
ALSO
BIG
DATA
TOOLS
DISK
TARGET
EXAMPLES
APPLIED
SENSOR
SHARED
MAY
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CURRENT
MOVING
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WITHIN
ZETTABYTES
PRACTITIONERS
CAPTURE
THOUGHT
INTERNET
BUSINESS
SETS
GENOMICS
DISTRIBUTED
DESCRIBING
RADIO-FREQUENCY
COMPLEXITY
MANAGEMENT
TERABYTES
CASE
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PETABYTES
INCLUDE
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SYSTEMS
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FORMS
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QUALITIES
SINCE
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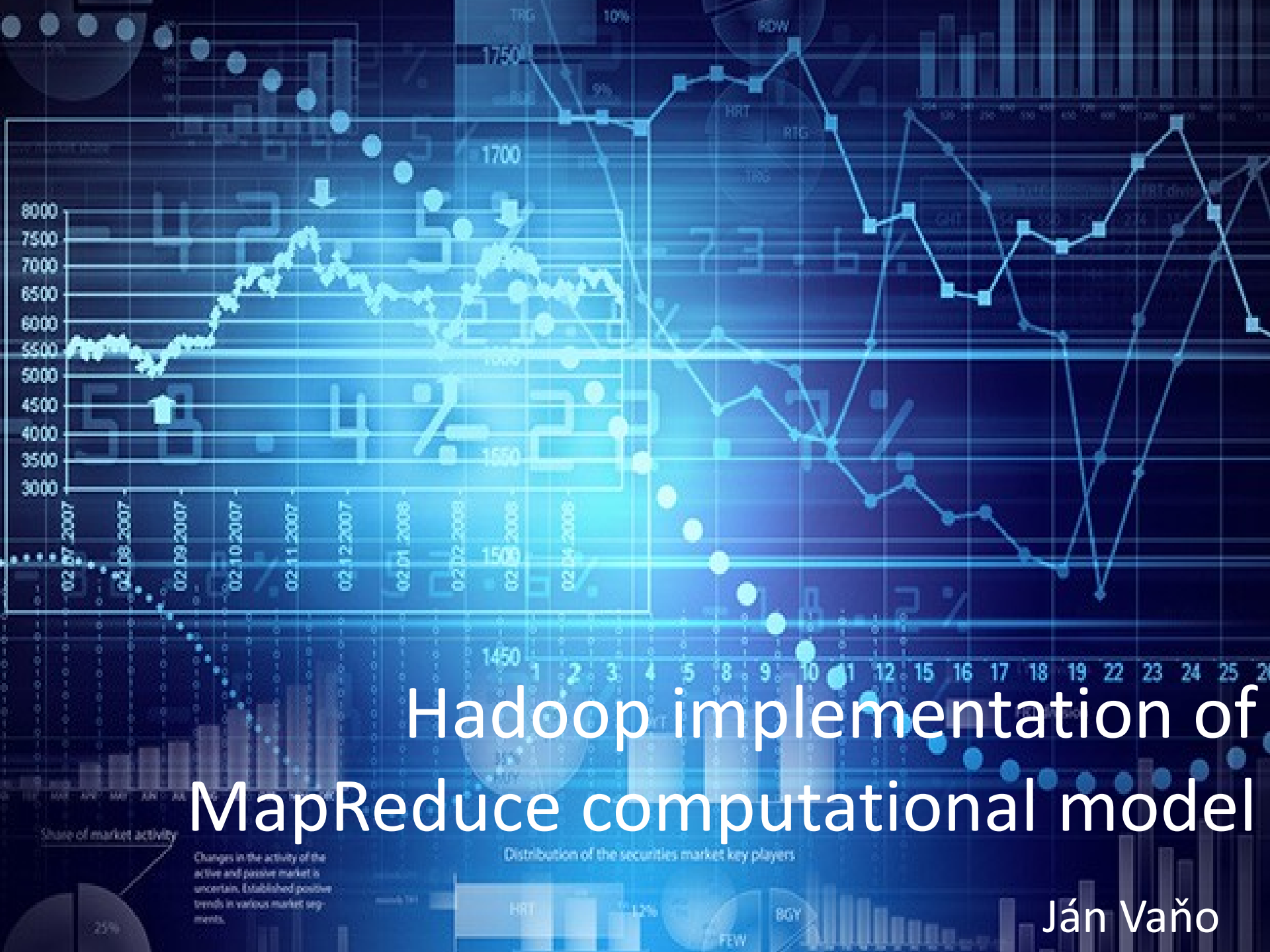


# Hadoop implementation of MapReduce computational model

Ján Vaňo

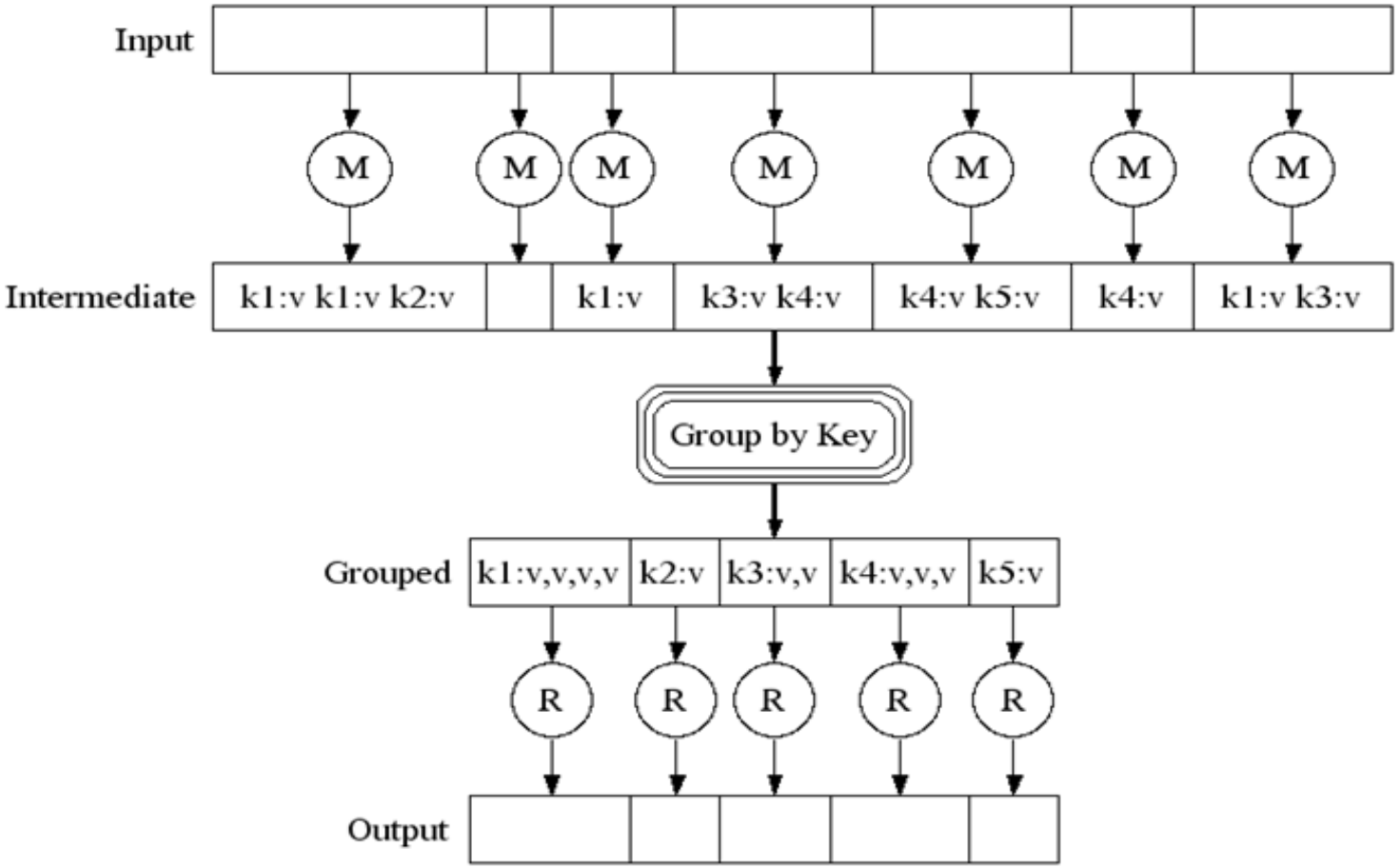
# What is MapReduce?

