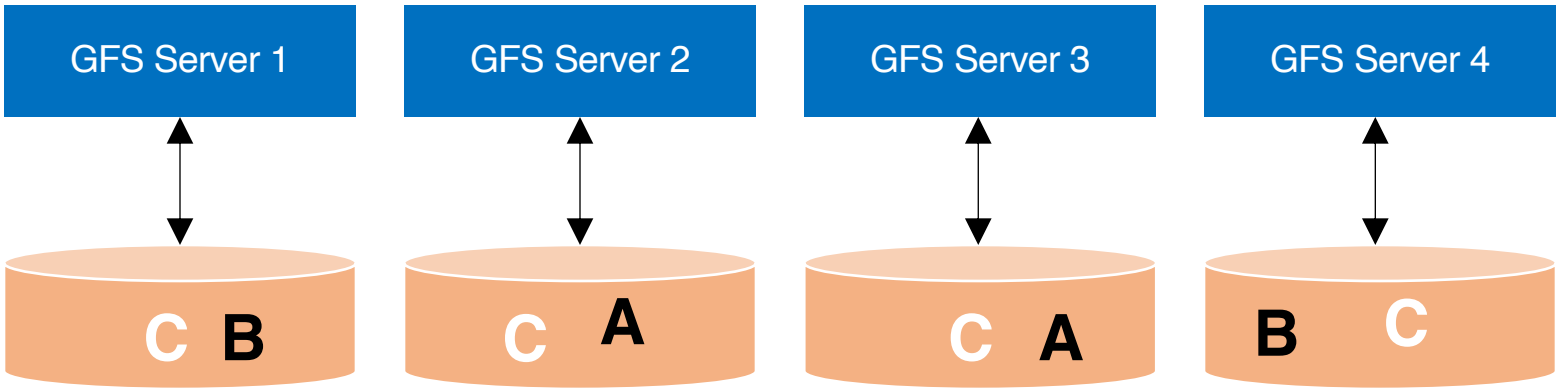
Data recovery



Data Rebalancing

Deleting one A to maintain a replication factor of 2

Data recovery



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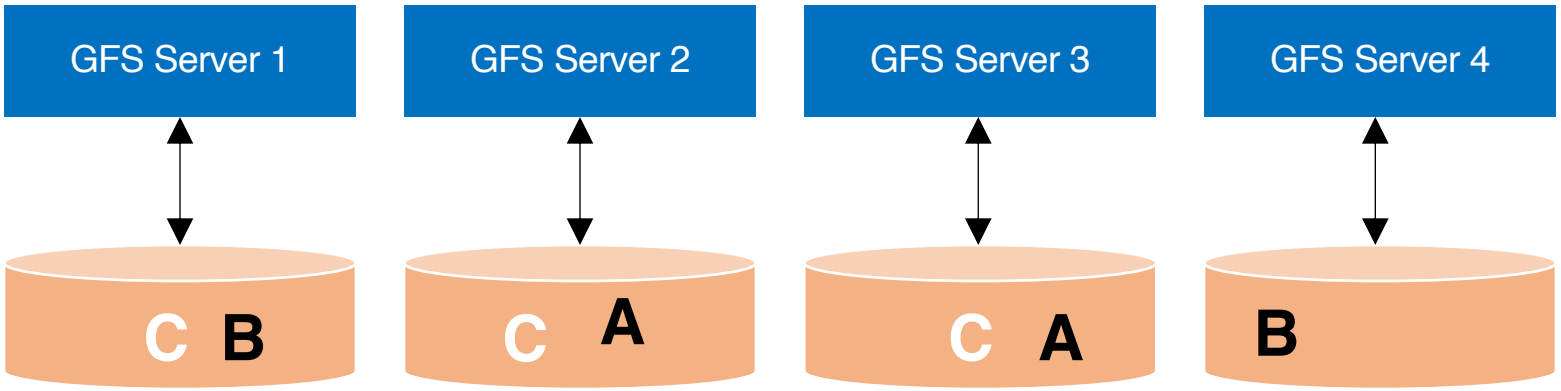
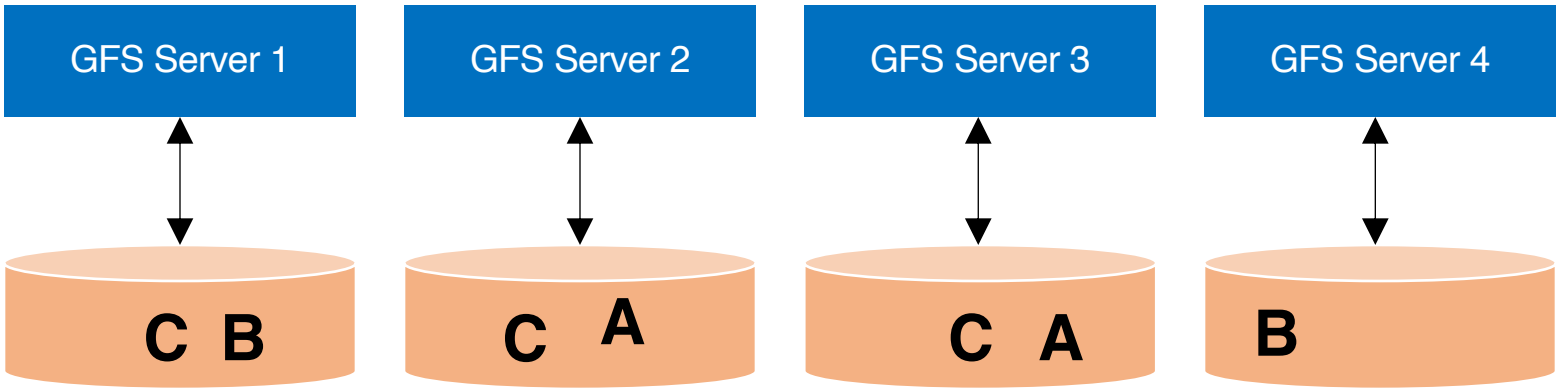


