

Introduction to Hadoop

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YAHOO!



Who Am I?

- Yahoo! Architect on Hadoop Map/Reduce
 - Design, review, and implement features in Hadoop
 - Working on Hadoop full time since Feb 2006
 - Before Grid team, I worked on Yahoos' WebMap
- VP of Apache for Hadoop
 - Chair of Hadoop Program Management Committee
 - Responsible for
 - Building the Hadoop community
 - Interfacing between the Hadoop PMC and the Apache Board



Problem

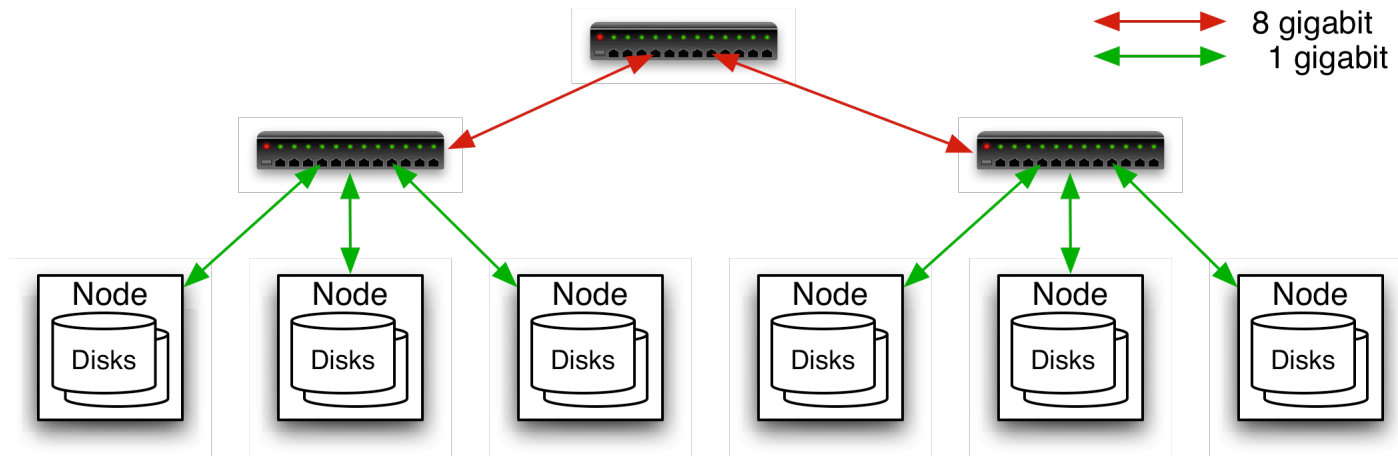
- How do you scale up applications?
 - 100's of terabytes of data
 - Takes 11 days to read on 1 computer
- Need lots of cheap computers
 - Fixes speed problem (15 minutes on 1000 computers), but...
 - Reliability problems
 - In large clusters, computers fail every day
 - Cluster size is not fixed
- Need common infrastructure
 - Must be efficient and reliable



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- Open Source Apache Project
 - Hadoop Core includes:
 - Distributed File System - distributes data
 - Map/Reduce - distributes application
 - Written in Java
 - Runs on
 - Linux, Mac OS/X, Windows, and Solaris
 - Commodity hardware



Commodity Hardware Cluster



- Typically in 2 level architecture
 - Nodes are commodity Linux PCs
 - 40 nodes/rack
 - Uplink from rack is 8 gigabit
 - Rack-internal is 1 gigabit all-to-all

Distributed File System

- Single petabyte file system for 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 in to large blocks.
 - Transparent to the client
 - Blocks are typically 128 MB
 - Replicated to several *datanodes*, for reliability
- Client talks to both namenode and datanodes
 - Data is not sent through the namenode.
 - Throughput of file system scales nearly linearly.
- Access from Java, C, or command line.

