Hadoop Architecture and its Usage at Facebook

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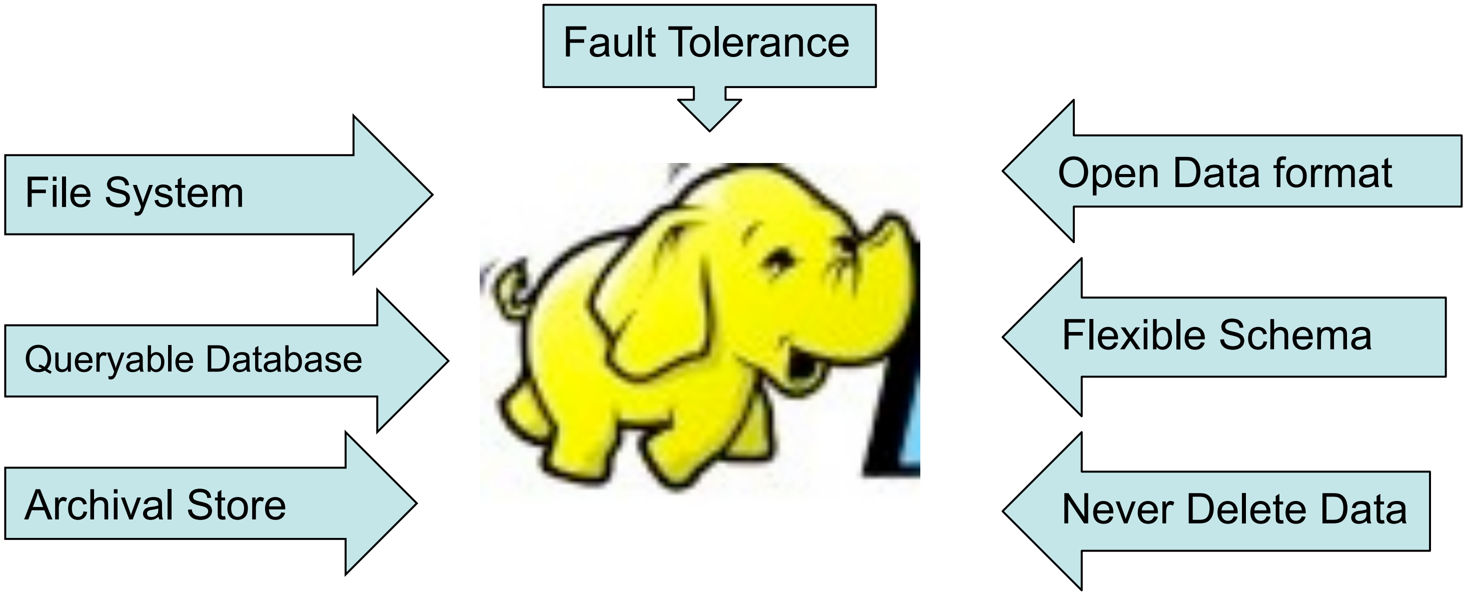
Outline

- Introduction
- Architecture of Hadoop Distributed File System
- Hadoop Usage at Facebook

Who Am I?

- **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)
- **UW 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 low hundreds of 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
- **Jul 2008 -** A 4000 node test cluster
- **May 2009 -** Hadoop sorts Petabyte in 17 hours

Who uses Hadoop?

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

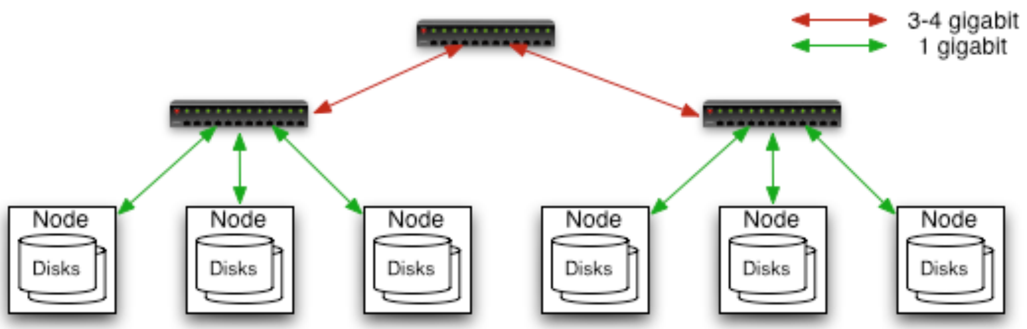
What is Hadoop used for?

