Big Data Analytics
Lecture 2

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* Some slides are adopted from Professor Kunpeng Zhang's Big Data course @UMD

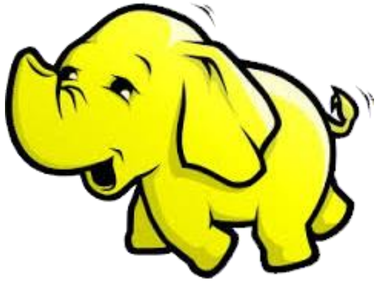
What we'll cover…

- Hadoop history and advantages
- Architecture
  - Hadoop distributed file system (HDFS)
- Hands-on **Preparation for Cloudera environment**
  - Installation of GitHub – Lab 1
  - Basic Linux commands – Lab 2

Brief History of Hadoop

Designed to answer the question:

"How to process big data with reasonable cost and time?"



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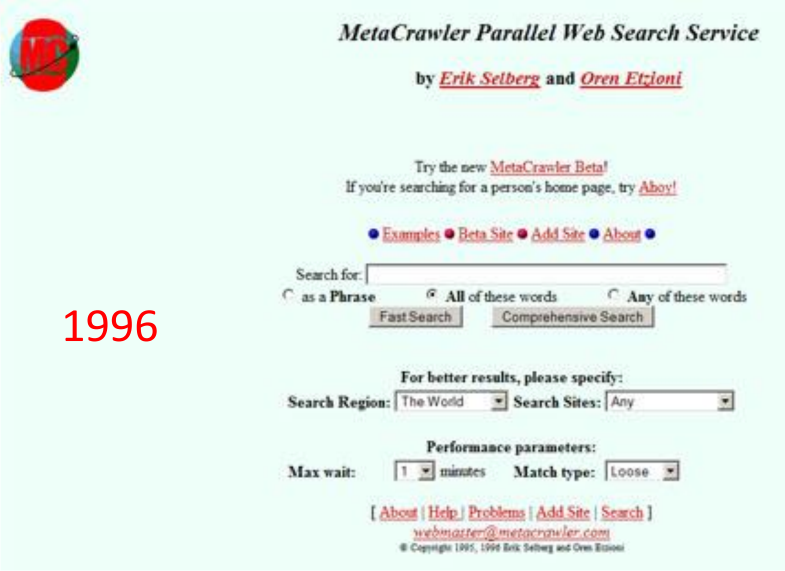
Search engines in 1990s



MetaCrawler Parallel Web Search Service

by *Erik Selberg* and *Oren Etzioni*

Try the new MetaCrawler Beta!
If you're searching for a person's home page, try Ahoy!

● Examples ● Beta Site ● Add Site ● About ●

Search for:
○ as a **Phrase** ● **All** of these words ○ **Any** of these words
Fast Search Comprehensive Search

For better results, please specify:
Search Region: The World **Search Sites:** Any

Performance parameters:
Max wait: 1 minutes **Match type:** Loose

[About | Help | Problems | Add Site | Search]
webmaster@metacrawler.com
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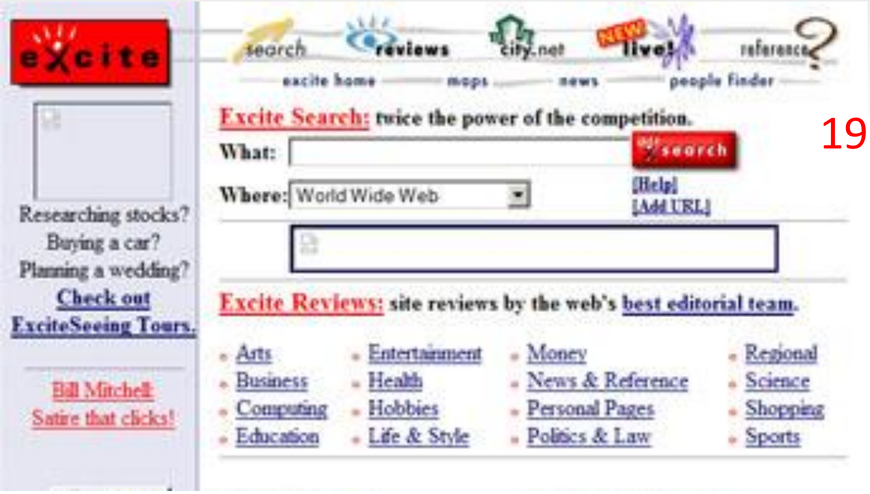
1996



Excite Search: twice the power of the competition.
What: search
Where: World Wide Web [Help] [Add URL]

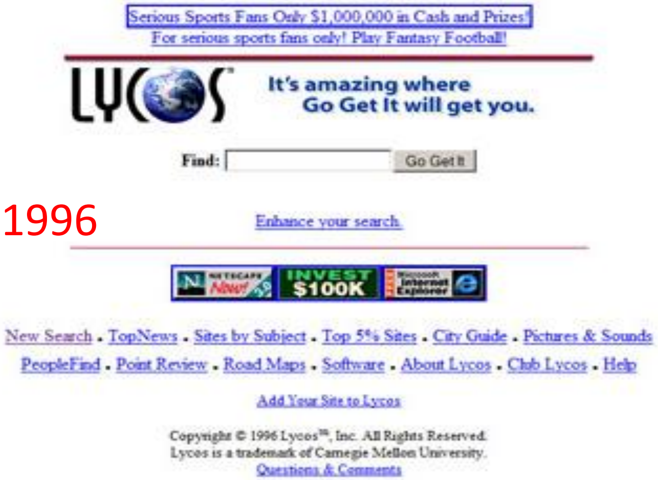
Researching stocks? Buying a car? Planning a wedding? Check out ExciteSeeing Tours.

Bill Mitchell Satire that clicks!

Excite Reviews: site reviews by the web's best editorial team.

Arts	Entertainment	Money	Regional
Business	Health	News & Reference	Science
Computing	Hobbies	Personal Pages	Shopping
Education	Life & Style	Politics & Law	Sports

1996



Serious Sports Fans Only $1,000,000 in Cash and Prizes!
For serious sports fans only! Play Fantasy Football!

