High Availability HDFS

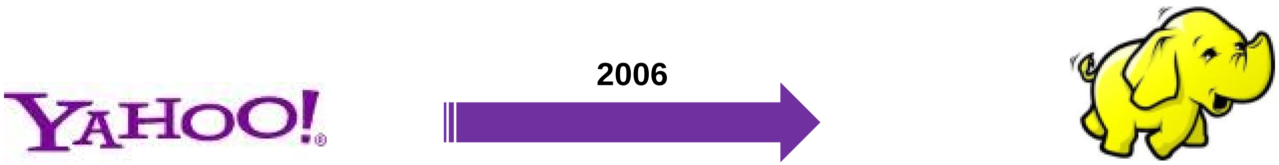
Matt Foley
Hortonworks, Inc.
mfoley@hortonworks.com

Matt Foley - Background

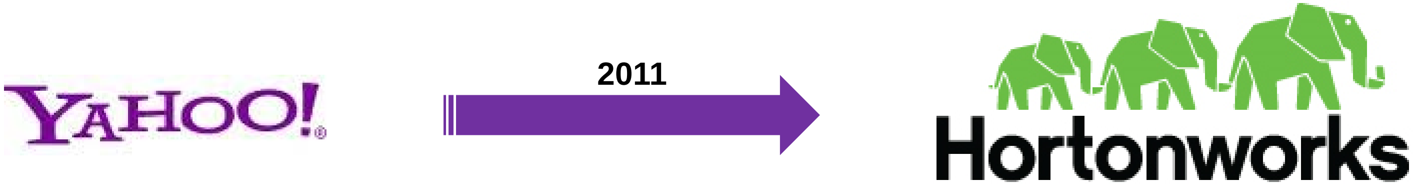
- **MTS at Hortonworks Inc.**
  - HDFS contributor, part of original ~25 in Yahoo! spin-out of Hortonworks
  - Currently managing engineering infrastructure for Hortonworks
  - My team also provides Build Engineering infrastructure services to ASF, for Hadoop core and several related projects within Apache
  - Formerly, led software development for back end of Yahoo Mail for three years – 20,000 servers with 30 PB of data under management, 400M active users
  - Did startups in Storage Management and Log Management

- **Apache Hadoop, ASF**
  - Committer and PMC member, Hadoop core
  - Release Manager – Hadoop-1.0

Company Background



- **In 2006, Yahoo! was a very early adopter of Hadoop, and became the principle contributor to it.**
- **Over time, invested *40K+ servers* and *170PB storage* in Hadoop**
- **Over 1000 active users run 5M+ Map/Reduce jobs per month**
- **In 2011, Yahoo! spun off ~25 engineers into Hortonworks, a company focused on advancing open source Apache Hadoop for the broader market (http://www.wired.com/wiredenterprise/2011/10/how-yahoo-spawned-hadoop)**



Agenda

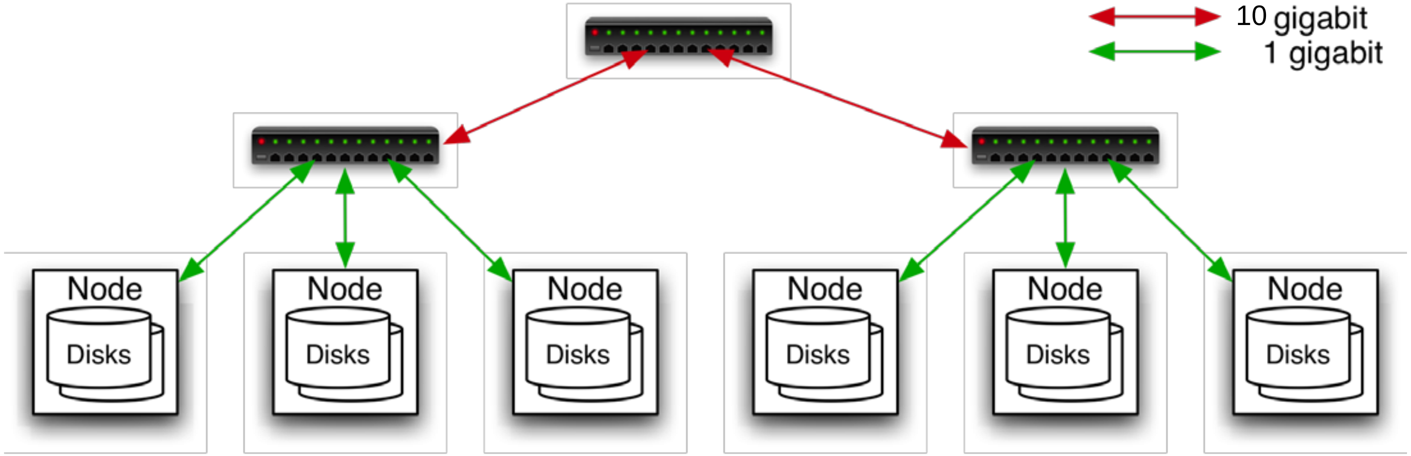
- **Overview of HDFS architecture**
- **Hadoop “ecosystem”**
- **Hadoop 2.0**

- **High Availability**
- **What has been the HDFS record?**
  - –reliability
  - –availability
- **HDFS-HA**

What is Hadoop?