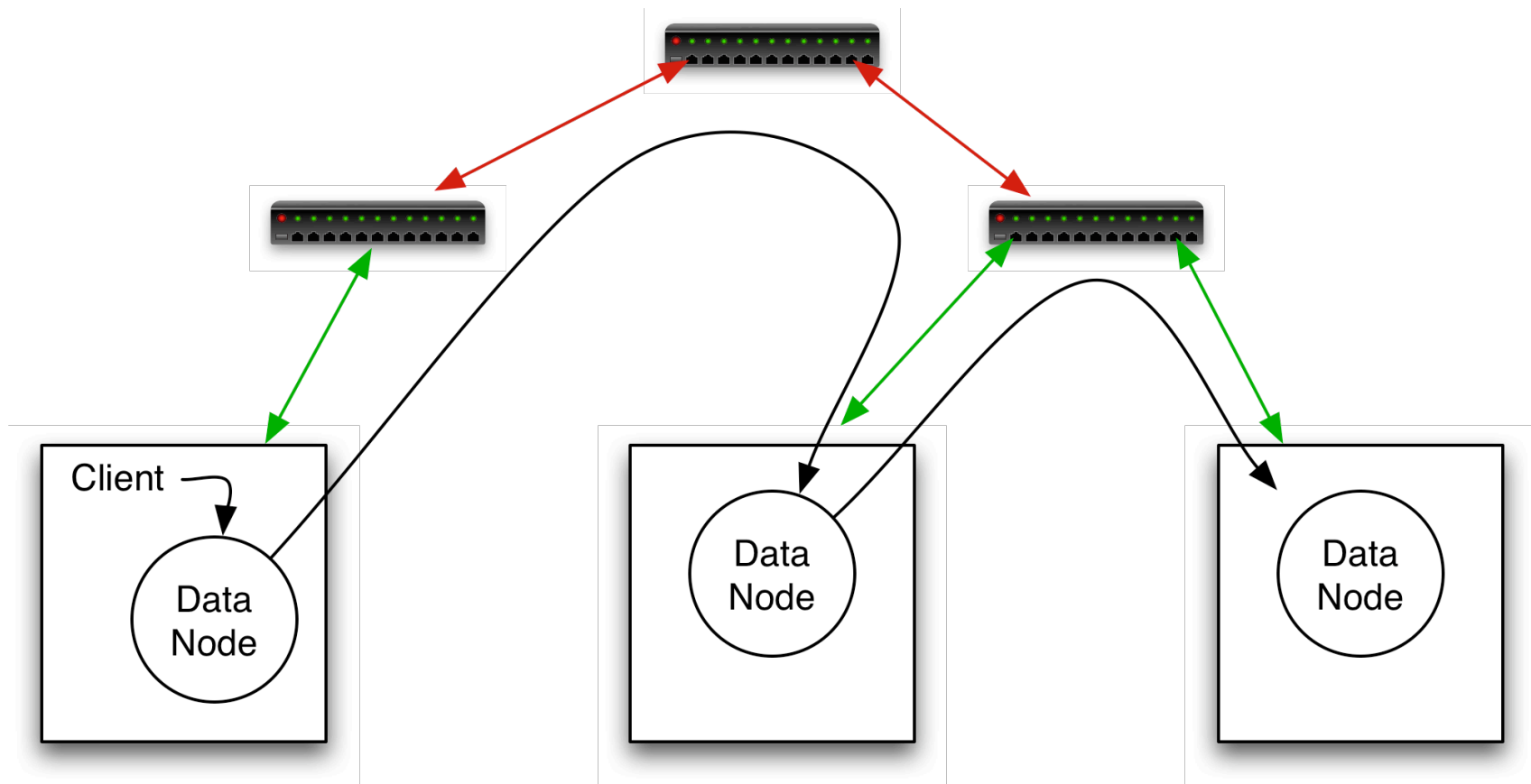


Block Placement

- Default is 3 replicas, but settable
- Blocks are placed (writes are pipelined):
 - On same node
 - On different rack
 - On the other rack
- Clients read from closest replica
- If the replication for a block drops below target, it is automatically re-replicated.



