BookKeeper

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Hadoop in China 2011

What's BookKeeper?

- Shared storage for writing fast sequences of byte arrays
- Data is replicated
- Writes are striped
- Many processes can access it

Motivation

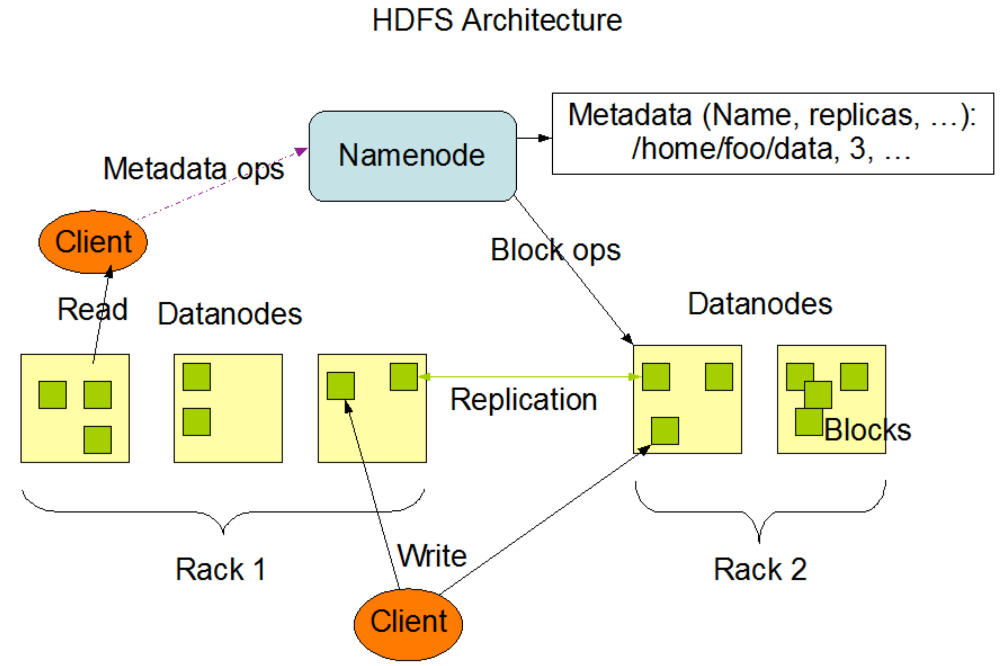
- Recoverable systems
  - ✓ Journal/write-ahead log
  - ✓ Integrity and durability
  - ✓ Efficient: sequential synchronous writes
- Why is writing sequentially important?
  - ✓ To avoid random seeks

More motivation

- Examples
  - ✓ Many databases (e.g., Postgres)
  - ✓ Hbase region server
  - ✓ ZooKeeper
  - ✓ HDFS namenode
  - ✓ Hedwig hubs

HDFS at a glance

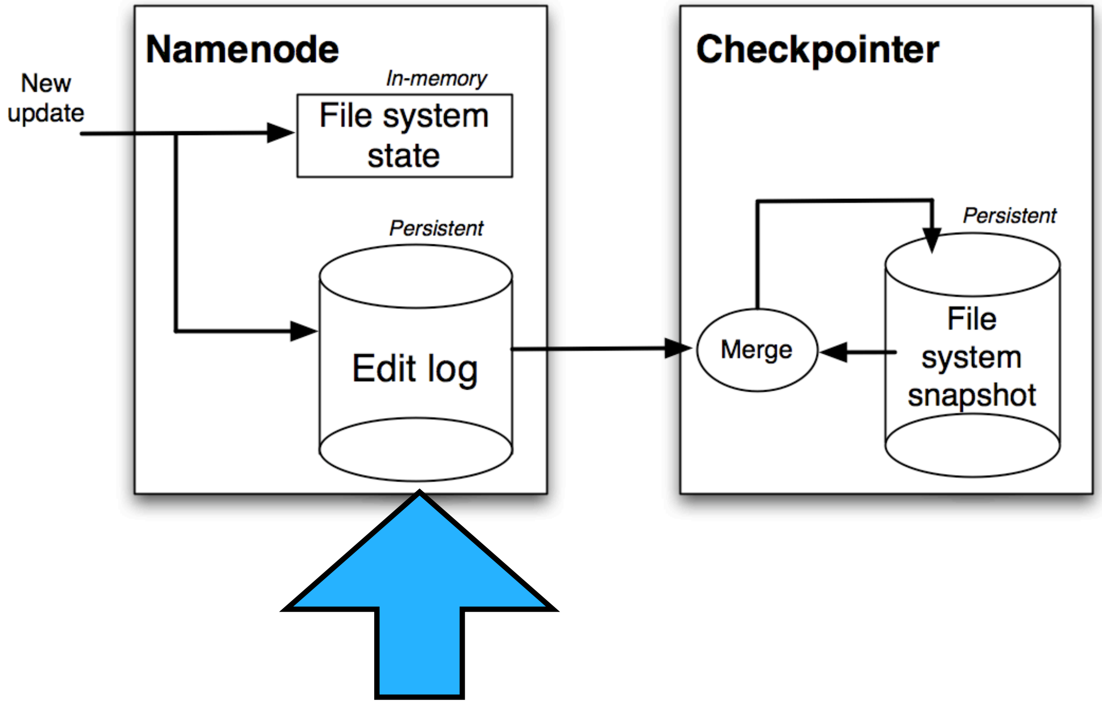
- Main components: namenode and datanode
  - ✓ Single name node
  - ✓ A number of data nodes
- Namenode
  - ✓ Manages FS namespace
  - ✓ Regulates access to the FS
  - ✓ Mapping of blocks to data nodes
- Datanode
  - ✓ Stores blocks
  - ✓ Serves reads and writes