- 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

Public Hadoop Clouds

- Hadoop Map-reduce on Amazon EC2
  - http://wiki.apache.org/hadoop/AmazonEC2
- IBM Blue Cloud
  - Partnering with Google to offer web-scale infrastructure
- Global Cloud Computing Testbed
  - Joint effort by Yahoo, HP and Intel
  - http://www.opencloudconsortium.org/testbed.html

Commodity Hardware



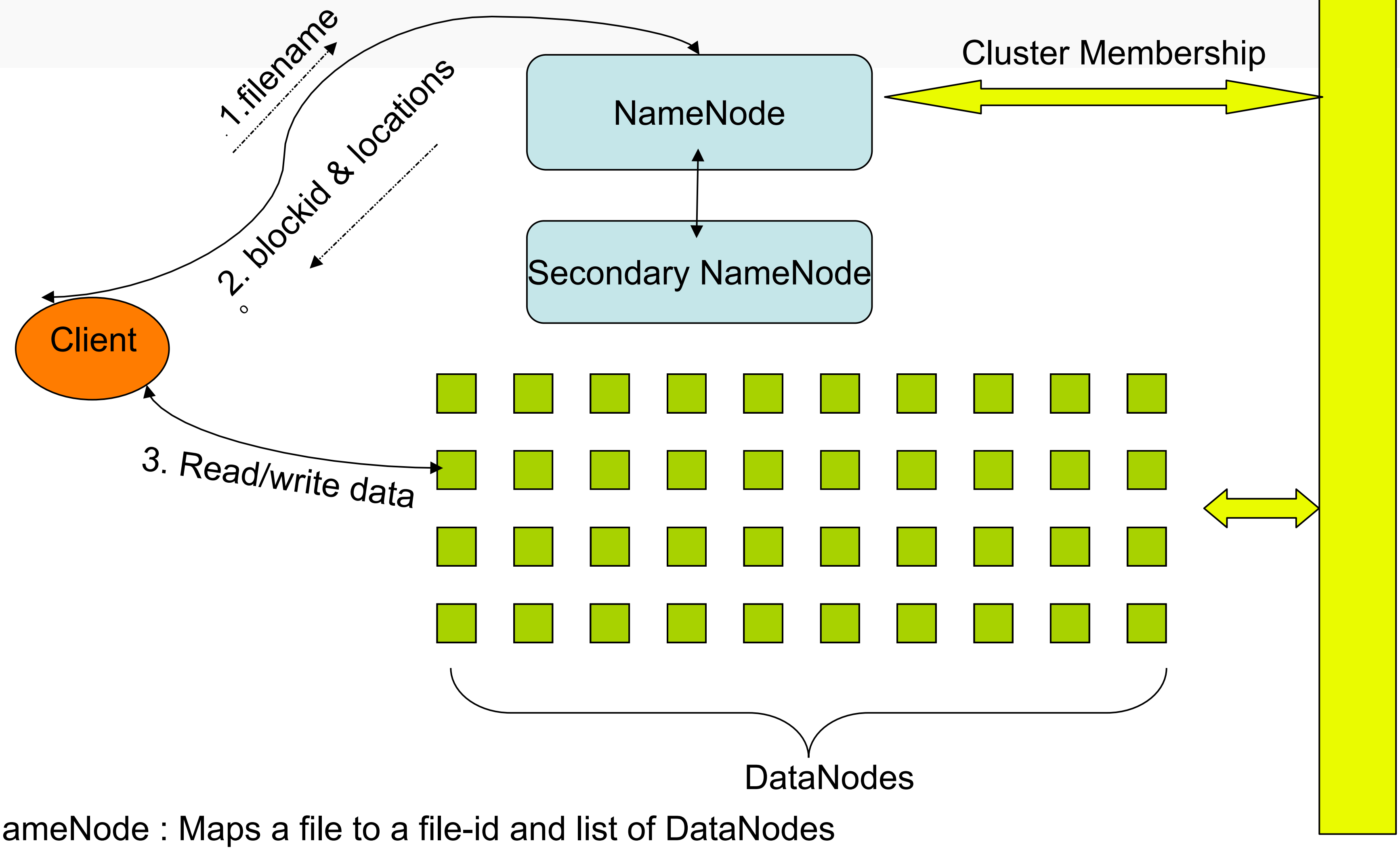
Typically in 2 level architecture

– Nodes are commodity PCs
– 30-40 nodes/rack
– Uplink from rack is 3-4 gigabit
– Rack-internal is 1 gigabit

Goals of HDFS

- **Very Large Distributed File System**
  - 10K nodes, 100 million files, 10 - 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

