Apache Hadoop FileSystem and its Usage in Facebook

Dhruba Borthakur
Project Lead, Apache Hadoop Distributed File System
dhruba@apache.org

Presented at Indian Institute of Technology
November, 2010
http://www.facebook.com/hadoopfs

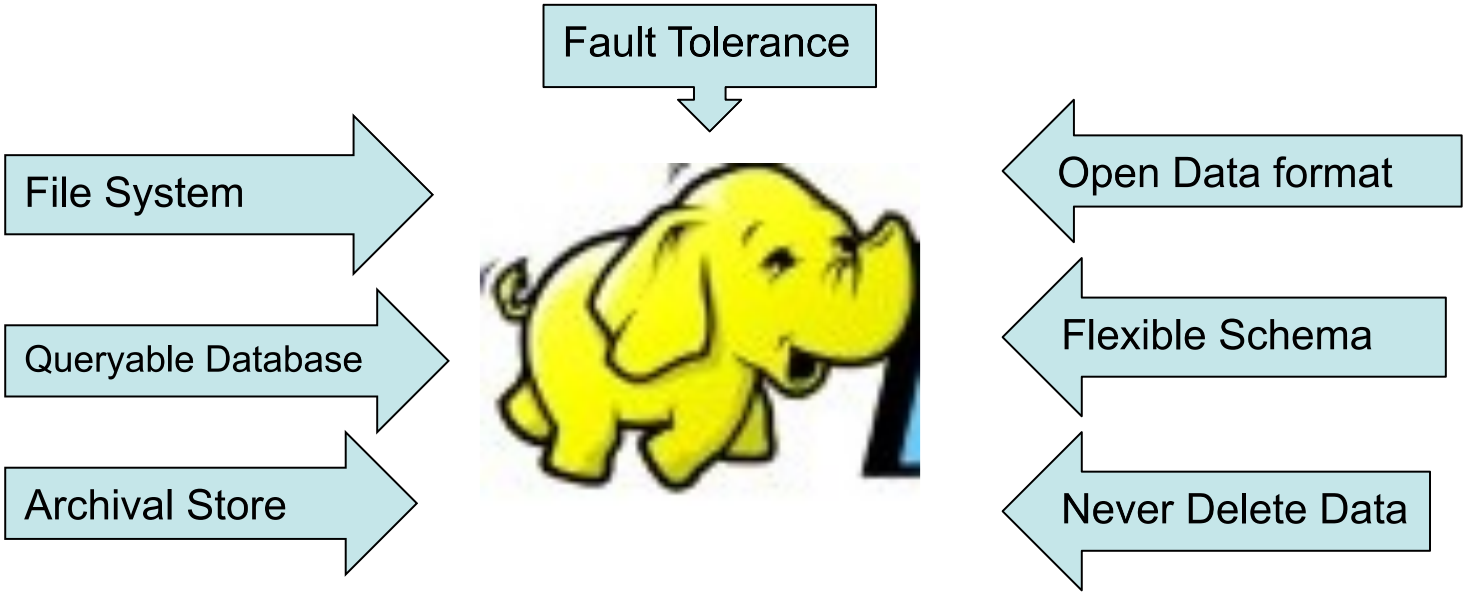
Outline

- **Introduction**
- **Architecture of Hadoop Distributed File System (HDFS)**
- **Usage of Hadoop in Facebook**
  - Data Warehouse
  - mySQL Backups
  - Online application storage

Who Am I?

- **Apache Hadoop FileSystem (HDFS)**
  - Project Lead
  - Core contributor since Hadoop's infancy
- **Facebook** (Hadoop, Hive, Scribe)
- **Yahoo!** (Hadoop in Yahoo Search)
- **Veritas** (San Point Direct, Veritas File System)
- **IBM Transarc** (Andrew File System)
- **Univ of Wisconsin** Computer Science Alumni (Condor Project)

A Confluence of Trends



Fault Tolerance

File System

Queryable Database

Archival Store

Open Data format

Flexible Schema

Never Delete Data

HADOOP: A Massively Scalable Queryable Store and Archive

Hadoop, Why?

- **Need to process Multi Petabyte Datasets**
- **Data may not have strict schema**
- **Expensive to build reliability in each application.**
- **Nodes fail every day**
  - Failure is expected, rather than exceptional.
  - The number of nodes in a cluster is not constant.
- **Need common infrastructure**
  - Efficient, reliable, Open Source Apache License

Is Hadoop a Database?

- Hadoop triggered upheaval in Database Research
  - "A giant step backward in the programming paradigm", Dewitt et el
  - "DBMS performance outshines Hadoop" – Stonebraker, Dewitt, SIGMOD 2009
- Parallel Databases
  - A few scales to 200 nodes and about 5 PB
  - Primary design goal is "performance"
  - Requires homogeneous hardware
  - Anomalous behavior is not well tolerated:
    - A slow network can cause serious performance degradation
    - Most queries fail when one node fails
- Scalability and Fault Tolerance: Hadoop to the rescue!