http://hadoop.apache.org/common/docs/current/hdfs_design.html

Namenode

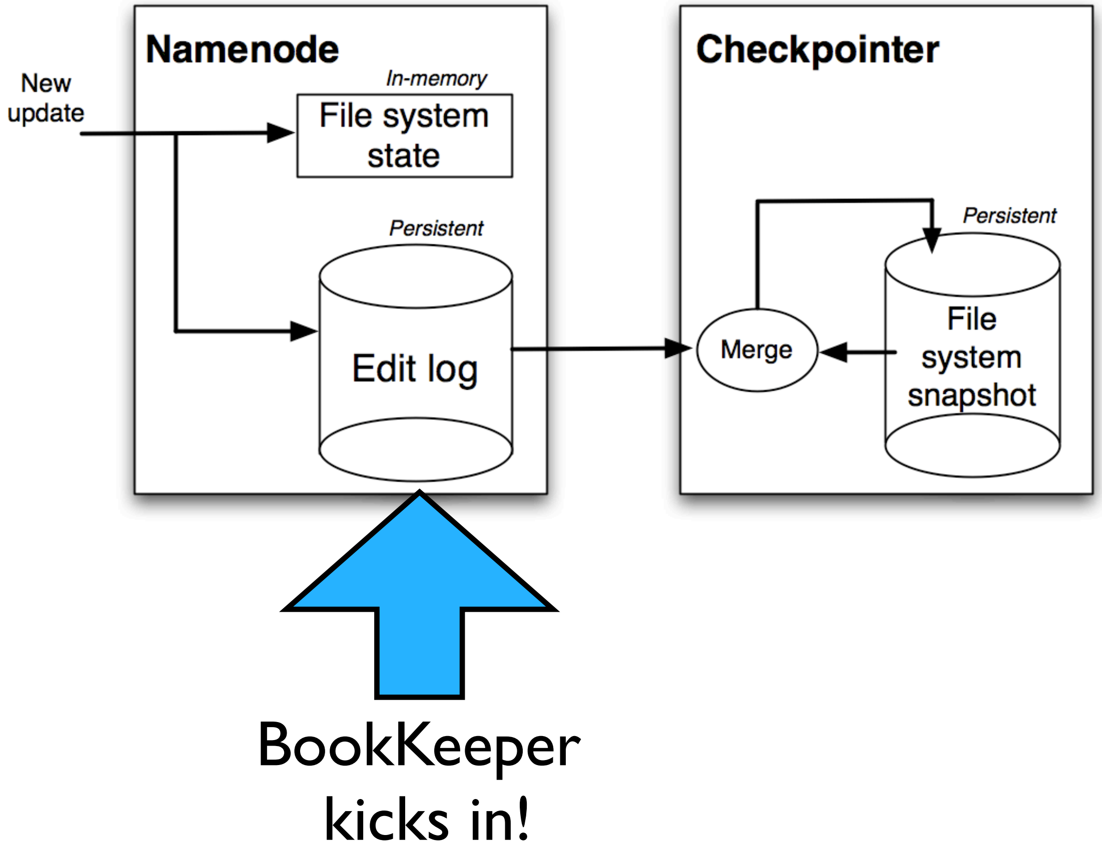
- File system state
  - ✓ Metadata, block map
  - ✓ In memory
- Checkpoint
  - ✓ On disk
  - ✓ Snapshot of the service state
- Edit log
  - ✓ Persists changes to the file system metadata
  - ✓ Written to disk



BookKeeper kicks in!