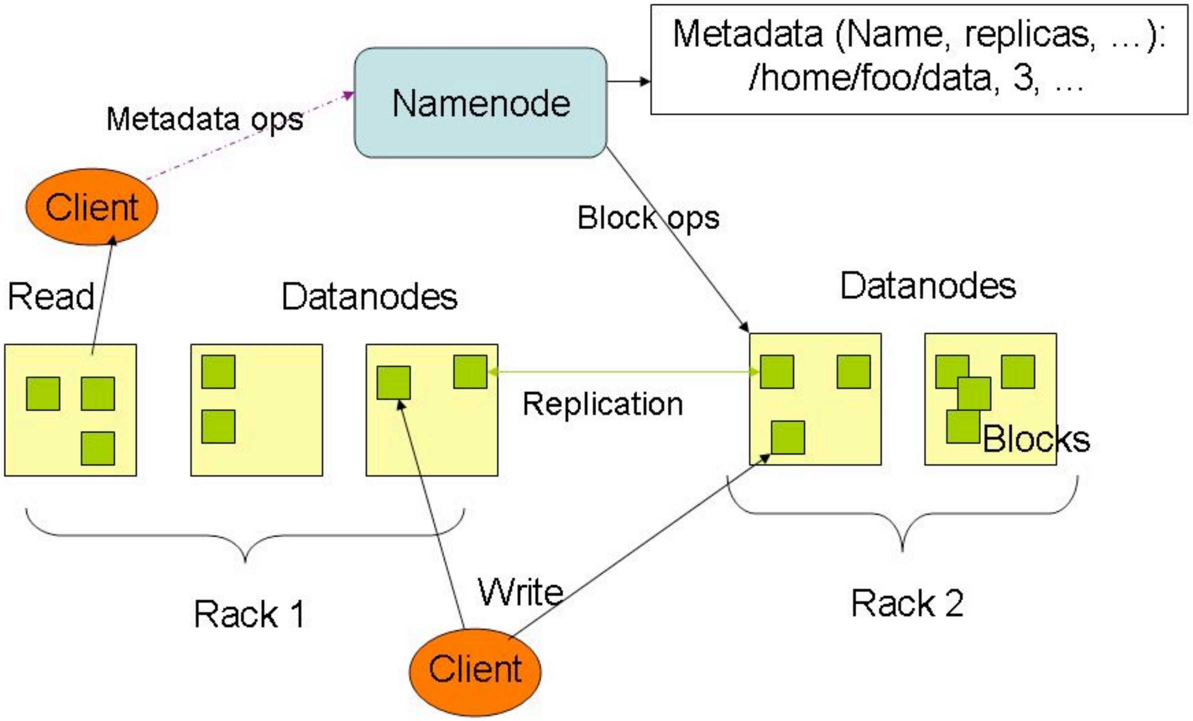


NameNode : Maps a file to a file-id and list of DataNodes
DataNode : Maps a block-id to a physical location on disk
SecondaryNameNode: Periodic merge of Transaction log

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 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)
- **Need to develop a real HA solution**
  - work in progress: BackupNode

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
  - Command line tool
- **Disadvantages**
  - Does not rebalance based on access patterns or load
  - No support for automatic handling of hotspots of data

Hadoop Map/Reduce

- **The Map-Reduce programming model**
  - Distributed processing of large data sets
  - Pluggable user code runs in generic framework
- **Common design pattern in data processing**

  cat * | grep | sort | unique -c | cat > file

  input | **map** | shuffle | **reduce** | output
- **Natural for:**
  - Log processing
  - Web search indexing
  - Ad-hoc queries