Hadoop History

- Dec 2004 – Google GFS paper published
- July 2005 – Nutch uses MapReduce
- Feb 2006 – Starts as a Lucene subproject
- Apr 2007 – Yahoo! on 1000-node cluster
- Jan 2008 – An Apache Top Level Project
- May 2009 – Hadoop sorts Petabyte in 17 hours
- Aug 2010 – World's Largest Hadoop cluster at Facebook
  - 2900 nodes, 30+ PetaByte

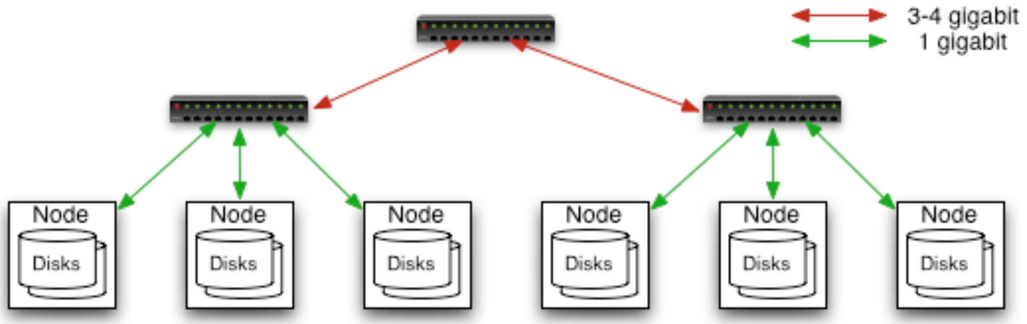
Who uses Hadoop?

- Amazon/A9
- Facebook
- Google
- IBM
- Joost
- Last.fm
- New York Times
- PowerSet
- Veoh
- Yahoo!

What is Hadoop used for?

- Search
  - Yahoo, Amazon, Zvents
- Log processing
  - Facebook, Yahoo, ContextWeb. Joost, Last.fm
- Recommendation Systems
  - Facebook
- Data Warehouse
  - Facebook, AOL
- Video and Image Analysis
  - New York Times, Eyealike

Commodity Hardware



Typically in 2 level architecture

– Nodes are commodity PCs

– 20-40 nodes/rack

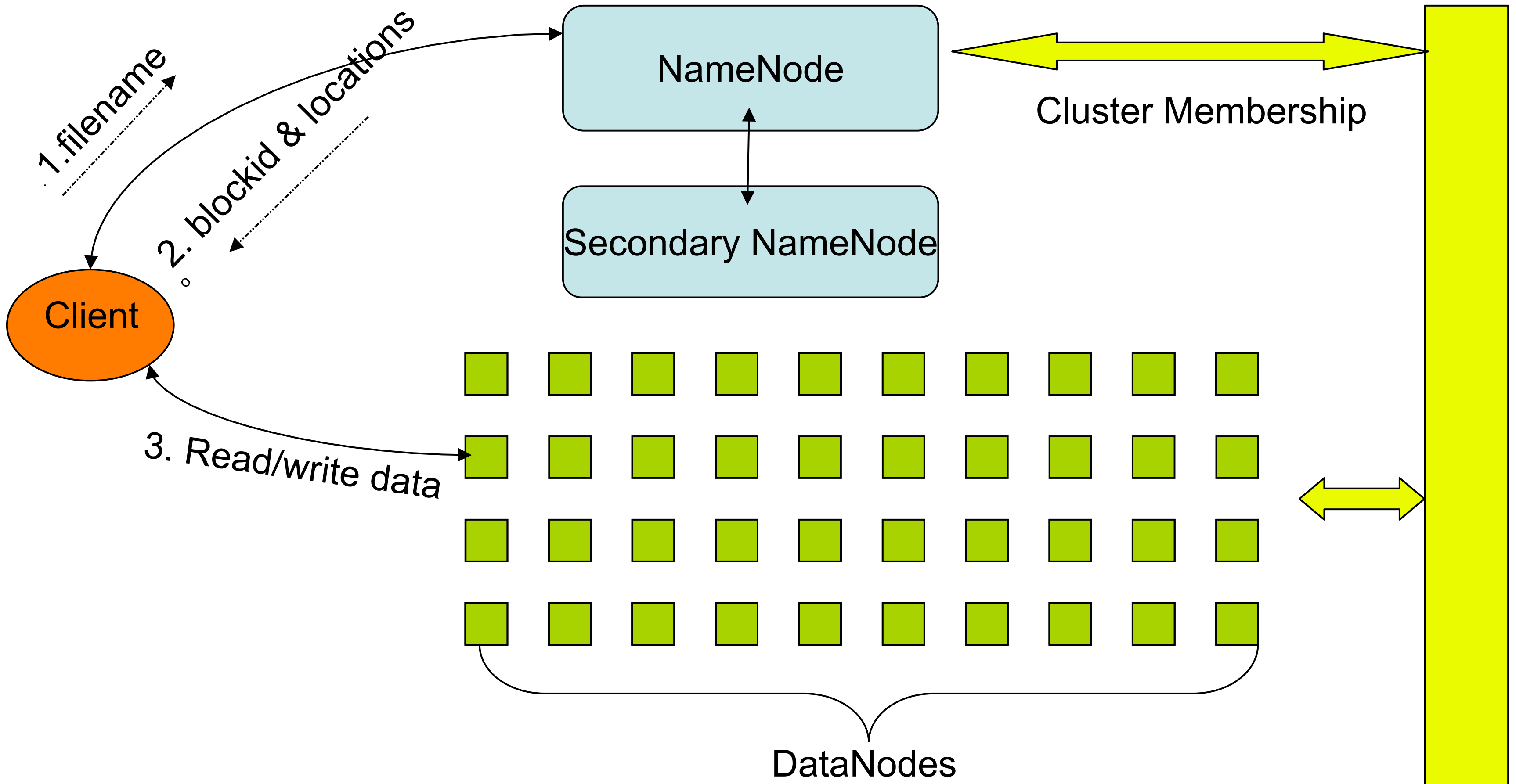
– Uplink from rack is 4 gigabit

– Rack-internal is 1 gigabit

Goals of HDFS

- ❒ **Very Large Distributed File System**
  - – 10K nodes, 1 billion files, 100 PB
- ❒ **Assumes Commodity Hardware**
  - – Files are replicated to handle hardware failure
  - – Detect failures and recovers from them
- ❒ **Optimized for Batch Processing**
  - – Data locations exposed so that computations can move to where data resides
  - – Provides very high aggregate bandwidth
- ❒ **User Space, runs on heterogeneous OS**

