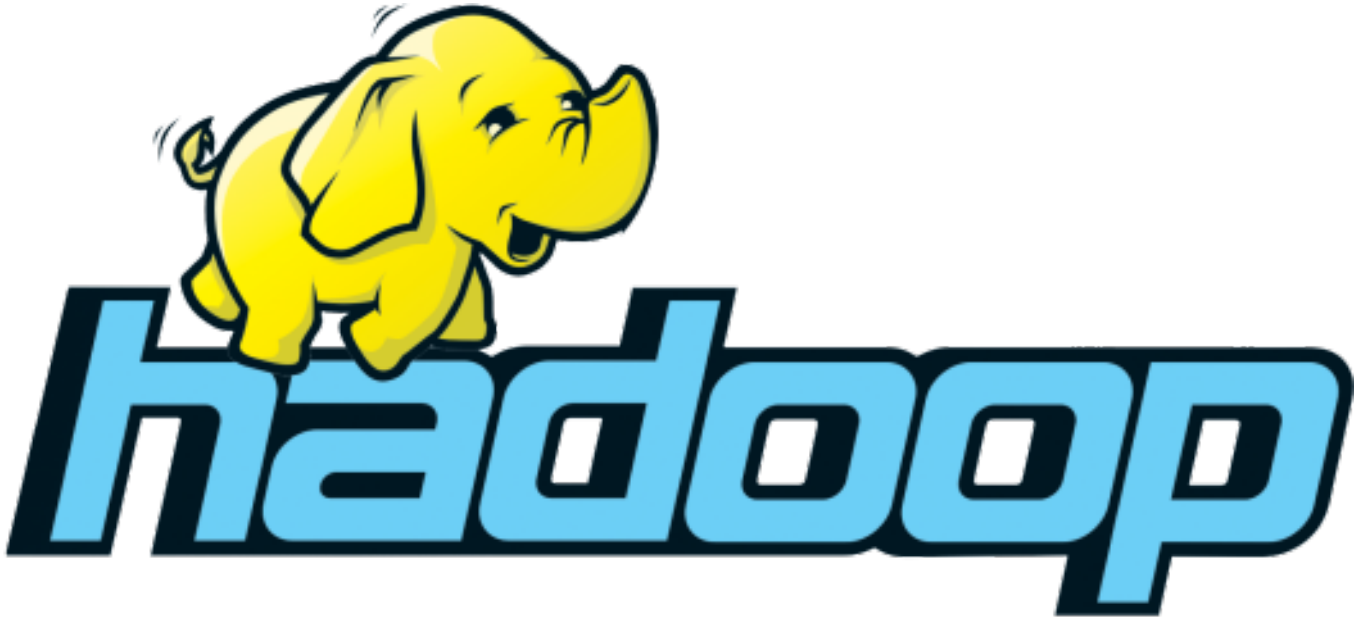

hadoop

What is Apache Hadoop?

- Open source software framework designed for storage and processing of large scale data on clusters of commodity hardware
- Created by Doug Cutting and Mike Carafella in 2005.
- Cutting named the program after his son’s toy elephant.

Uses for Hadoop

- Data-intensive text processing
- Assembly of large genomes
- Graph mining
- Machine learning and data mining
- Large scale social network analysis

Who Uses Hadoop?

