ZooKeeper Tutorial

Flavio Junqueira
Benjamin Reed

Yahoo! Research

https://cwiki.apache.org/confluence/display/ZOOKEEPER/EurosysTutorial

Plan for today

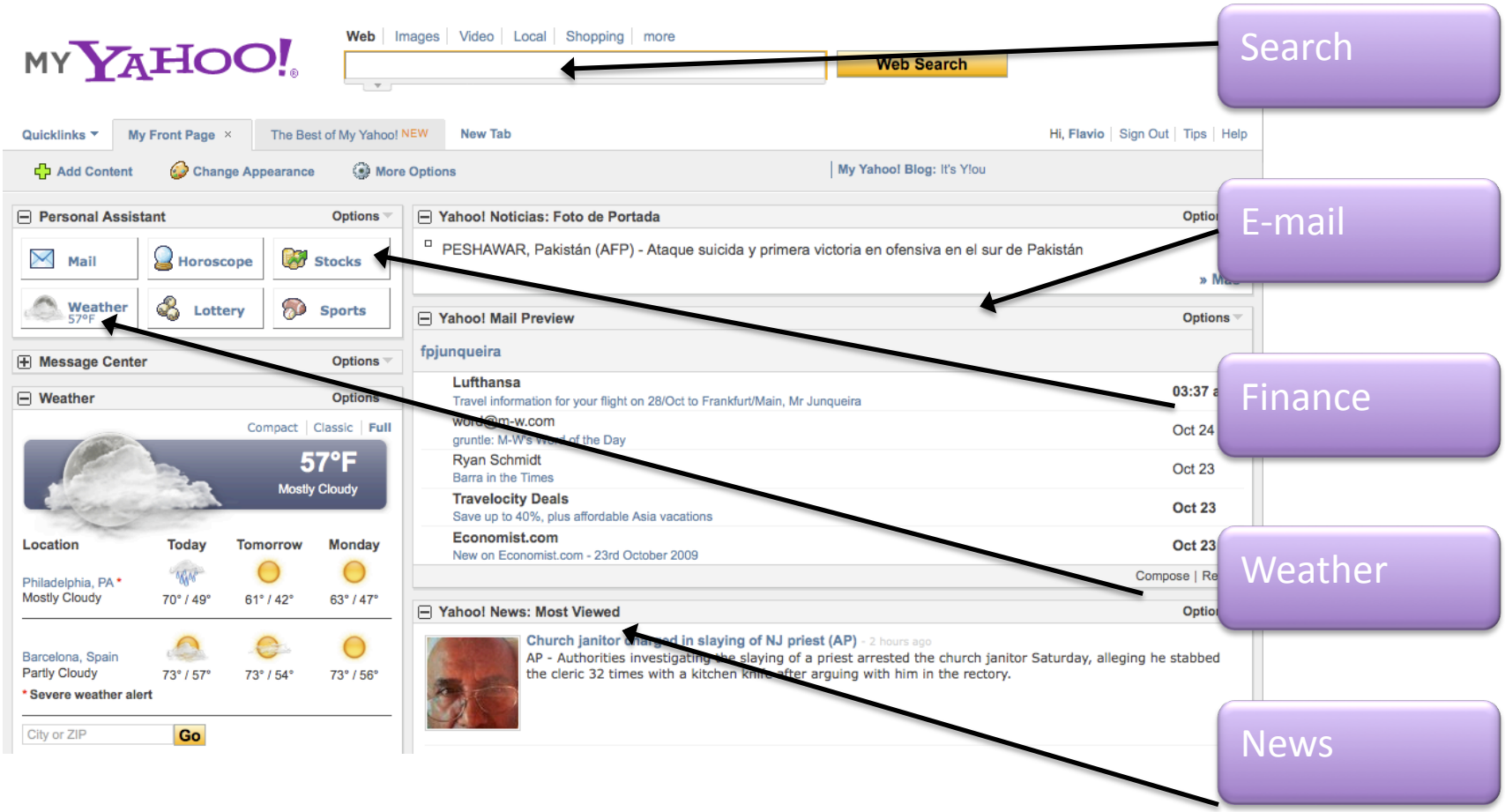
- First half
  - Part 1
    - Motivation and background
  - Part 2
    - How ZooKeeper works on paper
- Second half
  - Part 3
    - Share some practical experience
    - Programming exercises
  - Part 4
    - Some caveats
    - Wrap up