HDFS Architecture



1.filename

2. blockid & locations

NameNode

Secondary NameNode

Client

Cluster Membership

3. Read/write data

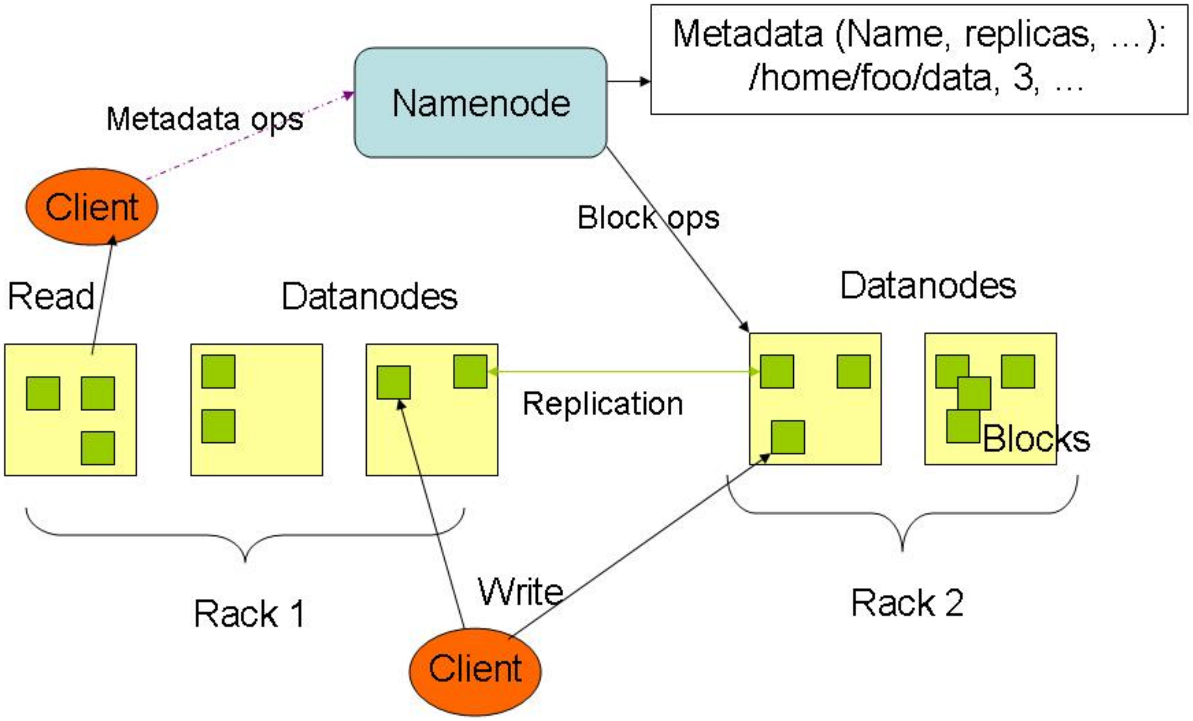
DataNodes

NameNode : Maps a file to a file-id and list of DataNodes
DataNode : Maps a block-id to a physical location on disk
SecondaryNameNode: Periodic merge of Transaction log

Distributed File System

- **Single Namespace for entire cluster**
- **Data Coherency**
  - Write-once-read-many access model
  - Client can only append to existing files
- **Files are broken up into blocks**
  - Typically 128 - 256 MB block size
  - Each block replicated on multiple DataNodes
- **Intelligent Client**
  - Client can find location of blocks
  - Client accesses data directly from DataNode

HDFS Architecture



NameNode Metadata

- **Meta-data in Memory**
  - The entire metadata is in main memory
  - No demand paging of meta-data
- **Types of Metadata**
  - List of files
  - List of Blocks for each file
  - List of DataNodes for each block
  - File attributes, e.g creation time, replication factor
- **A Transaction Log**
  - Records file creations, file deletions. etc

DataNode

- **A Block Server**
  - – Stores data in the local file system (e.g. ext3)
  - – Stores meta-data of a block (e.g. CRC32)
  - – Serves data and meta-data to Clients
  - - Periodic validation of checksums
- **Block Report**
  - – Periodically sends a report of all existing blocks to the NameNode
- **Facilitates Pipelining of Data**
  - – Forwards data to other specified DataNodes

Block Placement

- **Current Strategy**

  -- One replica on local node

  -- Second replica on a remote rack

  -- Third replica on same remote rack

  -- Additional replicas are randomly placed
- **Clients read from nearest replica**
- **Pluggable policy for placing block replicas**
  - Co-locate datasets that are often used together
  - http://hadoopblog.blogspot.com/2009/09/hdfs-block-replica-placement-in-your.html