- **Hadoop - Open Source Apache Project**
  - Framework for reliably storing & processing petabytes of data using *commodity* hardware and storage
- **Scalable solution**
  - Computation capacity
  - Storage capacity
  - I/O bandwidth
- **Core components**
  - HDFS: Hadoop Distributed File System - distributes data
  - Map/Reduce - distributes application processing and control
- **Move computation to data and not the other way**
- **Written in Java**
- **Runs on**
  - Linux, Windows, Solaris, and Mac OS/X

Commodity Hardware Cluster

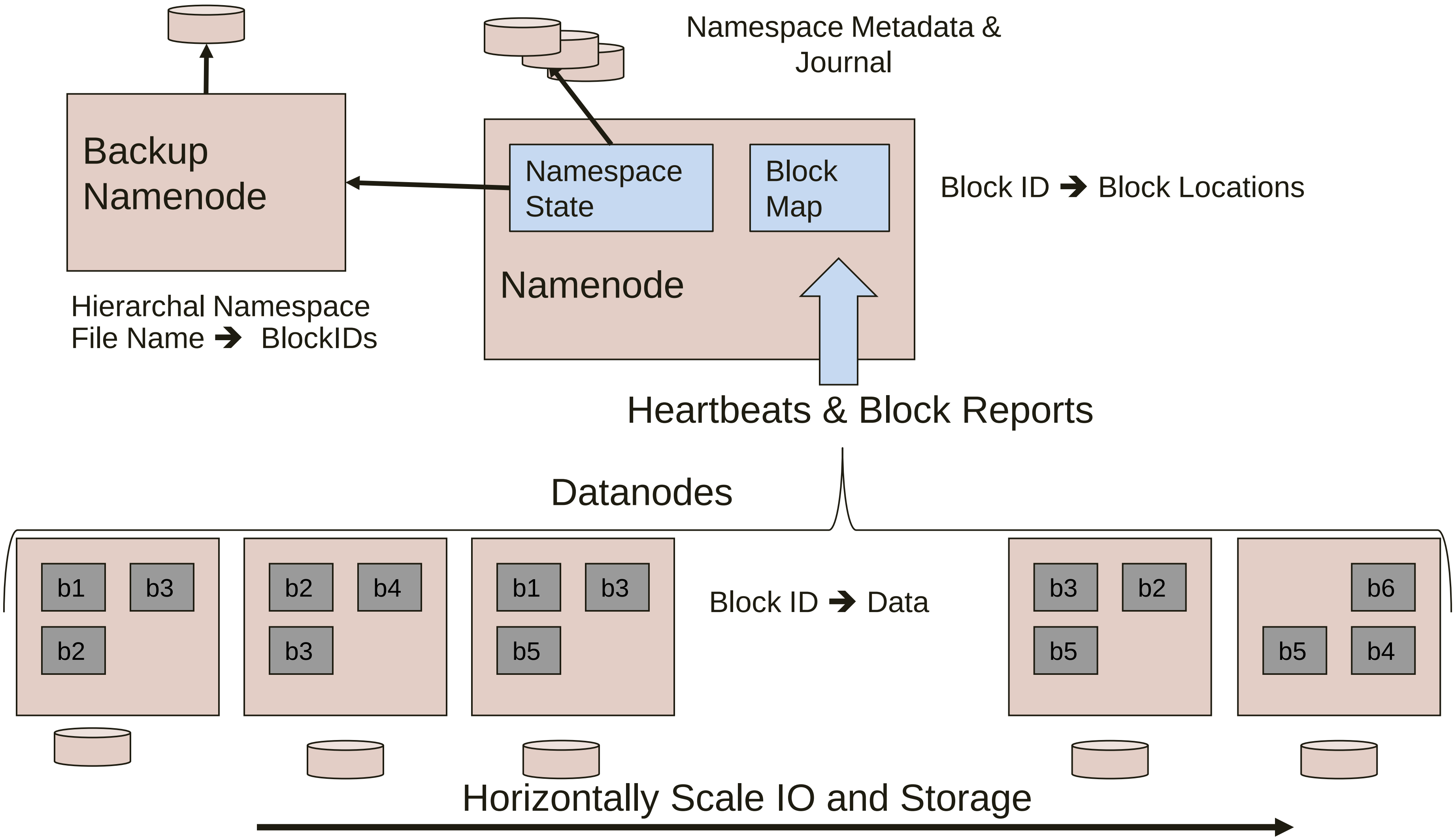


- **Typically in 2- or 3-level architecture**
  - – Nodes are commodity Linux servers
  - – 20 - 40 nodes/rack
  - – Uplink from rack is 10 or 2x10 gigabit
  - – Rack-internal is 1 or 2x1 gigabit all-to-all
- **“Flat fabric” 10Gbit network architectures being planned at growing number of sites**

Hadoop Distributed File System (HDFS)

- **One PB-scale file system for the entire cluster**
  - Managed by a single *Namenode*
  - Files are written, read, renamed, deleted, but append-only
  - Optimized for streaming reads of large files
- **Files are broken into uniform sized blocks**
  - Blocks are typically 128 MB (nominal – no wasted space)
  - Replicated to several *Datanodes*, for reliability
  - Exposes block placement so that computation can be migrated to data
- **Client library directly reads data from Data Nodes**
  - Bandwidth scales linearly with the number of nodes
  - System is topology-aware
  - Array of block locations is available to clients