The Hadoop Ecosystem

Motivations for Hadoop

- What considerations led to its design

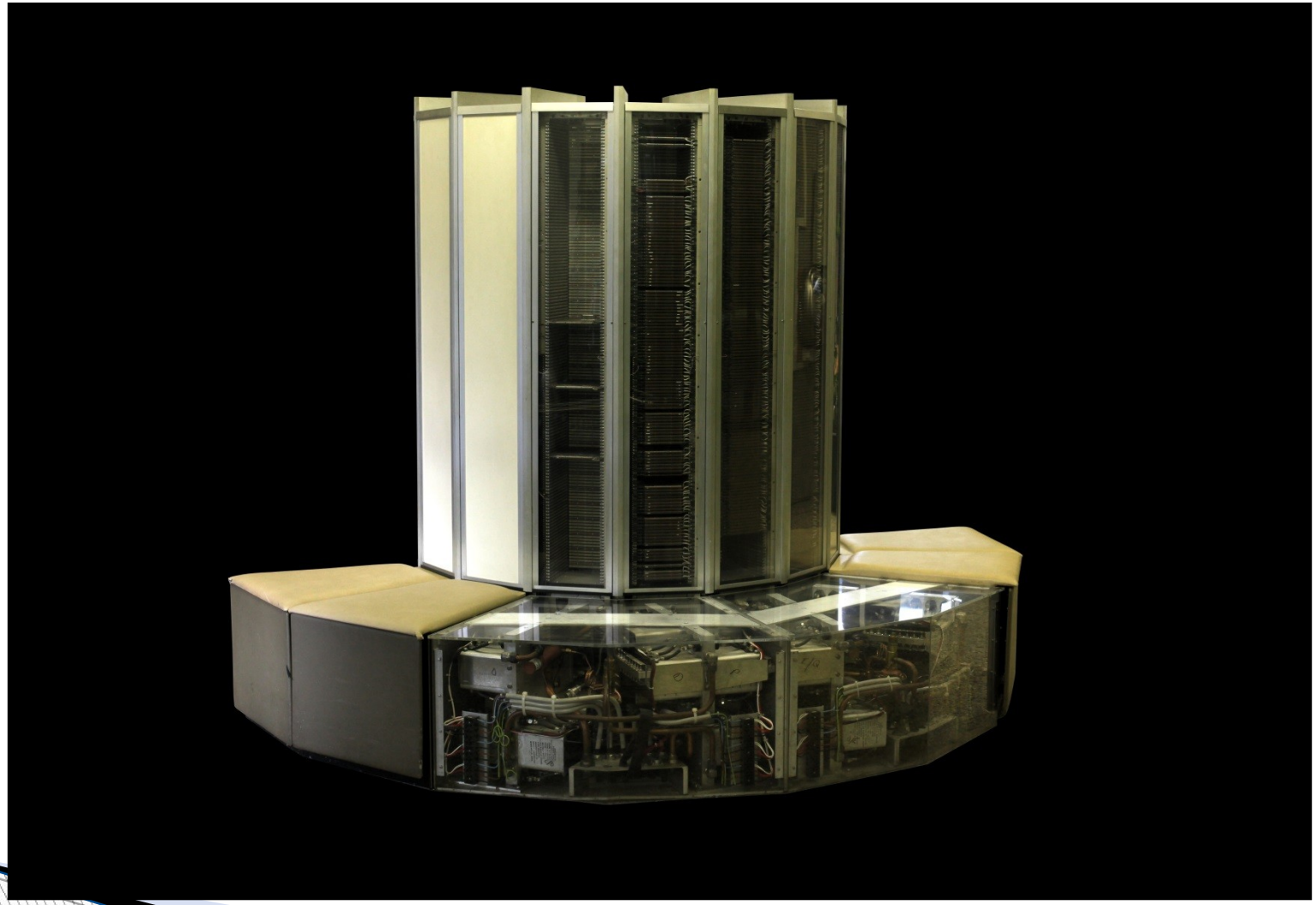
Motivations for Hadoop

- What were the limitations of earlier large-scale computing?
- What requirements should an alternative approach have?
- How does Hadoop address those requirements?