Find: Go Get It

Enhance your search

New Search . TopNews . Sites by Subject . Top 5% Sites . City Guide . Pictures & Sounds
PeopleFind . Point Review . Road Maps . Software . About Lycos . Club Lycos . Help

Add Your Site to Lycos

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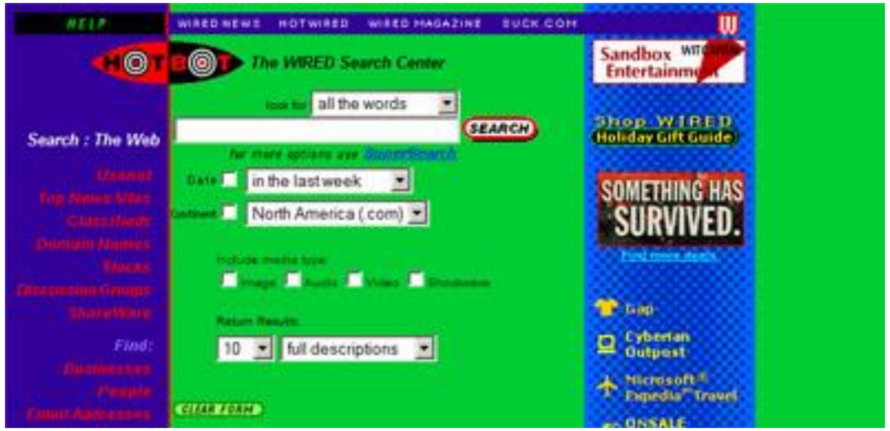
Lycos is a trademark of Carnegie Mellon University.
Questions & Comments

1996



The WIRED Search Center

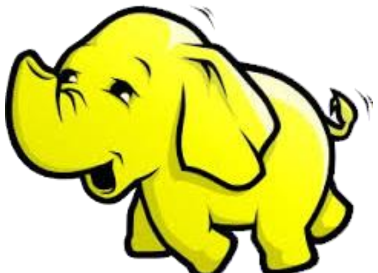
Search : The Web

Usenet
Top News Sites
Classifieds
Domain Names
Stocks
Discussion Groups
ShareWare

Find:
Businesses
People
Email Addresses

look for: all the words
SEARCH
for more options use SuperSearch
Date □ in the last week
Continent □ North America (.com)
Include media type:
□ Image □ Audio □ Video □ Shockwave
Return Results
10 full descriptions
CLEAR FORM

1997



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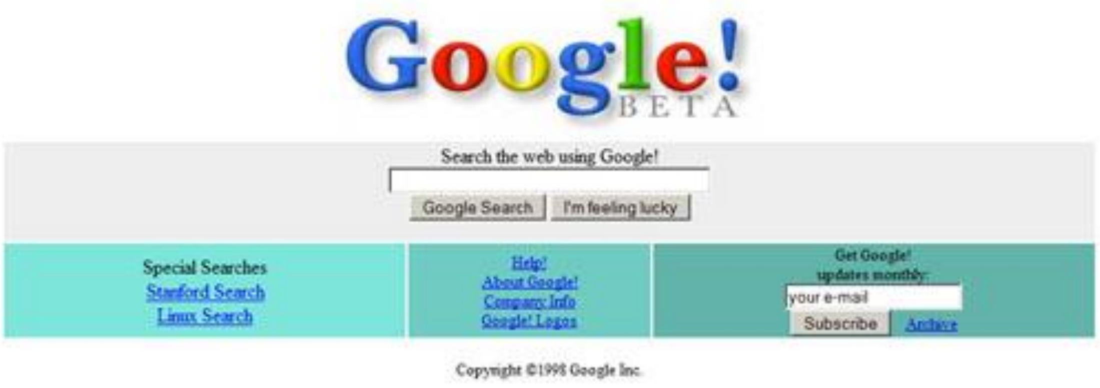
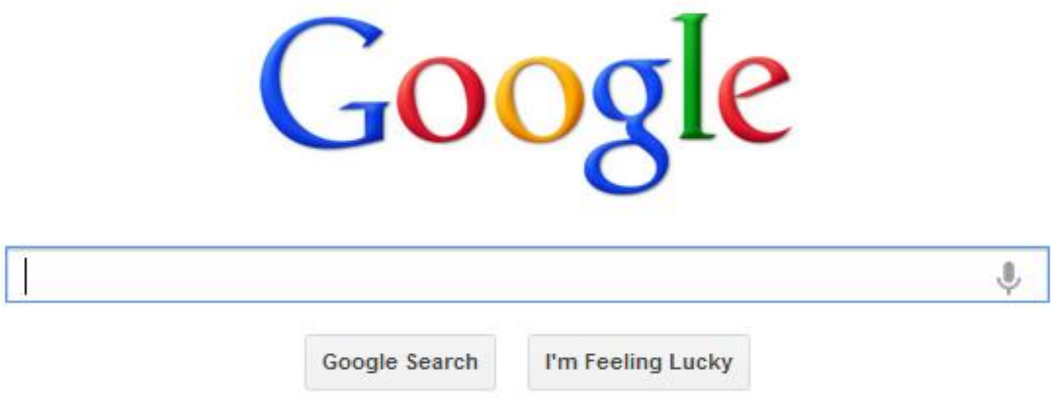
Google search engines



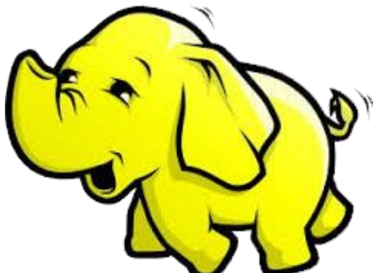
Search the web using Google!

Copyright ©1998 Google Inc.

1998



2013



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Early Large Scale Computing

- Historically computation was processor-bound
  - Data volume has been relatively small
  - Complicated computations are performed on that data
- Advances in computer technology has historically centered around improving the power of a single machine

Distributed System: Problems

"You know you have a distributed system when the crash of a computer you've never
heard of stops you from getting any work done." –Leslie Lamport

- Distributed systems must be designed with the expectation of failure

Component Recovery

- If a component fails, it should be able to recover without restarting the entire system

- Component failure or recovery during a job must not affect the final output

Hadoop

- Based on work done by Google in the early 2000s
  - “The Google File System” in 2003
  - “MapReduce: Simplified Data Processing on Large Clusters” in 2004
- The core idea was to distribute the data as it is initially stored
  - Each node can then perform computation on the data it stores without moving the data for the initial processing

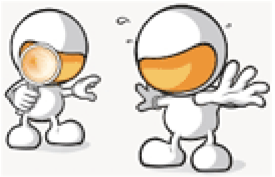
Hadoop’s Developers

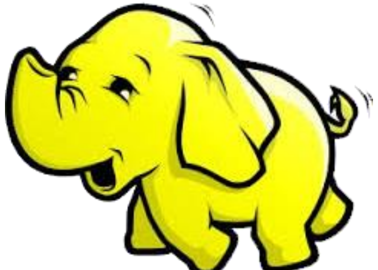
Doug Cutting

2005: Doug Cutting and Michael J. Cafarella developed Hadoop to support distribution for the Nutch search engine project.

The project was funded by Yahoo.

2006: Yahoo gave the project to Apache Software Foundation.