HDFS Diagram



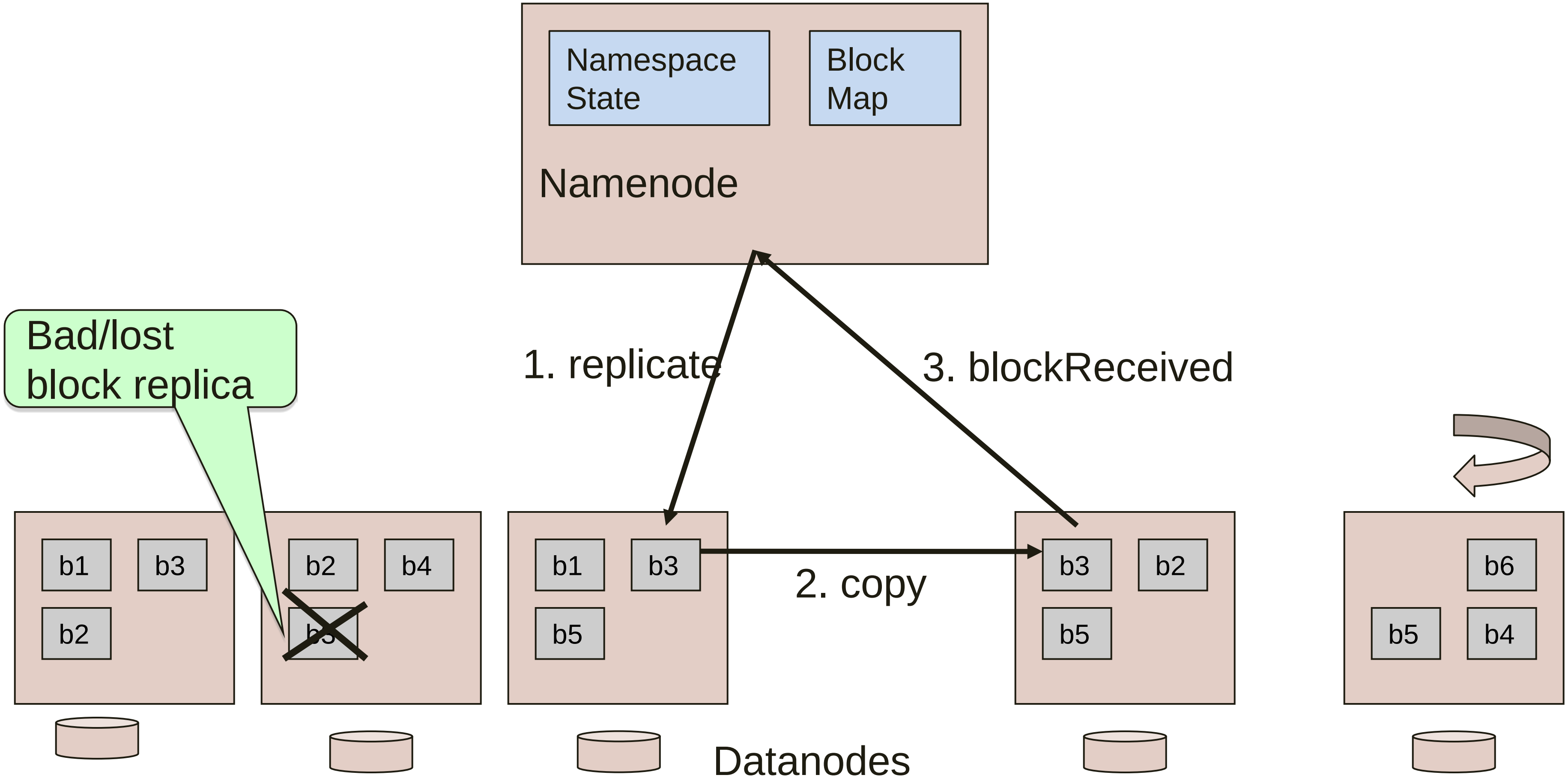
Block Placement

- **Default is 3 replicas, but settable**
- **Blocks are placed (writes are pipelined):**
  - –First replica on the local node or a random node on local rack
  - –Second replica on a remote rack
  - –Third replica on a node on same remote rack
  - –Other replicas randomly placed
- **Clients read from closest replica**
  - –System is topology-aware
- **Block placement policy is pluggable**

Block Correctness

- **Data is checked with CRC32**
- **File Creation**
  - –Client computes block checksums
  - –DataNode stores the checksums
- **File access**
  - –Client retrieves the data and checksum from DataNode
  - –If Validation fails, Client tries other replicas
- **Periodic validation by DataNode**
  - –Background DataBlockScanner task