Map/Reduce and Storage

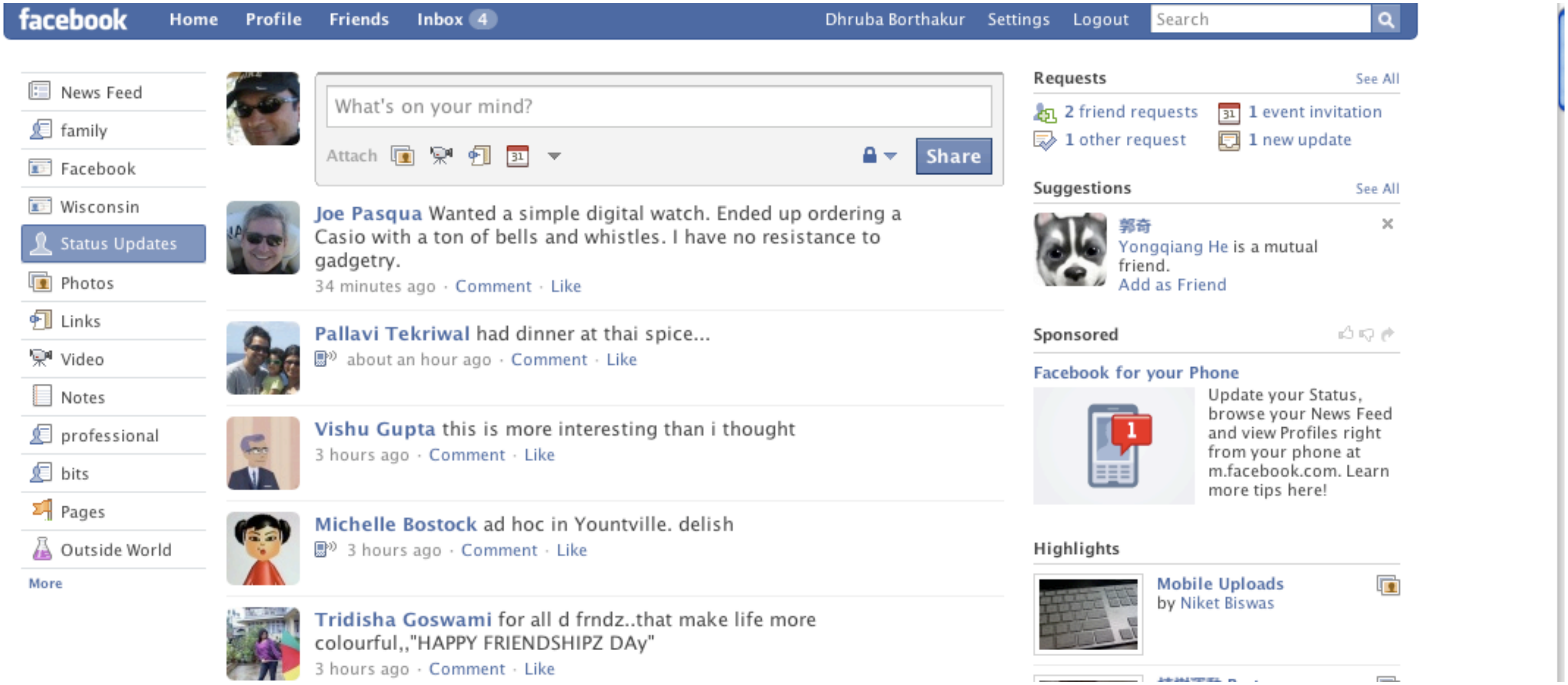
- **Clean API between Map/Reduce and HDFS**
- **Hadoop Map/Reduce and Storage Stacks**
  - Typical installations store data in HDFS
  - Hadoop Map/Reduce can run on data in MySQL
  - Demonstrated to run on IBM GPFS
- **External Schedulers and HDFS Storage**
  - Condor Job Scheduler on HDFS
  - Dryad-style DAG Scheduler on HDFS

Job Scheduling

- **Current state of affairs with Hadoop Scheduler**
  - Places computation close to data
  - FIFO and Fair Share scheduler
- **Work in progress**
  - Resource aware (cpu, memory, network)
  - Support for MPI workloads
  - Isolation of one job from another

facebook

Hadoop @ Facebook



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

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

郭奇
Yongqiang He is a mutual friend.
Add as Friend

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!

Mobile Uploads
by Niket Biswas

Who generates this data?

- **Lots of data is generated on Facebook**
  - 300+ million active users
  - 30 million users update their statuses at least once each day
  - More than 1 billion photos uploaded each month
  - More than 10 million videos uploaded each month
  - More than 1 billion pieces of content (web links, news stories, blog posts, notes, photos, etc.) shared each week