HDFS Dataflow





Data Correctness

- Data is checked with CRC32
- File Creation
 - Client computes checksum per 512 byte
 - DataNode stores the checksum
- File access
 - Client retrieves the data and checksum from DataNode
 - If Validation fails, Client tries other replicas
- Periodic validation by DataNode

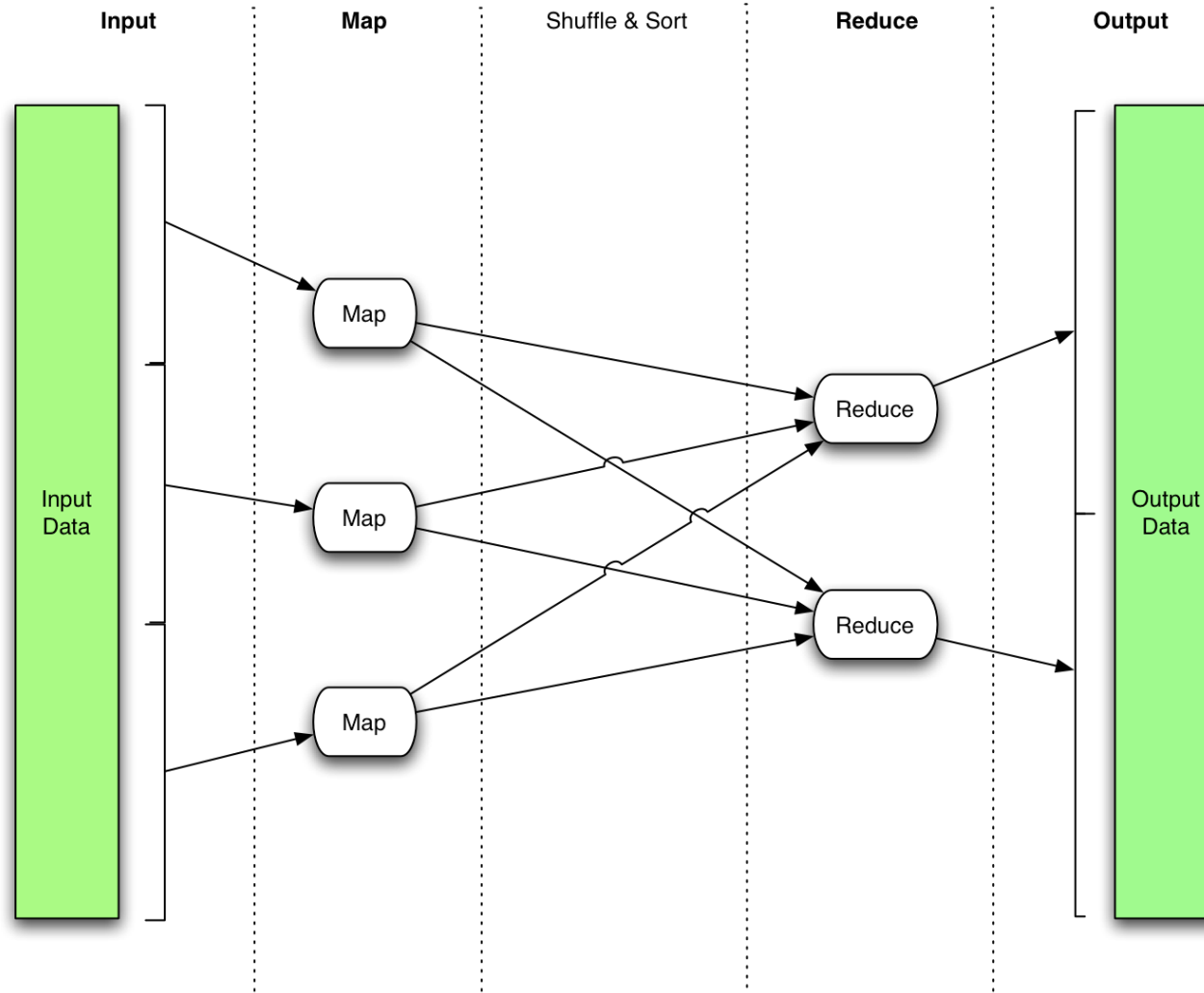


Map/Reduce

- Map/Reduce is a programming model for efficient distributed computing
- It works like a Unix pipeline:
 - `cat input | grep | sort | uniq -c | cat > output`
 - **Input** | **Map** | Shuffle & Sort | **Reduce** | **Output**
- Efficiency from
 - Streaming through data, reducing seeks
 - Pipelining
- A good fit for a lot of applications
 - Log processing
 - Web index building
 - Data mining and machine learning



Map/Reduce Dataflow





Map/Reduce features

- Java, C++, and text-based APIs
 - In Java use Objects and and C++ bytes
 - Text-based (streaming) great for scripting or legacy apps
 - Higher level interfaces: Pig, Hive, Jaql
- Automatic re-execution on failure
 - In a large cluster, some nodes are always slow or flaky
 - Framework re-executes failed tasks
- Locality optimizations
 - With large data, bandwidth to data is a problem
 - Map-Reduce queries HDFS for locations of input data
 - Map tasks are scheduled close to the inputs when possible