HDFS Data Reliability

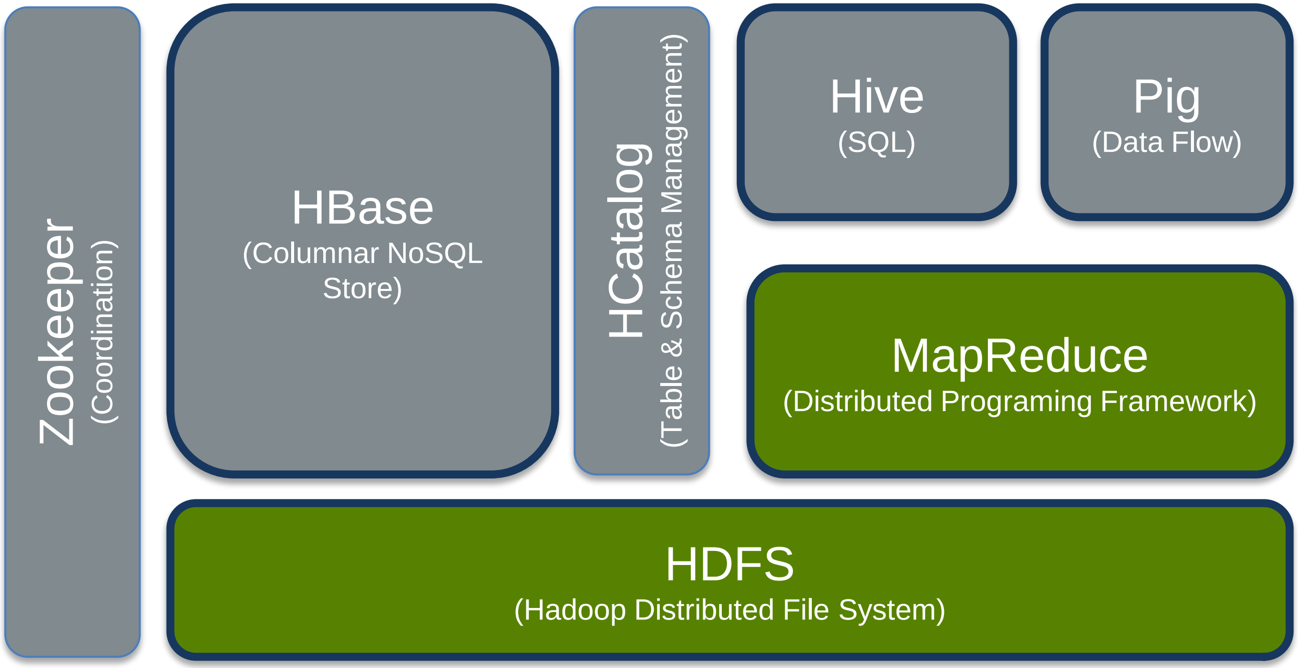


Active Data Management

- **Continuous replica maintenance**
- **End-to-end checksums**
- **Periodic checksum verification**
- **Decommissioning nodes for service**
- **Balancing storage utilization**

Other Hadoop Ecosystem Components

🟩 Core Apache Hadoop ⬜ Related Hadoop Projects



Zookeeper
(Coordination)

HBase
(Columnar NoSQL Store)

HCatalog
(Table & Schema Management)

Hive
(SQL)

Pig
(Data Flow)

MapReduce
(Distributed Programing Framework)

HDFS
(Hadoop Distributed File System)

Agenda

- **Overview of HDFS architecture**
- **Hadoop "ecosystem"**
- **Hadoop 2.0**

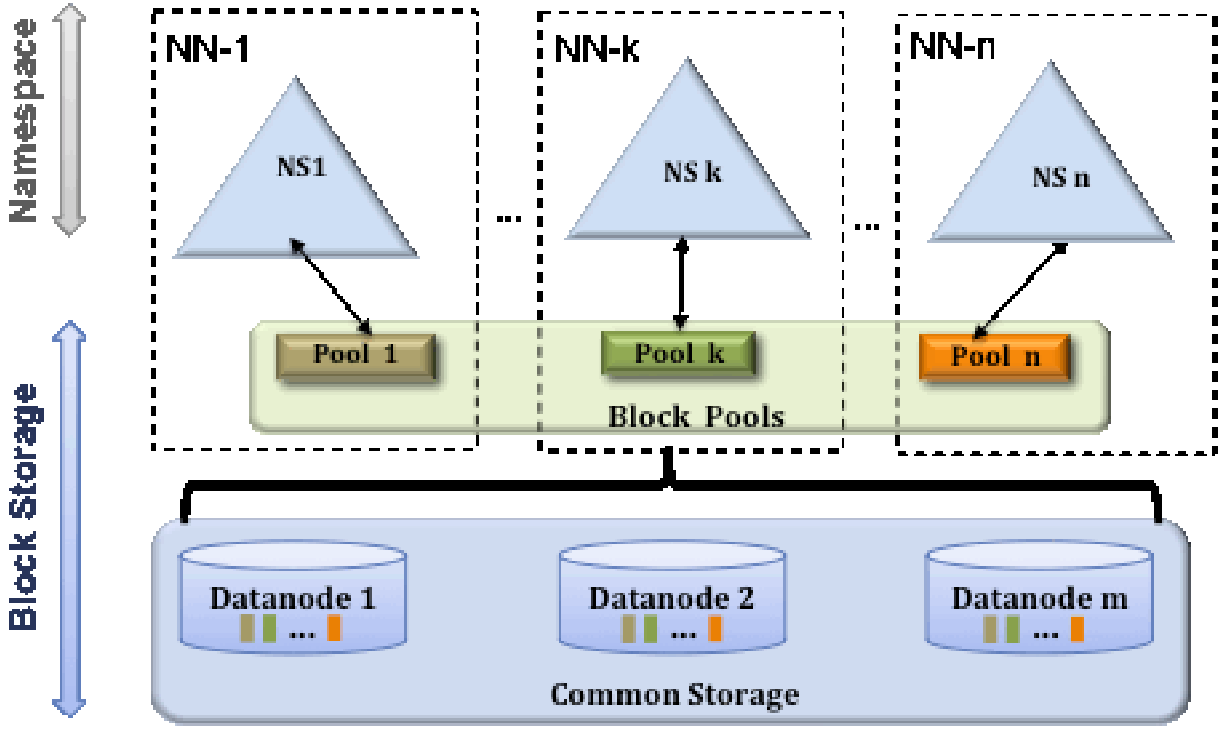
- **High Availability**
- **What has been the HDFS record?**
  - –reliability
  - –availability
- **HDFS-HA**