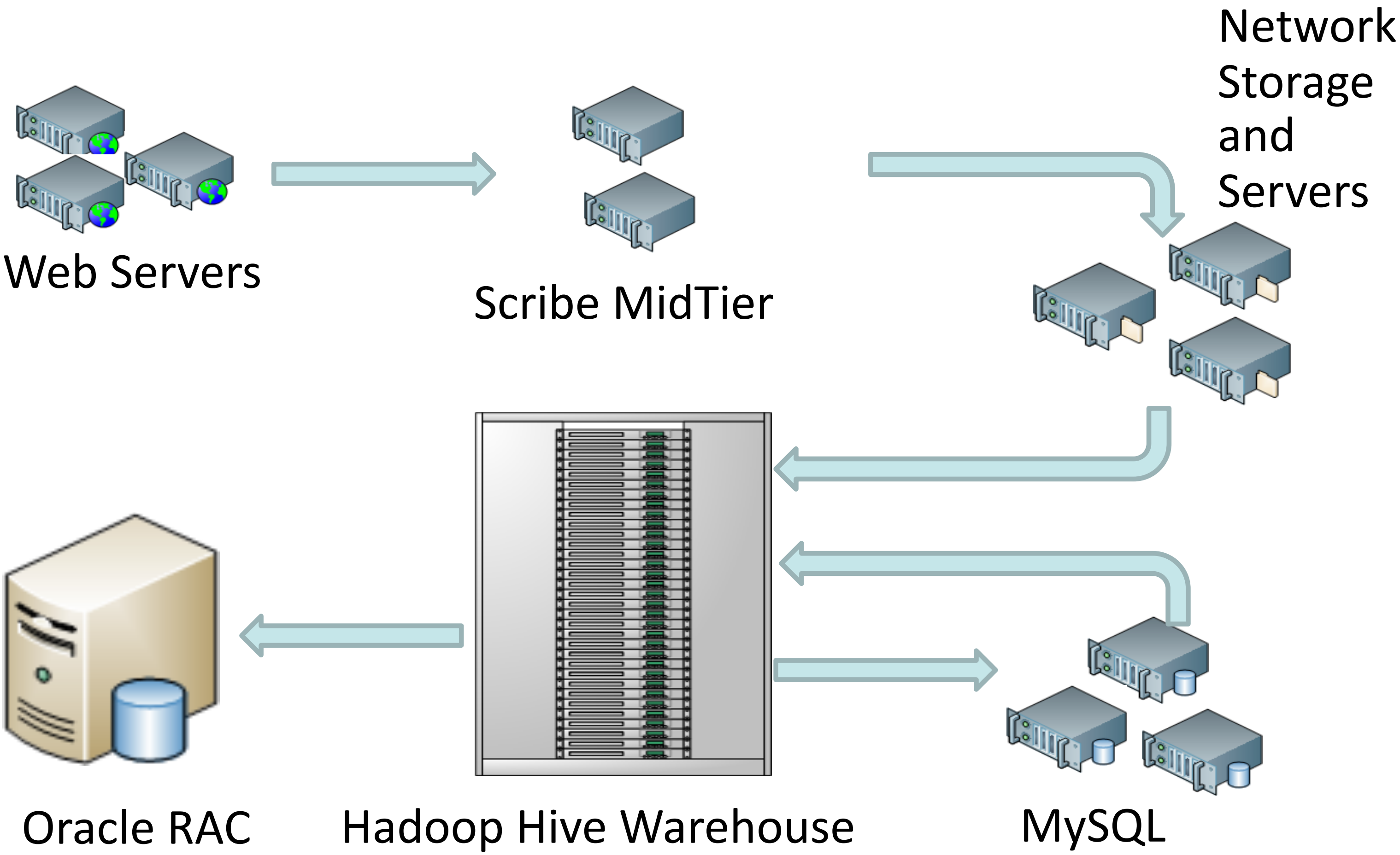
Data Usage

- **Statistics per day:**
  - 4 TB of compressed new data added per day
  - 135TB of compressed data scanned per day
  - 7500+ Hive jobs on production cluster per day
  - 80K compute hours per day