Why Yahoo! is investing in Hadoop

- We started with building better applications
 - Scale up web scale batch applications (search, ads, ...)
 - Factor out common code from existing systems, so new applications will be easier to write
 - Manage the many clusters we have more easily
- The mission now includes research support
 - Build a **huge** data warehouse with many Yahoo! data sets
 - Couple it with a huge compute cluster and programming models to make using the data easy
 - Provide this as a service to our researchers
 - We are seeing great results!
 - Experiments can be run much more quickly in this environment



Hadoop Timeline

- 2004 – HDFS & map/reduce started in Nutch
- Dec 2005 – Nutch ported to map/reduce
- Jan 2006 – Doug Cutting joins Yahoo
- Feb 2006 – Factored out of Nutch.
- Apr 2006 – Sorts 1.9 TB on 188 nodes in 47 hours
- May 2006 – Yahoo sets up research cluster
- Jan 2008 – Hadoop is a top level Apache project
- Feb 2008 – Yahoo creating Webmap with Hadoop
- Apr 2008 – Wins Terabyte sort benchmark
- Aug 2008 – Ran 4000 node Hadoop cluster



Running the Production WebMap

- Search needs a graph of the “known” web
 - Invert edges, compute link text, whole graph heuristics
- Periodic batch job using Map/Reduce
 - Uses a chain of ~100 map/reduce jobs
- Scale
 - 100 billion nodes and 1 trillion edges
 - Largest shuffle is 450 TB
 - Final output is 300 TB compressed
 - Runs on 10,000 cores
- Written mostly using Hadoop’s C++ interface



Inverting the Webmap

- One job inverts all of the edges in the Webmap
 - Finds the text in the links that point to each page.
- Input is cache of web pages
 - Key: URL, Value: Page HTML
- Map output is
 - Key: Target URL, Value: Source URL, Text from link
- Reduce adds column to URL table with set of linking pages and link text



Finding Duplicate Web Pages

- Find “close” textual matches in the corpus of web pages
- Use a loose hash based on visible text
- Input is same cache of web pages
 - Key: URL; Value: Page HTML.
- Map output is
 - Key: Page Text Hash, Goodness; Value: URL
- Reduce output is Key: Page Text Hash; Value: URL (best first)
- Second job resorts based on the URL
- Map output is URL, best URL
- Reduce creates a new column in URL table with best URL for duplicate pages



Research Clusters

- The grid team runs research clusters as a service to Yahoo researchers
 - Analytics as a Service
- Mostly data mining/machine learning jobs
- Most research jobs are *not* Java:
 - 42% Streaming
 - Uses Unix text processing to define map and reduce
 - 28% Pig
 - Higher level dataflow scripting language
 - 28% Java
 - 2% C++