Hadoop 2.0

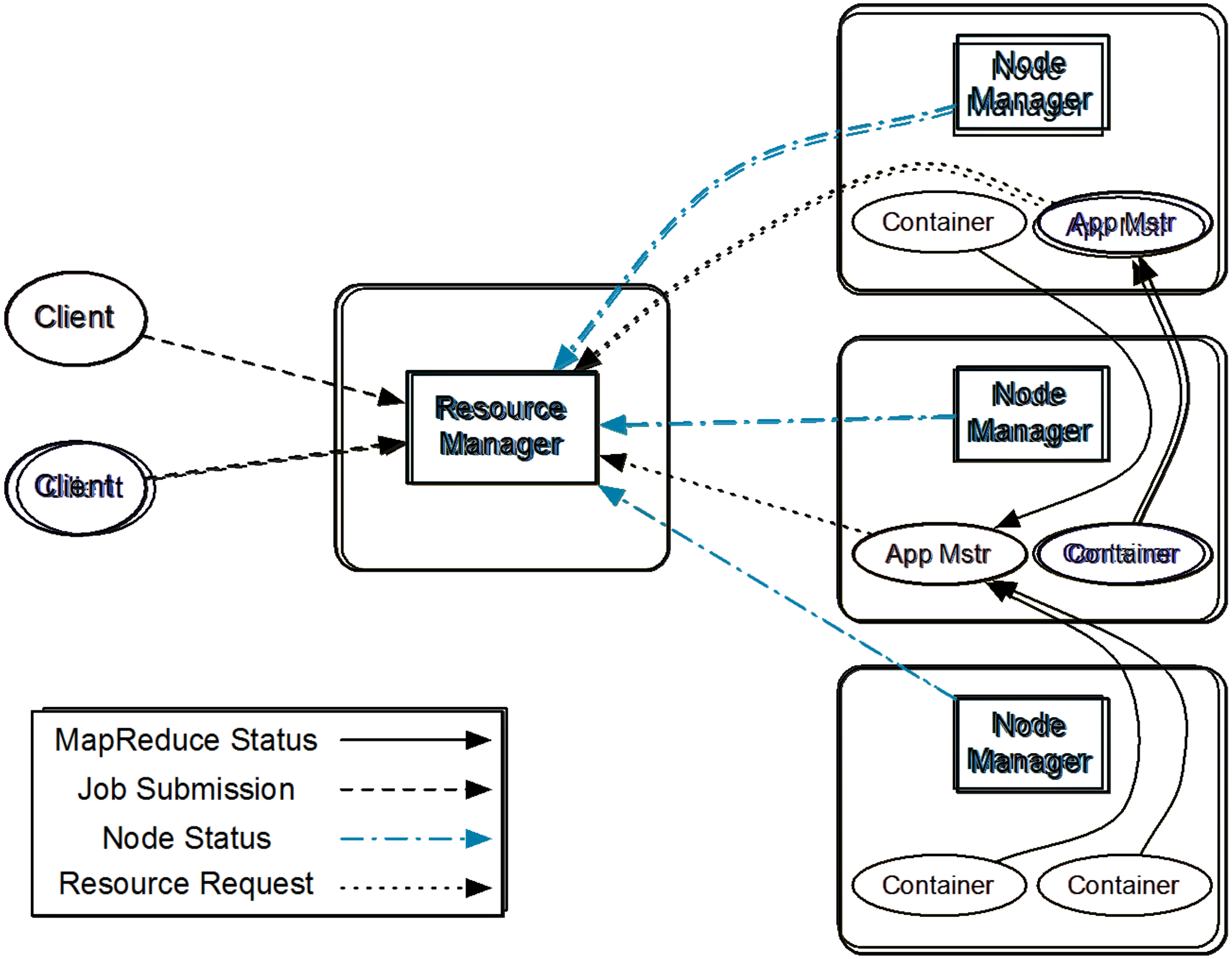
- **Developed on Hadoop branch 0.23**
- **Highlights:**
  - HDFS Namenode HA
  - HDFS Namenode Federation
  - Next-Generation MapReduce architecture (aka YARN)
  - Performance

HDFS Federation in v2.0

- **Improved scalability and isolation**
- **Clear separation of Namespace and Block Storage**



MapReduce2 - YARN



Agenda

- Overview of HDFS architecture
- Hadoop “ecosystem”
- Hadoop 2.0

- **High Availability**
- **What has been the HDFS record?**
  - –reliability
  - –availability
- **HDFS-HA**

Current HDFS Reliability & Availability

- **Block store – extremely high**
  - Block replicas stored in native FS on multiple nodes
    - Transparently ensure that blocks stay replicated
    - Serve from closest available replica
    - A lost node with 12 TB can be re-replicated in 7 minutes
    - A single lost disk of 1TB can be re-replicated in 30 seconds
  - With standard 3x replication, probability of data loss due to normal rates of server and disk failure is infinitesimally small
    - even assuming very casual approach to parts replacement
    - In study of 2009 data, lost 19 blocks out of 329M on 20,000 nodes, due to software bugs that have since been fixed.