Data Pipelining

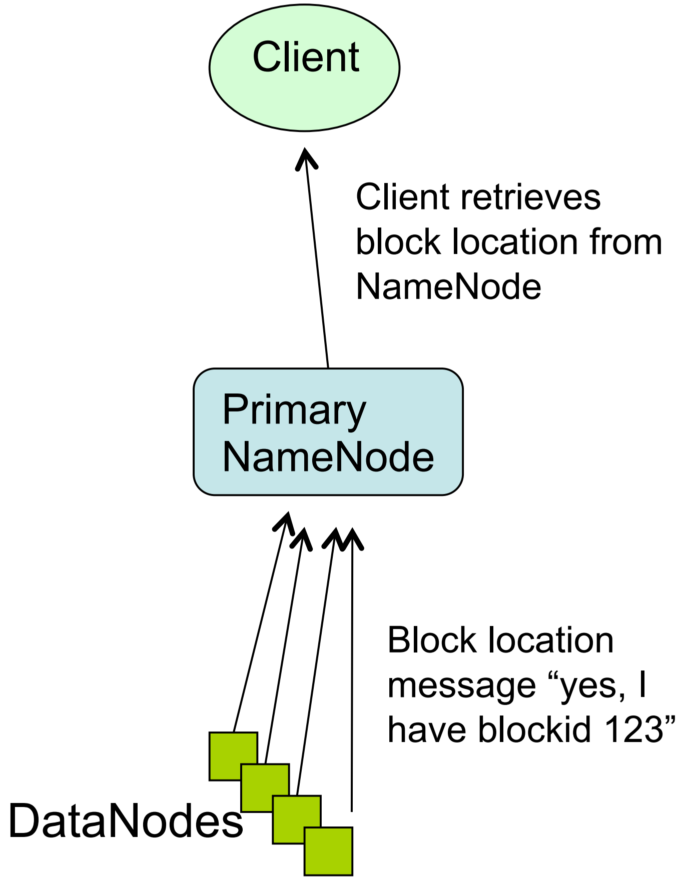
- Client writes block to the first DataNode
- The first DataNode forwards the data to the next DataNode in the Pipeline, and so on
- When all replicas are written, the Client moves on to write the next block in file

NameNode Failure

- **A Single Point of Failure**
- **Transaction Log stored in multiple directories**
  - A directory on the local file system
  - A directory on a remote file system (NFS/CIFS)
- **This is a problem with 24 x 7 operations**
  - AvatarNode comes to the rescue

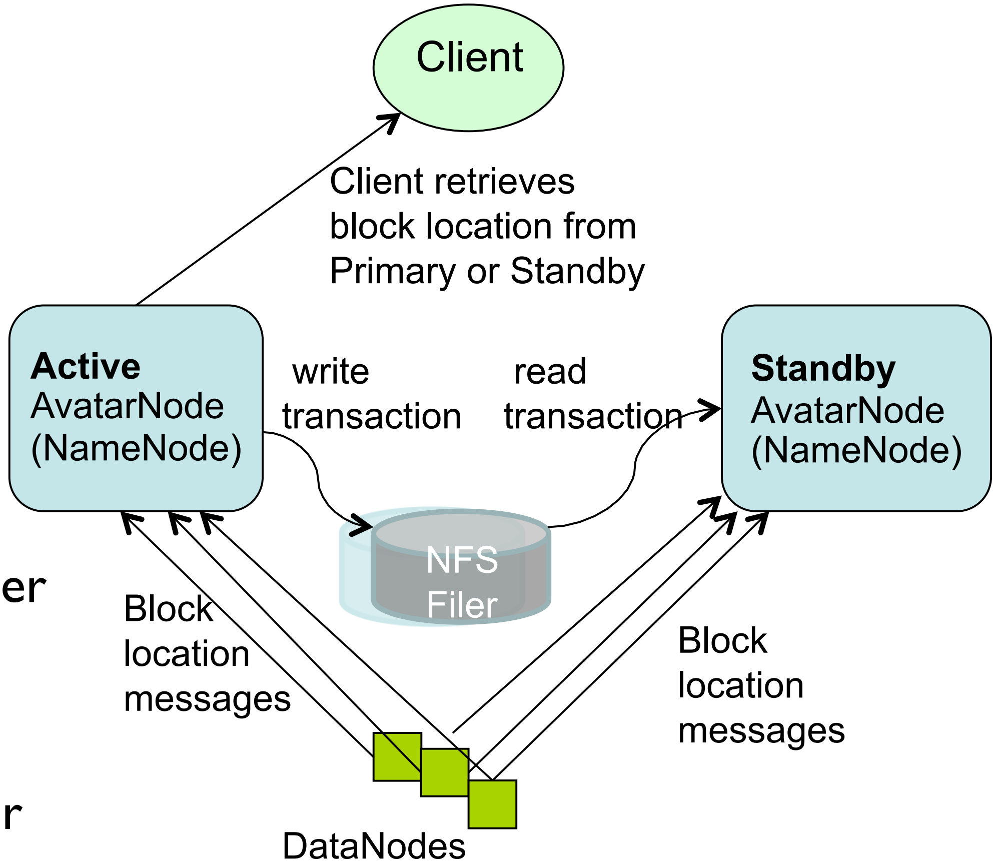
NameNode High Availability: Challenges

- DataNodes send block location information to only one NameNode
- NameNode needs block locations in memory to serve clients
- The in-memory metadata for 100 million files could be 60 GB, huge!


Client
Client retrieves block location from NameNode
Primary NameNode
Block location message “yes, I have blockid 123”
DataNodes

NameNode High Availability: AvatarNode

- **Active-Standby Pair**
  - Coordinated via zookeeper
  - Failover in few seconds
  - Wrapper over NameNode
- **Active AvatarNode**
  - Writes transaction log to filer
- **Standby AvatarNode**
  - Reads transactions from filer
  - Latest metadata in memory