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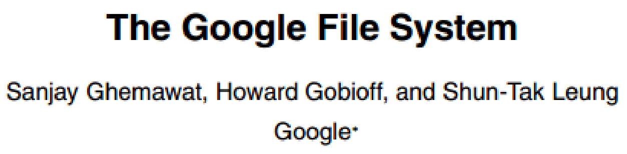
Google Origins

2003



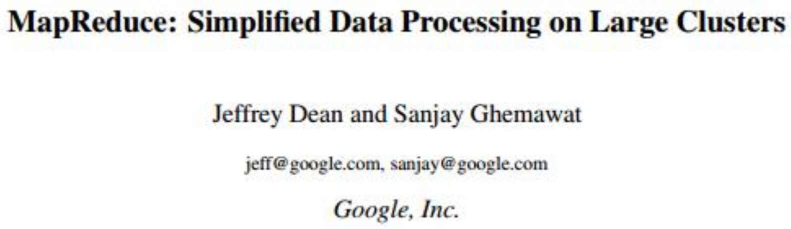
The Google File System

Sanjay Ghemawat, Howard Gobioff, and Shun-Tak Leung

Google*

hadoop
HDFS

2004



MapReduce: Simplified Data Processing on Large Clusters

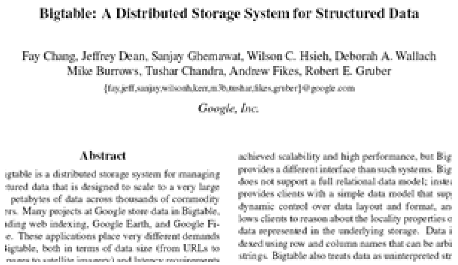
Jeffrey Dean and Sanjay Ghemawat

jeff@google.com, sanjay@google.com

Google, Inc.

hadoop
MapReduce

2006



Bigtable: A Distributed Storage System for Structured Data

Fay Chang, Jeffrey Dean, Sanjay Ghemawat, Wilson C. Hsieh, Deborah A. Wallach
Mike Burrows, Tushar Chandra, Andrew Fikes, Robert E. Gruber
{fay,jeff,sanjay,wilsonh,kerr,m3b,tushar,fikes,gruber}@google.com

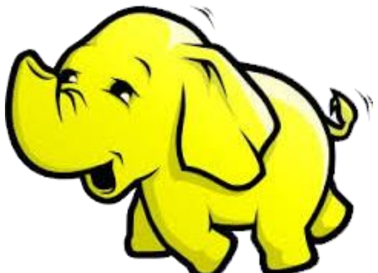
Google, Inc.

Abstract

gtable is a distributed storage system for managing
tured data that is designed to scale to a very large
petabytes of data across thousands of commodity
rs. Many projects at Google store data in Bigtable,
ding web indexing, Google Earth, and Google Fi-
e. These applications place very different demands
igtable, both in terms of data size (from URLs to
pages to satellite imagery) and latency requirements

achieved scalability and high performance, but Big
provides a different interface than such systems. Big
does not support a full relational data model; inste
provides clients with a simple data model that sup
dynamic control over data layout and format, an
lows clients to reason about the locality properties o
data represented in the underlying storage. Data i
dexed using row and column names that can be arbi
strings. Bigtable also treats data as uninterpreted str

APACHE
HBASE



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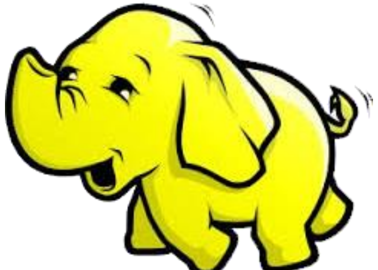
Some Hadoop Milestones

- **2008 - Hadoop Wins Terabyte Sort Benchmark (**sorted 1 terabyte of data in 209 seconds, compared to previous record of 297 seconds)
- 2009 - Avro and Chukwa became new members of Hadoop Framework family
- 2010 - Hadoop's Hbase, Hive and Pig subprojects completed, adding more computational power to Hadoop framework
- **2011 - ZooKeeper Completed**
- **2013 - Hadoop 1.1.2 and Hadoop 2.0.3 alpha.**

  - Ambari, Cassandra, Mahout have been added



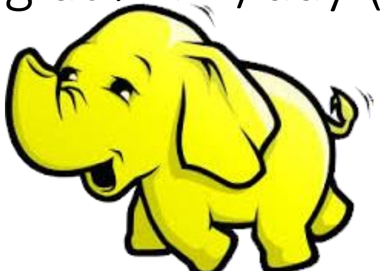
One popular solution: Hadoop

Hadoop Cluster at Yahoo!

Hadoop in the Wild

- Hadoop is in use at most organizations that handle big data:
    - Yahoo!
    - Facebook
    - Amazon
    - Netflix
    - Etc…

- Some examples of scale:
    - Yahoo!'s Search Webmap runs on 10,000 core Linux cluster and powers Yahoo! Web search
    - FB's Hadoop cluster hosts 100+ PB of data (July, 2012) & growing at ½ PB/day (Nov, 2012)



Three main applications of Hadoop

- Advertisement (Mining user behavior to generate recommendations)
- Searches (group related documents)
- Security (search for uncommon patterns)

Big data storage is challenging

- Data volumes are massive
- Reliability of storing PBs of data is challenging
- All kinds of failures: Disk/Hardware/Network Failures
- Probability of failures simply increase with the number of machines …

How much data?

- Facebook
  - 500 TB per day
- Yahoo
  - Over 170 PB
- eBay
  - Over 6 PB

- Getting the data to the processors becomes the bottleneck

Hadoop offers

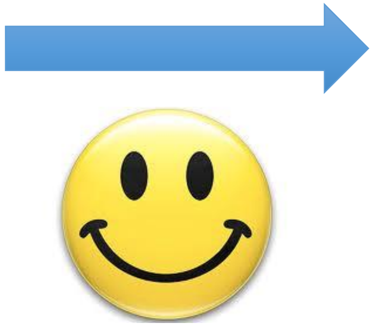
- Redundant, Fault-tolerant data storage
- Parallel computation framework
- Job coordination

Hadoop offers

- Redundant, Fault-tolerant data storage
- Parallel computation framework
- Job coordination

Programmers

No longer need to worry about



Q: Where file is located?

Q: How to handle failures & data lost?

Q: How to divide computation?

Q: How to program for scaling?

Who uses Hadoop?

Social

twitter

Twitter for Business

Small business advertisers, learn how to get $100 in free Twitter advertising from American Express.

ABCs

Learn the Basics
What is Twitter?
Twitter Glossary
Best Practices
Twitter on the Go