Current HDFS Reliability & Availability

- **Meta-data store**
  - –Single NameNode stores state
  - –Journaling and snapshot management to assure data persistence, to multiple local and NFS (HA) stores
  - –But SPOF with manual switch-over on failure
- **How well did it work?**
  - –18 month study of 25 clusters had 22 NN failures
    - –Only 8 of them would have been helped with HA
  - –Impacted availability, but never durability.

HA: Approach and Terminology

- **Initial goal is Active-Standby**
  - *Active Namenode:* actively serves read/write operations from clients
  - *Standby Namenode:* waits, becomes active when Active Namenode fails
    - Could serve read operations

- **Standby's State may be cold, warm or hot**
  - *Cold* : Standby has zero state (e.g. started after the Active is declared dead.
  - *Warm*: Standby has partial state:
    - has loaded fsImage & editLogs but has not received any block reports
    - has loaded fsImage and rolled logs and all block reports
  - *Hot Standby*: Standby has all most of the Active's state and start immediately

High Level Use Cases

- **Planned downtime**
  - Upgrades
  - Config changes
  - Main reason for downtime

- **Unplanned downtime**
  - Hardware failure
  - Server unresponsive
  - Software failures
  - Occurs infrequently

- **Supported failures**
  - Single hardware failure
    - Double hardware failure not supported
  - Some software failures
    - Same software failure affects both active and standby

Deployment Models

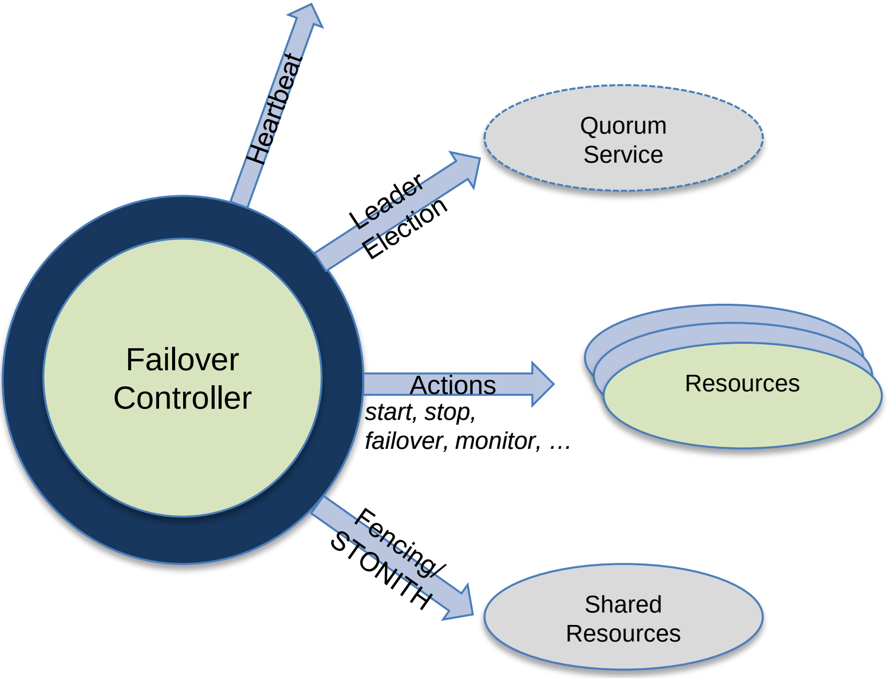
- **Single Namenode configuration; no failover**
- **Active and Standby with manual failover**
  - Standby could be cold/warm/hot
- **Active and Standby with automatic failover**
  - Hot standby