Client
Client retrieves block location from Primary or Standby
Active AvatarNode (NameNode)
write transaction
read transaction
Standby AvatarNode (NameNode)
NFS Filer
Block location messages
Block location messages
DataNodes

http://hadoopblog.blogspot.com/2010/02/hadoop-namenode-high-availability.html

Rebalancer

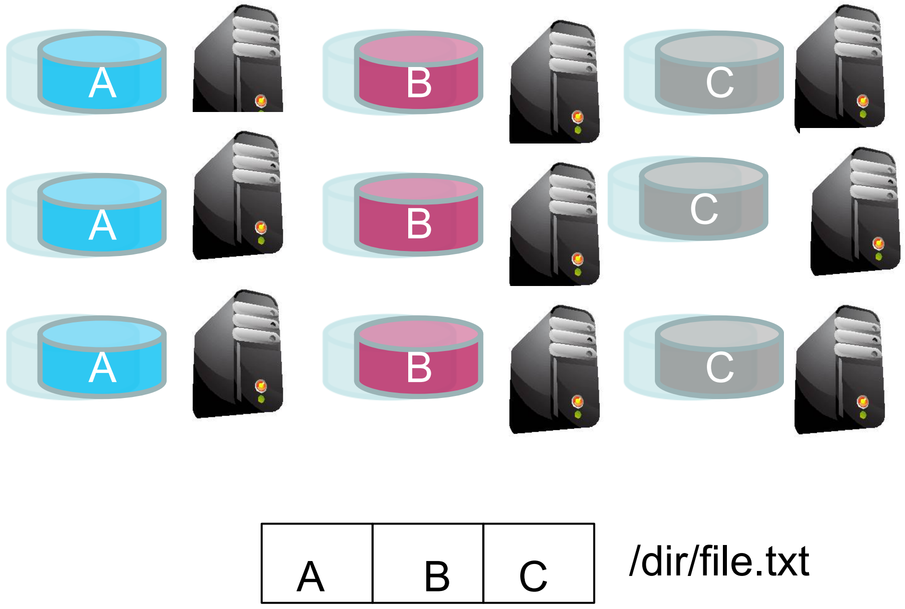
- **Goal: % disk full on DataNodes should be similar**
  - Usually run when new DataNodes are added
  - Cluster is online when Rebalancer is active
  - Rebalancer is throttled to avoid network congestion
- **Disadvantages**
  - Does not rebalance based on access patterns or load
  - No support for automatic handling of hotspots of data

Disk is not cheap! - RAID

- A Data Block is stored in triplicate

- File /dir/file.txt
  - three data blocks
  - nine physical blocks on disk

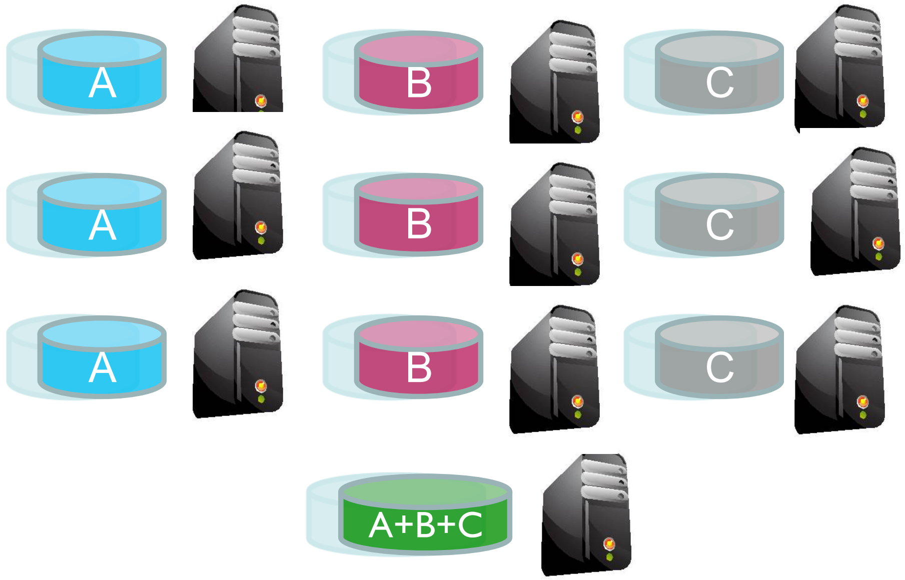
- HDFS RAID to the rescue
  - DiskReduce from CMU
  - Garth Gibson research