ZooKeeper Tutorial

Part 1

Fundamentals

Yahoo! Portal



Yahoo!: Workload generated

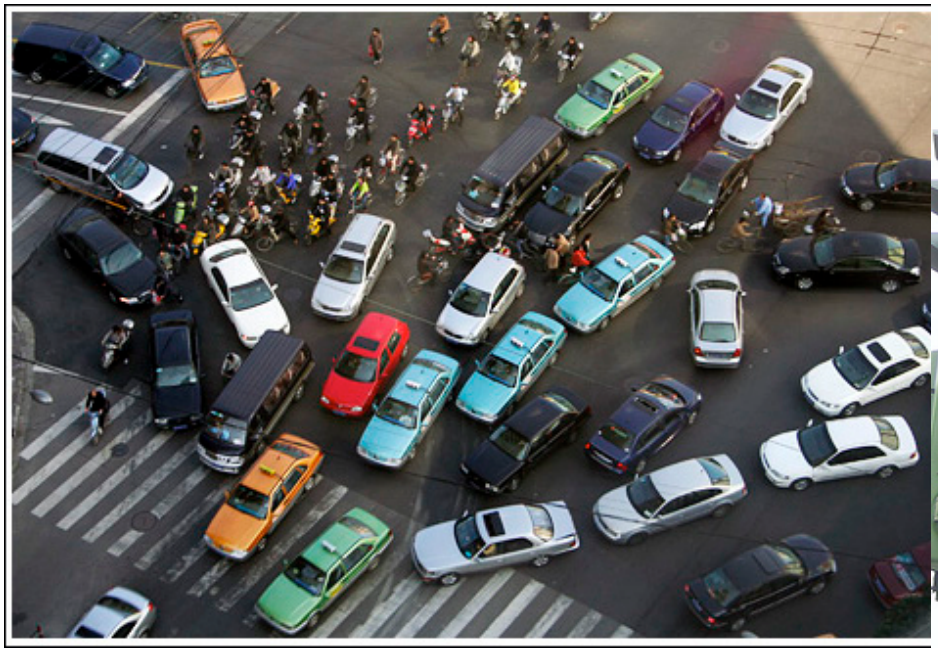
- Home page
  - 38 million users a day (USA)
  - 2.5 billion users a month (USA)
- Web search
  - 3 billion queries a month
- E-mail
  - 90 million actual users
  - 10 min/visit

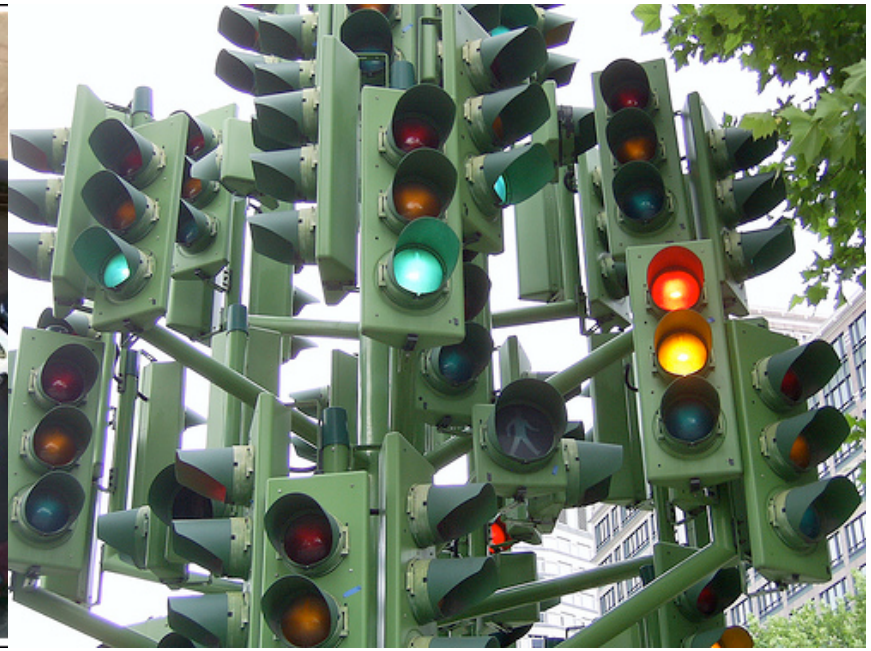
Yahoo! Infrastructure

- Lots of servers
- Lots of processes
- High volumes of data
- Highly complex software systems
- … and developers are mere mortals