- A computational model published in a paper by Google in 2004
- Based on distributed computation
- Complements Google‘s distributed file system (GFS)
- Works with key:value pairs

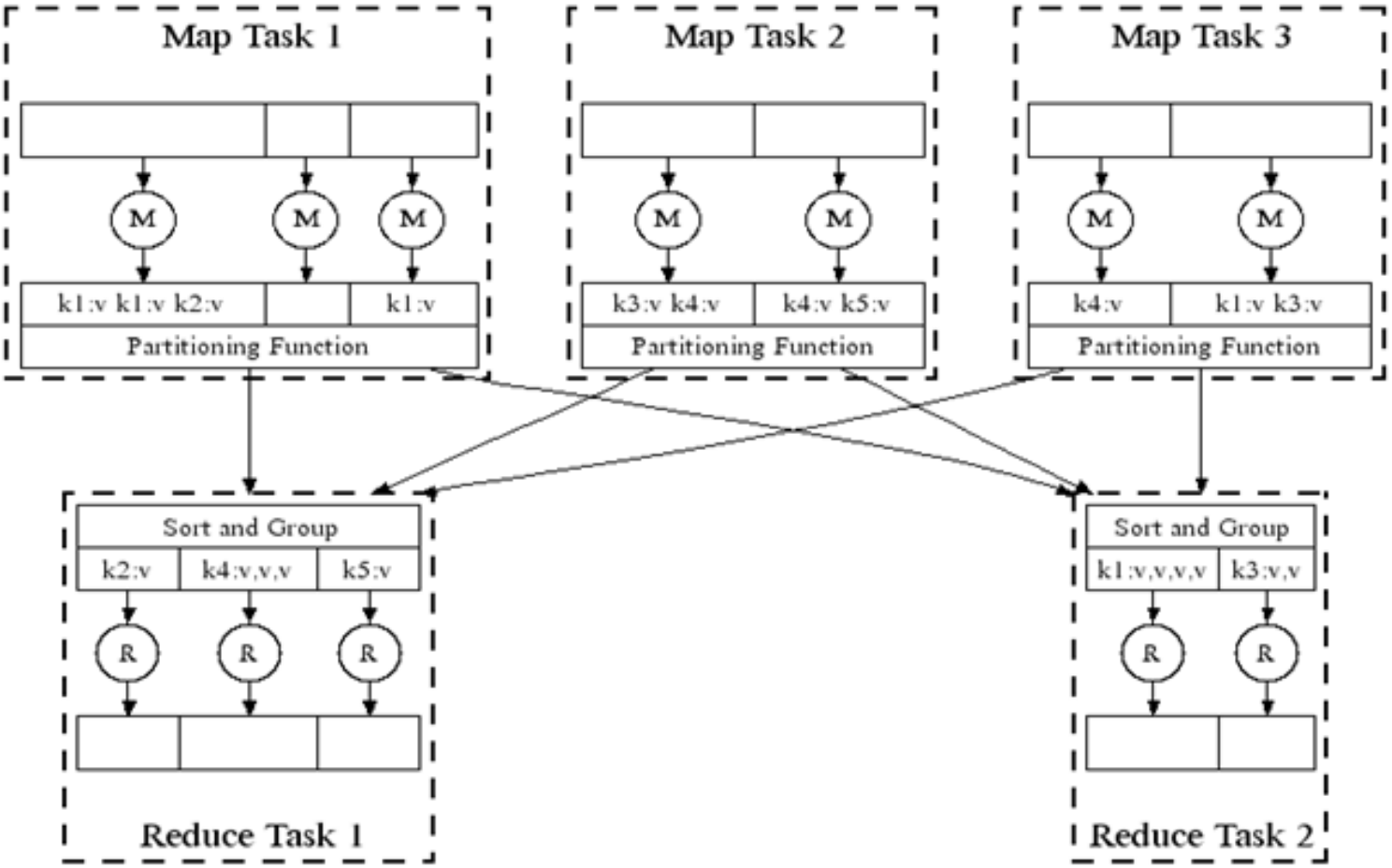
# Why MapReduce?

- It is the ‚answer‘ for Big Data problem
- Runs on commodity hardware
- Very scalable solution

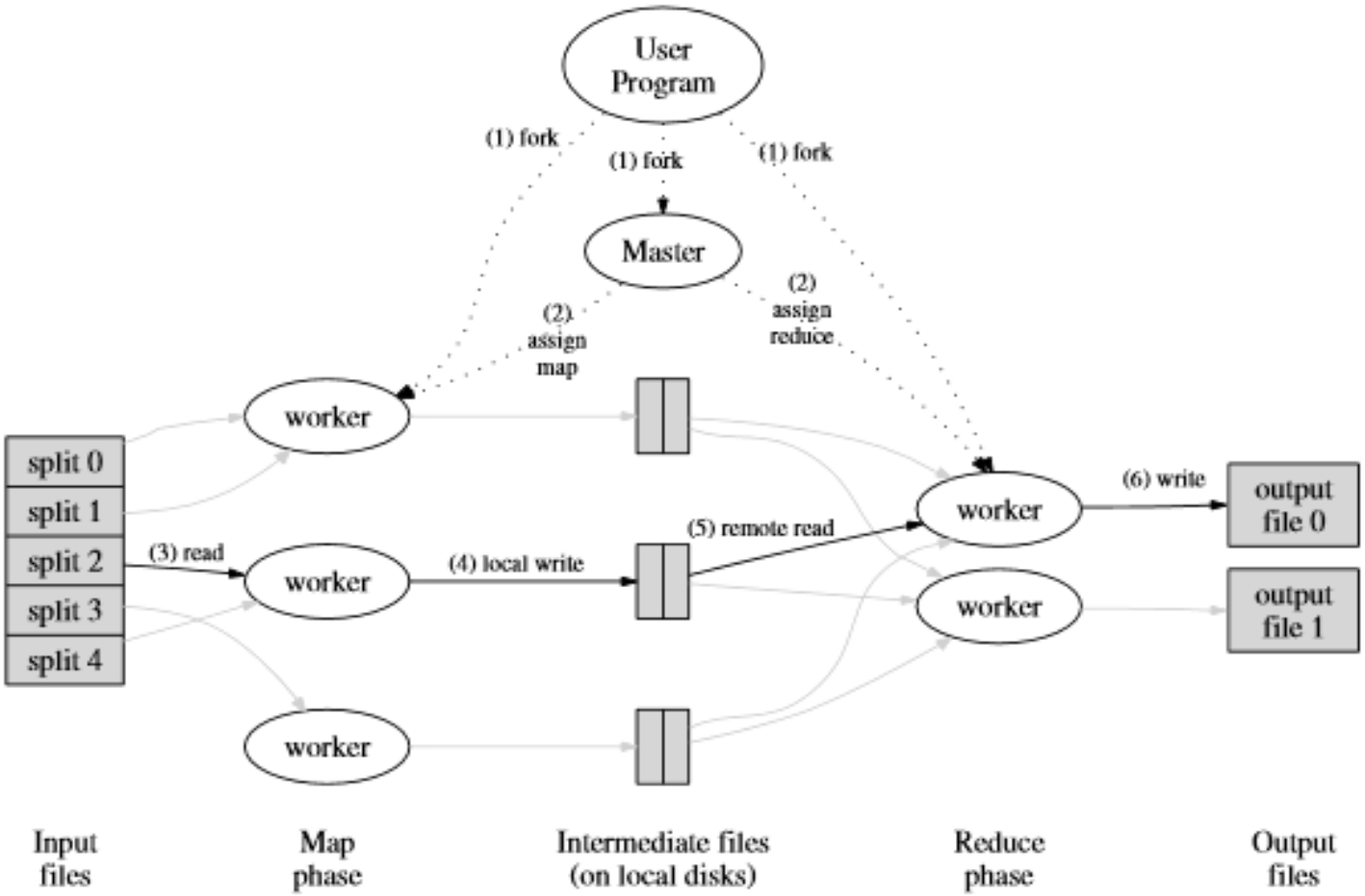
# MapReduce model



# MapReduce model



# MapReduce model



# MapReduce alternatives

- Hadoop – Top-level Apache project
- Spark – University of Berkeley project
- Disco – Open source Nokia project
- MapReduce-MPI – US Department of Energy project
- MARIANE – academic project of University of Binghamton
- Phoenix – University of Stanford project
- BashReduce - MapReduce for std. Unix commands

# MapReduce vs. RDBMS

| | Traditional RDBMS | MapReduce |
|---|---|---|
| Data Size | Gigabytes | Petabytes |
| Access | Interactive and batch | Batch |
| Updates | Read and write many times | Write once, read many times |
| Structure | Static schema | Dynamic schema |
| Integrity | High | Low |
| Scaling | Nonlinear | Linear |

# Data Structure

- Structured Data – data organized into entities that have a defined format.
  - Realm of RDBMS
- Semi-Structured Data – there may be a schema, but often ignored; schema is used as a guide to the structure of the data.
- Unstructured Data – doesn’t have any particular internal structure.
- MapReduce works well with semi-structured and unstructured data.