A file with three blocks A, B and C

HDFS Raid

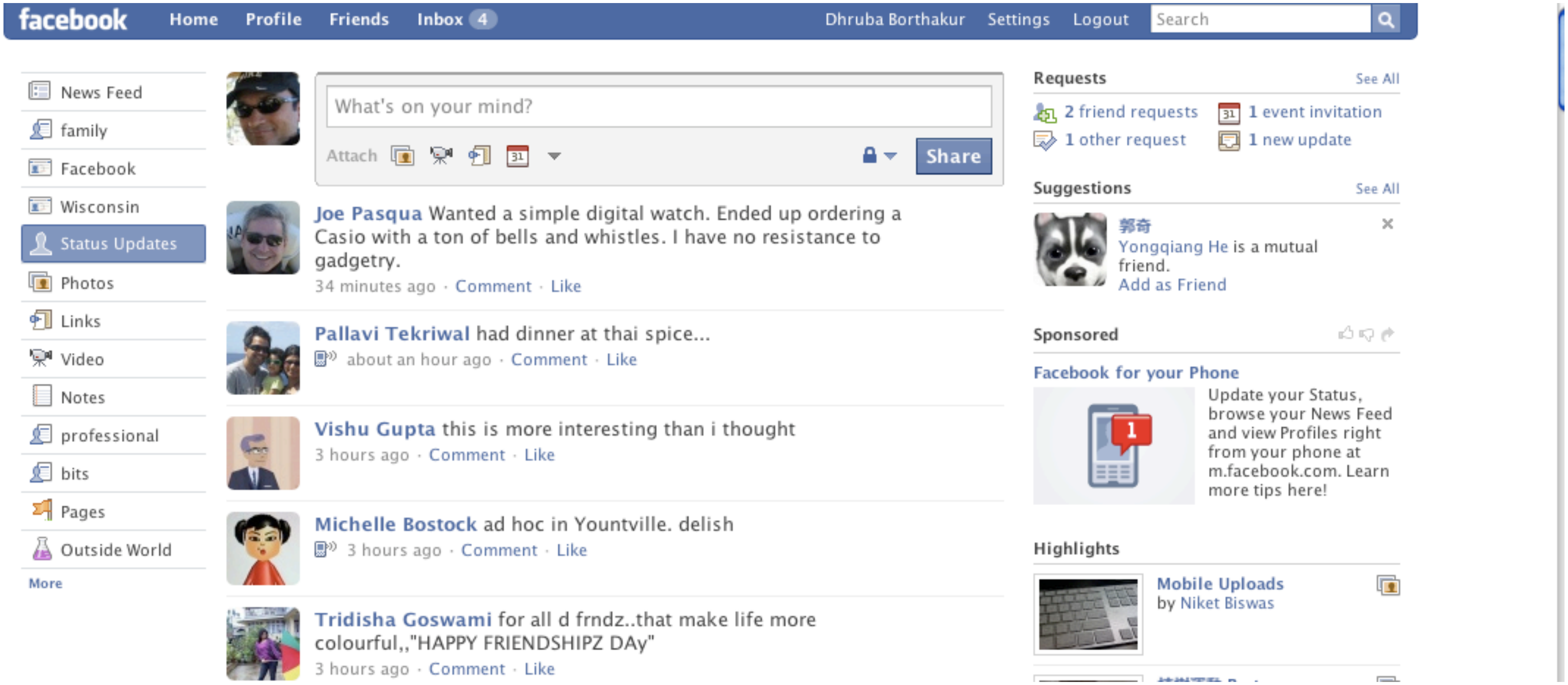
- Start the same: triplicate every data block
- Background encoding
  - Combine third replica of blocks from a single file to create parity block
  - Remove third replica
- RaidNode
  - Auto fix of failed replicas



A file with three blocks A, B and C

http://hadoopblog.blogspot.com/2009/08/hdfs-and-erasure-codes-hdfs-raid.html

Hadoop @ Facebook



Joe Pasqua Wanted a simple digital watch. Ended up ordering a Casio with a ton of bells and whistles. I have no resistance to gadgetry.
34 minutes ago · Comment · Like

Pallavi Tekriwal had dinner at thai spice...
about an hour ago · Comment · Like

Vishu Gupta this is more interesting than i thought
3 hours ago · Comment · Like

Michelle Bostock ad hoc in Yountville. delish
3 hours ago · Comment · Like

Tridisha Goswami for all d frndz..that make life more colourful,,"HAPPY FRIENDSHIPZ DAy"
3 hours ago · Comment · Like

Requests See All

2 friend requests 1 event invitation
1 other request 1 new update

Suggestions See All

郭奇
Yongqiang He is a mutual friend.
Add as Friend

Sponsored

Facebook for your Phone

Update your Status, browse your News Feed and view Profiles right from your phone at m.facebook.com. Learn more tips here!

Highlights

Mobile Uploads
by Niket Biswas

Who generates this data?

- **Lots of data is generated on Facebook**
  - 500+ million active users
  - 30 billion pieces of content shared every month (news stories, photos, blogs, etc)