- **See HDFS-1623 for detailed use cases**

Design

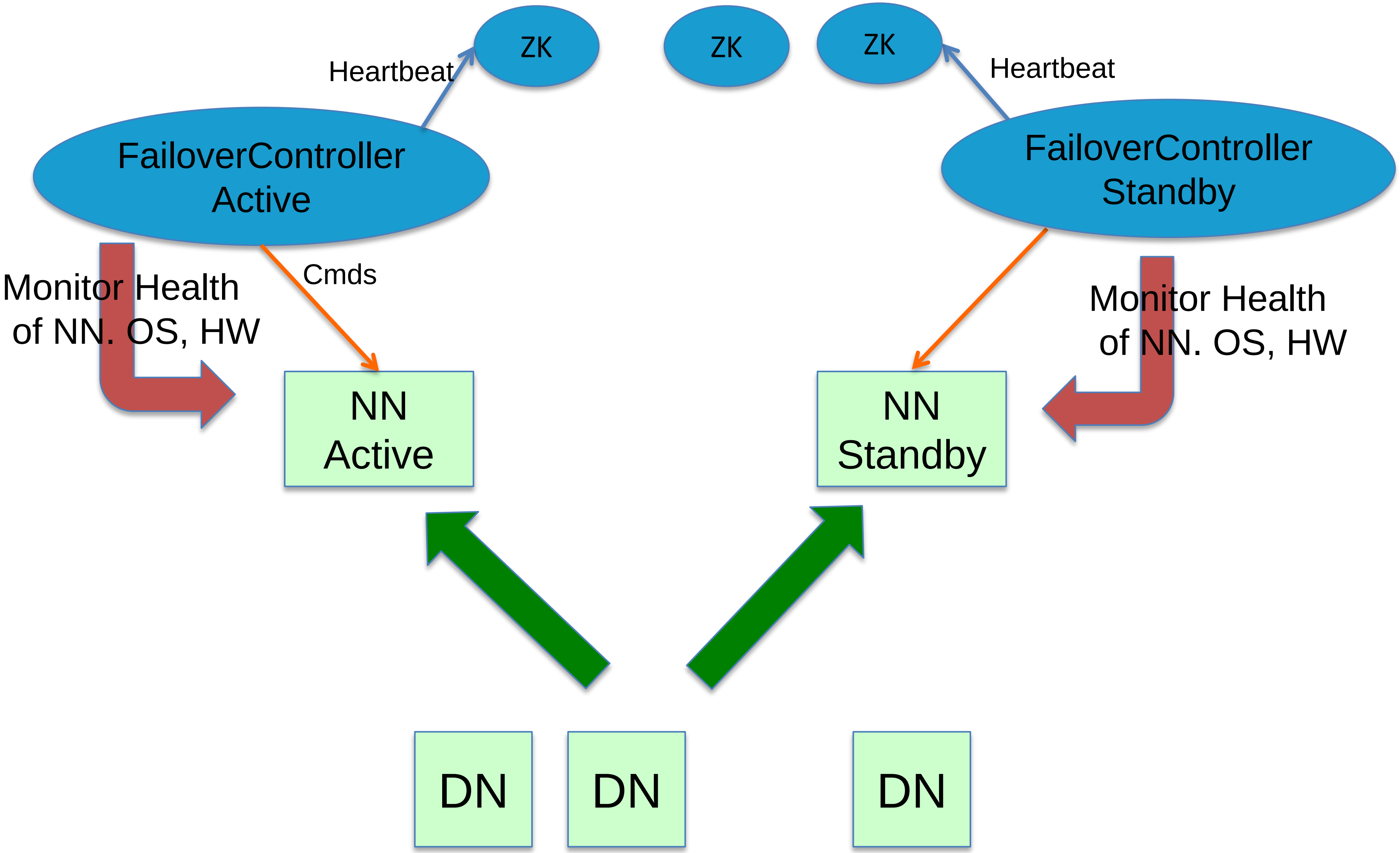
- **Failover control outside Namenode**
- **Parallel Block reports to Active and Standby (Hot failover)**
- **Shared or non-shared Namenode state**
- **Fencing of shared resources/data**
    - –Datanodes
    - –Shared Namenode state (if any)
- **Client failover**
    - –IP Failover
    - –Smart clients (e.g Zookeeper for coordination)

Failover Control Outside Namenode



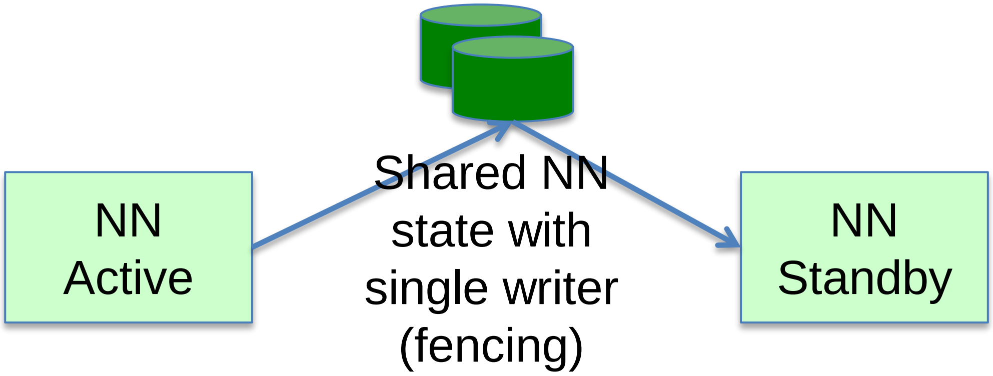
- **Failover Controller**
  - outside Namenode
- **Daemon manages resources**
  - All resources modeled uniformly
  - Resources – OS, HW, Network etc.
  - Namenode is just another resource
- **Heartbeat with other nodes**
- **Quorum based leader election**
  - Zookeeper for co-ordination and Quorum
- **Fencing during split brain**
  - Prevents data corruption

HA Namenode with ZooKeeper


ZK
ZK
ZK
Heartbeat
Heartbeat
FailoverController Active
FailoverController Standby
Cmds
Monitor Health of NN. OS, HW
Monitor Health of NN. OS, HW
NN Active
NN Standby
DN
DN
DN