Yahoo! Lockport Data Center

Coordination is important





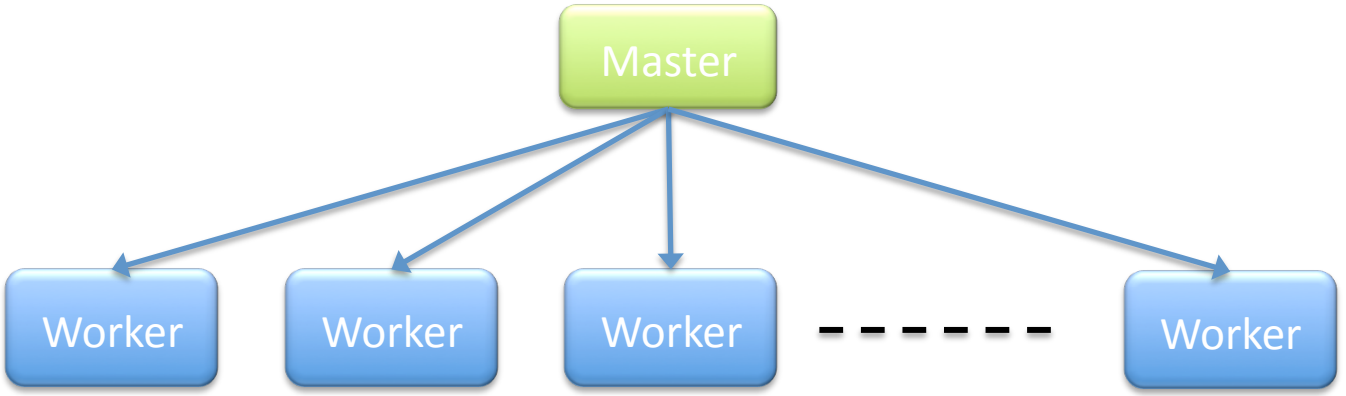
Coordination primitives

- Semaphores
- Queues
- Leader election
- Group membership
- Barriers
- Configuration

Even small is hard…

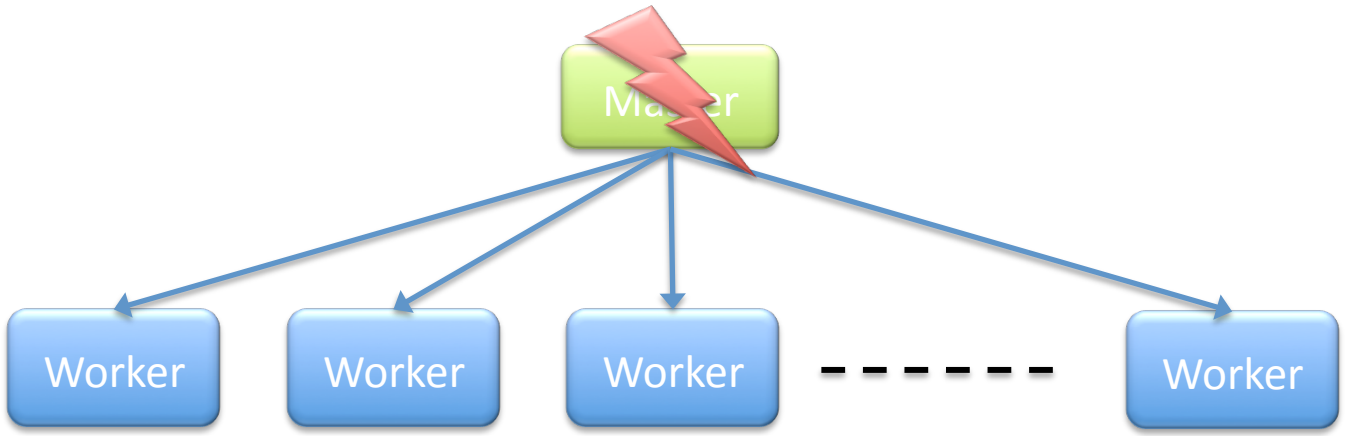
A simple model

- Work assignment
  - Master assigns work
  - Workers execute tasks assigned by master