Optimize
Cas
Resource
API

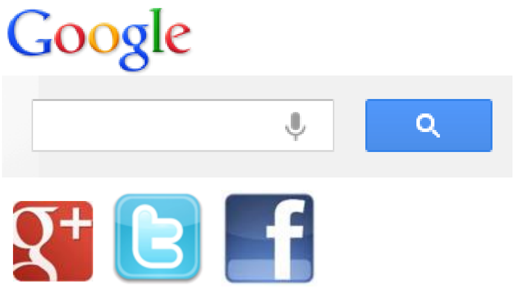
User Tracking & Engagement

Homeland Security

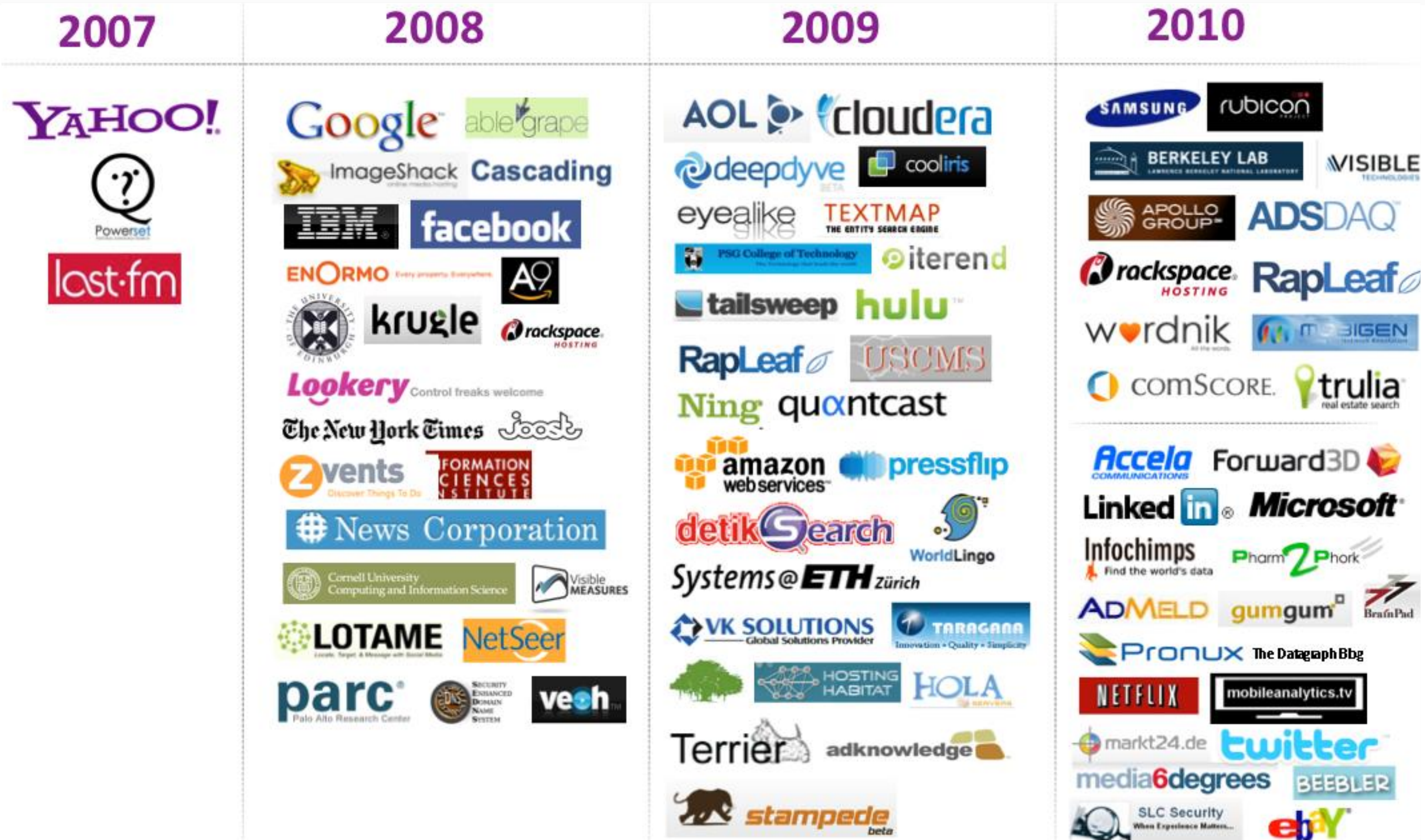
eCommerce

Financial Services

Real Time Search

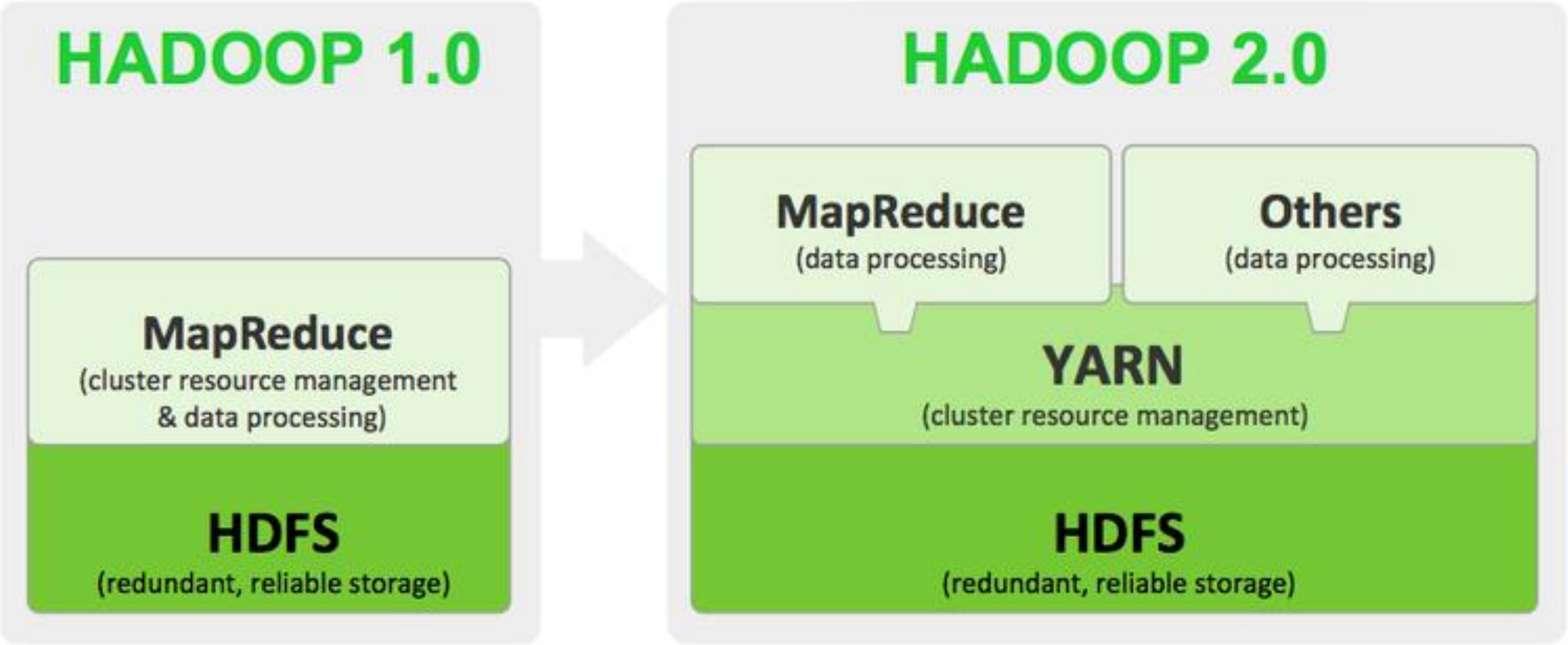


Who uses Hadoop?