Data Rebalancing

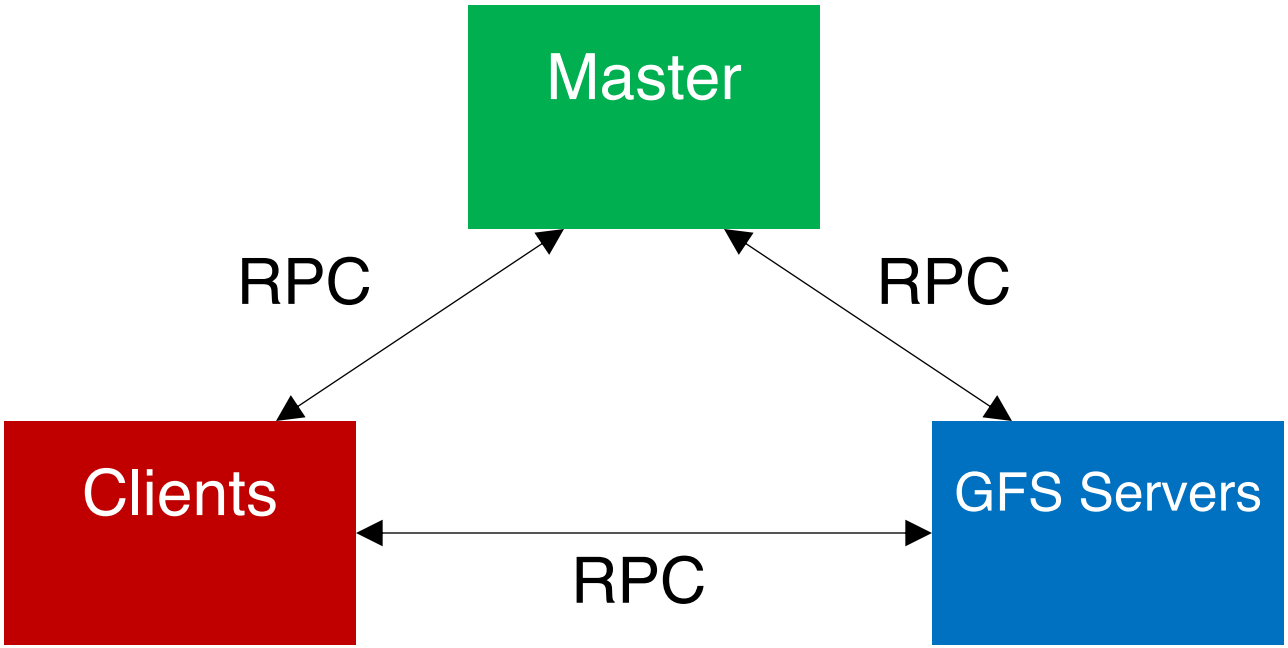
Deleting one C to maintain a replication factor of 3