# What is Hadoop?

- Software platform that lets one easily write and run applications that process vast amounts of data
- Hadoop is most popular implementation of MapReduce so far

# Why Hadoop?

- It has been Apache top-level project for a long time (6 years)
- Hadoop Ecosystem
- Hadoop exclusive technologies

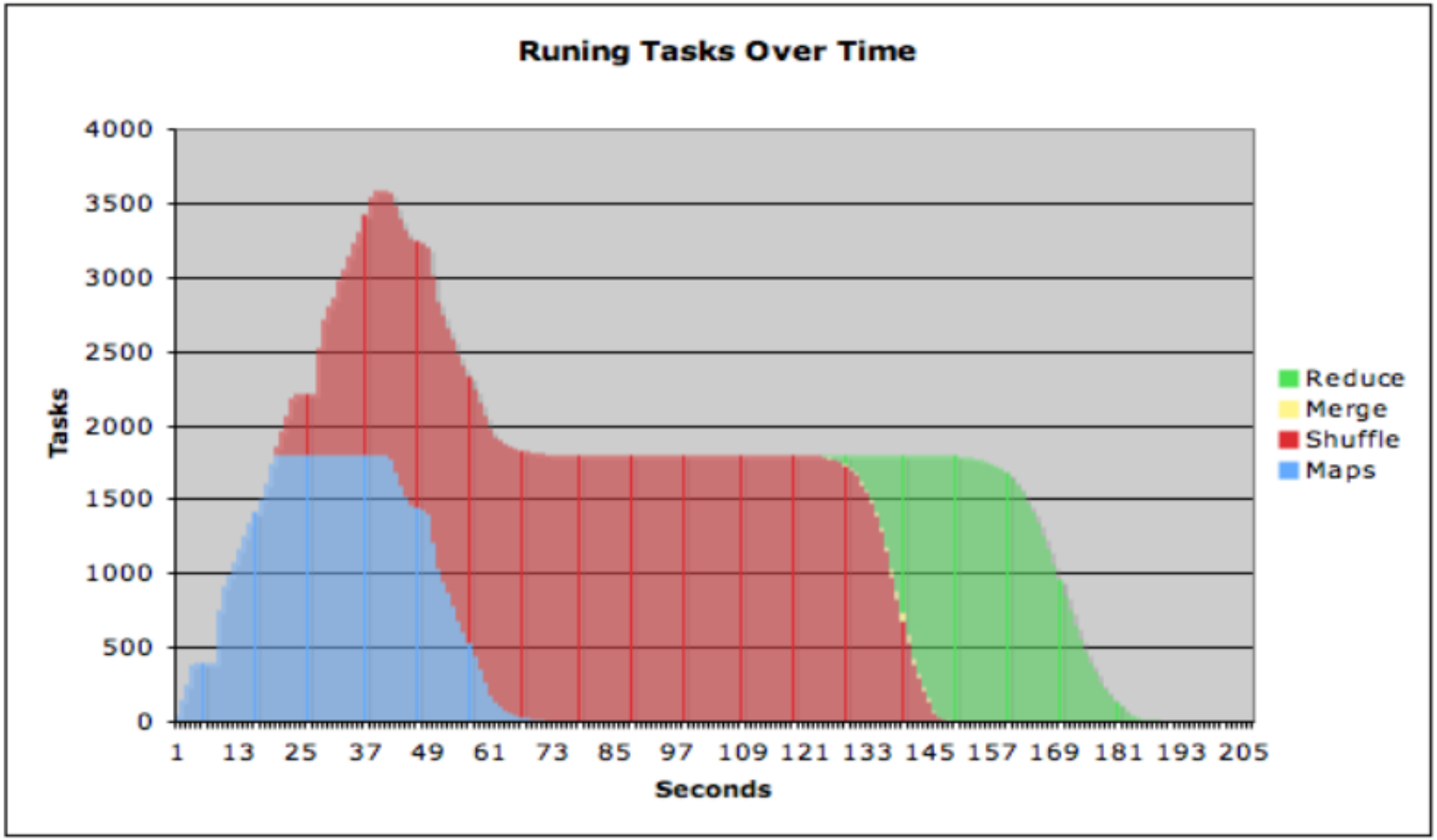
# Why Hadoop?

- Scalable: It can reliably store and process petabytes
- Economical: It distributes the data and processing across clusters of commonly available computers (in thousands)
- Efficient: By distributing the data, it can process it in parallel on the nodes where the data is located
- Reliable: It automatically maintains multiple copies of data and automatically redeploys computing tasks based on failures

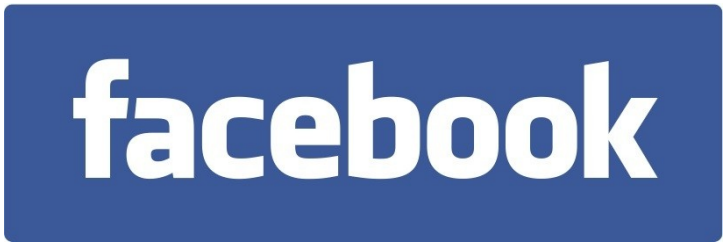
# Brief history

- 2002 - Project Nutch started (open source web search engine) – **Doug Cutting**
- 2003 - GFS (Google File System) paper published
- 2004 - Implementation of GFS started
- 2004 - Google published MapReduce paper
- 2005 - Working implementations of MapReduce and GFS (NDFS)
- 2006 - System applicable beyond realm of search
- 2006 - Nutch moved to Hadoop project, Doug Cutting joins Yahoo!
- 2008 - Yahoo!s production index generated by 10,000 core Hadoop cluster
- 2008 - Hadoop moved under Apache Foundation
- April 2008 - Hadoop broke world record - fastest sorting of 1 TB of data (209 seconds, previously 297)
- November 2008 - Google's implementation sorted 1 TB in 68 seconds
- May 2009 - Yahoo! team sort 1 TB in 62 seconds