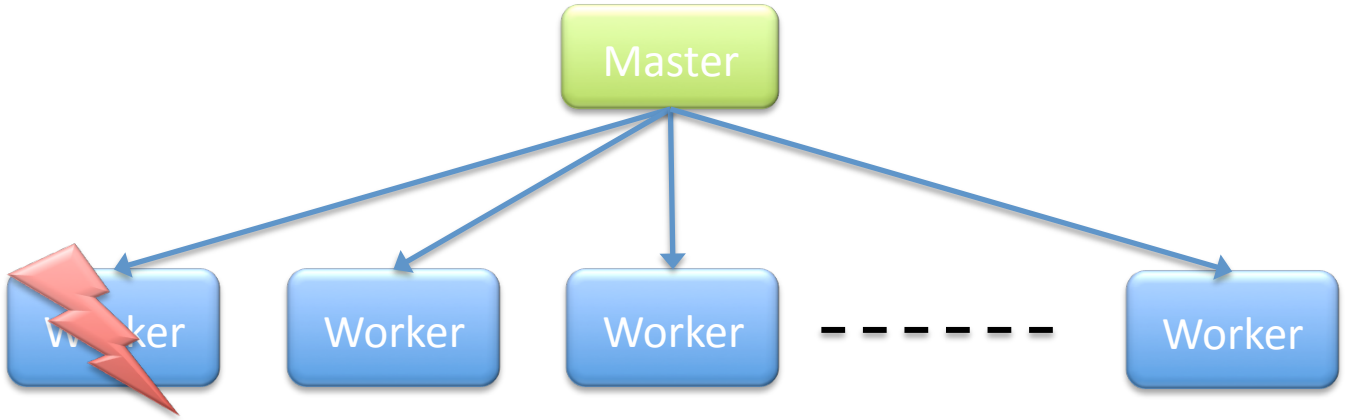
Master crashes

- Single point of failure
- No work is assigned
- Need to select a new master



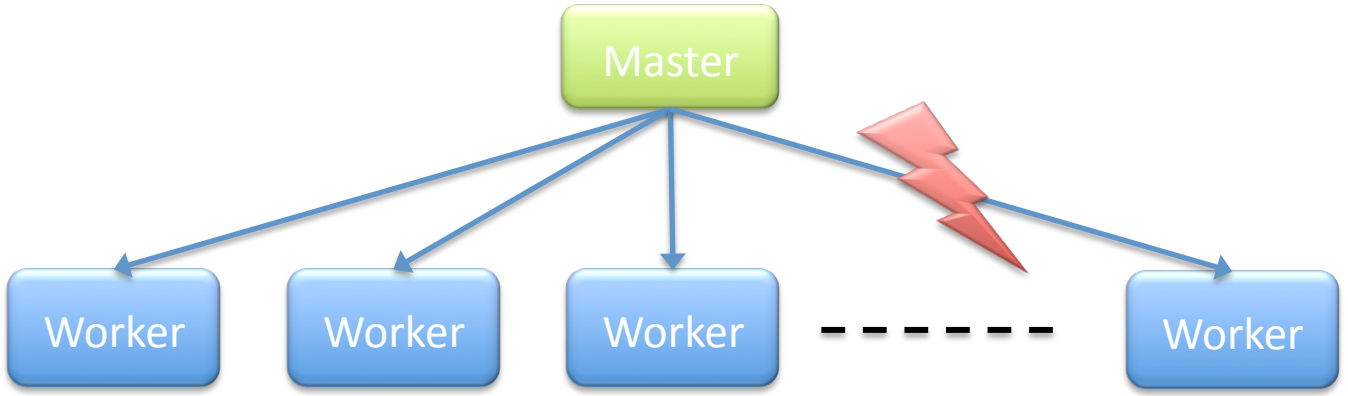
Worker crashes

- Not as bad… Overall system still works
  - Does not work if there are dependencies
- Some tasks will never be executed
- Need to detect crashed workers