Data recovery

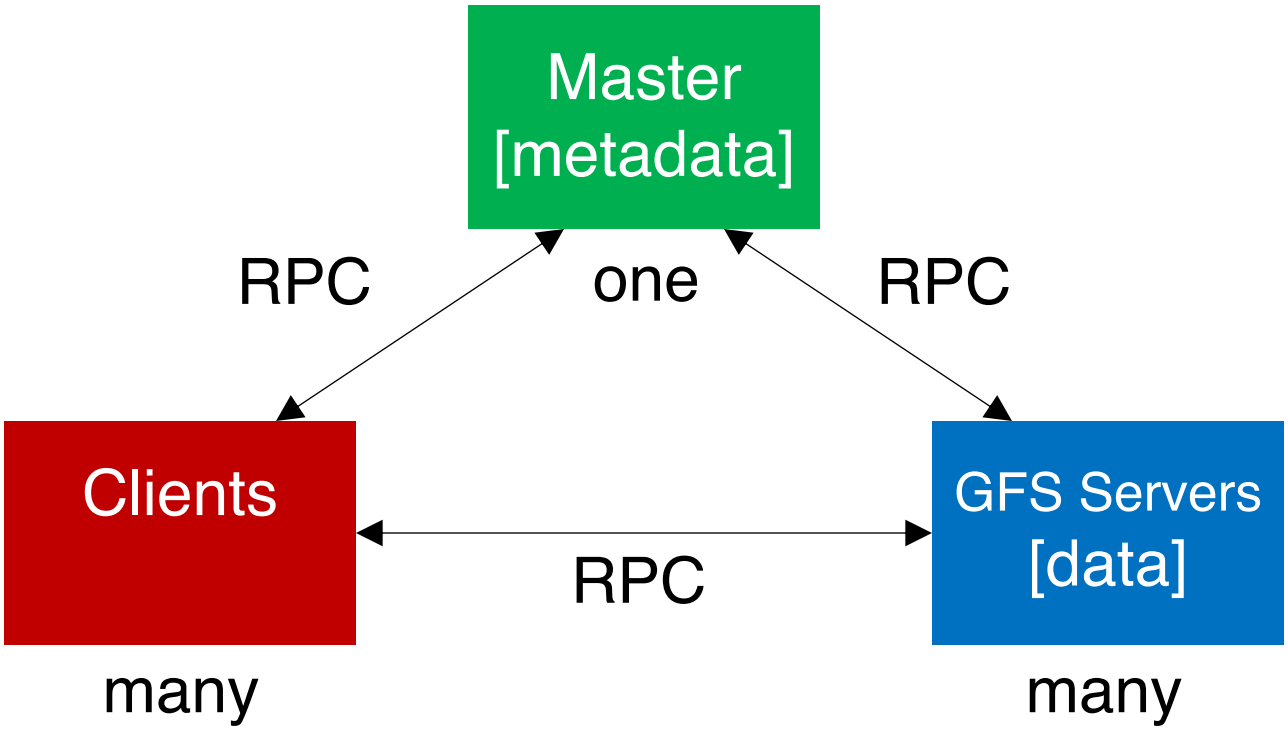


Question: how to maintain a global view of all data distributed across machines?