# 1TB sort by Hadoop



# Who uses Hadoop?













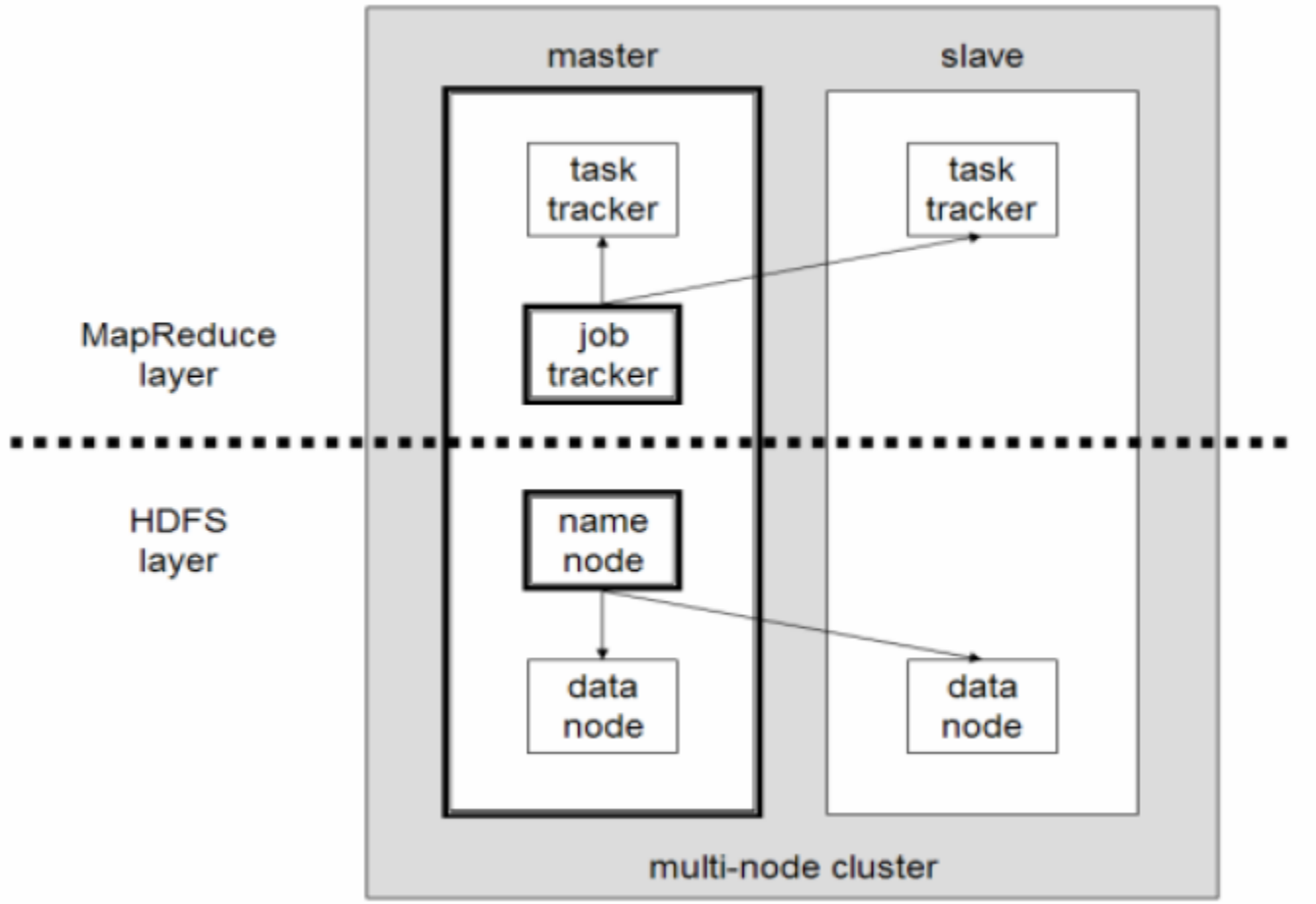
# Assumptions

- Hardware will fail
- Processing will be run in batches. Thus there is an emphasis on high throughput as opposed to low latency
- Applications that run on HDFS have large data sets. A typical file in HDFS is gigabytes to terabytes in size
- It should provide high aggregate data bandwidth and scale to hundreds of nodes in a single cluster. It should support tens of millions of files in a single instance
- Applications need a write-once-read-many access model
- Moving Computation is Cheaper than Moving Data
- Portability is important

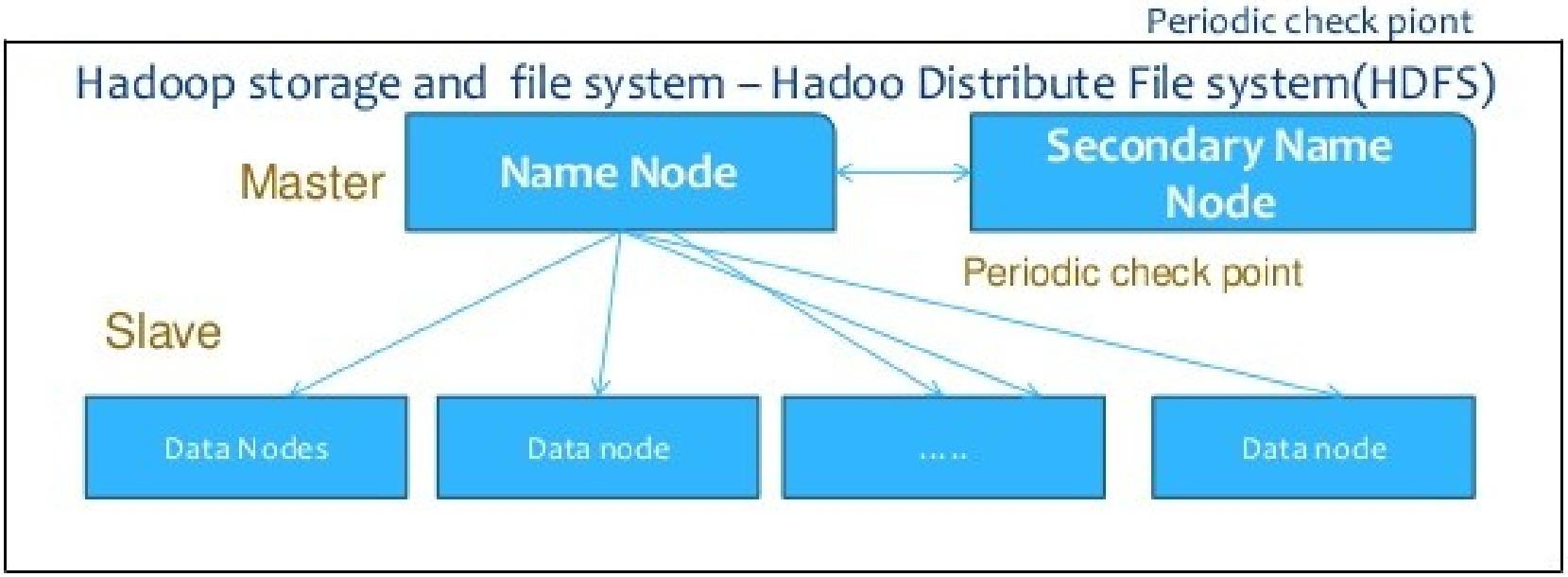
# Hadoop modules

- Hadoop Common - contains libraries and utilities needed by other Hadoop modules
- Hadoop Distributed File System (HDFS) - a distributed file-system that stores data on the commodity machines, providing very high aggregate bandwidth across the cluster
- Hadoop MapReduce - a programming model for large scale data processing
- Hadoop YARN - a resource-management platform responsible for managing compute resources in clusters and using them for scheduling of users' applications
  - Provides base for MapReduce v2