Namenode

- Edit log is a journal
  - ✓ Local disk
  - ✓ NFS server
- Production use
  - ✓ Enterprise-class NFS
  - ✓ Expensive devices
  - ✓ *E.g.*, Netapp Filer
  - ✓ Robust, but still a single point of failure

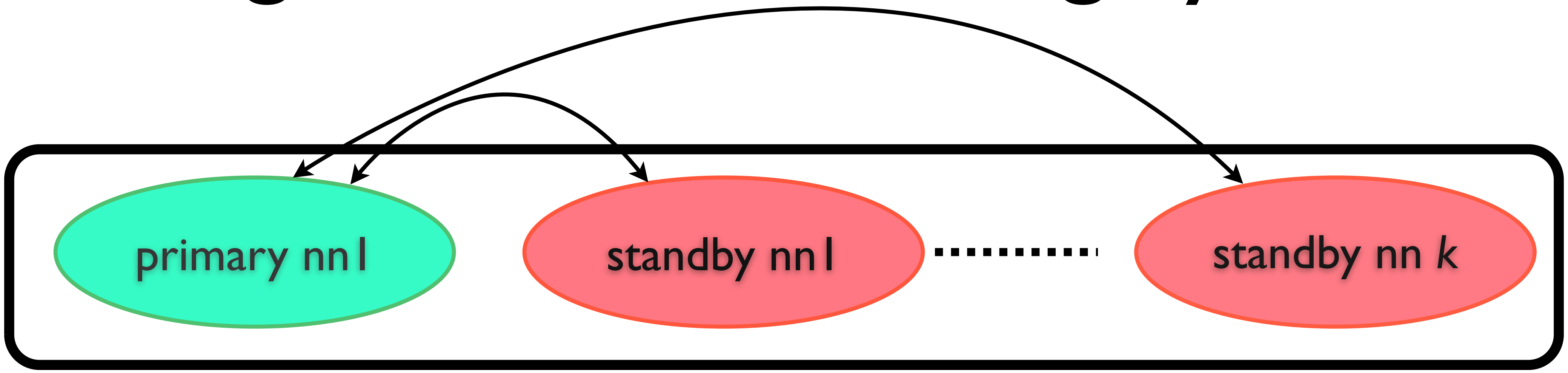


Making the namenode highly available

- Backup node
  - ✓ One step ahead
  - ✓ Receives a stream of updates
  - ✓ Warm standby
- Shortcomings
  - ✓ Cannot guarantee consistency
  - ✓ Difficult to have multiple backups

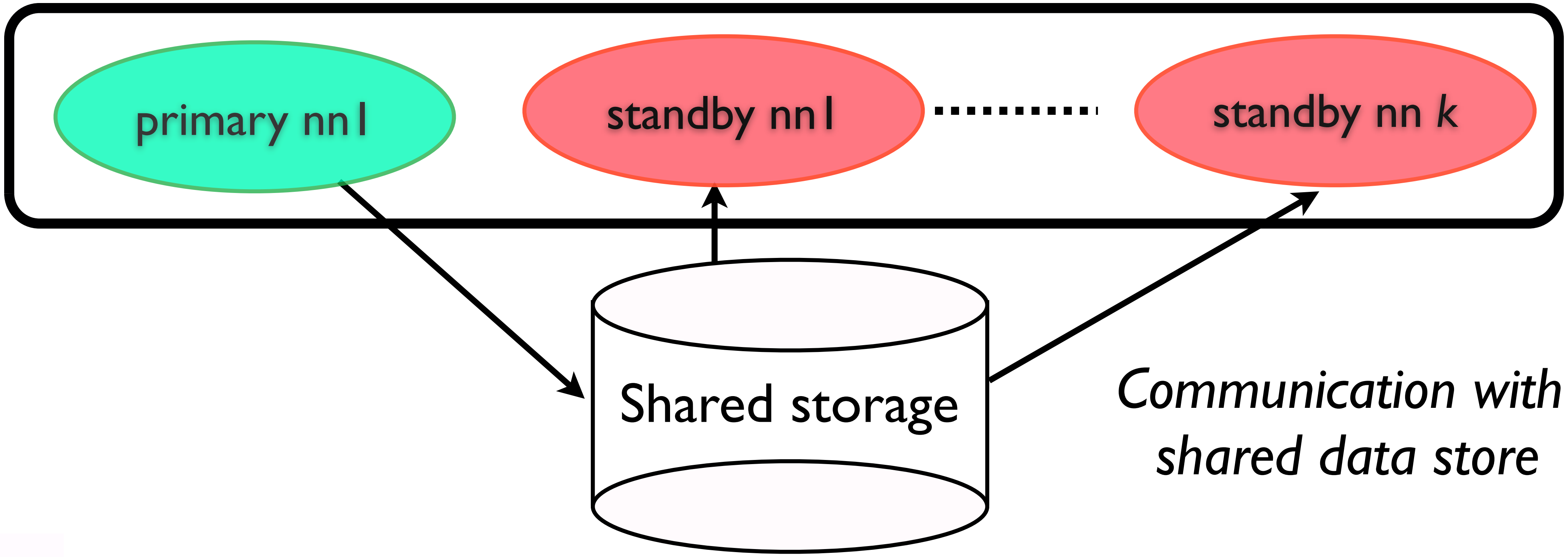
Making the namenode highly available

1)