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

Cray-1

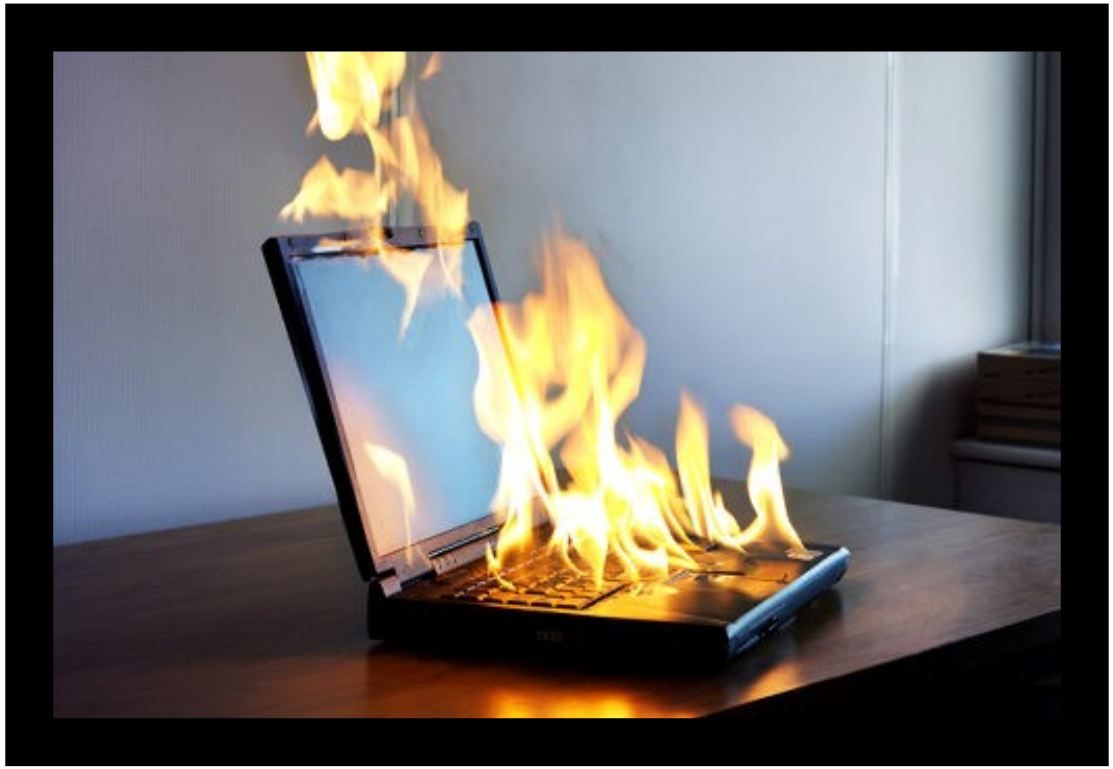


Advances in CPUs

- Moore’s Law
  - The number of transistors on a dense integrated circuit doubles every two years
- Single-core computing can’t scale with current computing needs

Single-Core Limitation

- Power consumption limits the speed increase we get from transistor density



Distributed Systems

- Allows developers to use multiple machines for a single task

Distributed System: Problems

- Programming on a distributed system is much more complex
  - Synchronizing data exchanges
  - Managing a finite bandwidth
  - Controlling computation timing is complicated

Distributed System: Problems

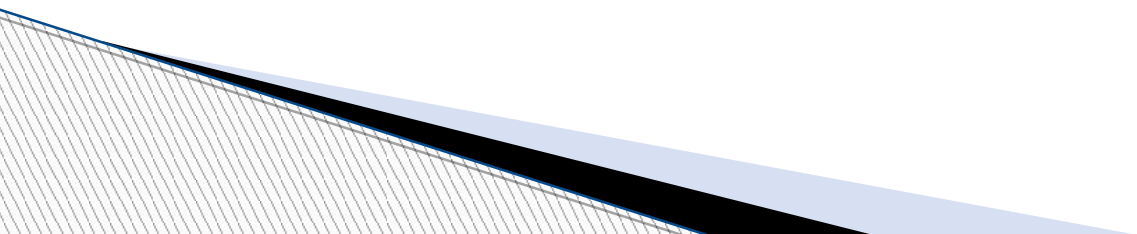
“You know you have a distributed system when the crash of a computer you’ve never heard of stops you from getting any work done.” –Leslie Lamport

- Distributed systems must be designed with the expectation of failure

Distributed System: Data Storage

- Typically divided into Data Nodes and Compute Nodes
- At compute time, data is copied to the Compute Nodes
- Fine for relatively small amounts of data

- Modern systems deal with far more data than was gathering in the past



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

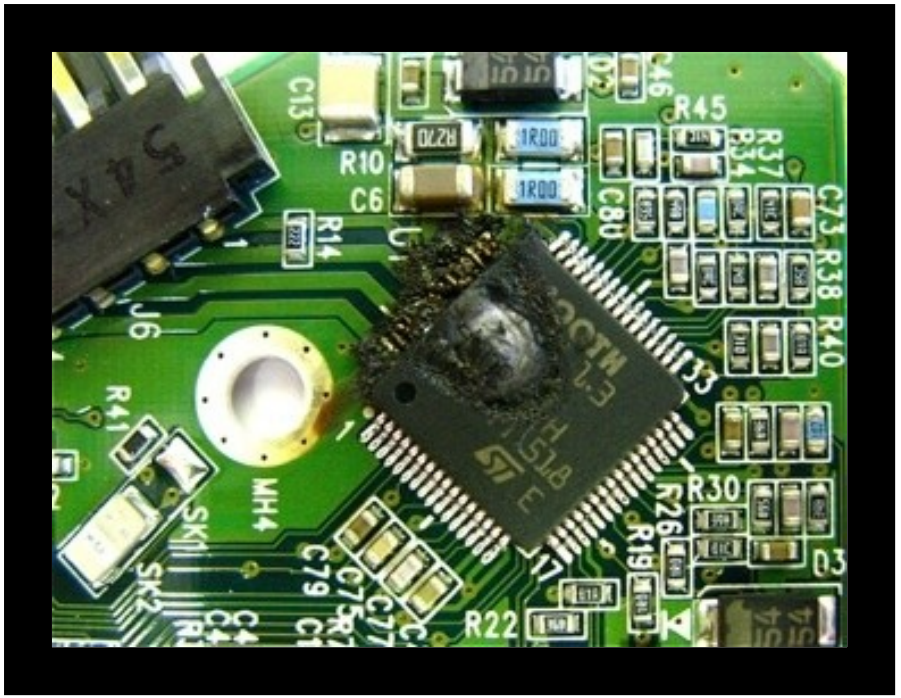
Requirements for Hadoop

- Must support partial failure
- Must be scalable

Partial Failures

- Failure of a single component must not cause the failure of the entire system only a degradation of the application performance

- Failure should not result in the loss of any data



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

Scalability

- Increasing resources should increase load capacity
- Increasing the load on the system should result in a graceful decline in performance for all jobs
  - Not system failure