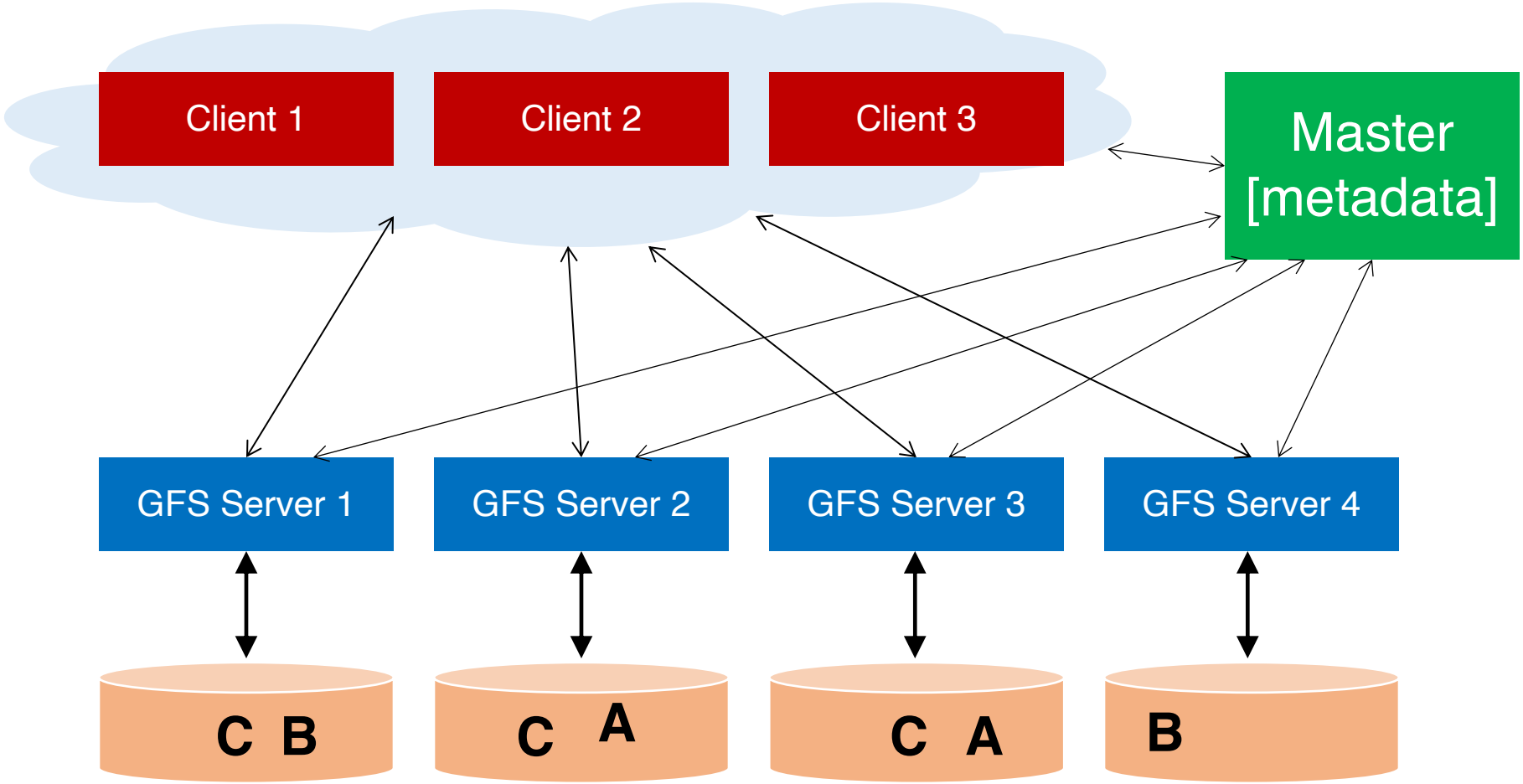
GFS architecture



GFS architecture



GFS architecture



Data chunks

- Break large GFS files into coarse-grained data chunks (e.g., 64MB)
- GFS servers store physical data chunks in local Linux file system
- Centralized master keeps track of mapping between logical and physical chunks

