Hello!

CS 744: GOOGLE FILE SYSTEM

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Fall 2021

ANNOUNCEMENTS

- Assignment 1 out later today
- Group submission form
- Anybody on the waitlist?

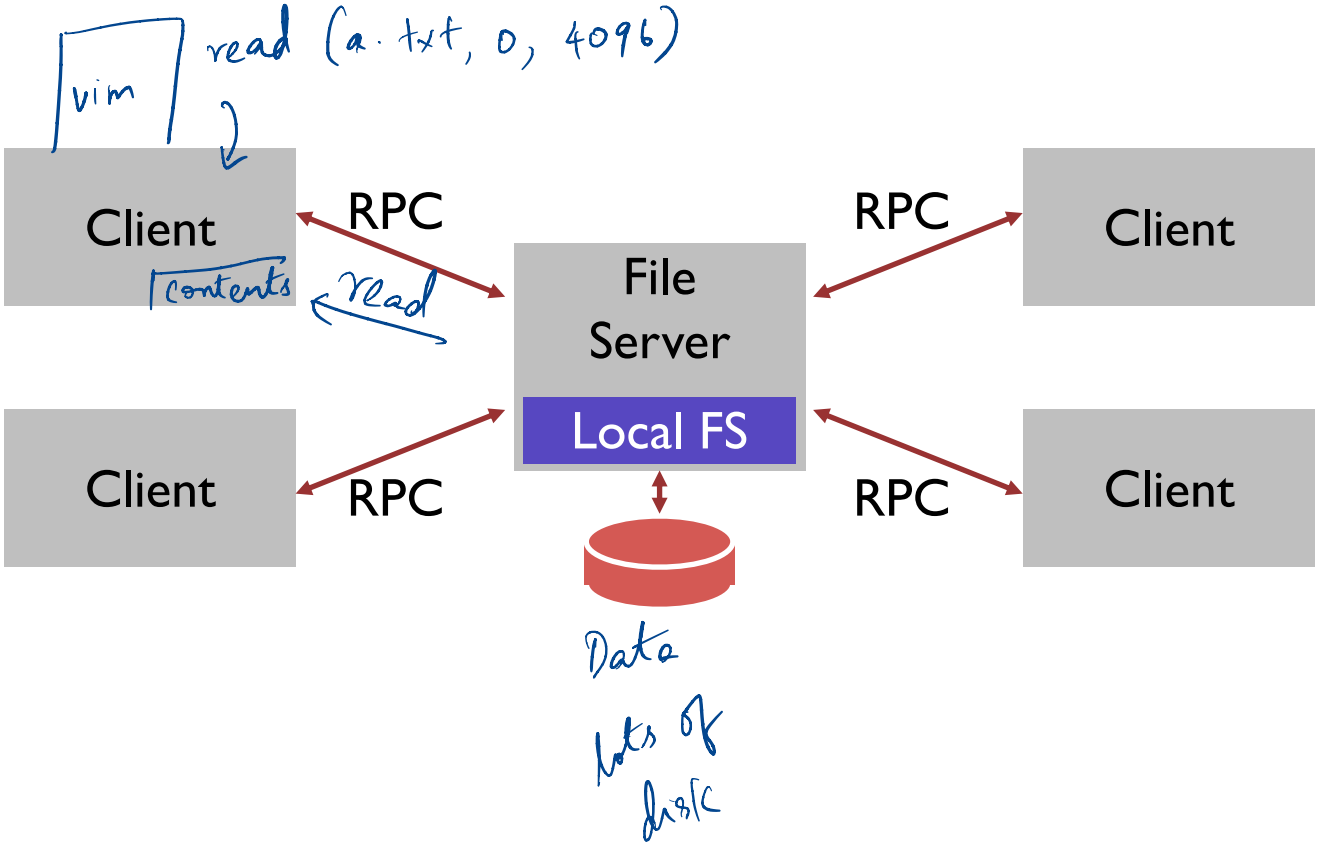
OUTLINE

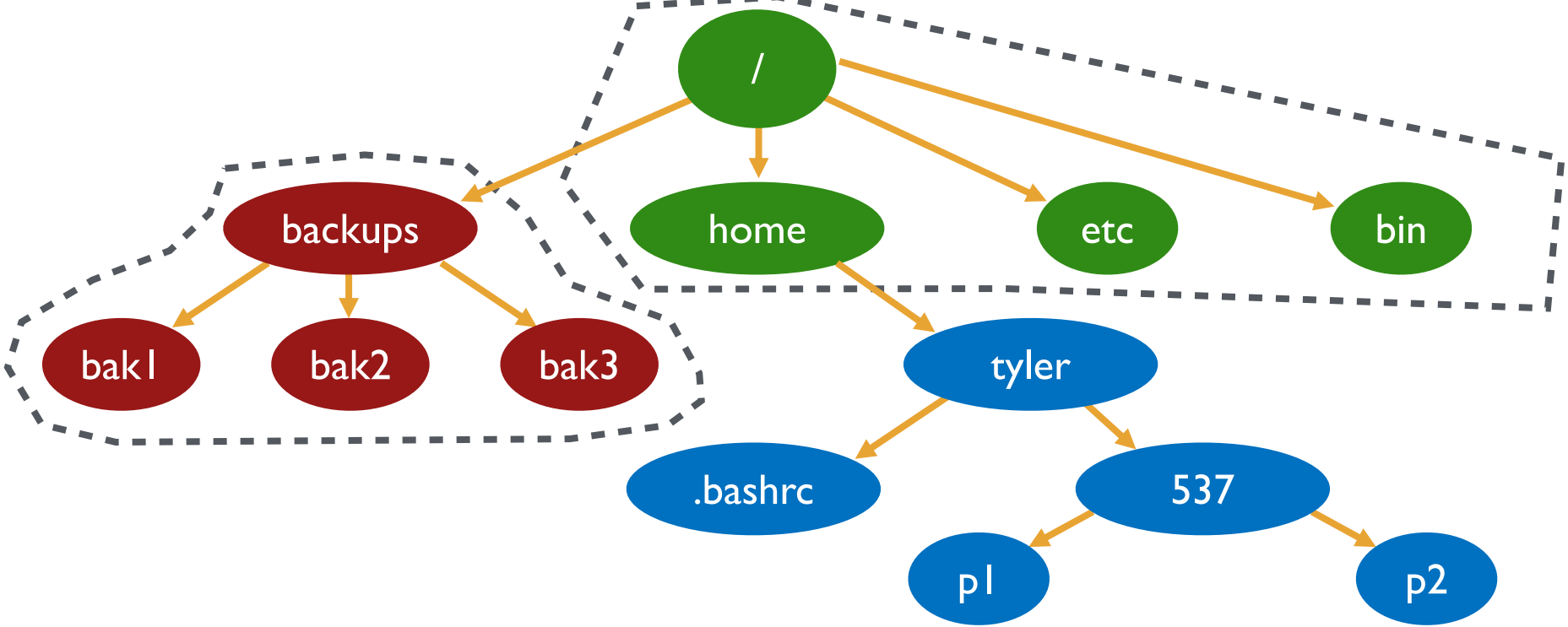
1. Brief history
2. GFS
3. Discussion
4. What happened next?