- **Barrier to entry is significantly reduced:**
  - New engineers go though a Hive training session
  - ~200 people/month run jobs on Hadoop/Hive
  - Analysts (non-engineers) use Hadoop through Hive

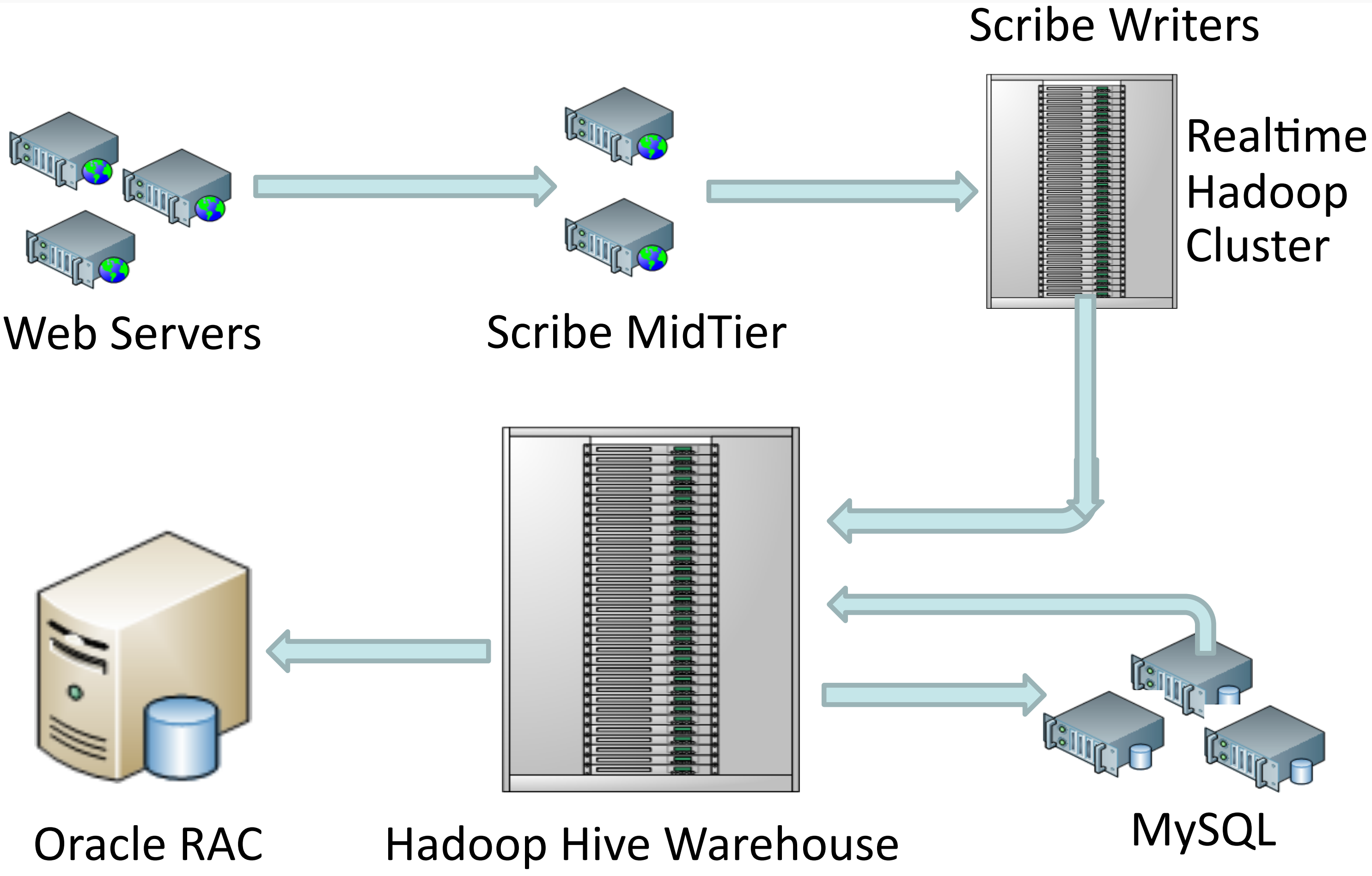
Where is this data stored?