Communication among processes to coordinate

2)



Communication with shared data store

Making the namenode highly available

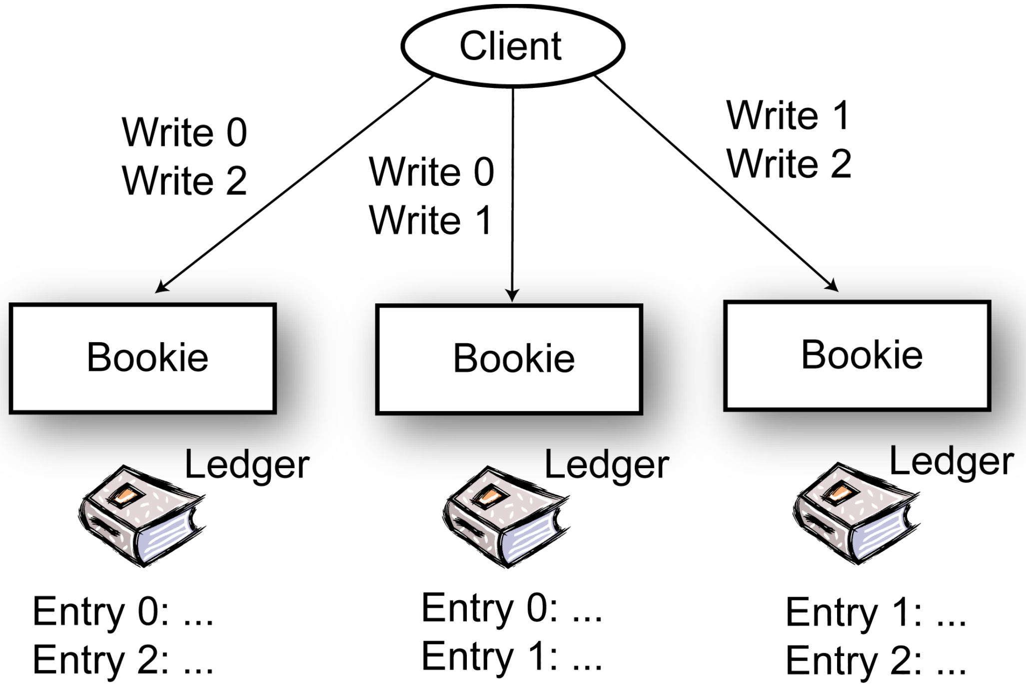
- Replicate the functionality of the name node
  - ✓ Performance penalty
  - ✓ Not scalable
- Write log to external device
  - ✓ NFS
    - Avatarnode
    - Replication is not transparent
  - ✓ External high-performance logging/journaling service
    - BookKeeper

BookKeeper

- Shared storage for logs
- Design goals
  - ✓ Efficient sequential writes
  - ✓ Fault tolerance
  - ✓ Scalability