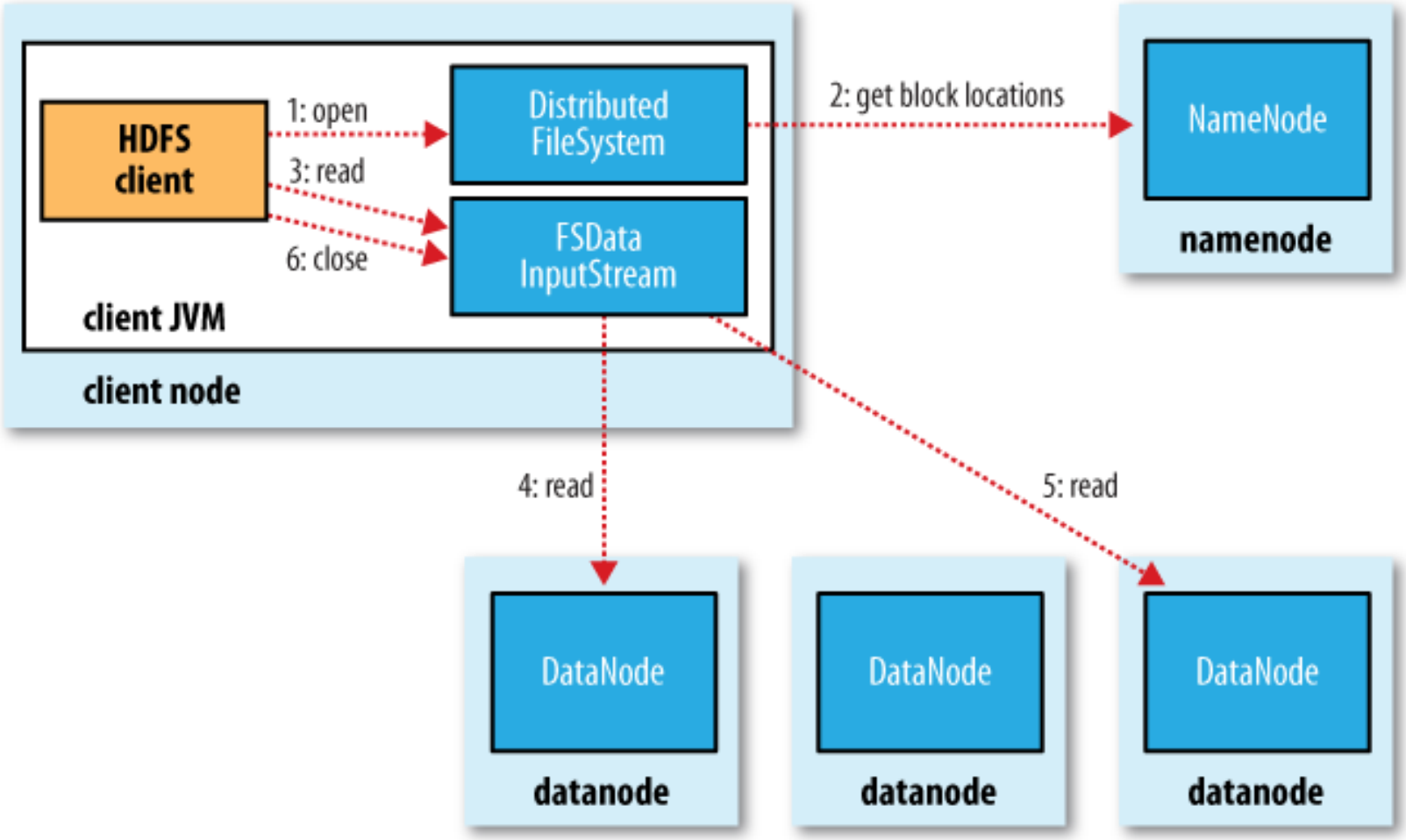
# Hadoop architecture



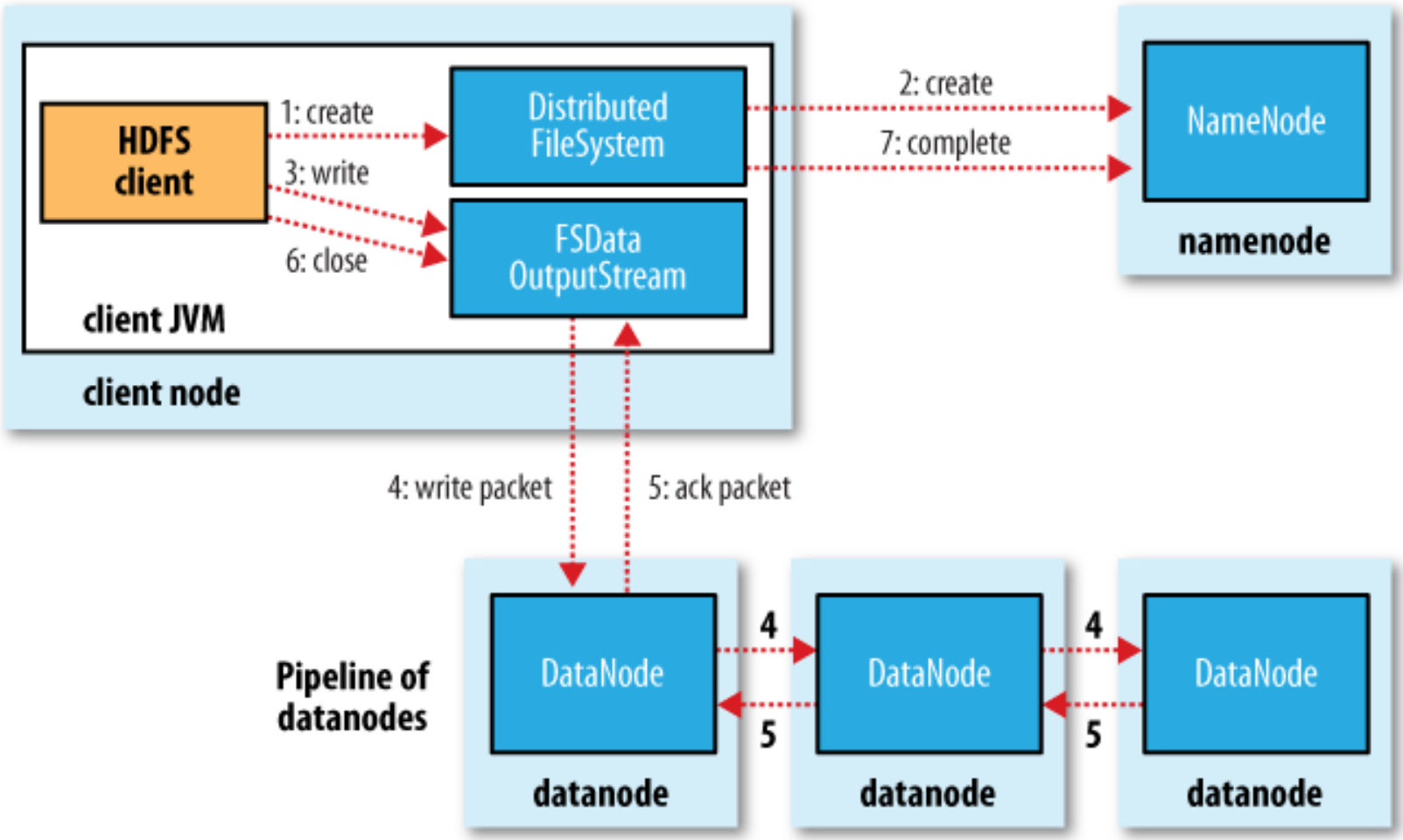
# HDFS architecture



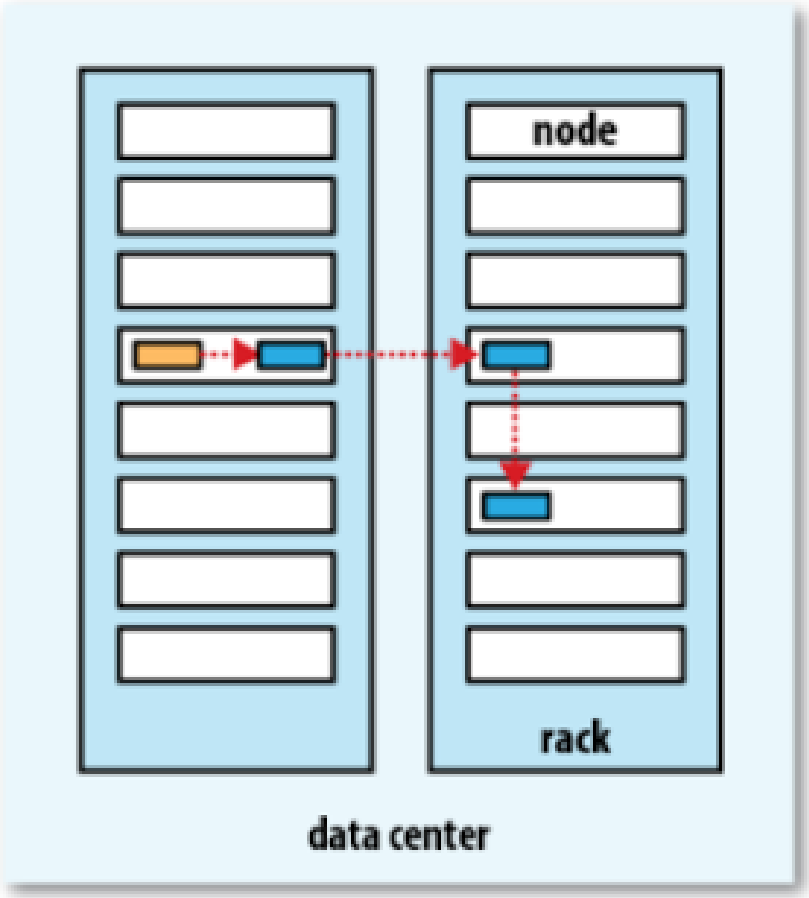
# HDFS architecture (reading)