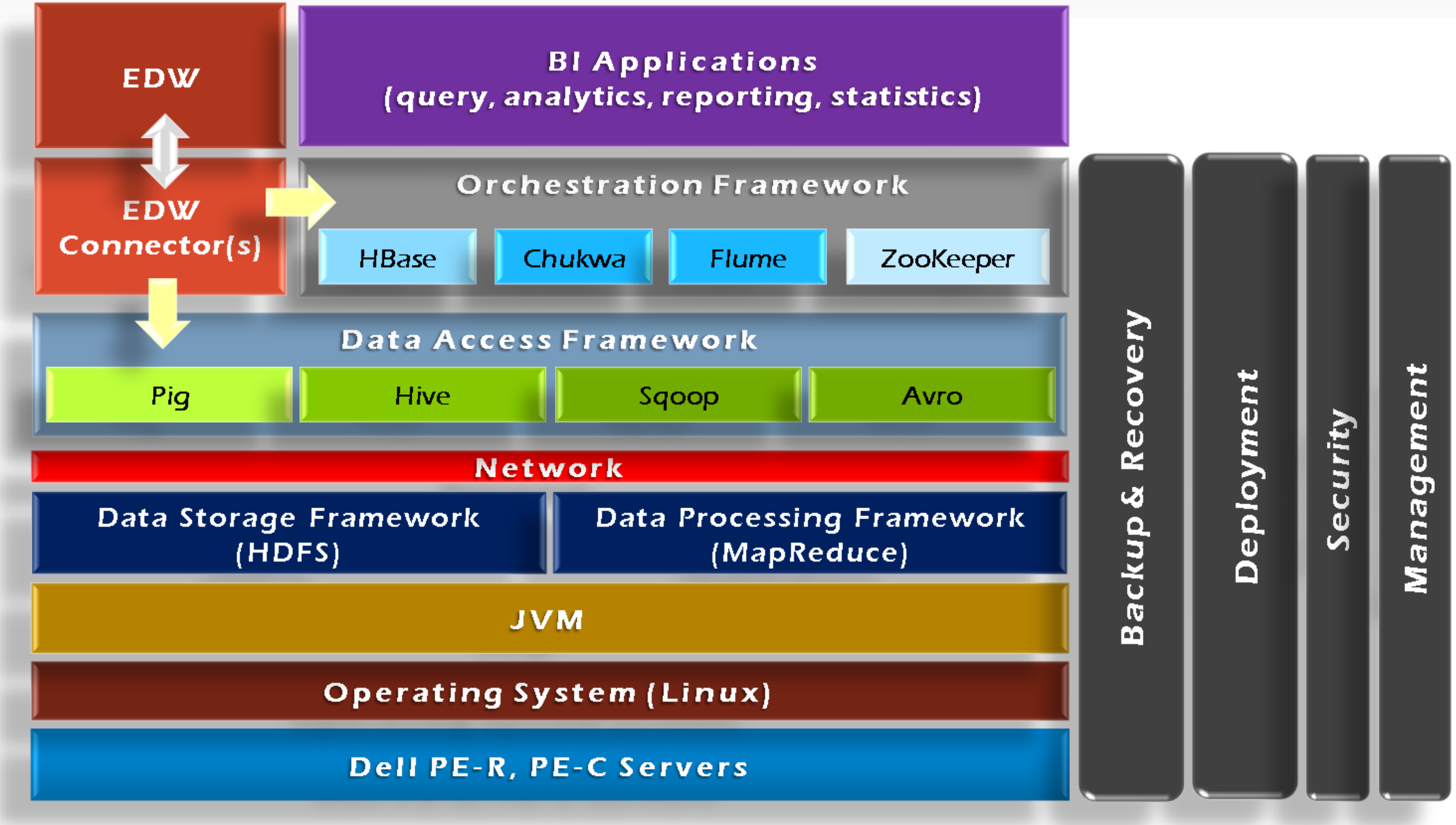
Hadoop big picture

MapReduce: Programming
YARN: Resource Scheduling
Hadoop: Data Management


HADOOP 1.0
MapReduce
(cluster resource management & data processing)
HDFS
(redundant, reliable storage)
HADOOP 2.0
MapReduce
(data processing)
Others
(data processing)
YARN
(cluster resource management)
HDFS
(redundant, reliable storage)

HDFS + MapReduce is core to get work done

Hadoop Framework Tools



Hadoop goals

- **Scalable**: Petabytes (10^{15} Bytes) of data on thousands on nodes
- **Economical**: Commodity components only
- **Reliable**: fault tolerance

Hadoop Distributed File System
HDFS

Overview

- Responsible for storing data on the cluster

- Data files are split into blocks and distributed across the nodes in the cluster

- Each block is replicated multiple times

HDFS Basic Concepts

- HDFS is a file system written in Java based on the Google’s GFS

- Provides redundant storage for massive amounts of data

HDFS

- Master-Slave architecture
- Single NameNode

  Sometimes a backup: secondary NameNode
- Many (Thousands) DataNodes
- Files are split into fixed sized blocks and stored on data nodes (default: 64MB)
- Data blocks are replicated for fault tolerance and fast access (default: 3)

HDFS Basic Concepts

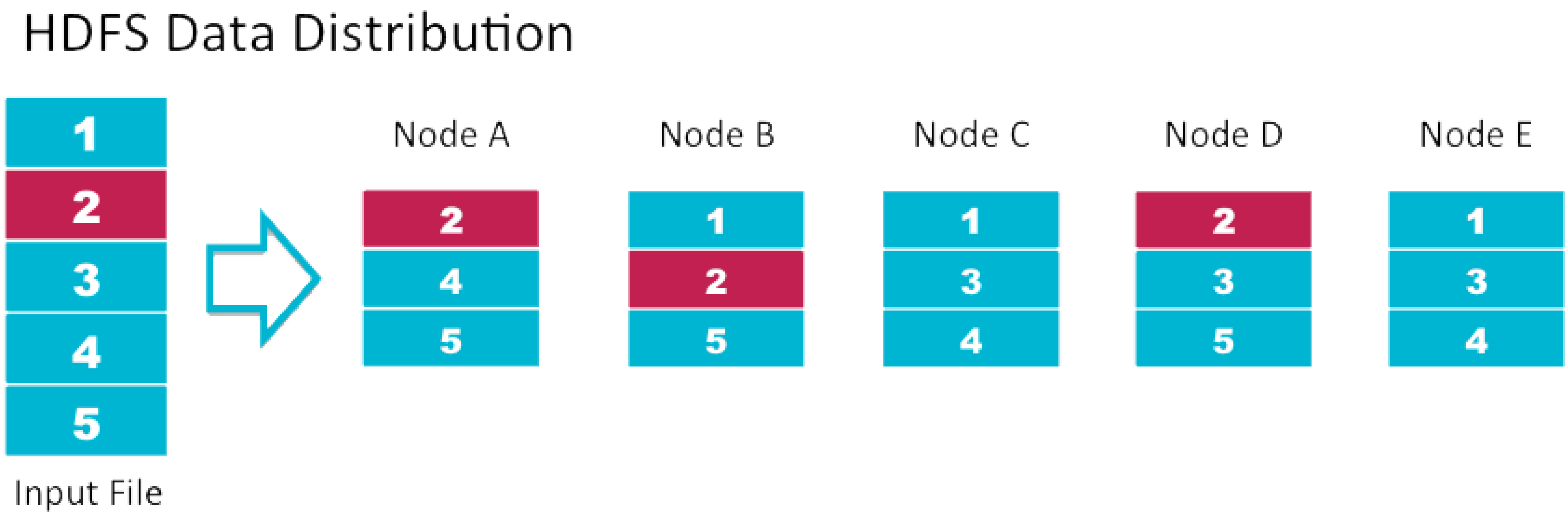
- HDFS works best with a smaller number of large files
  - Millions as opposed to billions of files
  - Typically 100MB or more per file
- Files in HDFS are write once
- Optimized for streaming reads of large files and not random reads