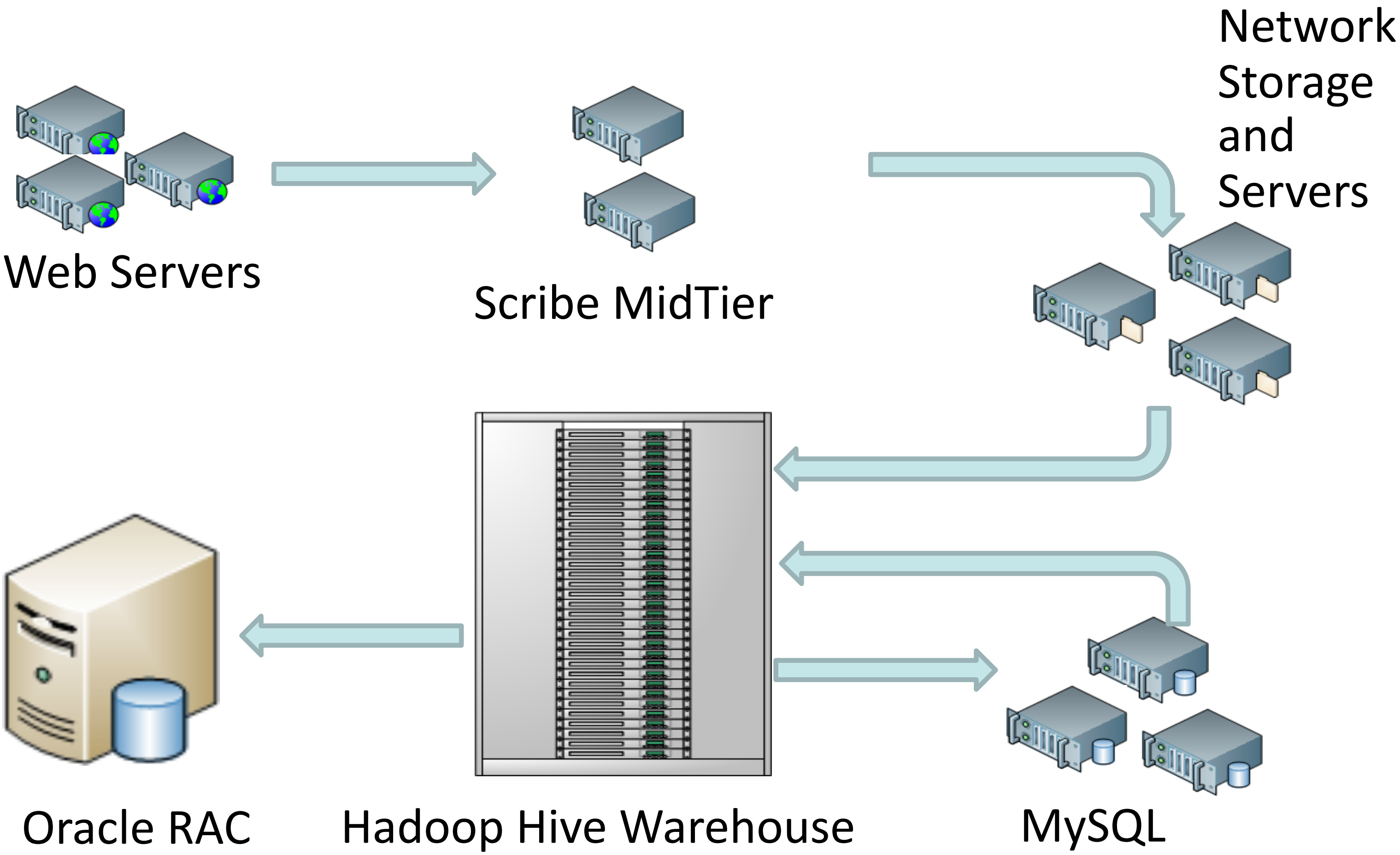
Data Usage

- **Statistics per day:**
  - 20 TB of compressed new data added per day
  - 3 PB of compressed data scanned per day
  - 20K jobs on production cluster per day
  - 480K compute hours per day
- **Barrier to entry is significantly reduced:**
  - New engineers go though a Hadoop/Hive training session
  - 300+ people run jobs on Hadoop
  - Analysts (non-engineers) use Hadoop through Hive

Where is this data stored?

- **Hadoop/Hive Warehouse**
  - 24K cores, 30 PetaBytes
  - 12 or 24 TB per node
  - Two level network topology
    - 1 Gbit/sec from node to rack switch
    - 4 Gbit/sec to top level rack switch