HISTORY OF DISTRIBUTED FILE SYSTEMS

~ 1980s

SUN NFS





/dev/sda1 **on** /

/dev/sdb1 **on** /backups

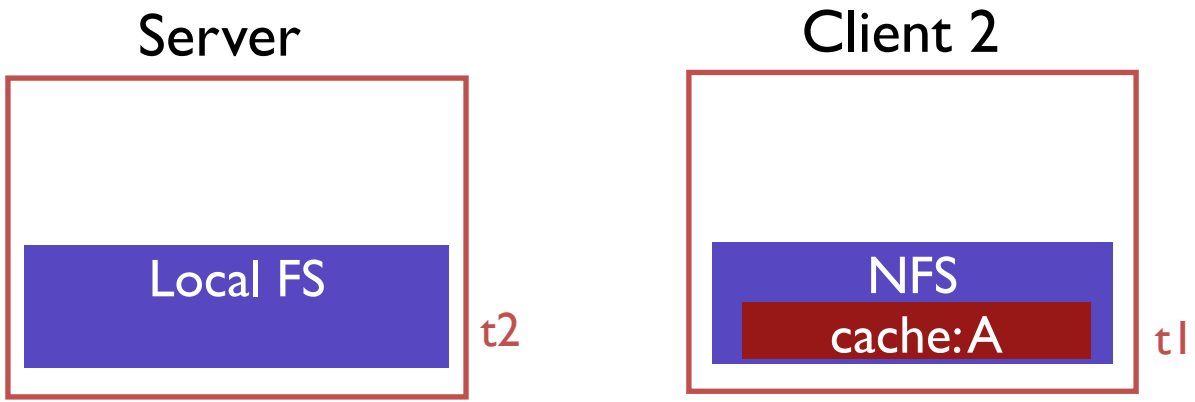
NFS **on** /home

Transparent to the user

NFS provided POSIX semantics

CACHING

Client - side caching + STAT requests to validate cache entries



Client cache records time when data block was fetched (t1)

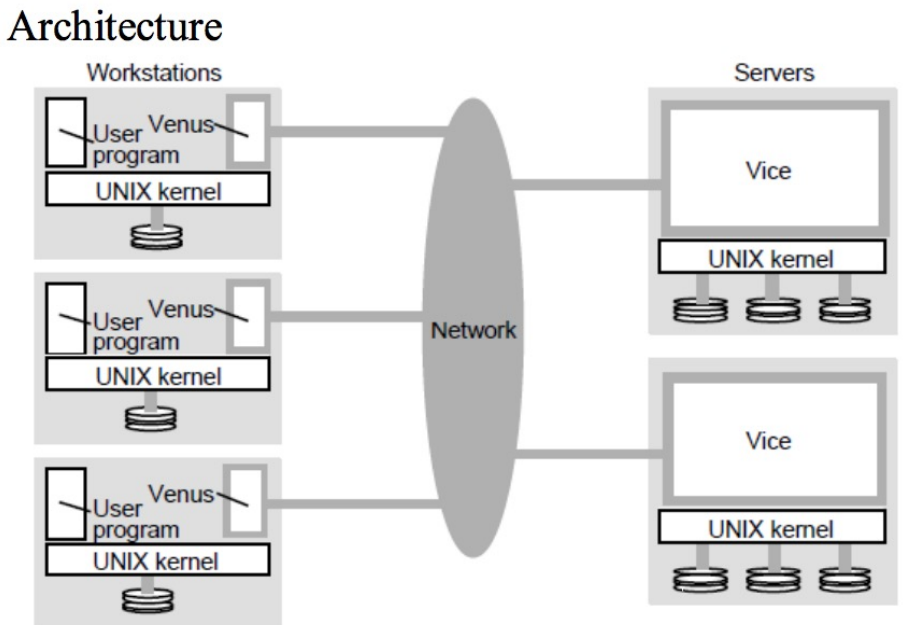
Before using data block, client does a STAT request to server

- get's last modified timestamp for this file (t2) (not block…)
- compare to cache timestamp
- refetch data block if changed since timestamp (t2 > t1)

ANDREW FILE SYSTEM (AFS)

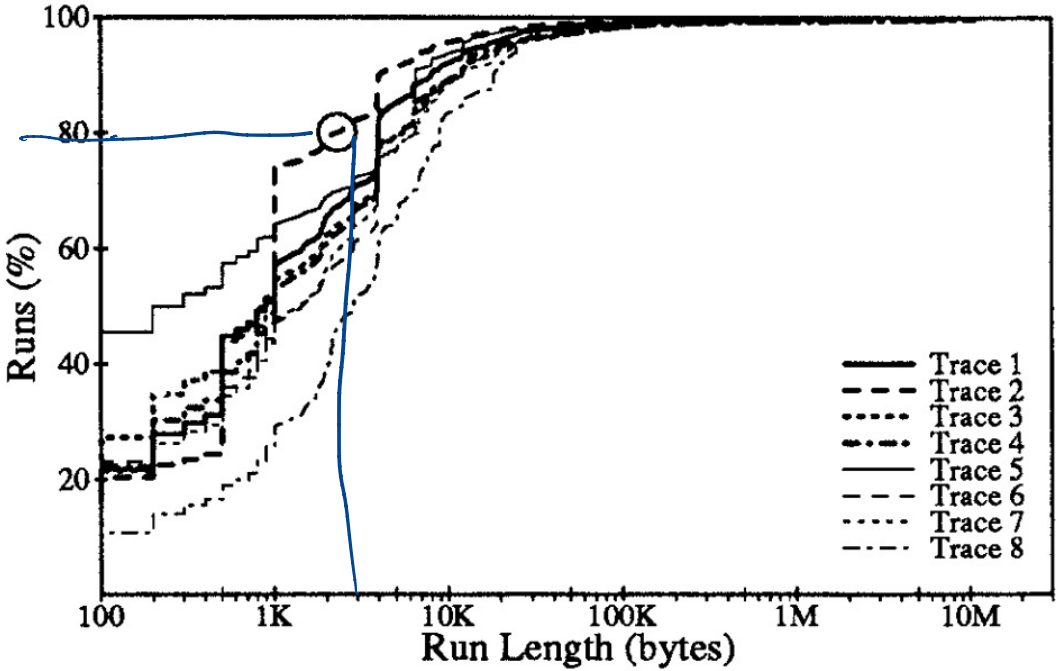
when you open a file, entire file is read from server and cached at client