Chunk map

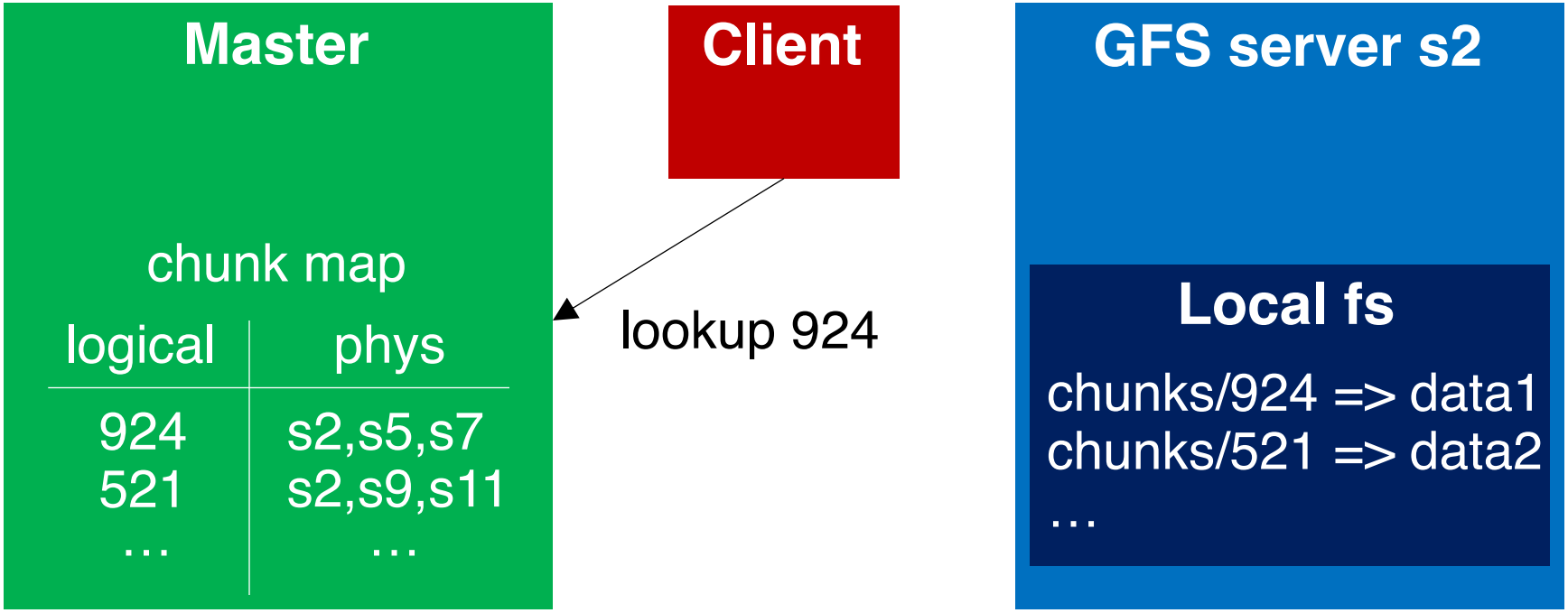
Master

chunk map

logical	phys
924	s2,s5,s7
521	s2,s9,s11
…	…

GFS server s2

Client reads a chunk



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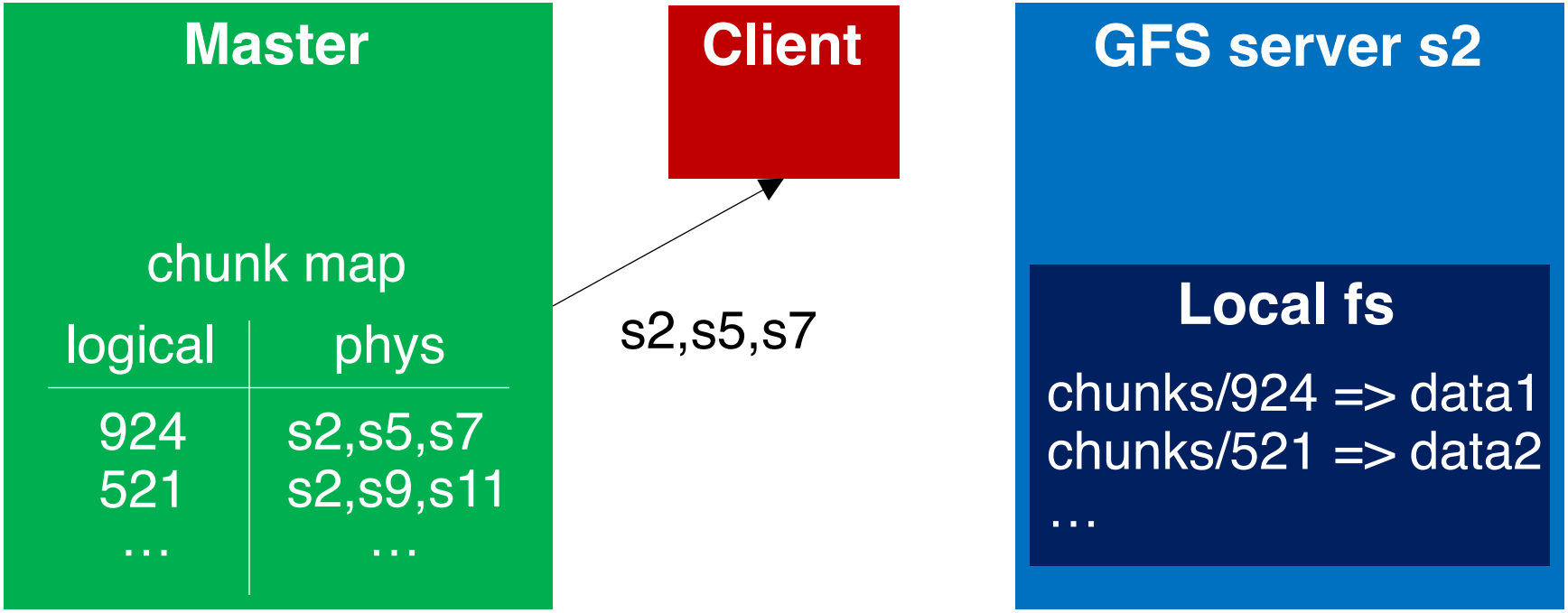