How are Files Stored

- Files are split into blocks
- Blocks are split across many machines at load time
  - Different blocks from the same file will be stored on different machines
- Blocks are replicated across multiple machines
- The NameNode keeps track of which blocks make up a file and where they are stored

Data Replication

- Default replication is 3-fold



Hadoop's Architecture

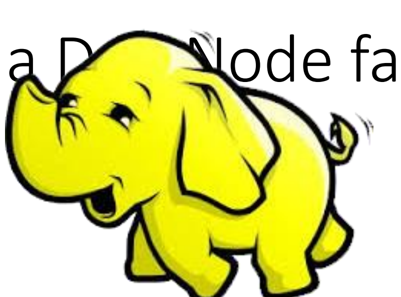
- <u>NameNode:</u>

- Stores metadata for the files, like the directory structure of a typical FS.

- The server holding the NameNode instance is quite crucial, as there is only one.

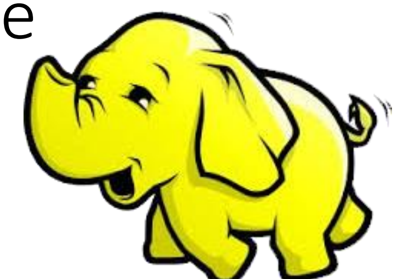
- Transaction log for file deletes/adds, etc. Does not use transactions for whole blocks or file-streams, only metadata.

- Handles creation of more replica blocks when necessary after a DataNode failure

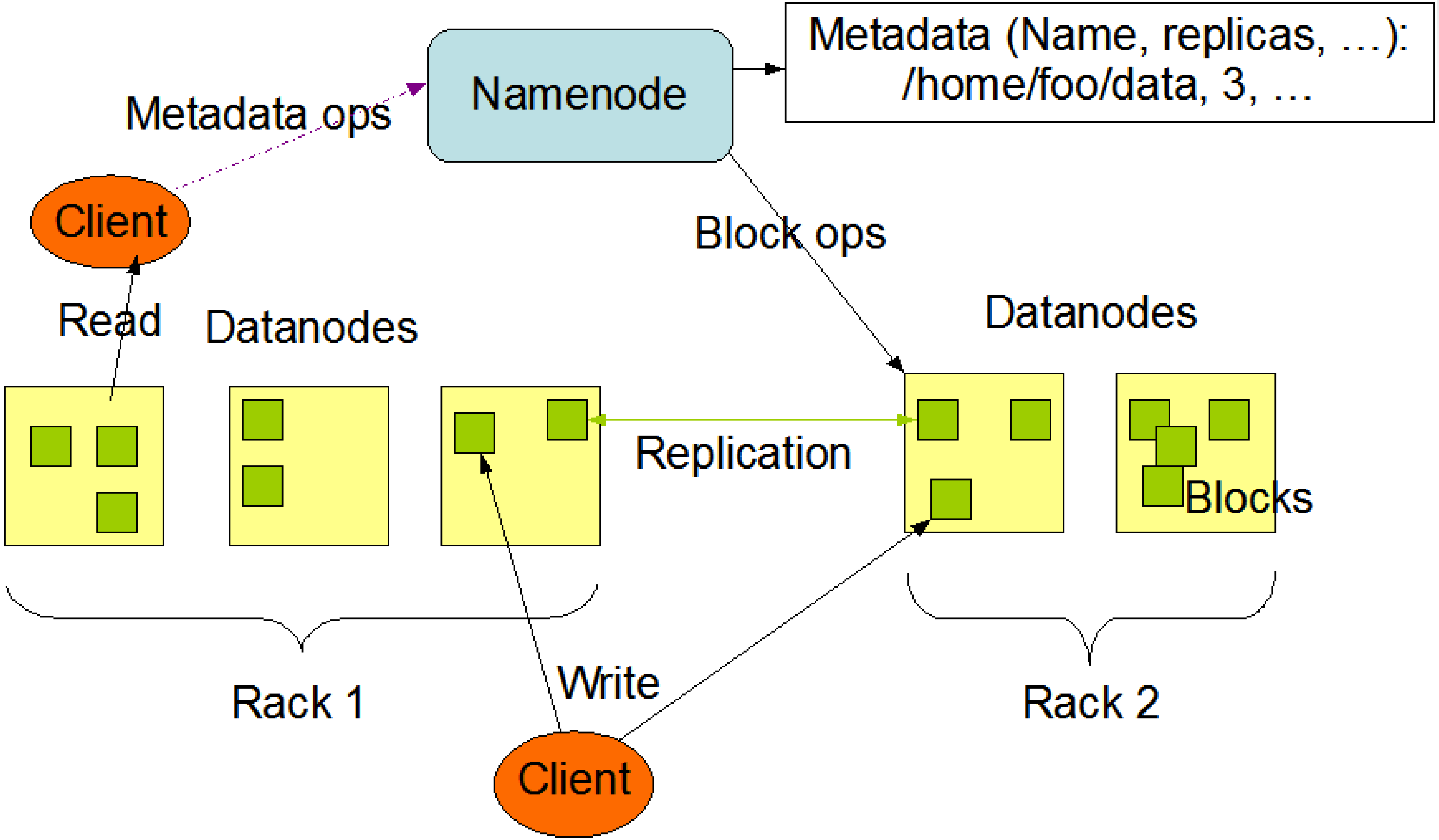


Hadoop's Architecture

- **DataNode:**
- Stores the actual data in HDFS
- Can run on any underlying filesystem (ext3/4, NTFS, etc)
- Notifies NameNode of what blocks it has
- NameNode replicates blocks 2x in local rack, 1x elsewhere



HDFS Architecture



Data Retrieval

- When a client wants to retrieve data
  - Communicates with the NameNode to determine which blocks make up a file and on which data nodes those blocks are stored
  - Then communicated directly with the data nodes to read the data

MapReduce

Distributing computation across nodes

MapReduce Overview

- A method for distributing computation across multiple nodes

- Each node processes the data that is stored at that node

- Consists of two main phases
  - Map
  - Reduce

MapReduce Features

- Automatic parallelization and distribution
- Fault-Tolerance
- Provides a clean abstraction for programmers to use