- Design for scale
- Whole-file caching
- Callbacks from server



WORKLOAD PATTERNS (1991)

~80 % of files L = 4K



Mary G. Baker, John H. Hartman, Michael D. Kupfer, Ken W. Shirriff, and John K. Ousterhout

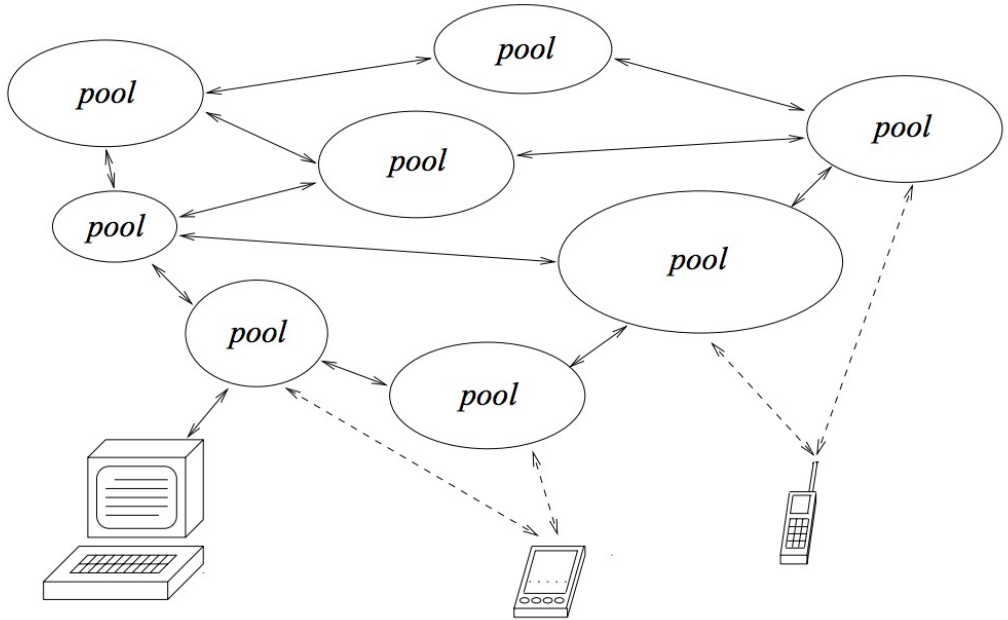
OCEANSTORE/PAST

late 90s to early 2000s

Wide area storage systems

Fully decentralized

Built on distributed hash tables (DHT)



lots of data

↳ very large files

Fault tolerance

GFS: WHY ?

Workload patterns

- Primarily append
- latency was not a concern
  - maximize bandwidth use

Components with failures

Files are huge !

GFS: WHY ?