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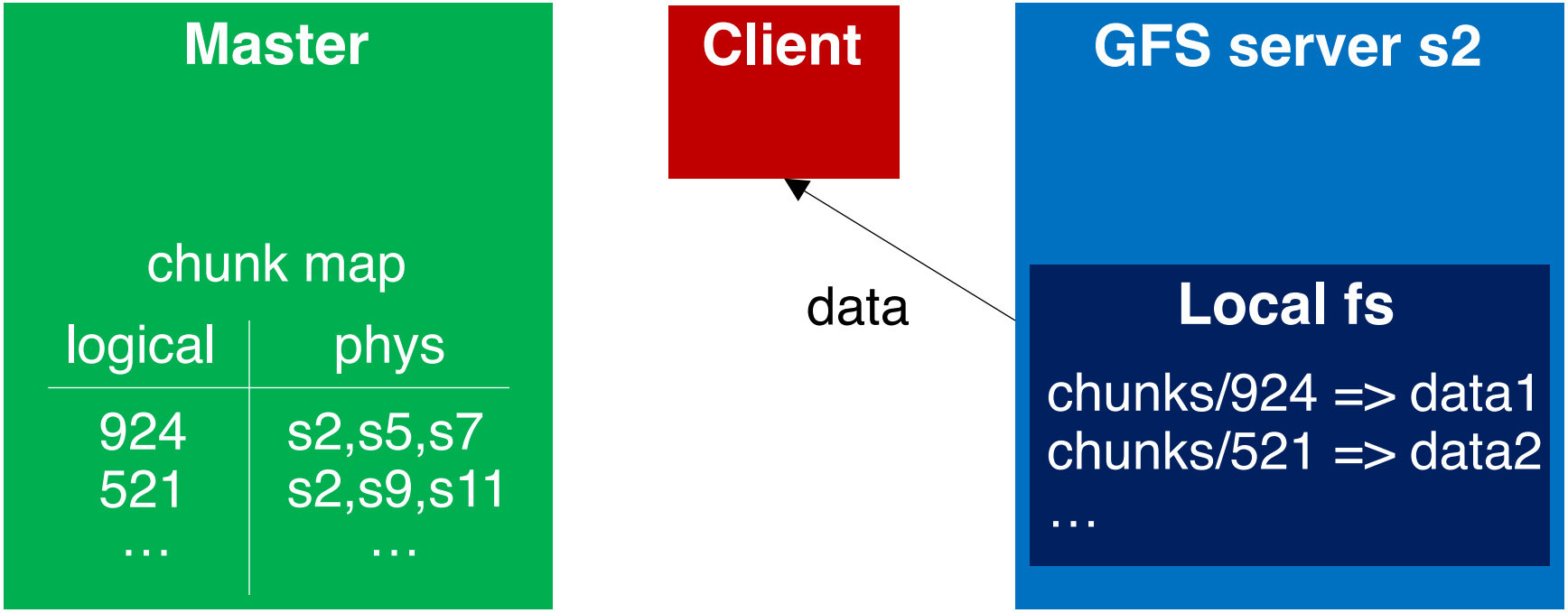