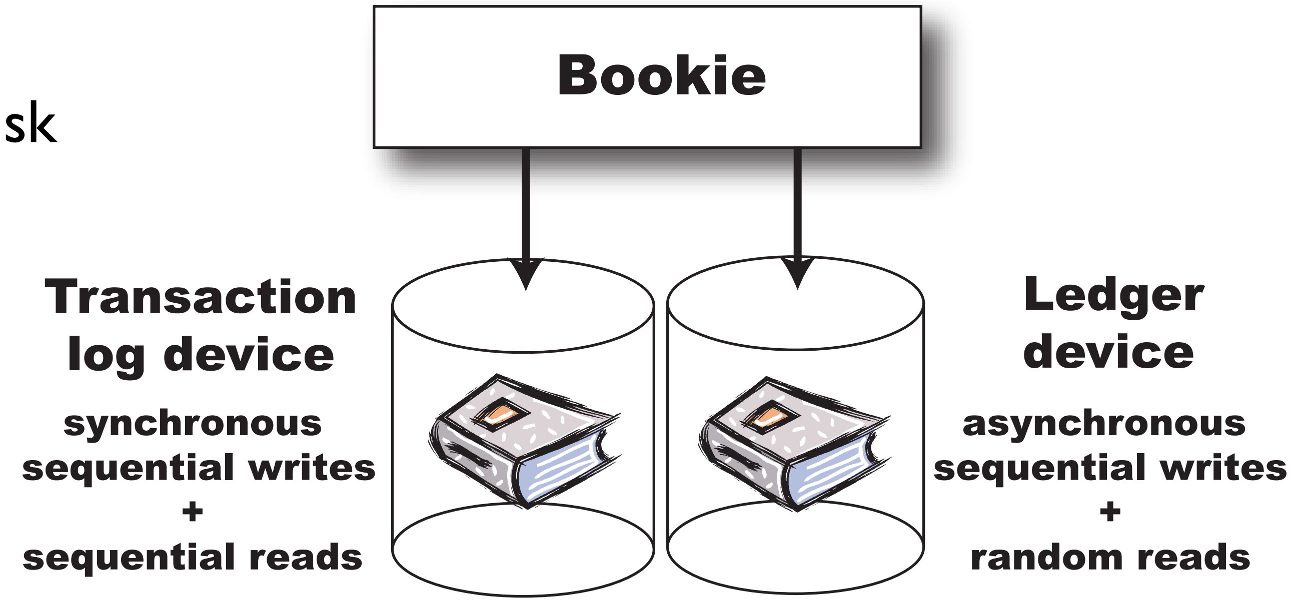
BookKeeeper architecture

- **Bookie**: Storage node
- **Ledger**: log file
- **Ensemble**: group of bookies storing a ledger
- Writes to quorums of Bookies
- Parallel writes to quorums
- Reads from the same quorum



The anatomy of a bookie

- Transaction log
  - ✓ Pre-allocates, batches
  - ✓ Return upon write/sync to disk
- Index
  - ✓ Position of entry
- Entries
  - ✓ Written sequentially to entry log



Scalability of writes

- Write quorums do not necessarily intersect
- Assuming that:

1. Each bookie performs *e* entries/s
2. Number of bookies: *r*
3. Write quorum: *q* bookies

- Ideal maximum throughput: $\frac{r \times e}{q}$
- In practice, network bandwidth or cpu limits the total capacity in bytes written per second

API at a glance

- `createLedger`
- `openLedger`
- `addEntry`
  - ✓ Async and sync
- `readEntries`
  - ✓ Async and sync
- `closeLedger`
  - ✓ Writes the last entry id to ZooKeeper

Why keep last entry id?

- Acknowledgement
  - ✓ Ledger closed properly
- Agreement
  - ✓ Two readers don't read different sets of entries
- What if no last entry id has been written?

Recovery procedure

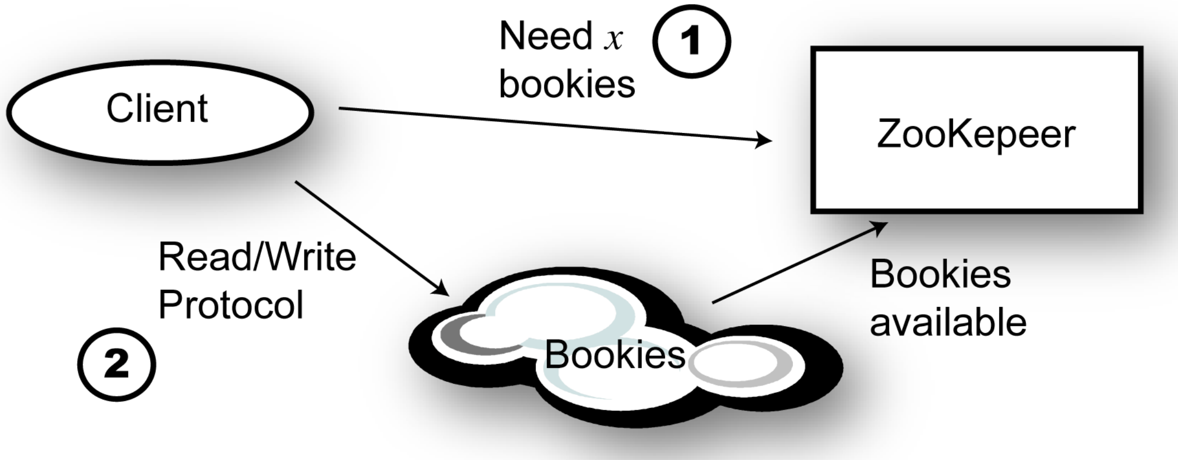
- Reader client executes a **ledger recovery** procedure
- Hints on ledger entries
- **Procedure**
  - ✓ Request last entry hint from bookies
  - ✓ Try to read as many entries greater than the hint
  - ✓ Make sure entries are written to a quorum