Applications are different

GFS: WORKLOAD ASSUMPTIONS

"Modest" number of large files

Two kinds of reads: Large Streaming and small random

Writes: Many large, sequential writes. Few random

High bandwidth more important than low latency

"gfs.h"

GFS: DESIGN

- Single Master for metadata

- Chunkservers for storing data

- No POSIX API !
- No Caches!

files are chunked into fixed size chunks

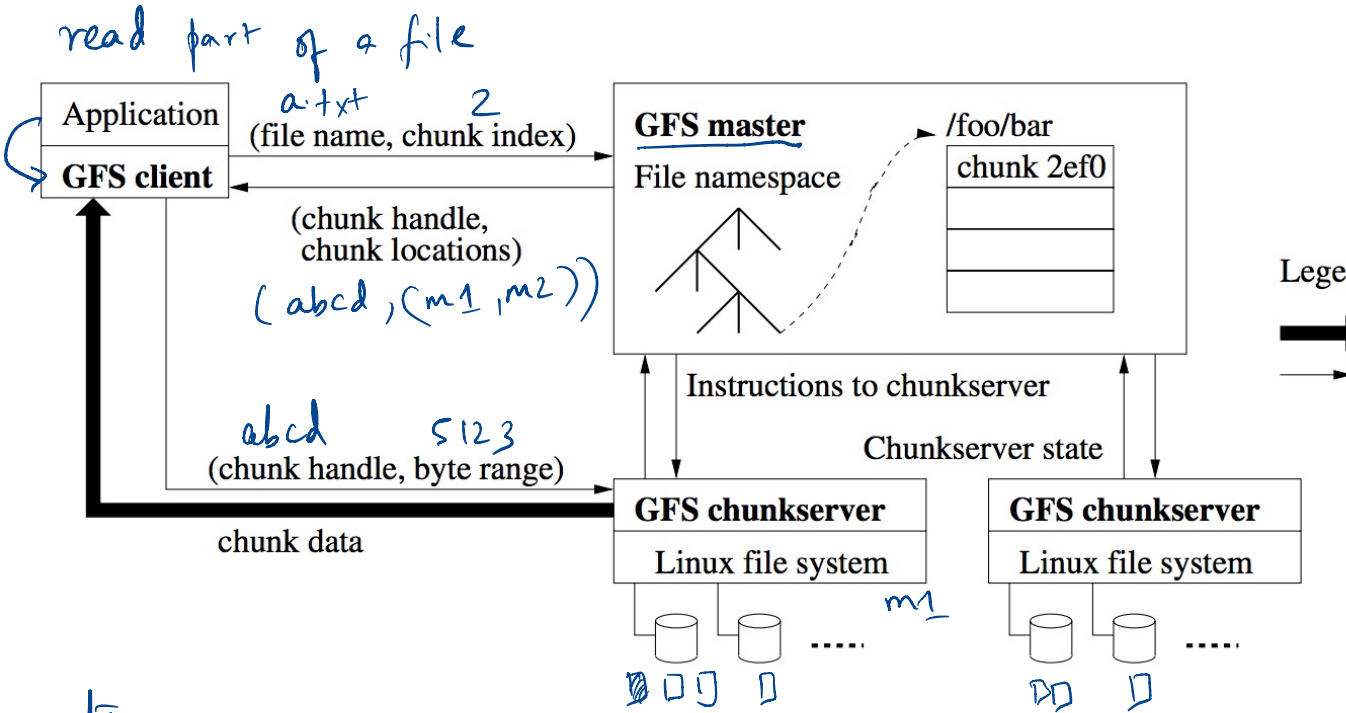


Figure 1: GFS Architecture

CHUNK SIZE TRADE-OFFS

Client → Master

if chunk size is small more calls to Master

Client → Chunkserver

too small ⇒ need to open connections to many chunk servers

Metadata

too large

↳ hotspot at chunk servers

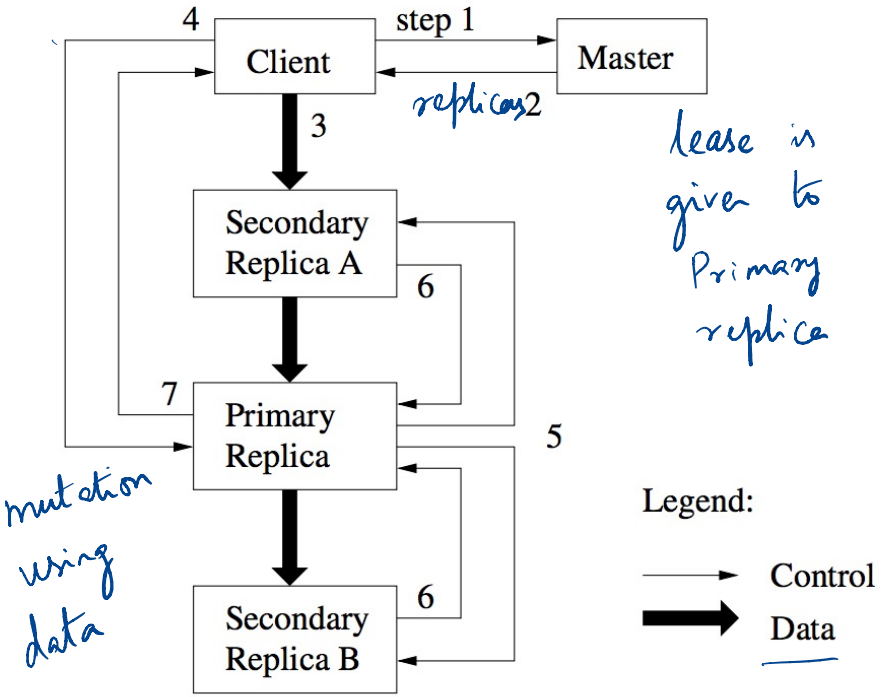
smaller chunks

⇒ more metadata

⇒ 64 MB

HDFS ~ 128MB more ??

GFS: REPLICATION



- 3-way replication to handle faults