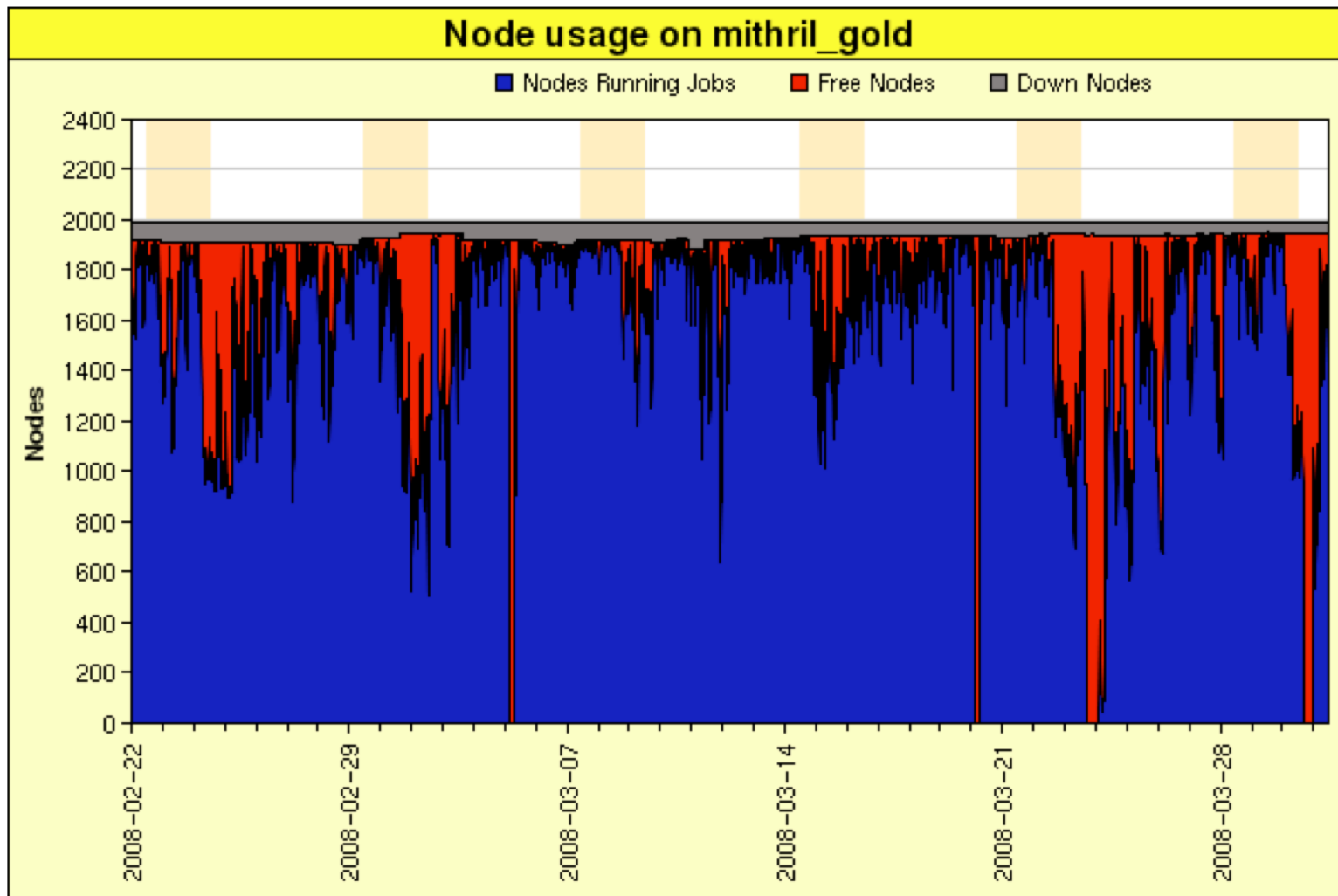
Hadoop clusters

- We have ~20,000 machines running Hadoop
- Our largest clusters are currently 2000 nodes
- Several petabytes of user data (compressed, unreplicated)
- We run hundreds of thousands of jobs every month





Research Cluster Usage



- Needed offline conversion of public domain articles from 1851-1922.
- Used Hadoop to convert scanned images to PDF
- Ran 100 Amazon EC2 instances for around 24 hours
- 4 TB of input
- 1.5 TB of output

A COMPUTER WANTED.

WASHINGTON, May 1.—A civil service examination will be held May 18 in Washington, and, if necessary, in other cities, to secure eligibles for the position of computer in the Nautical Almanac Office, where two vacancies exist—one at \$1,000, the other at \$1,400..

The examination will include the subjects of algebra, geometry, trigonometry, and astronomy. Application blanks may be obtained of the United States Civil Service Commission.

Published 1892, copyright New York Times



Terabyte Sort Benchmark

- Started by Jim Gray at Microsoft in 1998
- Sorting 10 billion 100 byte records
- Hadoop won general category in 209 seconds (prev was 297)
 - 910 nodes
 - 2 quad-core Xeons @ 2.0Ghz / node
 - 4 SATA disks / node
 - 8 GB ram / node
 - 1 gb ethernet / node and 8 gb ethernet uplink / rack
 - 40 nodes / rack
- Only hard parts were:
 - Getting a total order
 - Converting the data generator to map/reduce
- <http://developer.yahoo.net/blogs/hadoop/2008/07>