How to use it

- Application writer
  - ✓ Creates a ledger
  - ✓ Add entries to the ledger
  - ✓ Return upon confirmation from quorum
  - ✓ Closes the ledger
- Application readers
  - ✓ Open ledger
  - ✓ Read from the ledger
- Application does not reopen to append

BookKeeper service

- Service
  - ✓ Bookies in the cloud
  - ✓ Through ZooKeeper
- ZooKeeper
  - ✓ Bookies online
  - ✓ Ledger metadata



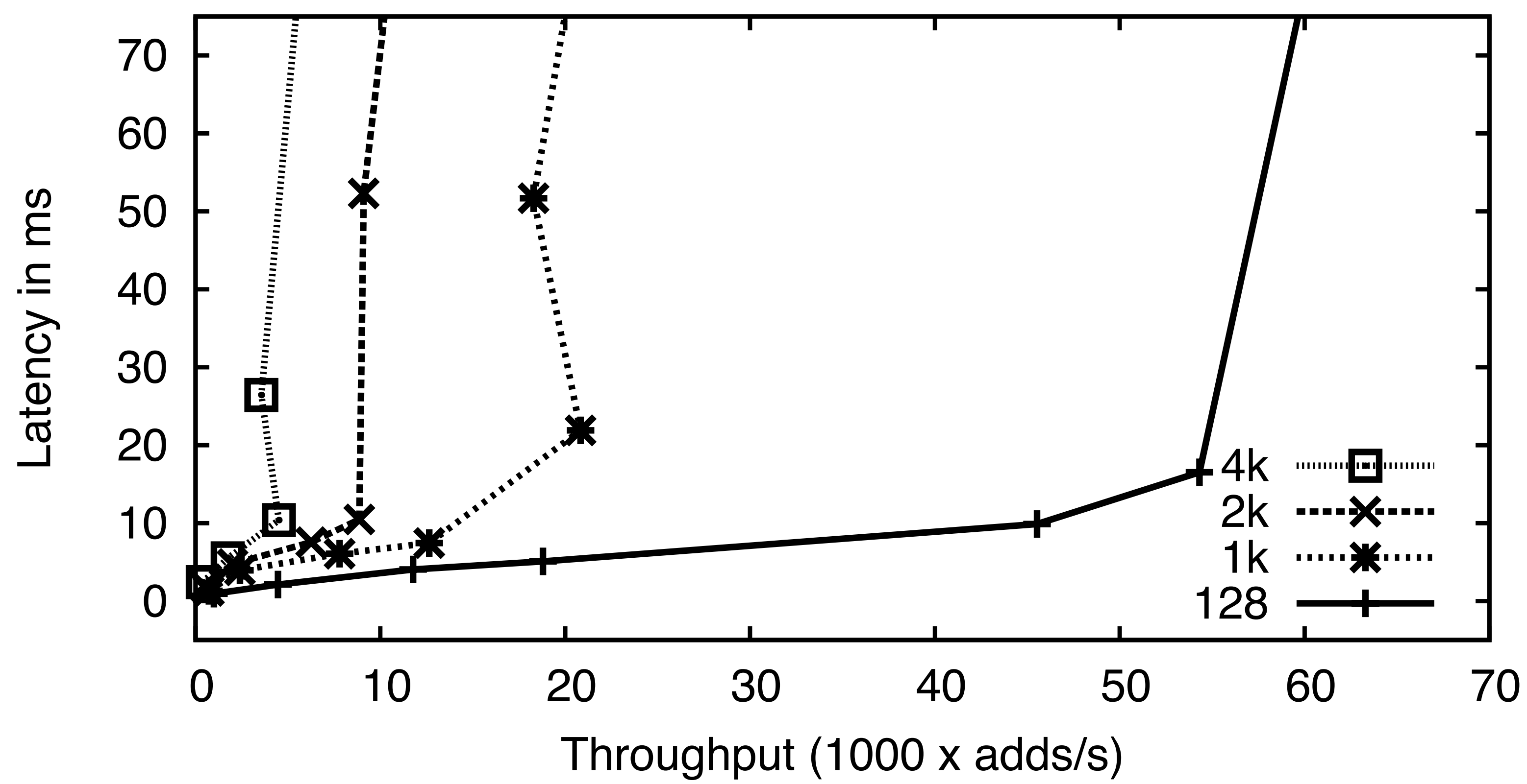
Performance

Setup

- Cluster of identical machines
- 2 Quad Core Intel Xeon 2.5GHz
- 16GB of RAM
- Four SATA disks, 7,200 RPMs
- 1Gbit/s network interface