The Mapper

- Reads data as key/value pairs
  - The key is often discarded

- Outputs zero or more key/value pairs

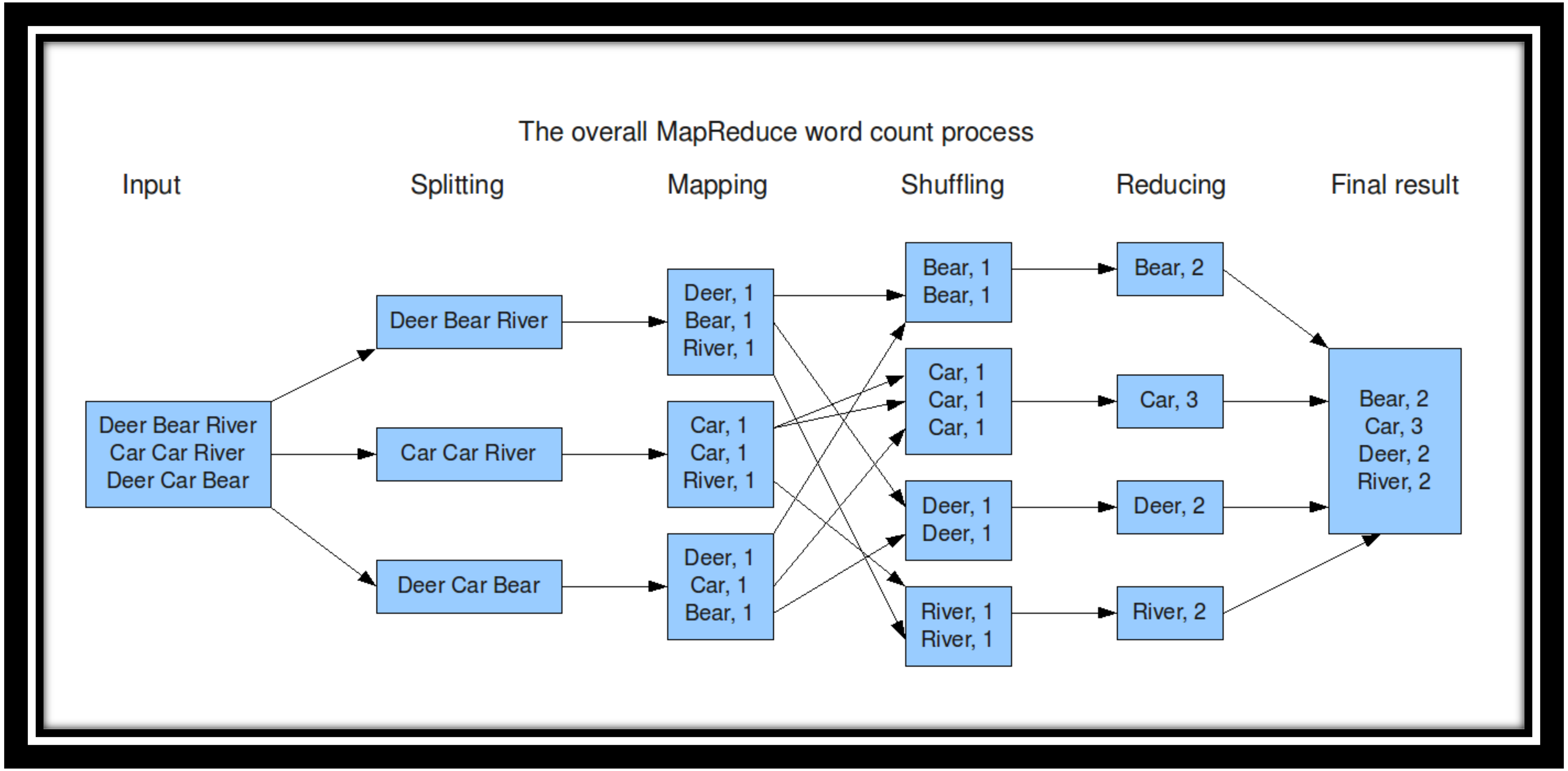
Shuffle and Sort

- Output from the mapper is sorted by key
- All values with the same key are guaranteed to go to the same machine

The Reducer

- Called once for each unique key
- Gets a list of all values associated with a key as input
- The reducer outputs zero or more final key/value pairs
  - Usually just one output per input key

MapReduce: Word Count



The overall MapReduce word count process

Hadoop Architecture

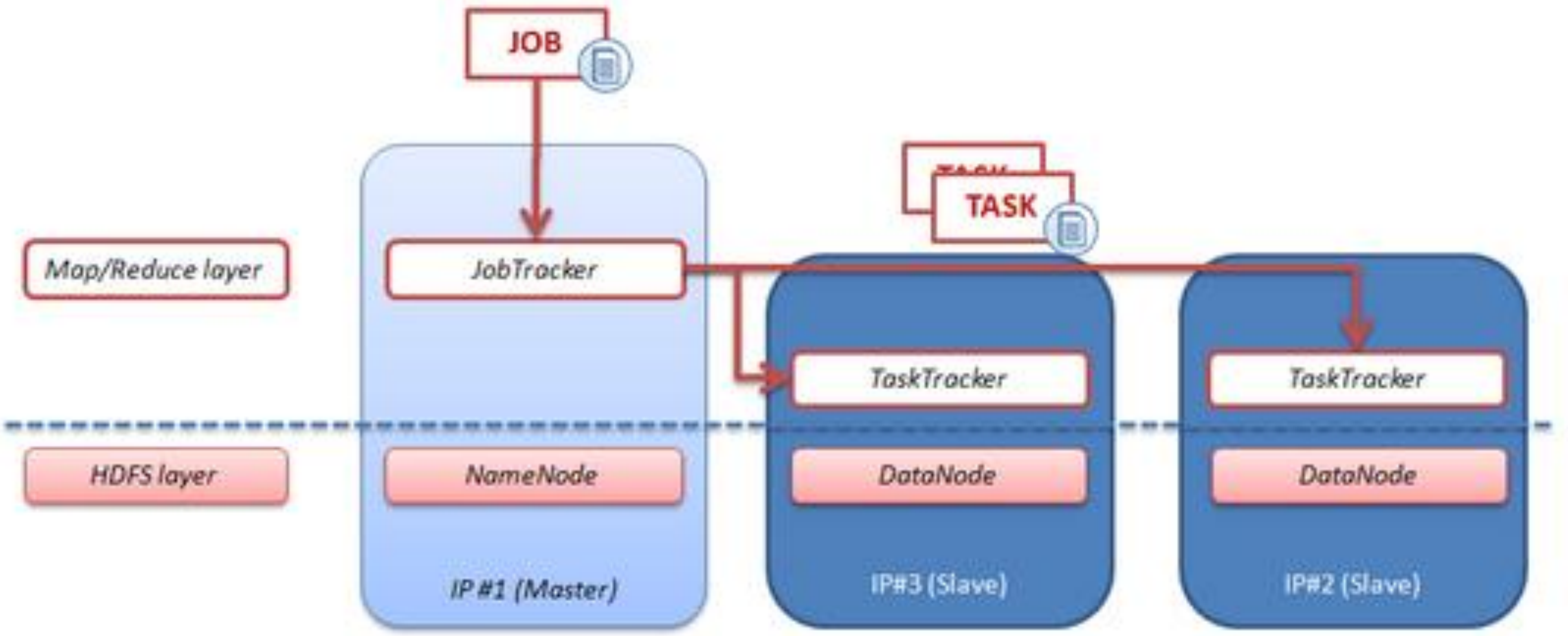
What parts actually make up a Hadoop cluster