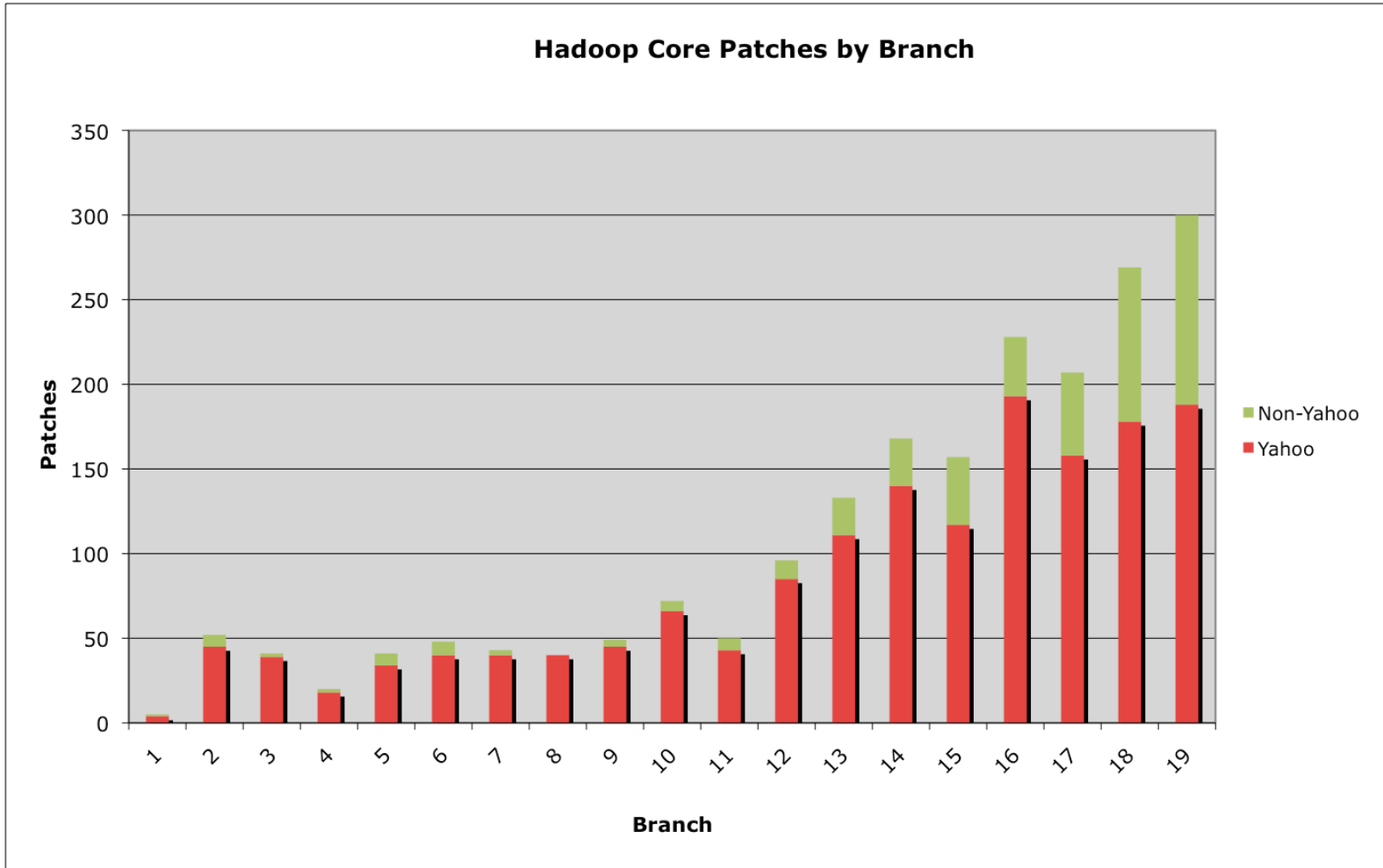


Hadoop Community

- Apache is focused on project communities
 - Users
 - Contributors
 - write patches
 - Committers
 - can commit patches **too**
 - Project Management Committee
 - vote on new committers and releases **too**
- Apache is a meritocracy
- Use, contribution, and diversity is growing
 - But we need and want more!