BookKeeper performance

- Single writer



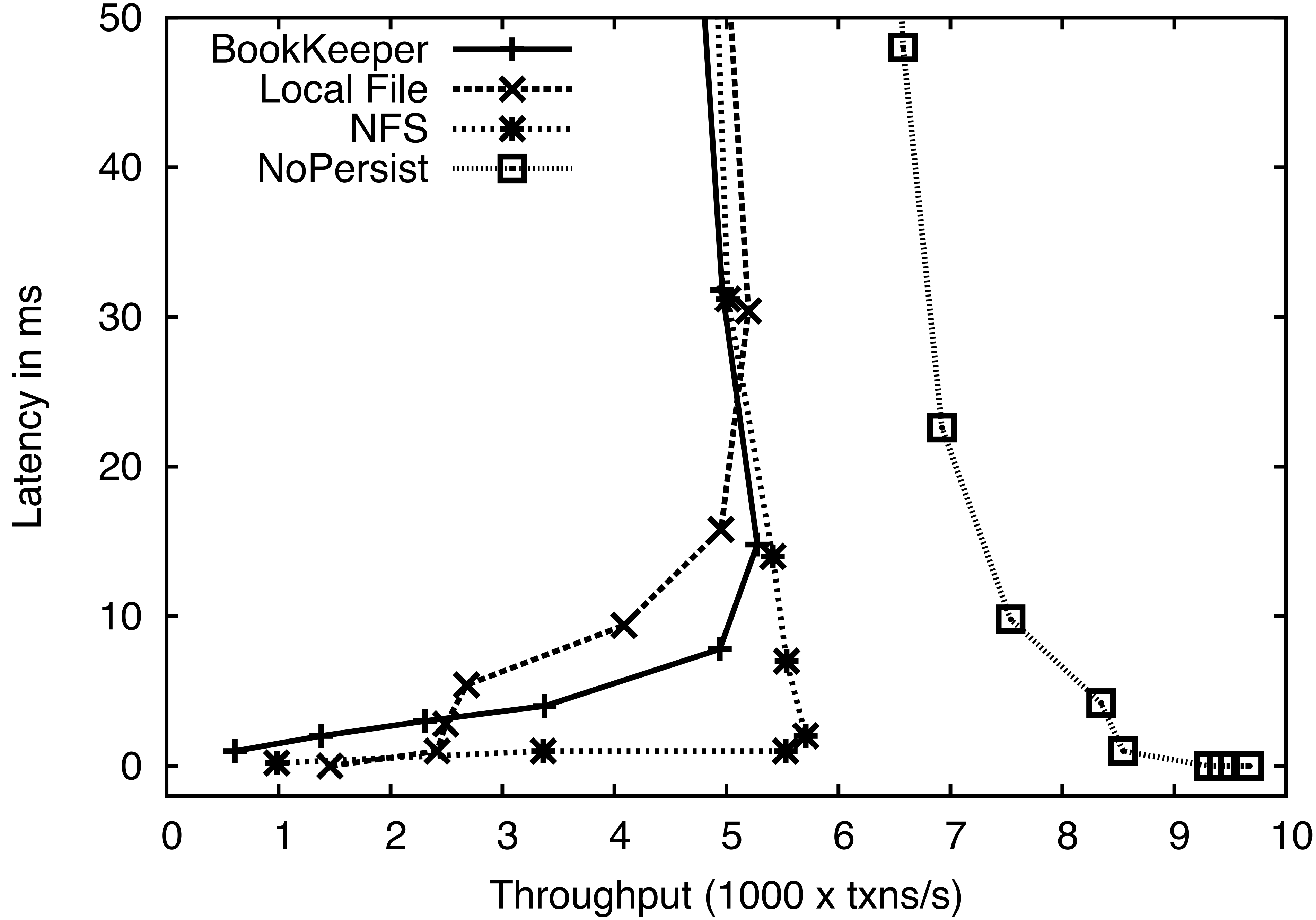
BookKeeper performance

- Multi-writer
  - ✓ Aggregate throughput
- Concurrent ledgers
  - ✓ Up to 40k ledgers

bytes	2Q		3Q	
	3E	6E	3E	6E
128	87k	116K	57k	108k
1024	31k	54k	20k	38k
4096	8k	16k	5k	11k