- **Hadoop/Hive Warehouse**
  - 4800 cores, 5.5 PetaBytes
  - 12 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



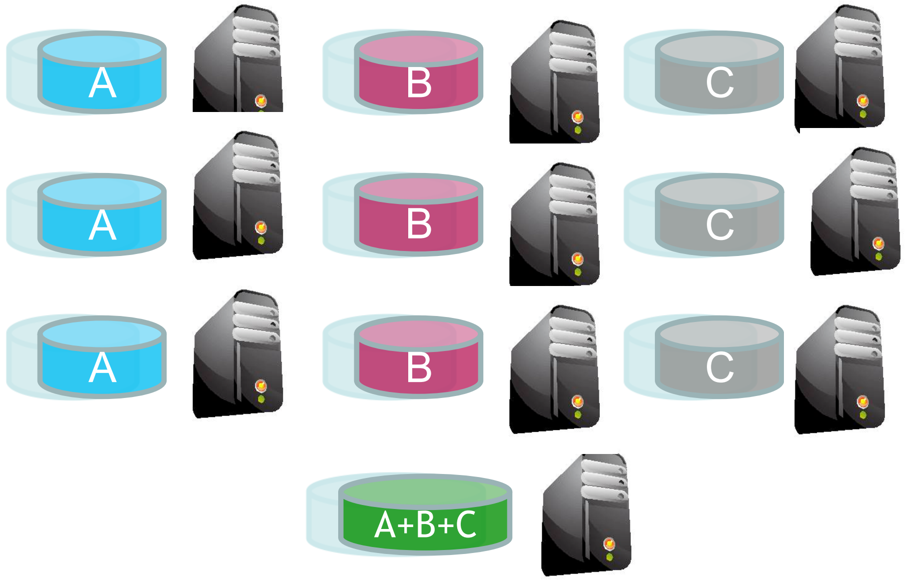
Hadoop Scribe: Avoid Costly Filers



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

HDFS Raid

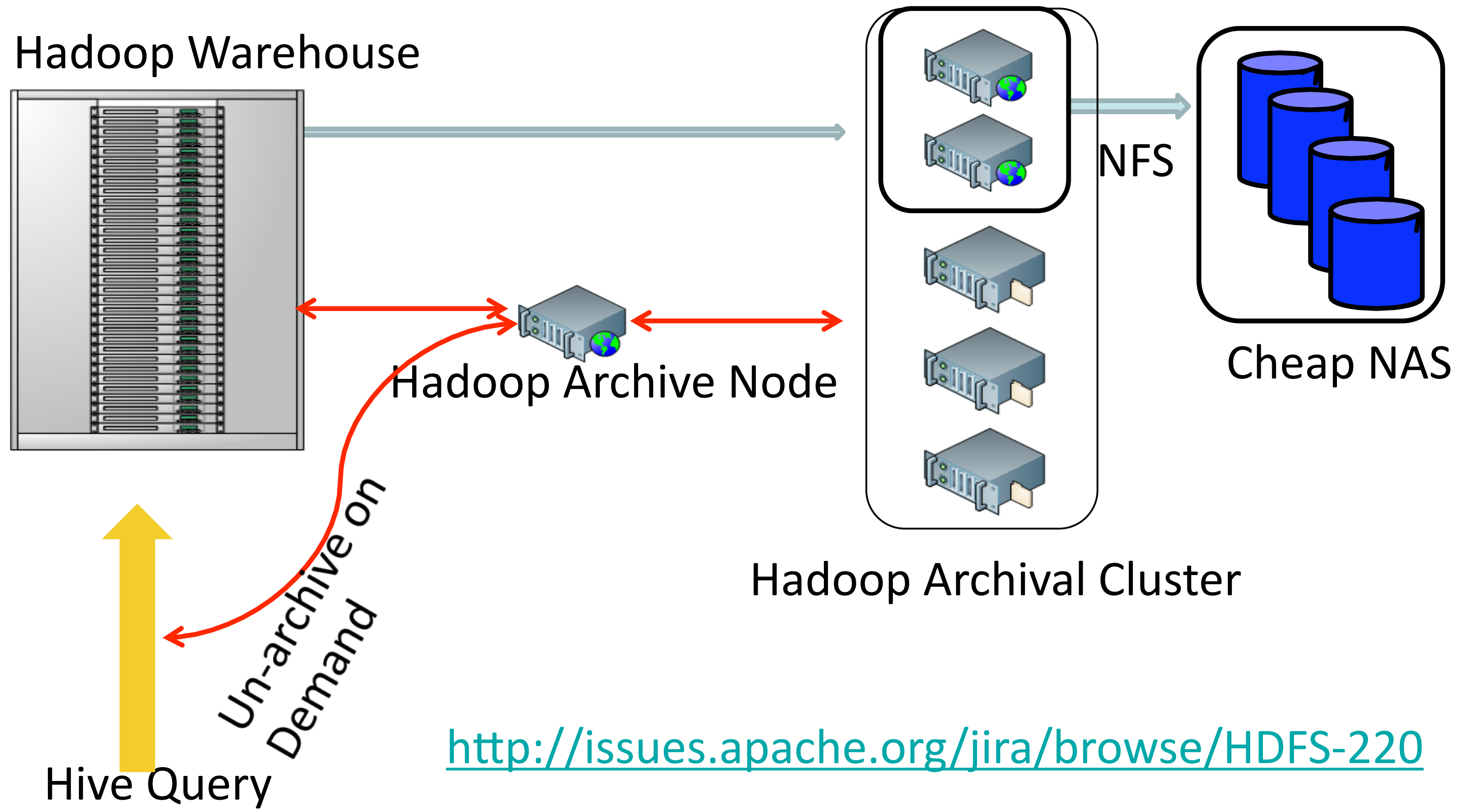
- Start the same: triplicate every data block
- Background encoding
  - Combine third replica of blocks from a single file to create parity block
  - Remove third replica
  - Apache Hadoop 0.22 release
- DiskReduce from CMU
  - Garth Gibson research



A file with three blocks A, B and C

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

Archival: Move old data to cheap storage



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

Dynamic-size MapReduce Clusters

- **Why multiple compute clouds in Facebook?**
  - Users unaware of resources needed by job
  - Absence of flexible Job Isolation techniques
  - Provide adequate SLAs for jobs
- **Dynamically move nodes between clusters**
  - Based on load and configured policies
  - Apache Jira MAPREDUCE-1044

Resource Aware Scheduling (Fair Share Scheduler)

- **We use the Hadoop Fair Share Scheduler**
  - Scheduler unaware of memory needed by job
- **Memory and CPU aware scheduling**
  - RealTime gathering of CPU and memory usage
  - Scheduler analyzes memory consumption in realtime
  - Scheduler fair-shares memory usage among jobs
  - Slot-less scheduling of tasks (in future)
  - Apache Jira MAPREDUCE-961