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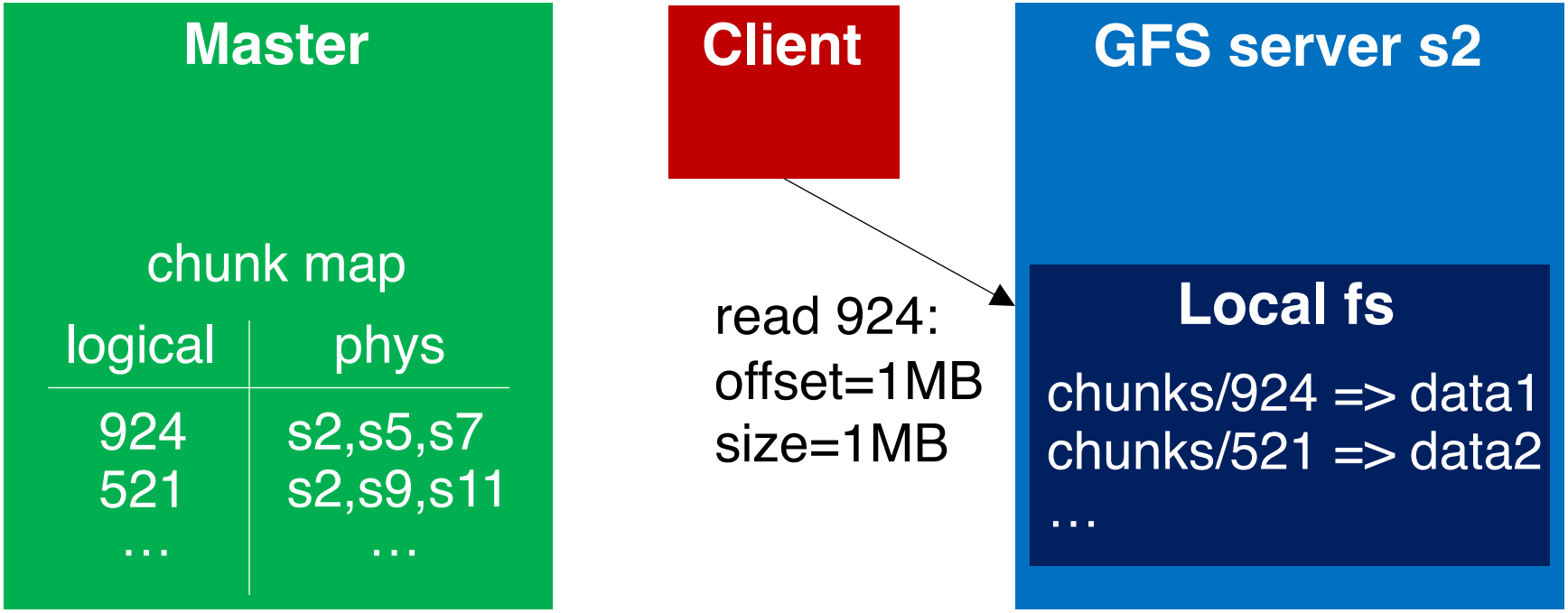