add operations/s

BookKeeper and the Namenode

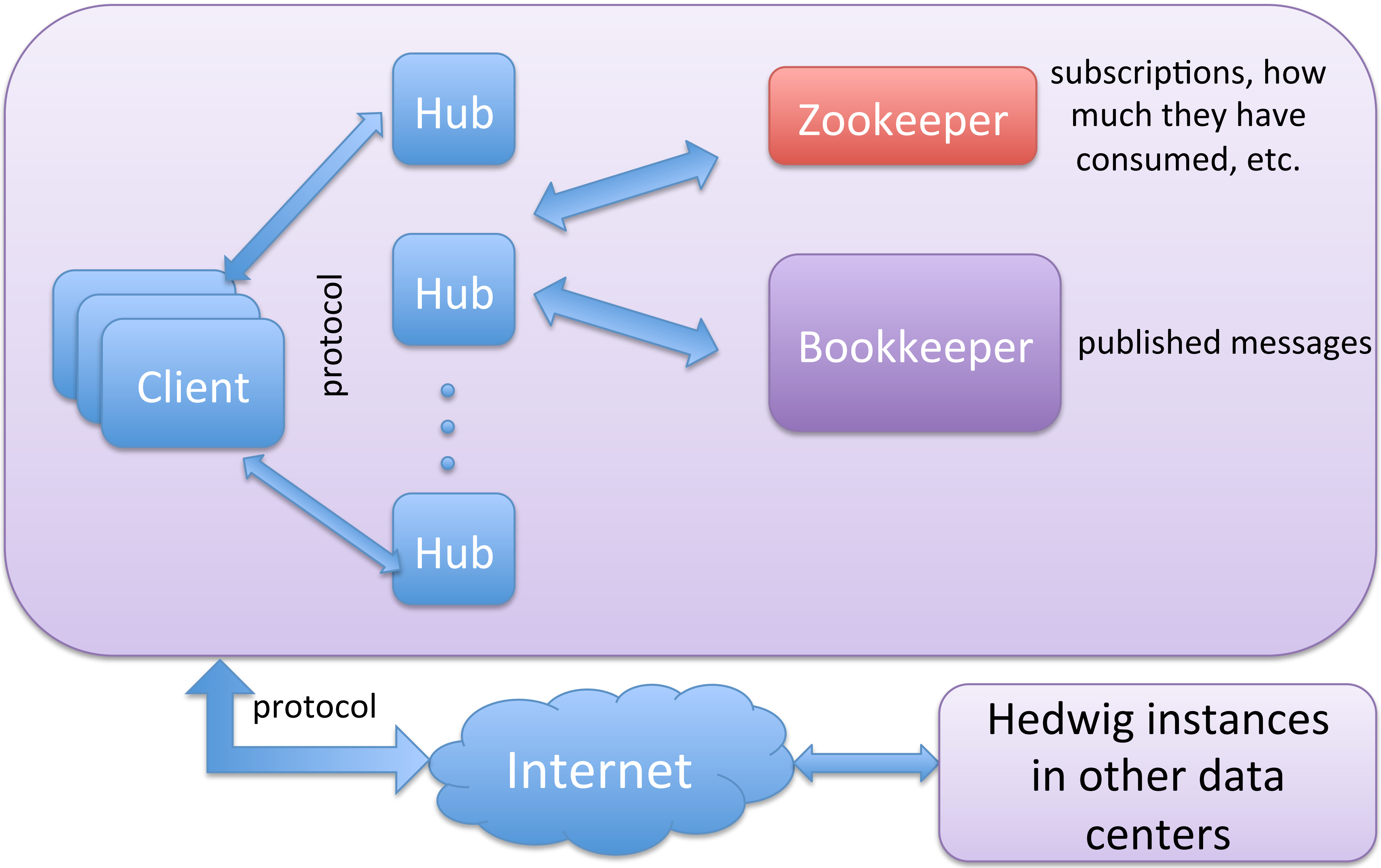


Hedwig

Hedwig

- Multi-region pub/sub system
- Guaranteed-delivery topic-based pub-sub system
- Extremely High Performance
- Elastically scalable
  - ✓ Deployed over commodity machines
  - ✓ Capacity can be added on-the-fly by adding machines
- Low Operational Complexity
  - ✓ Tolerate failures without manual intervention
  - ✓ Automatic load balancing
- Designed for multiple data-centers

Hedwig overview



Wrap up

Advanced features

- Opening without recovery
  - ✓ Warm standbys
  - ✓ Must know what you're doing
- Fencing
  - ✓ Consistency despite concurrent accesses
  - ✓ Prevents new sucessful writes once recovered

Status

- Release on the way
  - ✓ Candidate should be out this week
- BookKeeper and the namenode
  - ✓ Watch HDFS-1580 and HDFS-234

The team

- Dhruba Borthakur (Facebook)
- Flavio Junqueira (Yahoo!)
- Ivan Kelly (Yahoo!)
- Benjamin Reed (Yahoo!)
- Utkarsh Srivastava (Twitter)

Contributing

- Sign up for the lists
- Discuss with the community
- Propose improvements
  - ✓ Bug fixes
  - ✓ New features

http://zookeeper.apache.org/bookkeeper

Questions?

http://zookeeper.apache.org/bookkeeper