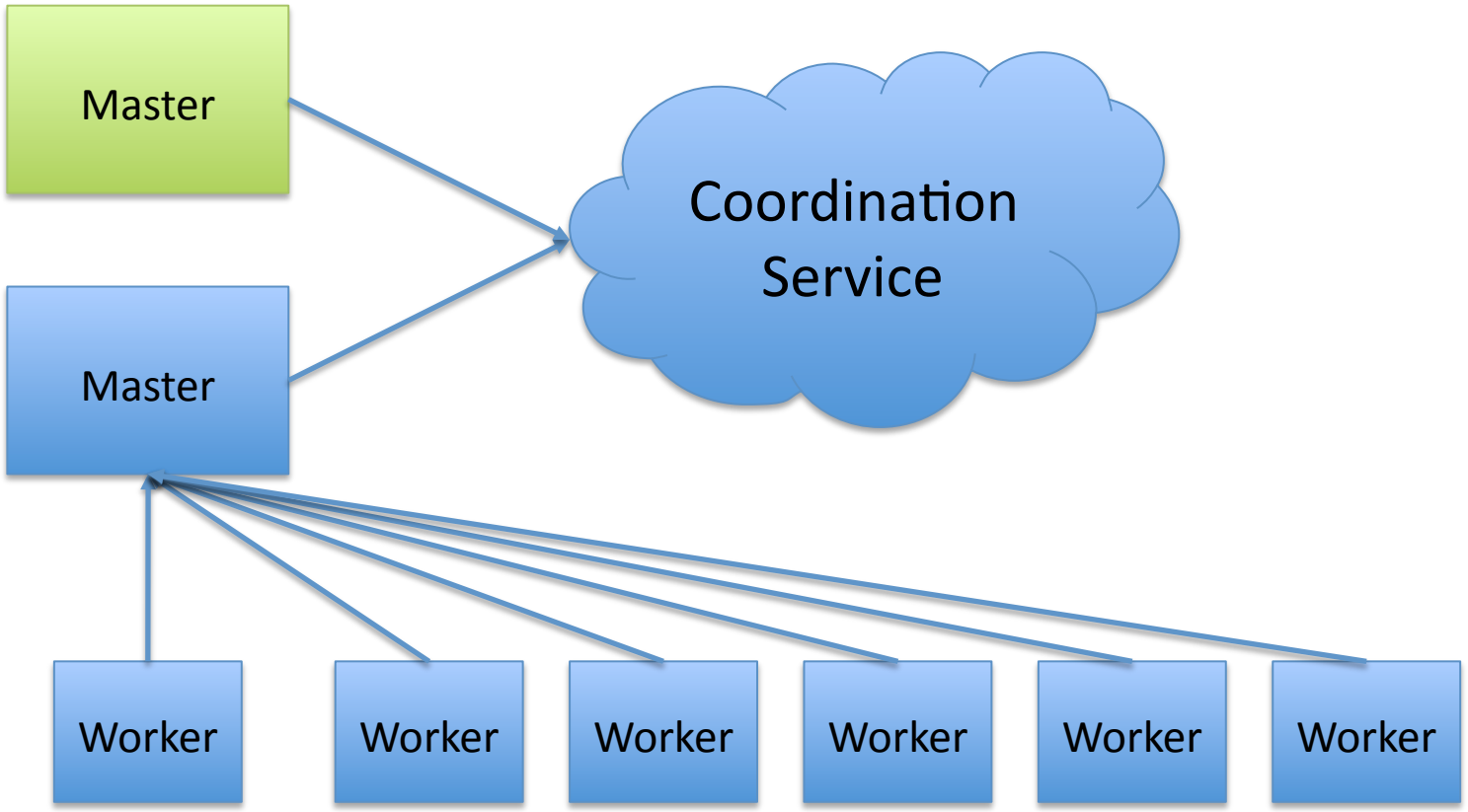


Worker does not receive assignment

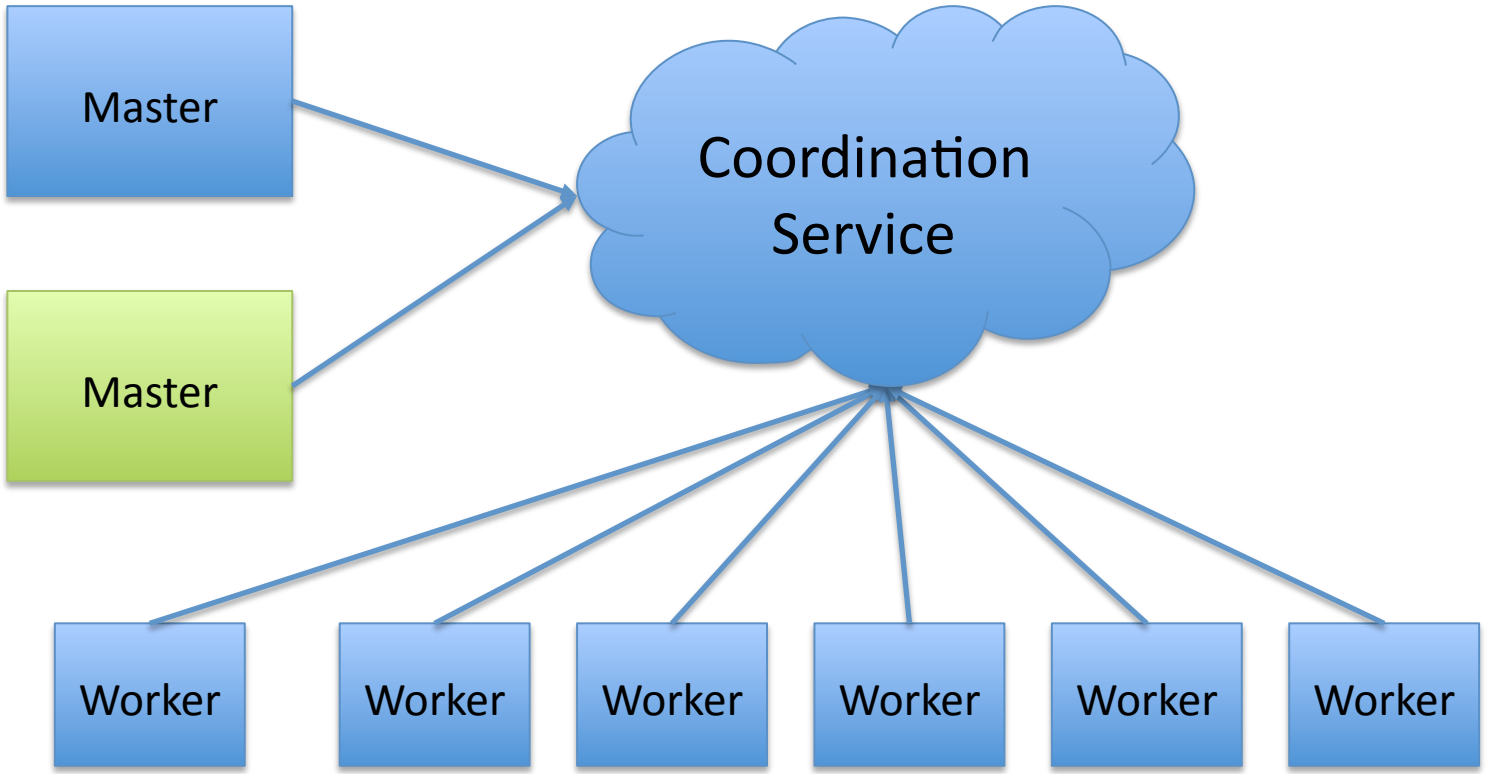
- Same problem as before
- Some tasks may not be executed
- Need to guarantee that worker receives assignment