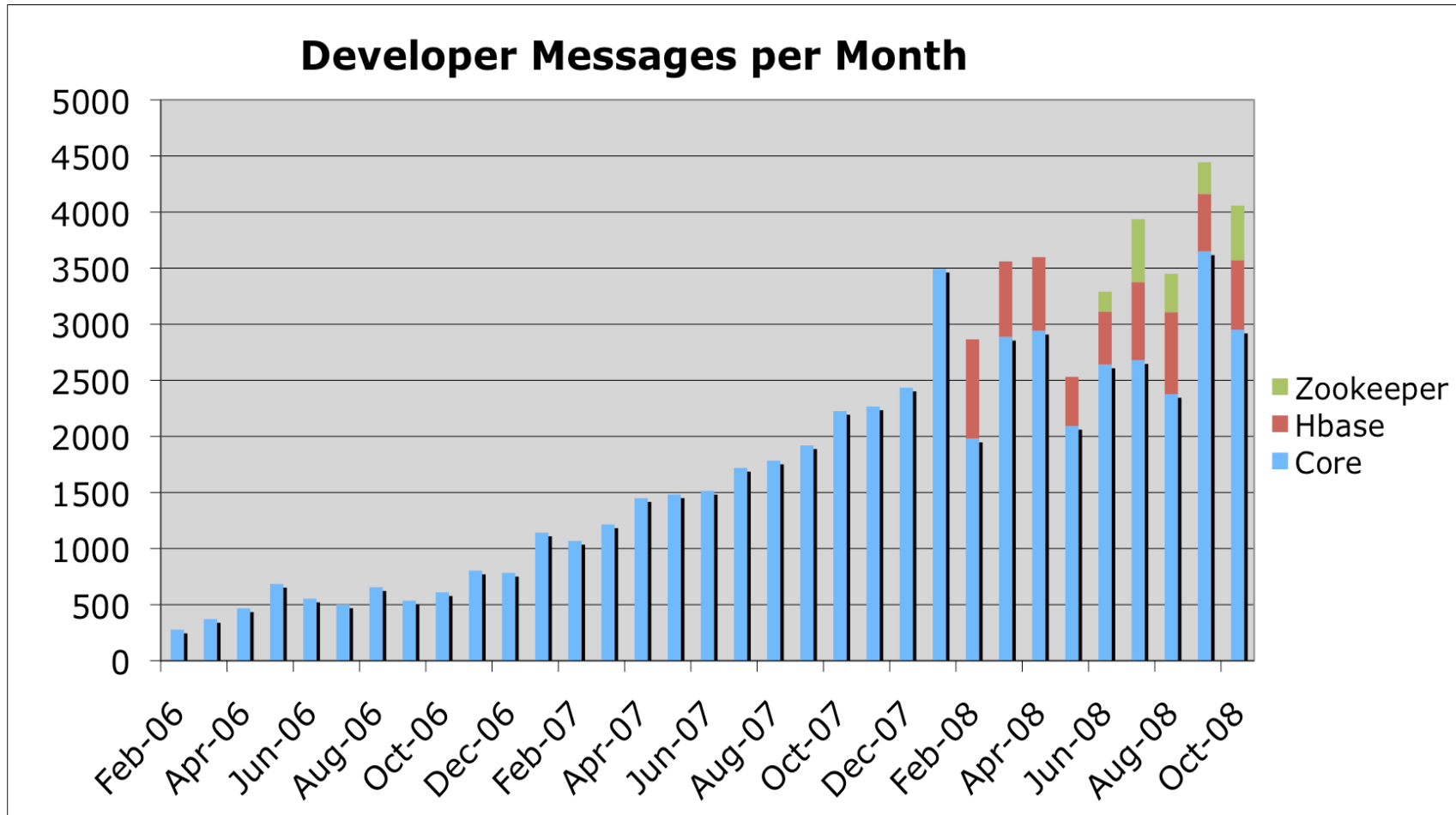


Size of Releases



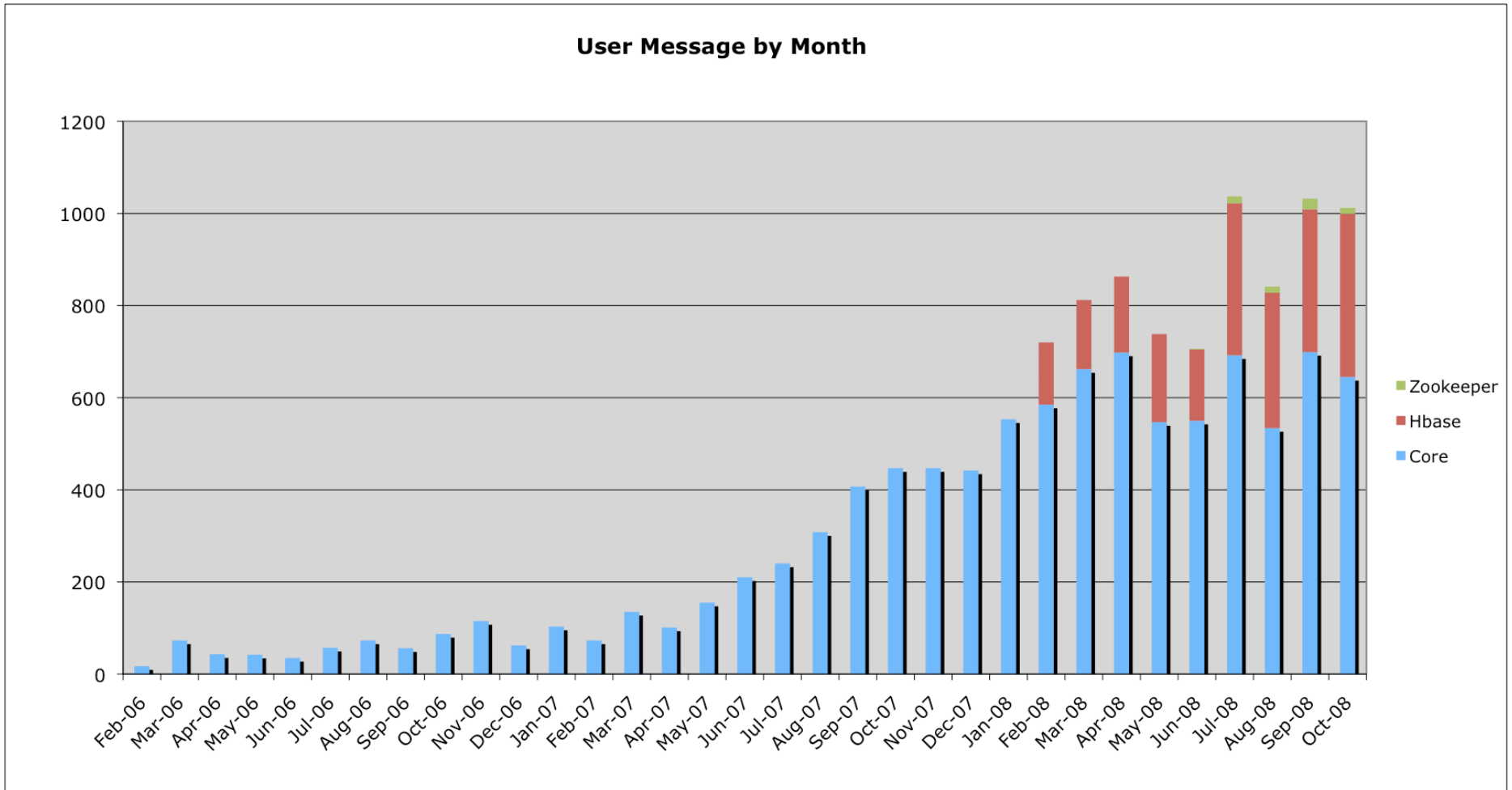


Size of Developer Community





Size of User Community





Who Uses Hadoop?

- Amazon/A9
- Facebook
- Google
- IBM
- Joost
- Last.fm
- New York Times
- PowerSet (now Microsoft)
- Quantcast
- Veoh
- Yahoo!
- More at <http://wiki.apache.org/hadoop/PoweredBy>



What's Next?

- 0.19
 - File Appends
 - Total Order Sampler and Partitioner
 - Pluggable scheduler
- 0.20
 - New map/reduce API
 - Better scheduling for sharing between groups
 - Splitting Core into sub-projects (HDFS, Map/Reduce, Hive)
- And beyond
 - HDFS and Map/Reduce security
 - High Availability via Zookeeper
 - Get ready for Hadoop 1.0



- For more information:
 - Website: <http://hadoop.apache.org/core>
 - Mailing lists:
 - core-dev@hadoop.apache
 - core-user@hadoop.apache
 - IRC: [#hadoop](irc://irc.freenode.org/#hadoop) on irc.freenode.org