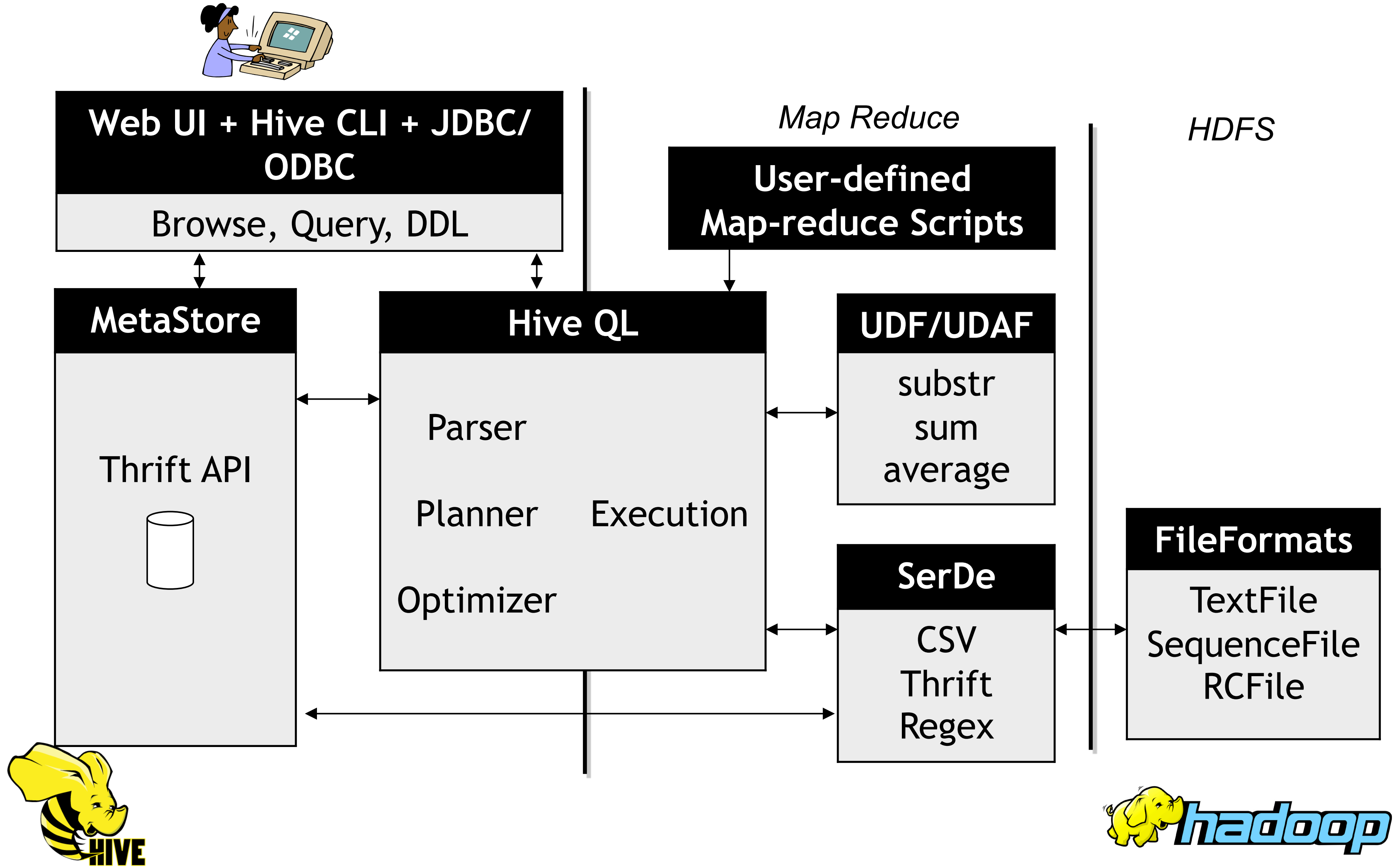
Hive – Data Warehouse

- Efficient SQL to Map-Reduce Compiler

- Mar 2008: Started at Facebook
- May 2009: Release 0.3.0 available
- Now: Preparing for release 0.4.0

- Countable for 95%+ of Hadoop jobs @ Facebook
- Used by ~200 engineers and business analysts at Facebook every month

Hive Architecture



Web UI + Hive CLI + JDBC/ODBC

Browse, Query, DDL

Map Reduce

HDFS

User-defined Map-reduce Scripts

MetaStore

Thrift API

Hive QL

Parser

Planner

Execution

Optimizer

UDF/UDAF

substr
sum
average

SerDe

CSV
Thrift
Regex

FileFormats

TextFile
SequenceFile
RCFile

File Formats

- TextFile:
  - Easy for other applications to write/read
  - Gzip text files are not splittable
- SequenceFile:
  - Only hadoop can read it
  - Support splittable compression
- RCFile: Block-based columnar storage
  - Use SequenceFile block format
  - Columnar storage inside a block
  - 25% smaller compressed size
  - On-par or better query performance depending on the query

SerDe

- Serialization/Deserialization
- Row Format
  - CSV (LazySimpleSerDe)
  - Thrift (ThriftSerDe)
  - Regex (RegexSerDe)
  - Hive Binary Format (LazyBinarySerDe)
- LazySimpleSerDe and LazyBinarySerDe
  - Deserialize the field when needed
  - Reuse objects across different rows
  - Text and Binary format

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/