# HDFS architecture (writing)



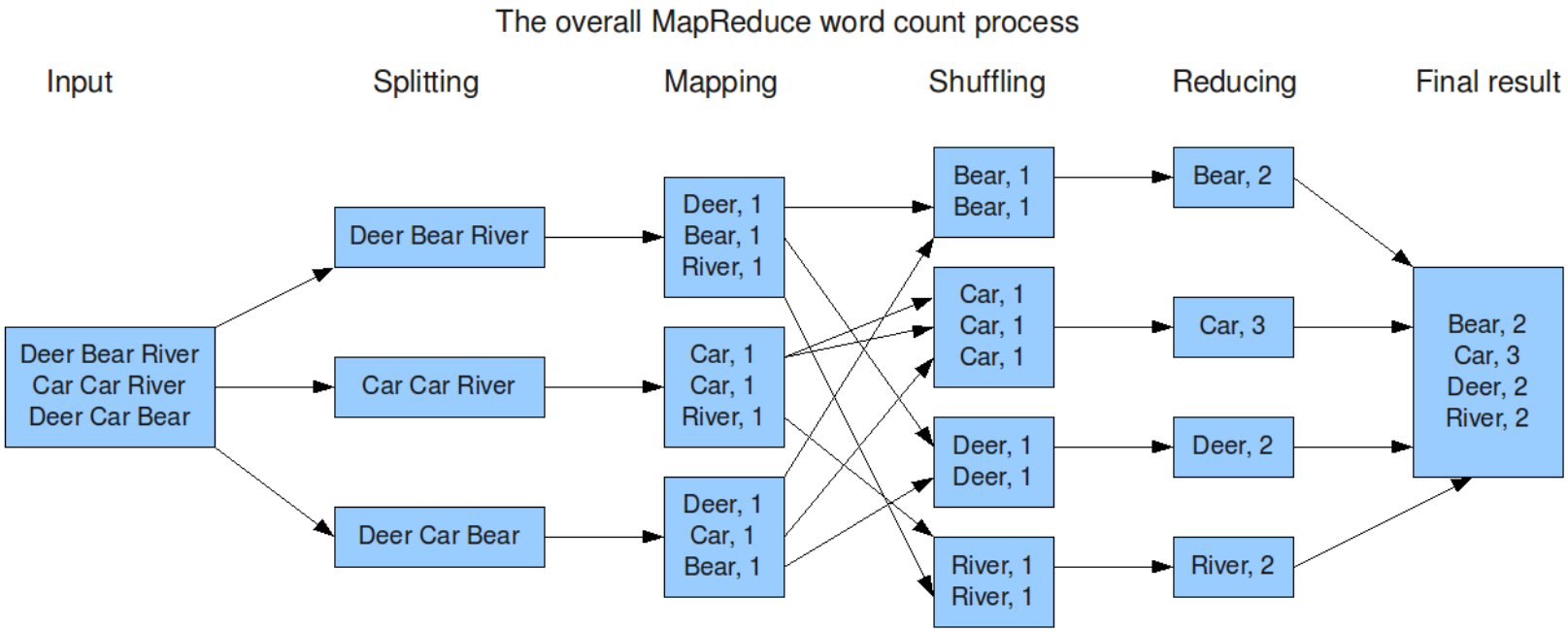
# Data replication in HDFS



# How to use Hadoop MapReduce?

- Implement 2 basic functions:
  - Map
  - Reduce
- Implement Driver class

# MapReduce structure



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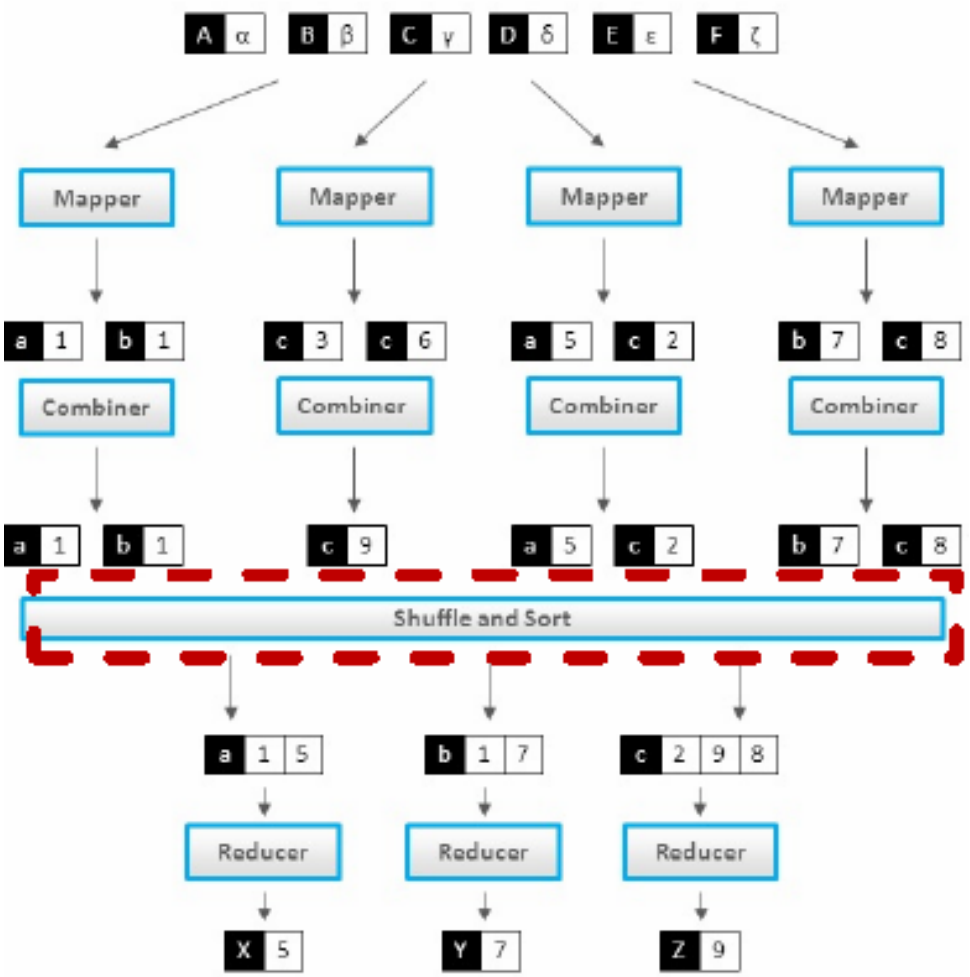
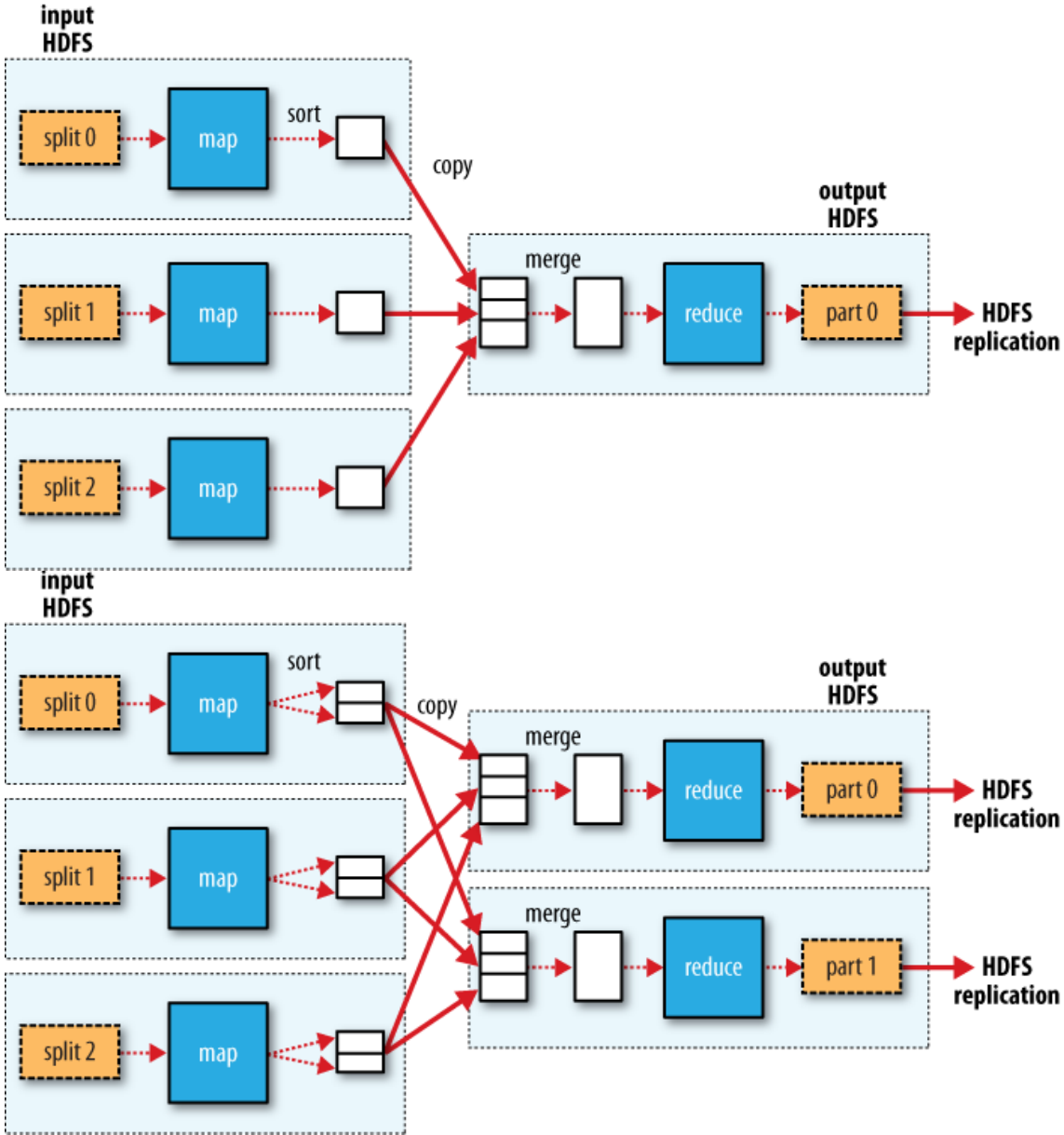
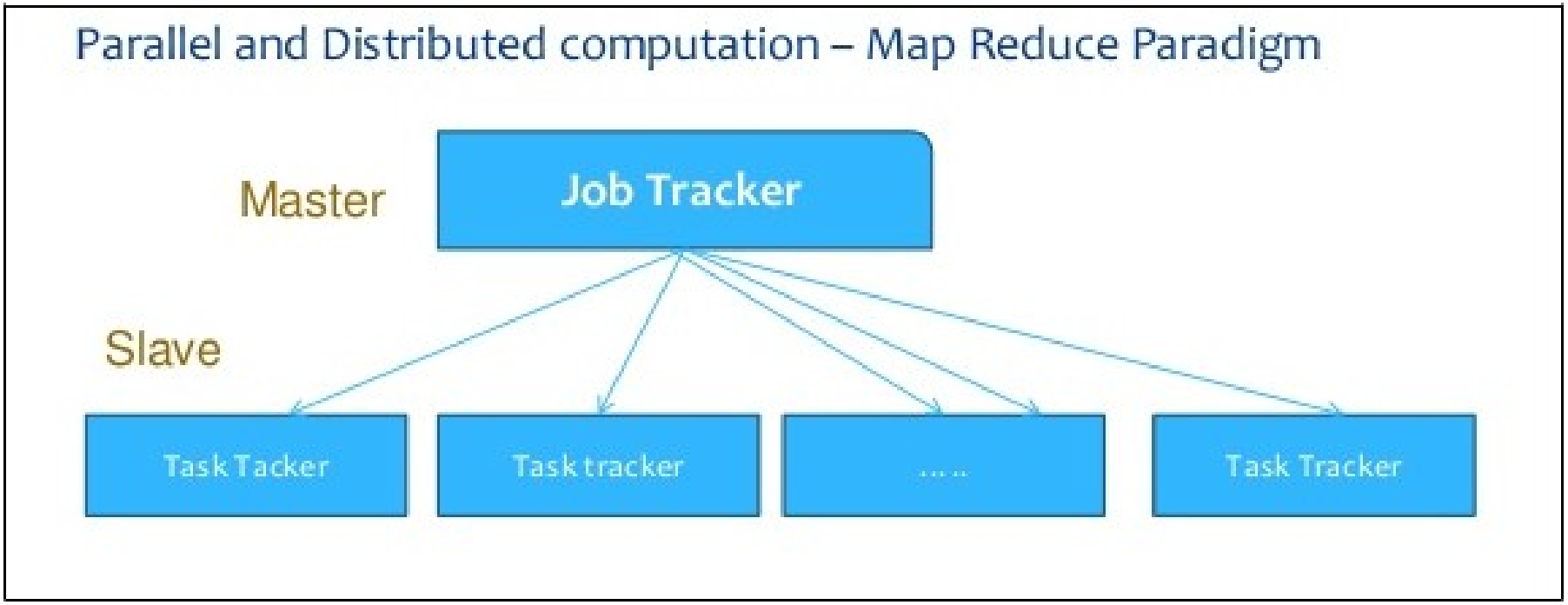