Data Flow into Hadoop Cloud



Web Servers

Scribe MidTier

Network Storage and Servers

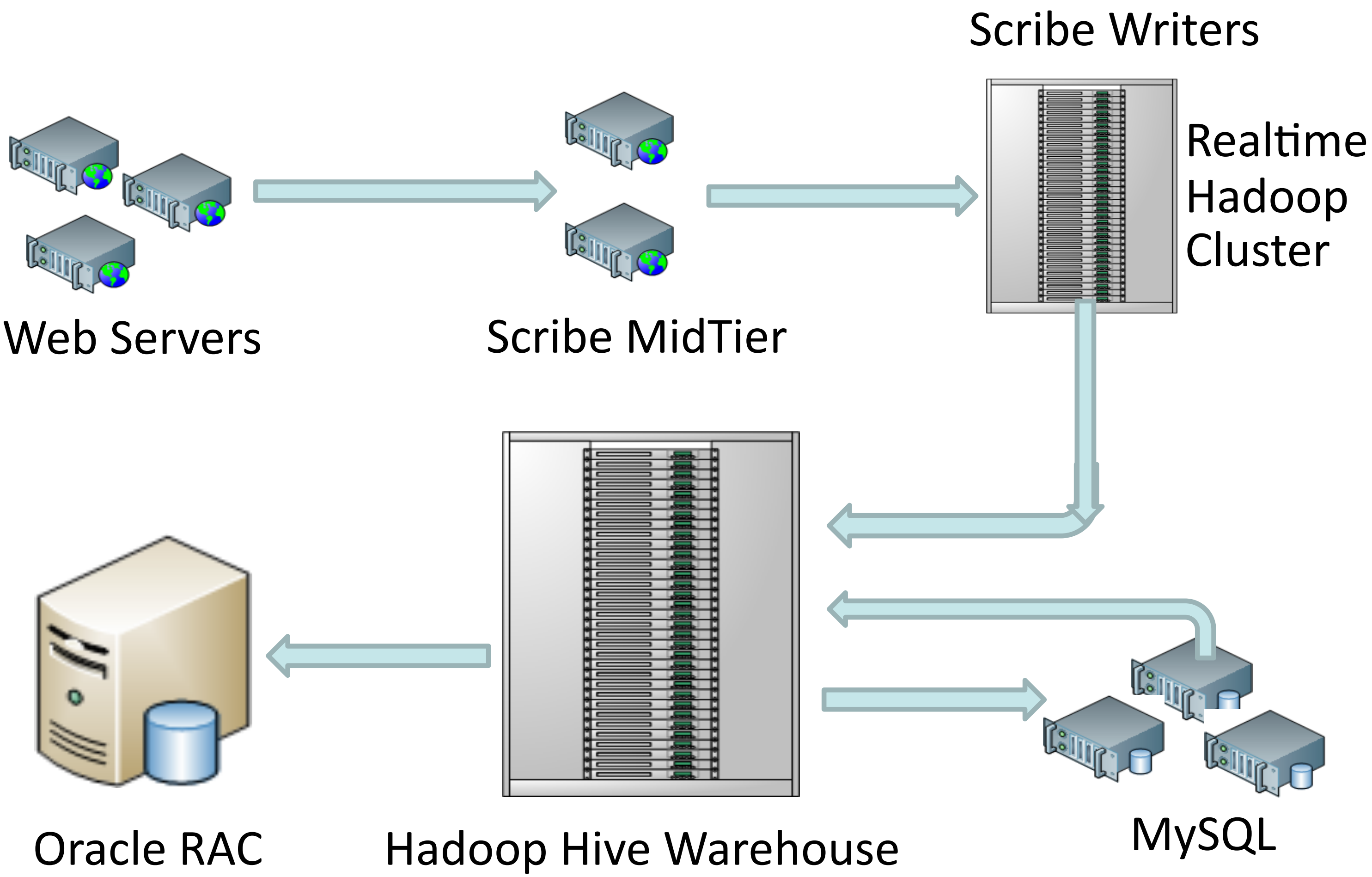
Oracle RAC

Hadoop Hive Warehouse

MySQL

hadoop

Hadoop Scribe



Scribe Writers

Realtime Hadoop Cluster

Web Servers

Scribe MidTier

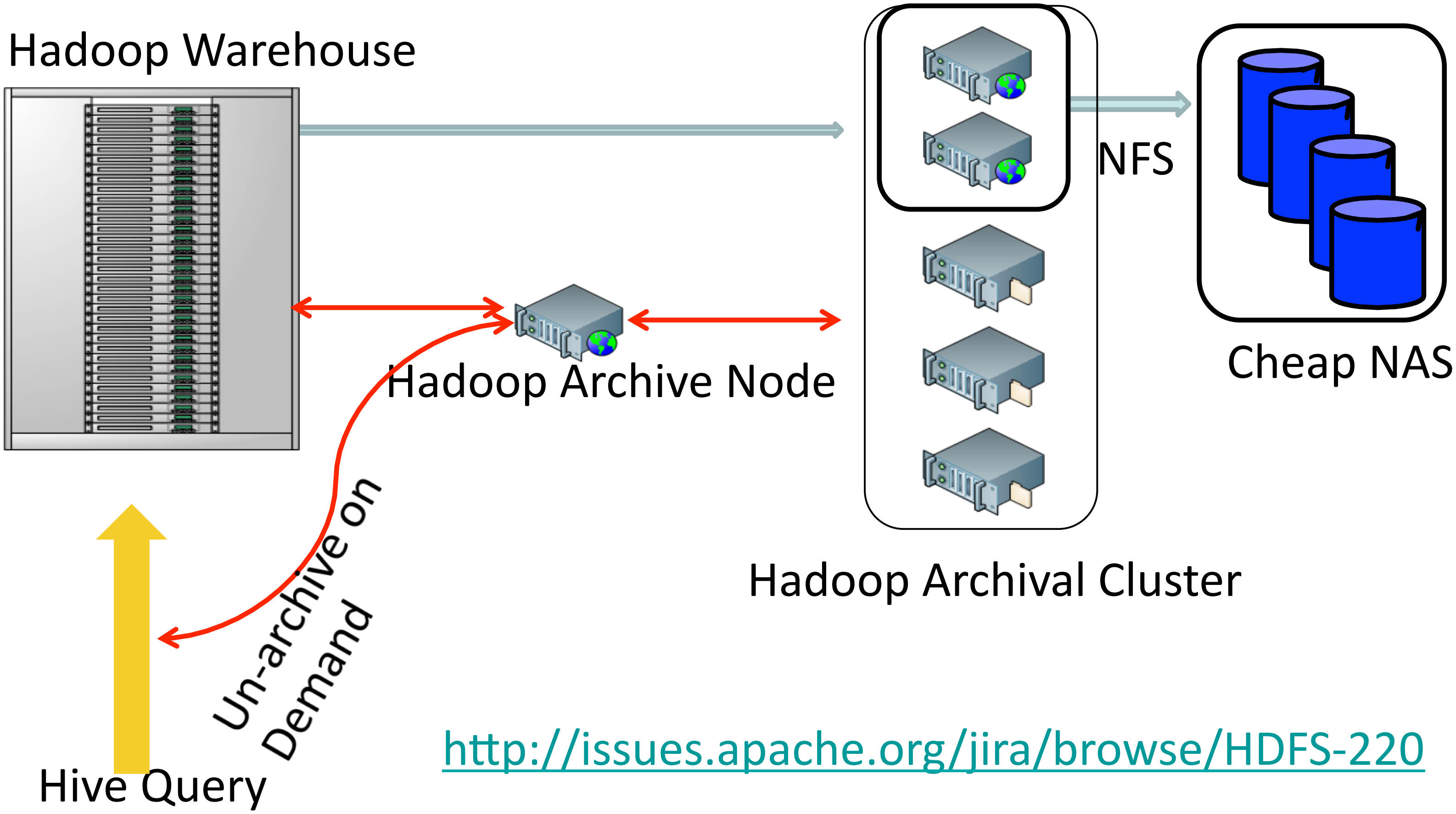
Oracle RAC

Hadoop Hive Warehouse

MySQL

http://hadoopblog.blogspot.com/2009/06/hdfs-scribe-integration.html

Archival: Move old data to cheap storage



http://issues.apache.org/jira/browse/HDFS-220

Hive – SQL Query Language for Hadoop

- Efficient SQL to Map-Reduce Compiler
- Mar 2008: Started at Facebook

- Countable for 95%+ of Hadoop jobs @ Facebook
- Used by ~300 engineers and business analysts at Facebook every month

Other uses for HDFS

- **Backup of all mySQL databases**
  - Mysql dump files stored in HDFS
- **Storage for Online Application**
  - Apache HBase layered on HDFS
  - HBase is a key-value store
  - 500 TB in size

Useful Links

- HDFS Design:
  - http://hadoop.apache.org/core/docs/current/hdfs_design.html
- Hadoop API:
  - http://hadoop.apache.org/core/docs/current/api/
- My Hadoop Blog:
  - http://hadoopblog.blogspot.com/
  - http://www.facebook.com/hadoopfs