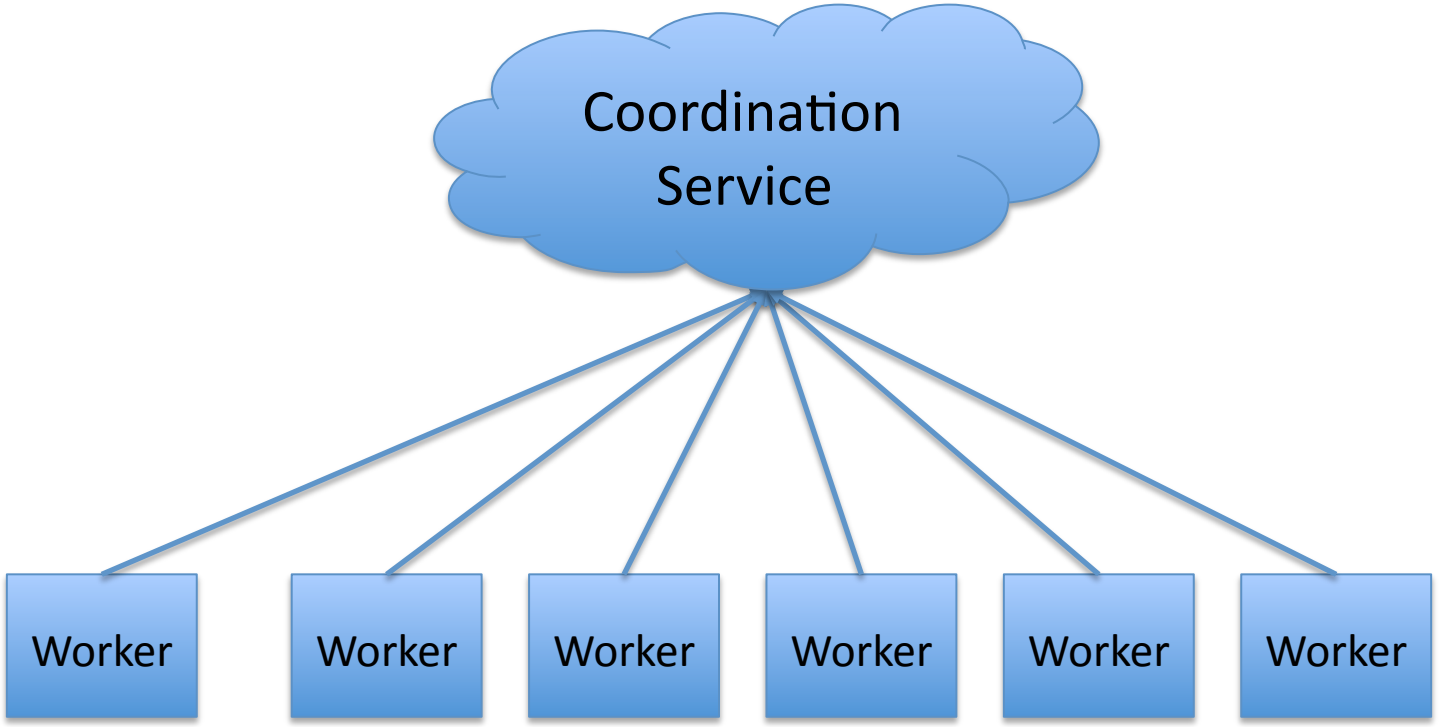
Fault-tolerant distributed system



Fault-tolerant distributed system



Fully distributed

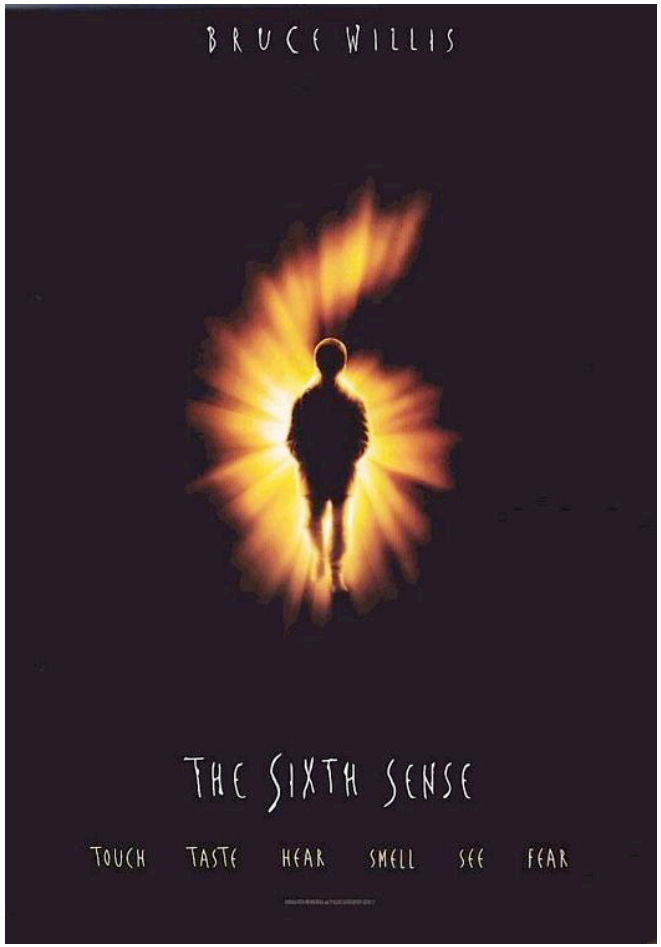


Fallacies of distributed computing

1. The network is reliable.
2. Latency is zero.
3. Bandwidth is infinite.
4. The network is secure.
5. Topology doesn't change.
6. There is one administrator.
7. Transport cost is zero.
8. The network is homogeneous.

Peter Deutsch, http://blogs.sun.com/jag/resource/Fallacies.html

One more fallacy



- You know who is alive

Why is it difficult?

- FLP impossibility result
  - Asynchronous systems
  - Consensus is impossible if a single process can crash

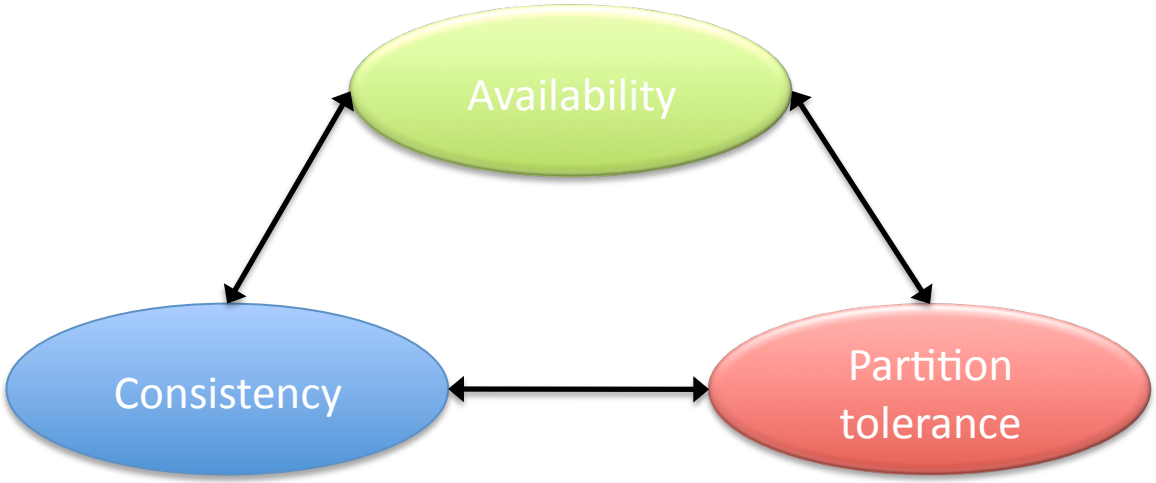
Fischer, Lynch, Paterson, ACM PODS, 1983

- According to Herlihy, we do need consensus
  - Wait-free synchronization
  - Wait-free: completion in a finite number of steps
  - Universal object: equivalent to solving consensus for *n* processes

Herlihy, ACM TOPLAS, 1991

Why is it difficult?

- CAP principle
  - Can't obtain availability, consistency, and partition tolerance simultaneously



Gilbert, Lynch, ACM SIGACT NEWS, 2002

The case for a coordination service

- Many impossibility results
- Many fallacies to stumble upon
- Several common requirements across applications
  - Duplicating is bad
  - Duplicating poorly is even worse
- Coordination service
  - Implement it once and well
  - Share by a number of applications