- Primary replica for each chunk
- Chain replication (consistency)

- Decouple data, control flow
- Dataflow: Pipelining, network-aware

RECORD APPENDS

Write — Client specifies the offset → write(a.txt, 2142, "abcd")

Record Append — GFS chooses offset

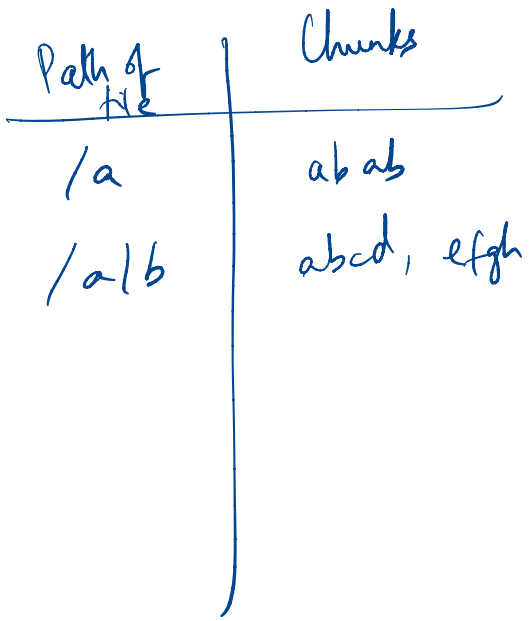
["wisconsin", 20ms, 200 OK] → record

Consistency

- At-least once → the appended record will appear at least once in the chunk
- Atomic
  - ↳ the entire record will appear

MASTER OPERATIONS

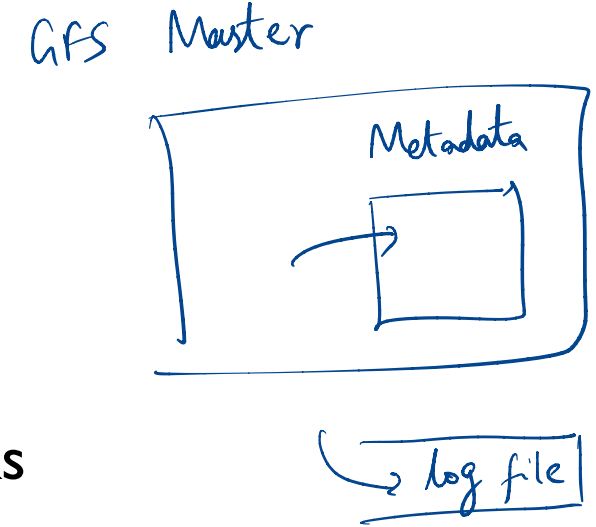
- No "directory" inode! Simplifies locking
- Replica placement considerations
  - → load, disk utilization
  - → failure probability
- Implementing deletes
  - → lazy. Rename the file
    garbage collection



FAULT TOLERANCE

- Chunk replication with 3 replicas
- Master
  - Replication of log, checkpoint
  - Shadow master