# MapReduce structure



# Job submission (MapReduce v1)



# Job submission (MapReduce v1)

- Client applications submit jobs to the Job tracker
- The JobTracker talks to the NameNode to determine the location of the data
- The JobTracker locates TaskTracker nodes with available slots at or near the data
- The JobTracker submits the work to the chosen TaskTracker nodes
- The TaskTracker nodes are monitored. If they do not submit heartbeat signals often enough, they are deemed to have failed and the work is scheduled on a different TaskTracker

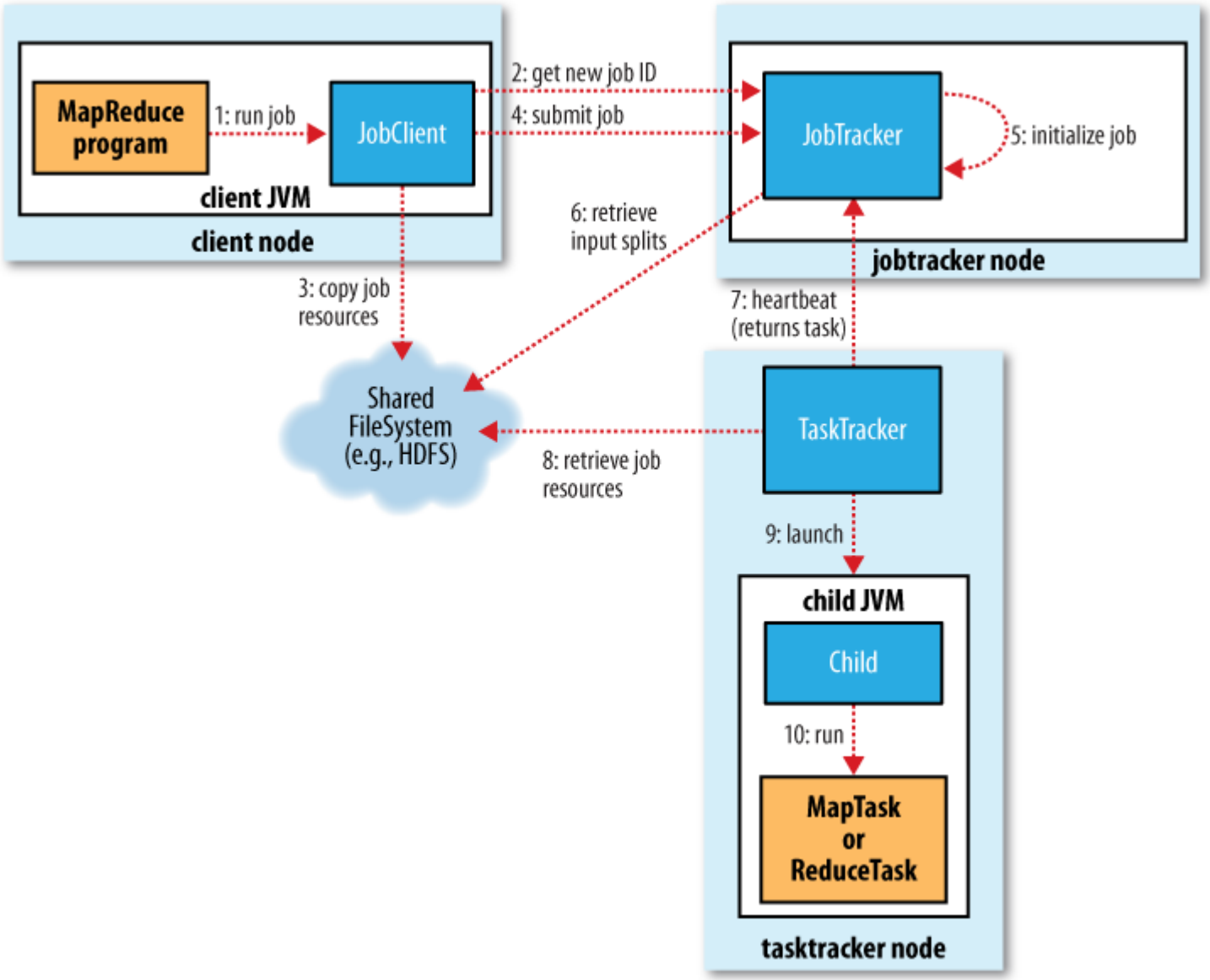
# Job submission (MapReduce v1)

- A TaskTracker will notify the JobTracker when a task fails. The JobTracker decides what to do then: it may resubmit the job elsewhere, it may mark that specific record as something to avoid, and it may may even blacklist the TaskTracker as unreliable