Current systems

- Chubby, Google
  - Lock service

Burrows, USENIX OSDI, 2006

- Centrifuge, Microsoft
  - Lease service

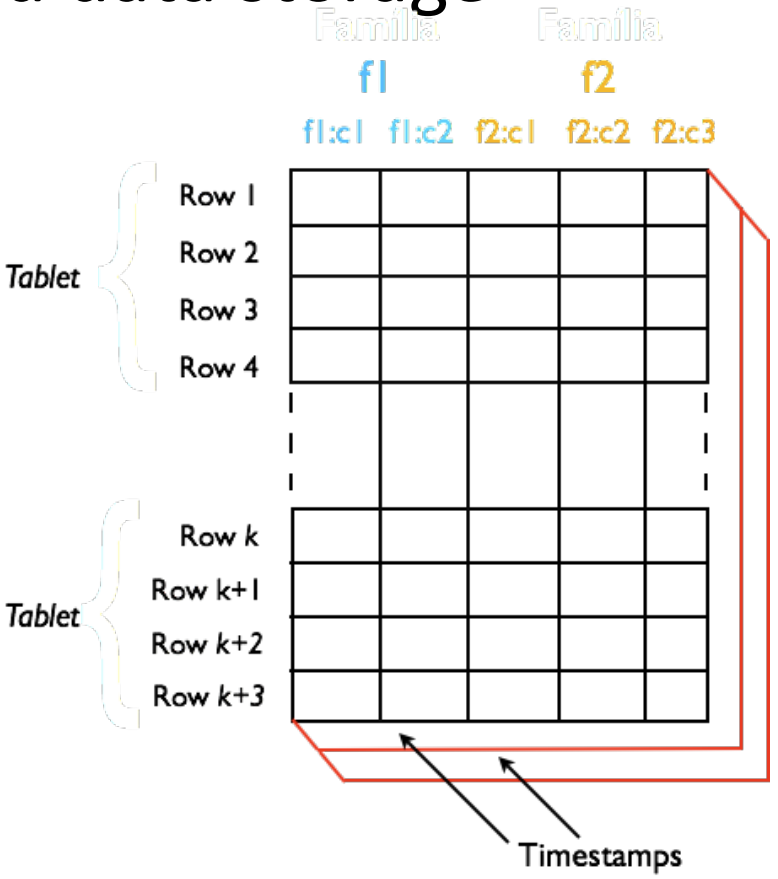
Adya et al., USENIX NSDI, 2010

- ZooKeeper, Yahoo!
  - Coordination kernel
  - On Apache since 2008

Hunt et al., USENIX ATC, 2010

Example – Bigtable, HBase

- Sparse column-oriented data storage
  - Tablet: range of rows
  - Unit of distribution
- Architecture
  - Master
  - Tablet servers

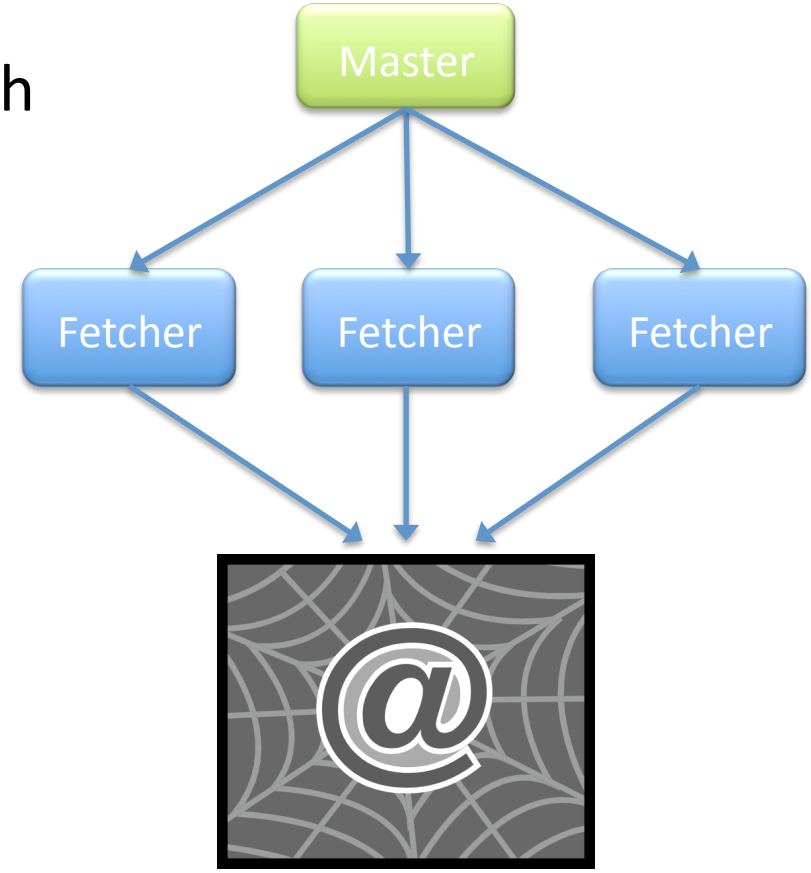


Example – Bigtable, HBase

- Master election
  - Tolerate master crashes
- Metadata management
  - ACLs, Tablet metadata
- Rendezvous
  - Find tablet server
- Crash detection
  - Live tablet servers

Example – Web crawling

- Fetching service
  - Fetch Web pages for search engine
- Master election
  - Assign work
- Metadata management
  - Politeness constraints
  - Shards
- Crash detection
  - Live workers



And more examples…

- GFS – Google File System
  - Master election
  - File system metadata
- Katta - Document indexing system
  - Shard information
  - Index version coordination
- Hedwig – Pub-Sub system
  - Topic metadata
  - Topic assignment

Summary of Part 1

- Large infrastructures require coordination
- Fallacies of distributed computing
- Theory results: FLP, CAP
- Coordination services
- Examples
  - Web search
  - Storage systems