- Data integrity using checksum blocks



DISCUSSION

https://forms.gle/YpDcxPncdqnZ7JXG6

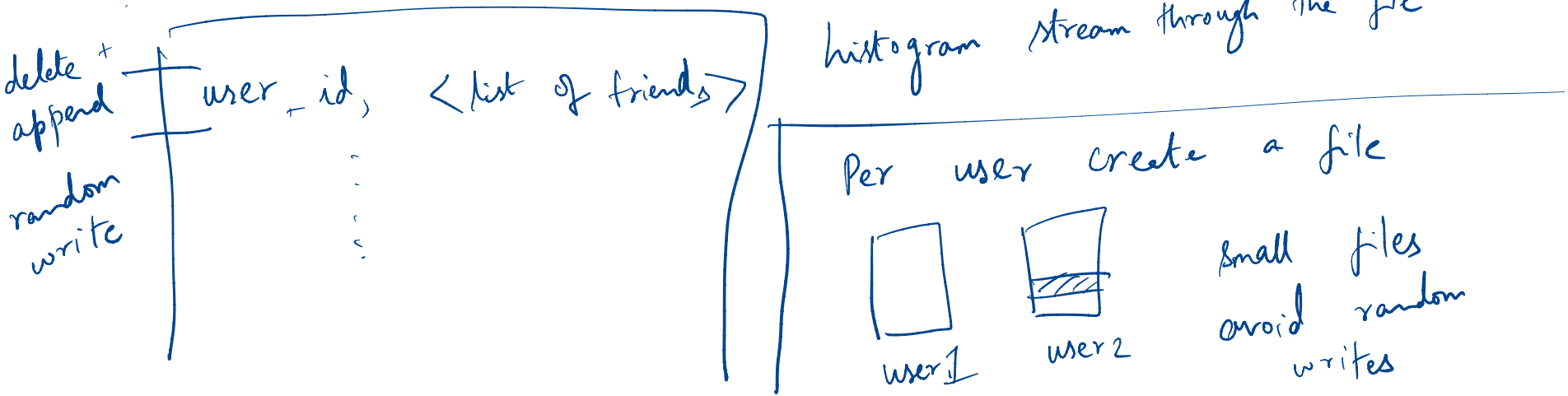
GFS SOCIAL NETWORK

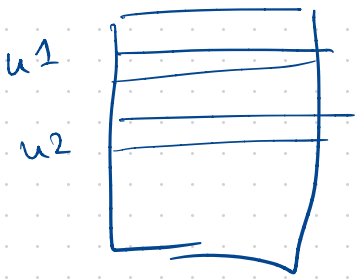
You are building a new social networking application. The operations you will need to perform are

(a) add a new friend id for a given user

(b) generate a histogram of number of friends per user.

How will you do this using GFS as your storage system ?





group users

u1, < u3 >

u1, < u5 >

u2, u7

⋮

u1, u8

append only

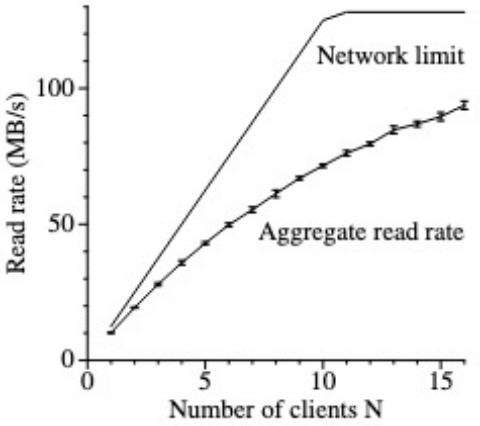
histogram needs grouping

Store a count

u1, u8, 3

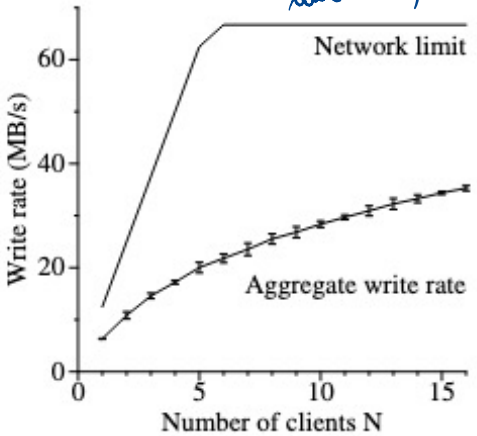
GFS EVAL

List your takeaways from "Table 3: Performance metrics"