- NameNode
  - Holds the metadata for the HDFS
- Secondary NameNode
  - Performs housekeeping functions for the NameNode
- DataNode
  - Stores the actual HDFS data blocks
- JobTracker
  - Manages MapReduce jobs
- TaskTracker
  - Monitors individual Map and Reduce tasks

JobTracker and TaskTracker

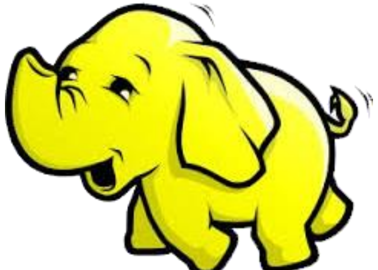
- JobTracker
  - Determines the execution plan for the job
  - Assigns individual tasks
- TaskTracker
  - Keeps track of the performance of an individual mapper or reducer

High-level architecture of Hadoop



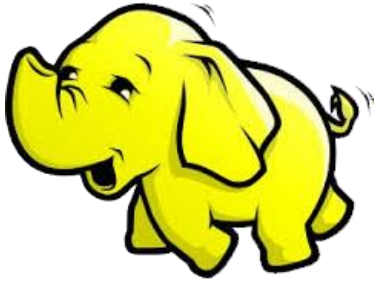
Hadoop’s Architecture

- Hadoop Distributed Filesystem
- Tailored to needs of MapReduce
- Targeted towards many reads of filestreams
- Writes are more costly
- High degree of data replication (3x by default)
- No need for RAID on normal nodes
- Large blocksize (64MB)
- Location awareness of DataNodes in network



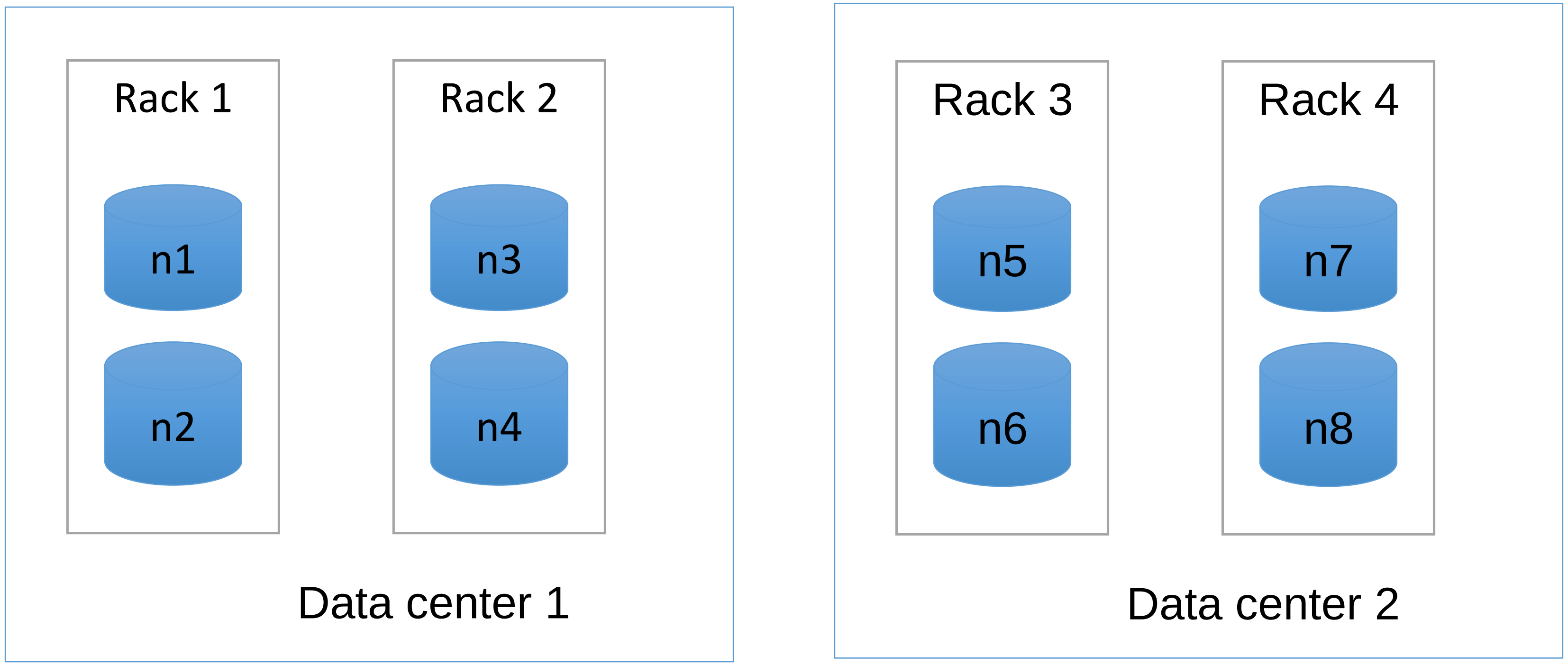
Hadoop’s Architecture

- Distributed, with some centralization
- Main nodes of cluster are where most of the computational power and storage of the system lies
- Main nodes run **TaskTracke**r to accept and reply to MapReduce tasks, and also **DataNode** to store needed blocks closely as possible
- Central control node runs **NameNode** to keep track of HDFS directories & files, and **JobTracker** to dispatch compute tasks to TaskTracker
- Written in Java, also supports Python and Ruby



HDFS network topology

- HDFS takes a simple approach:
  - ❑See the network as a tree
  - ❑Distance between two nodes is the sum of their distances to their closest common ancestor



HDFS filesystem commands

1. List the contents of a directory
   - `hadoop fs -ls`
2. Create a directory in HDFS at given path(s)
   - `hadoop fs -mkdir <directory name>`
3. Upload and download a file in HDFS
   - Upload: `hadoop fs -put <local file> <remote path>`
   - Download: `hadoop fs -get <file in HDFS> <local path>`
4. See contents of a file
   - `hadoop fs -cat <filename>`
5. Delete a file/directory in HDFS
   - `hadoop fs -rm/rmr <file or directory>`

HDFS filesystem commands

6. Move file from source to destination
   - `hadoop fs -mv <src> <dst>`
7. Report the amount of space used and availability
   - `hadoop fs -df hdfs:/`
8. How much space a directory occupies
   - `hadoop fs -du -s -h <dir name>`
9. Change permission of files
   - `sudo hadoop fs -chmod 600 <file>`
10. Change owner and group of files
    - `sudo hadoop fs -chown root:root <file>`

*HDFS admin commands

- DFSAdmin command
  - -report: reports basic statistics of HDFS
  - -safemode: though usually not required, an administrator can manually enter or leave safemode
    - enter, leave, get, wait
  - -refreshNodes: updates the set of hosts allowed to connect to namenode

Usage: hadoop dfsadmin [-report] [-safemode enter | leave | get | wait] [-refreshNodes] [-finalizeUpgrade] [-upgradeProgress status | details | force] [-metasave filename] [-setQuota <quota> <dirname>...<dirname>] [-clrQuota <dirname>...<dirname>] [-help [cmd]]

Installation and configuration

Next week: Lab 3: Cloudera Hadoop Installation

Questions?