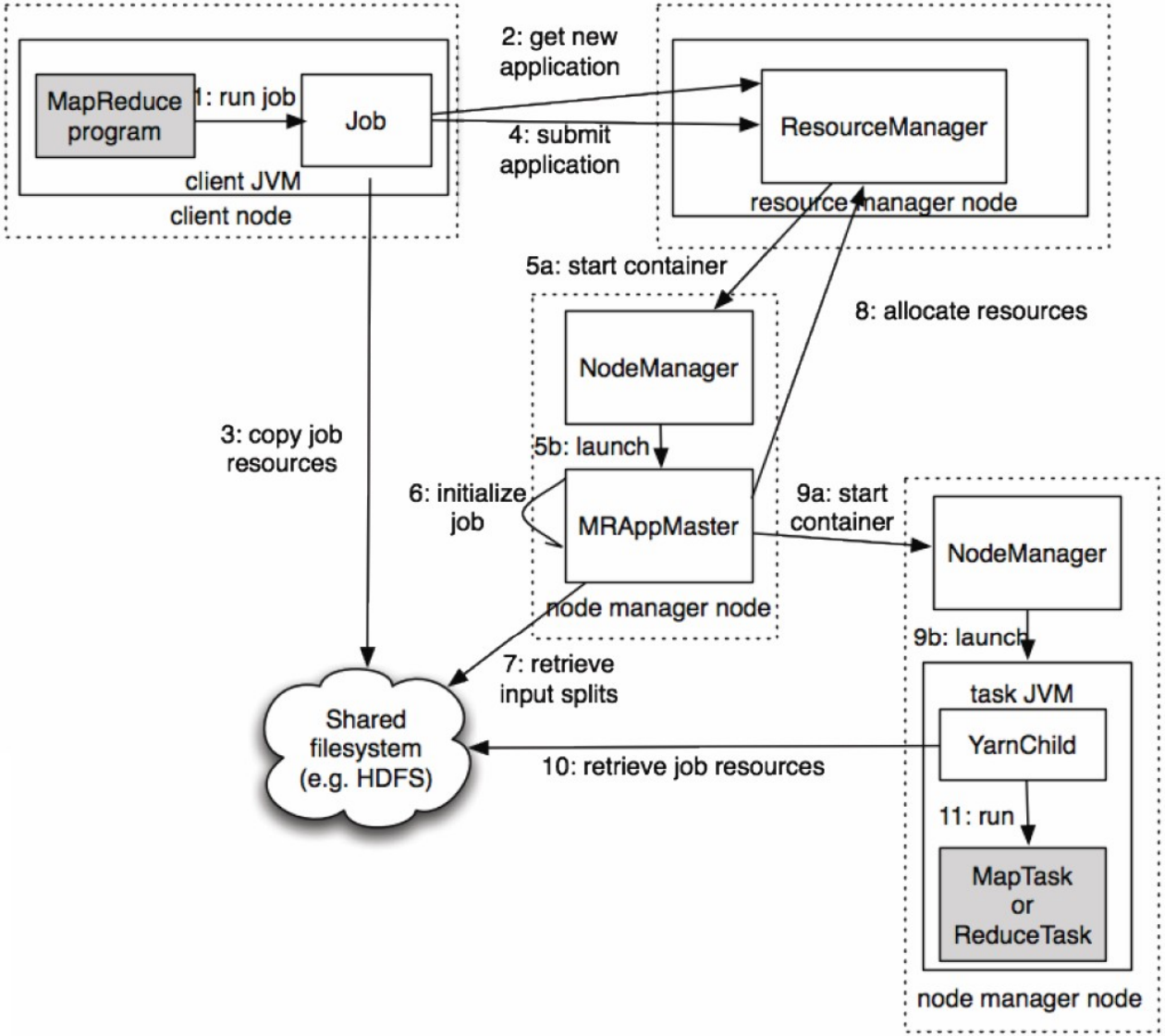
- When the work is completed, the JobTracker updates its status

- Client applications can poll the JobTracker for information

# Job flow (MapReduce v1)



# Job flow (MapReduce v2)



# Hadoop Ecosystem

- Apache Avro (serialization system for persistent data)
- Apache Pig (high-level dataflow querying language)
- Apache Hive (data warehouse infrastructure)

# Hadoop Ecosystem

- Apache HBase (database for real-time access)
- Apache Sqoop (tool for moving data from SQL to Hadoop or opposite)
- Apache ZooKeeper (distributed coordination service providing high availability) – library for building distributed systems

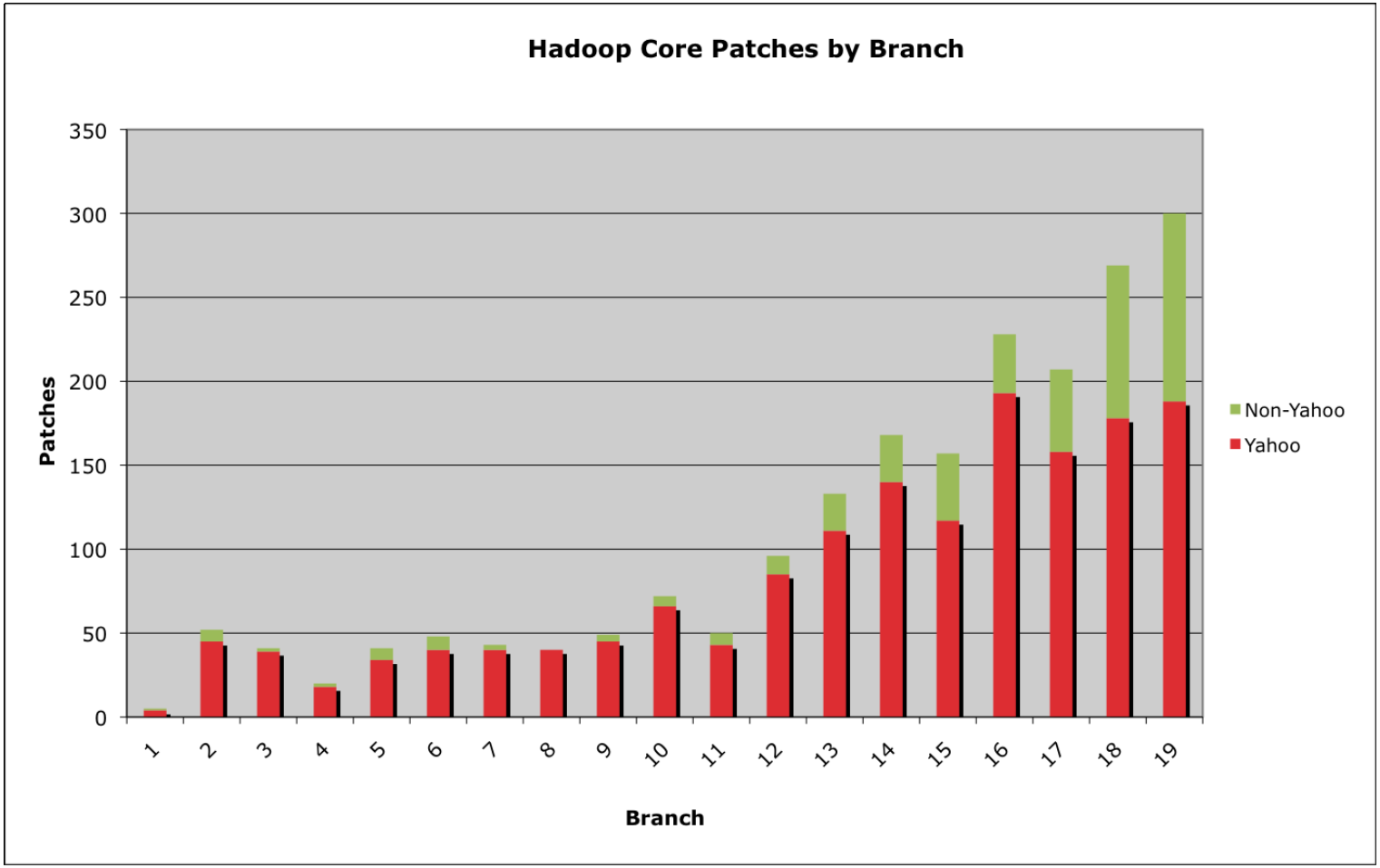
# Hadoop exclusive technologies

- YARN – Yet Another Resource Negotiator
- HDFS federation – possibility of partitioning namespace across several namenodes to support high number of files
- HDFS high-availability – techniques for for removing the namenode as the single point of failure

# Examples of production use

- Yahoo! : More than 100,000 CPUs in ~20,000 computers running Hadoop; biggest cluster: 2000 nodes (2*4cpu boxes with 4TB disk each); used to support research for Ad Systems and Web Search
- Facebook: To store copies of internal log and dimension data sources and use it as a source for reporting/analytics and machine learning; 320 machine cluster with 2,560 cores and about 1.3 PB raw storage

# Size of releases



# Hadoop

+ Framework for applications on large clusters
+ Built for commodity hardware
+ Provides reliability and data motion
+ Implements a computational paradigm named Map/Reduce
+ Very own distributed file system (HDFS) (very high aggregate bandwidth across the cluster)
+ Failures handles automatically

# Hadoop

- Time consuming development
- Documentation sufficient, but not the most helpful
- HDFS is complicated and has plenty issues of its own
- Debugging a failure is a "nightmare"
- Large clusters require a dedicated team to keep it running properly
- Writing a Hadoop job becomes a software engineering task rather than a data analysis task