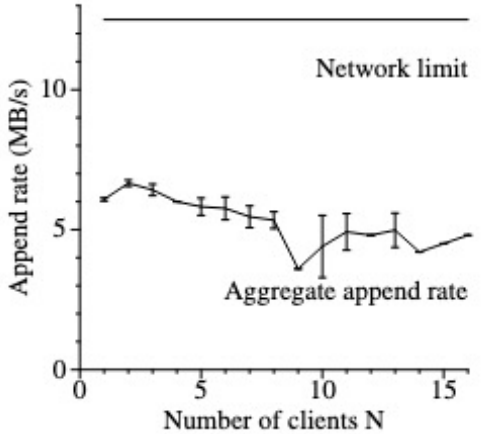
(a) Reads

replication lower tput



(b) Writes

all append go to same chunkserver



(c) Record appends

WHAT HAPPENED NEXT

Cluster-Level Storage @ Google

How we use *Colossus* to improve storage efficiency

Denis Serenyi
Senior Staff Software Engineer
dserenyi@google.com

Keynote at PDSW-DISCS 2017: 2nd Joint International Workshop On Parallel Data Storage & Data Intensive Scalable Computing Systems

GFS EVOLUTION

Motivation:

- GFS Master
  - One machine not large enough for large FS
  - Single bottleneck for metadata operations (data path offloaded)
  - Fault tolerant, but not HA

- Lack of predictable performance
  - No guarantees of latency
  - (GFS problems: one slow chunkserver -> slow writes)

GFS EVOLUTION

GFS master replaced by Colossus

Metadata stored in BigTable

Recursive structure ? If Metadata is ~1/10000 the size of data

100 PB data → 10 TB metadata

10TB metadata → 1GB metametadata

1GB metametadata → 100KB meta...

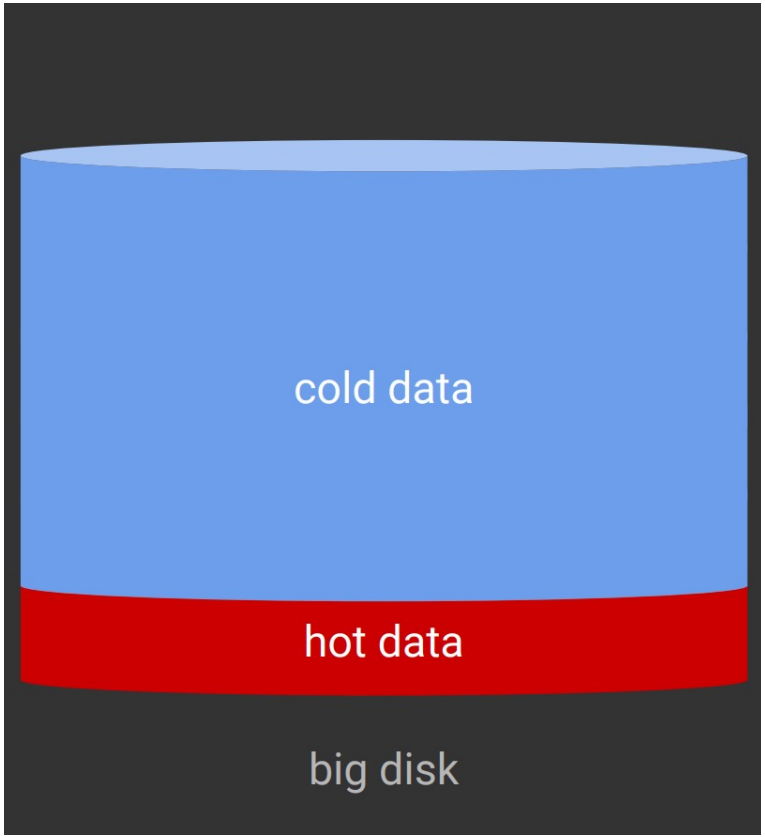
GFS EVOLUTION

Need for Efficient Storage

Rebalance old, cold data

Distributes newly written data evenly across disk

Manage both SSD and hard disks



HETEROGENEOUS STORAGE

F4: Facebook

Blob stores

Key Value Stores

NEXT STEPS

- Assignment 1 out tonight!
- Next up: MapReduce, Spark