Sharing the Namenode's Persistent State

medium term – 6 month timeframe

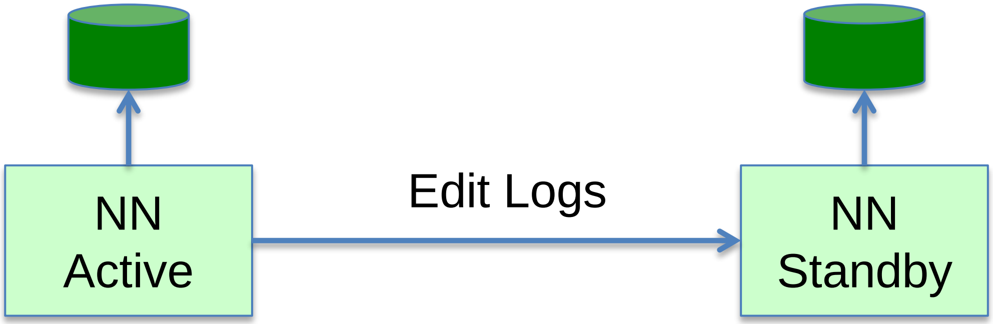


NN Active

Shared NN state with single writer (fencing)

NN Standby

Shared Storage Approach



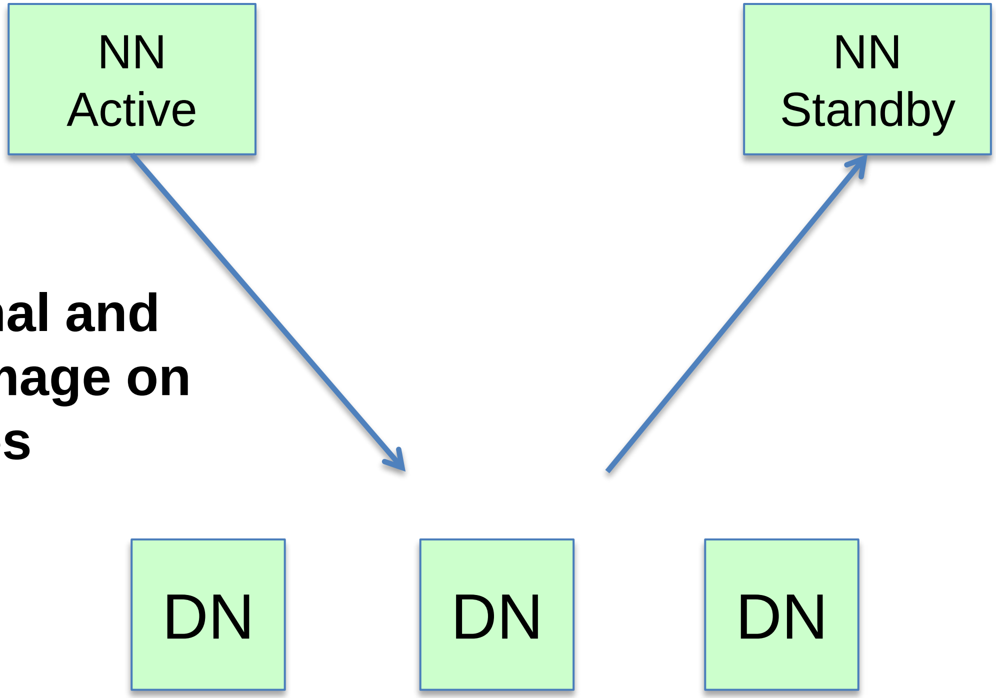
NN Active

Edit Logs

NN Standby

Direct stream to Standby NN

Sharing the Namenode's Persistent State
long term



Store NN journal and checkpointed image on Datanodes

Hadoop 2.0 “Availability” (in the field)

- **Requires LOTS of testing**
- **In small-scale test (500-800 nodes) 2Q2012**
- **Ramping up over rest of year, with full range of application testing**
- **Expected to be in production at multiple sites by end/2012**

Credits

For major contributions to Hadoop technology, and help with this presentation:

- **Sanjay Radia and Suresh Srinivas, Hortonworks**
  - Architect and Team Lead, HDFS
  - HA and Federation
- **Owen O’Malley, Hortonworks**
  - Hadoop lead Architect
  - Security, Map/Reduce
- **Arun Murthy, Hortonworks**
  - Architect and Team Lead, Map/Reduce
  - M/R2, YARN, etc.
- **Rob Chansler, Yahoo!**
  - Team Lead, HDFS
  - Analysis of Data Availability and Durability

Help getting started

- **Apache Hadoop Projects**
  - http://hadoop.apache.org/
  - http://wiki.apache.org/hadoop/
- **Apache Hadoop Email lists:**
  - common-user@hadoop.apache.org
  - hdfs-user@hadoop.apache.org
  - mapreduce-user@hadoop.apache.org
- **O'Reilly Books**
  - Hadoop, The Definitive Guide
  - HBase, The Definitive Guide
- **Hortonworks, Inc.**
  - Installable Data Platform distribution (100% OSS, conforming to Apache releases)
    - http://hortonworks.com/technology/techpreview/
  - Training and Certification programs
    - http://hortonworks.com/training/
- **Hadoop Summit 2012 (June 13-14, San Jose)**
    - http://hadoopsummit.org/

Thanks for Listening!

Questions?