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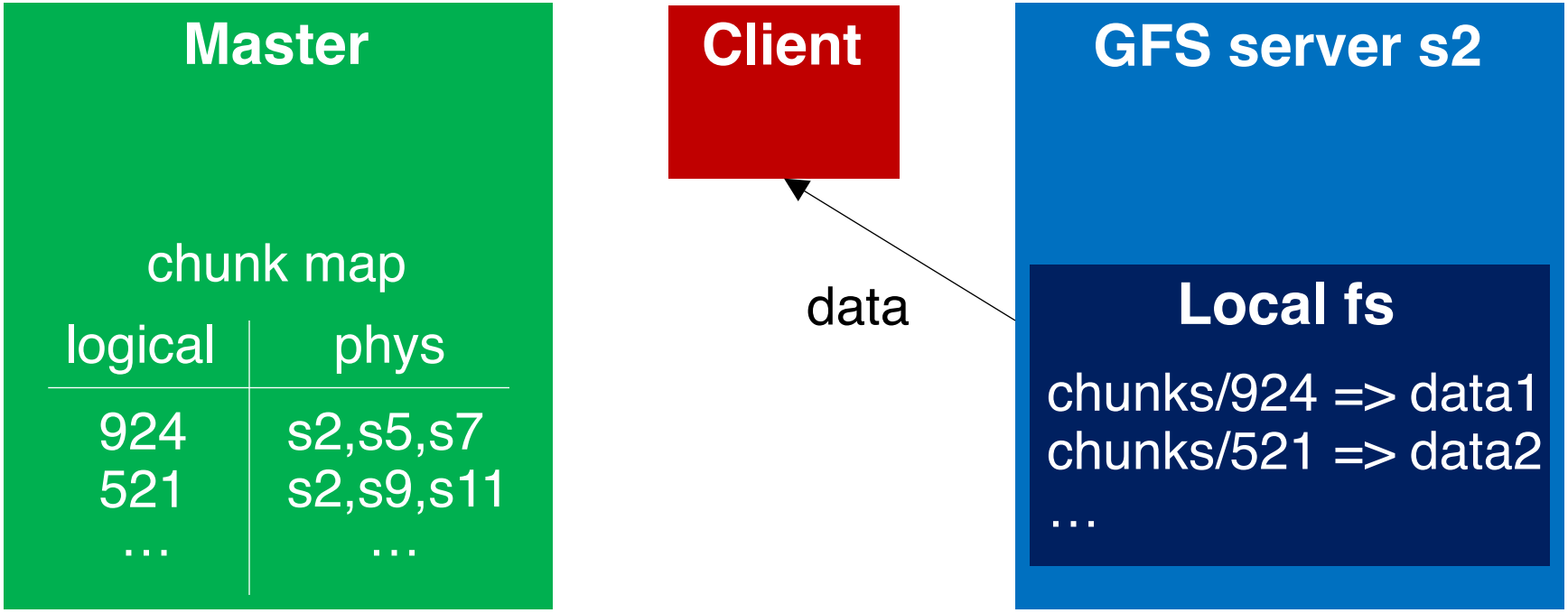
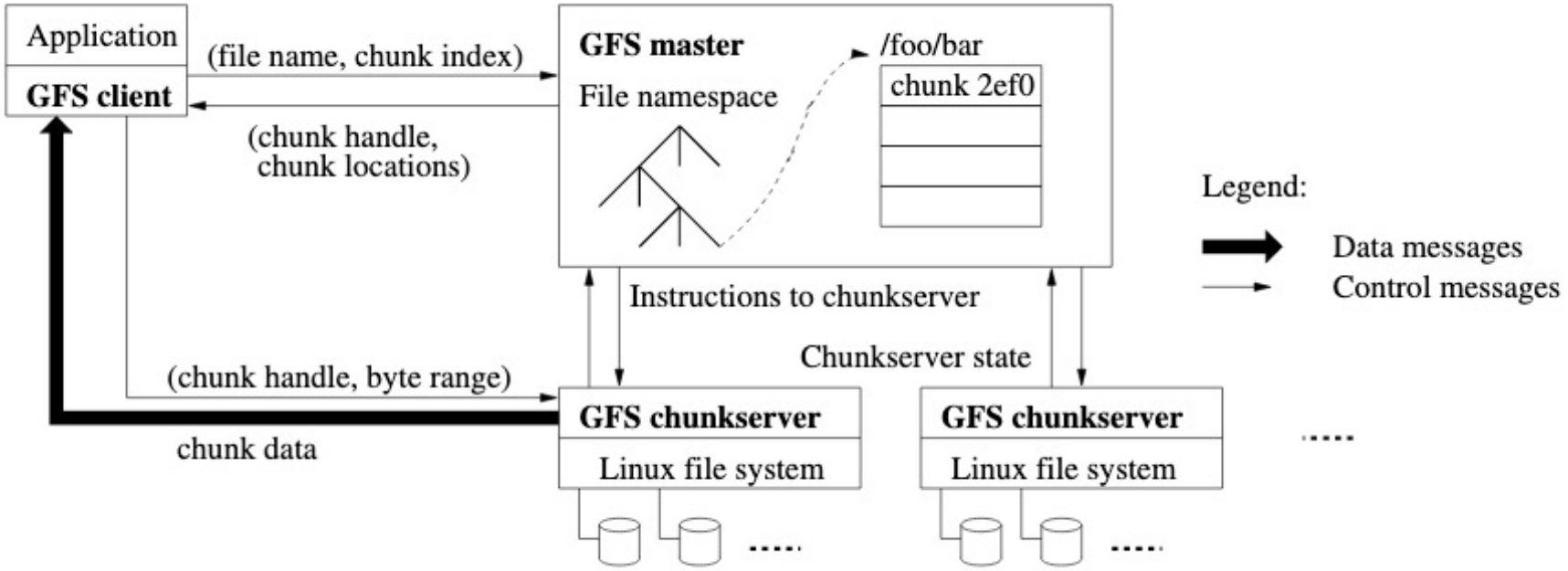


File namespace

path names mapped to logical names

GFS architecture (original paper)



MapReduce+GFS: Put everything together