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

Core Hadoop Concepts

- Applications are written in a high-level programming language
  - No network programming or temporal dependency
- Nodes should communicate as little as possible
  - A “shared nothing” architecture
- Data is spread among the machines in advance
  - Perform computation where the data is already stored as often as possible

High-Level Overview

- When data is loaded onto the system it is divided into blocks
  - Typically 64MB or 128MB
- Tasks are divided into two phases
  - Map tasks which are done on small portions of data where the data is stored
  - Reduce tasks which combine data to produce the final output
- A master program allocates work to individual nodes

Fault Tolerance

- Failures are detected by the master program which reassigns the work to a different node
- Restarting a task does not affect the nodes working on other portions of the data
- If a failed node restarts, it is added back to the system and assigned new tasks
- The master can redundantly execute the same task to avoid slow running nodes

Hadoop Distributed File System

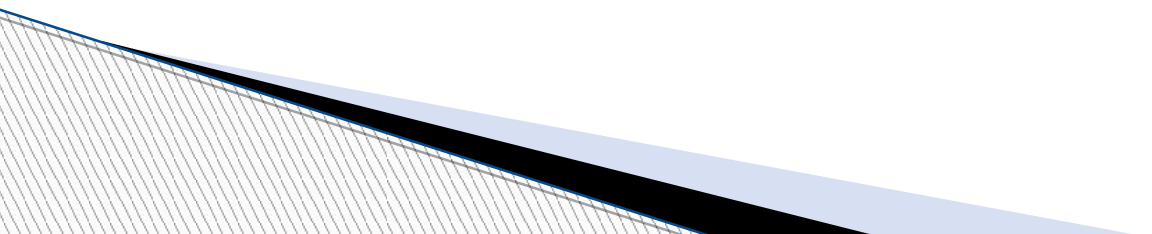
- HDFS

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 Basic Concepts

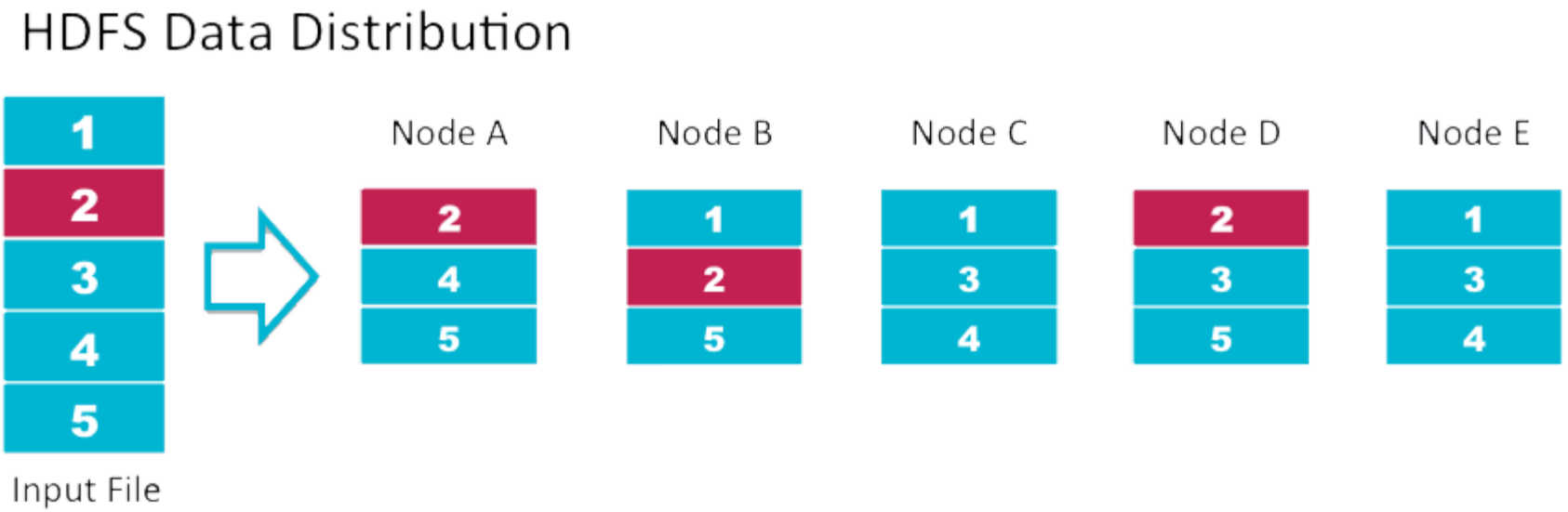
- HDFS works best with a smaller number of large files
  - Millions as opposed to billions of files
  - Typically 100MB or more per file
- Files in HDFS are write once
- Optimized for streaming reads of large files and not random reads

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



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

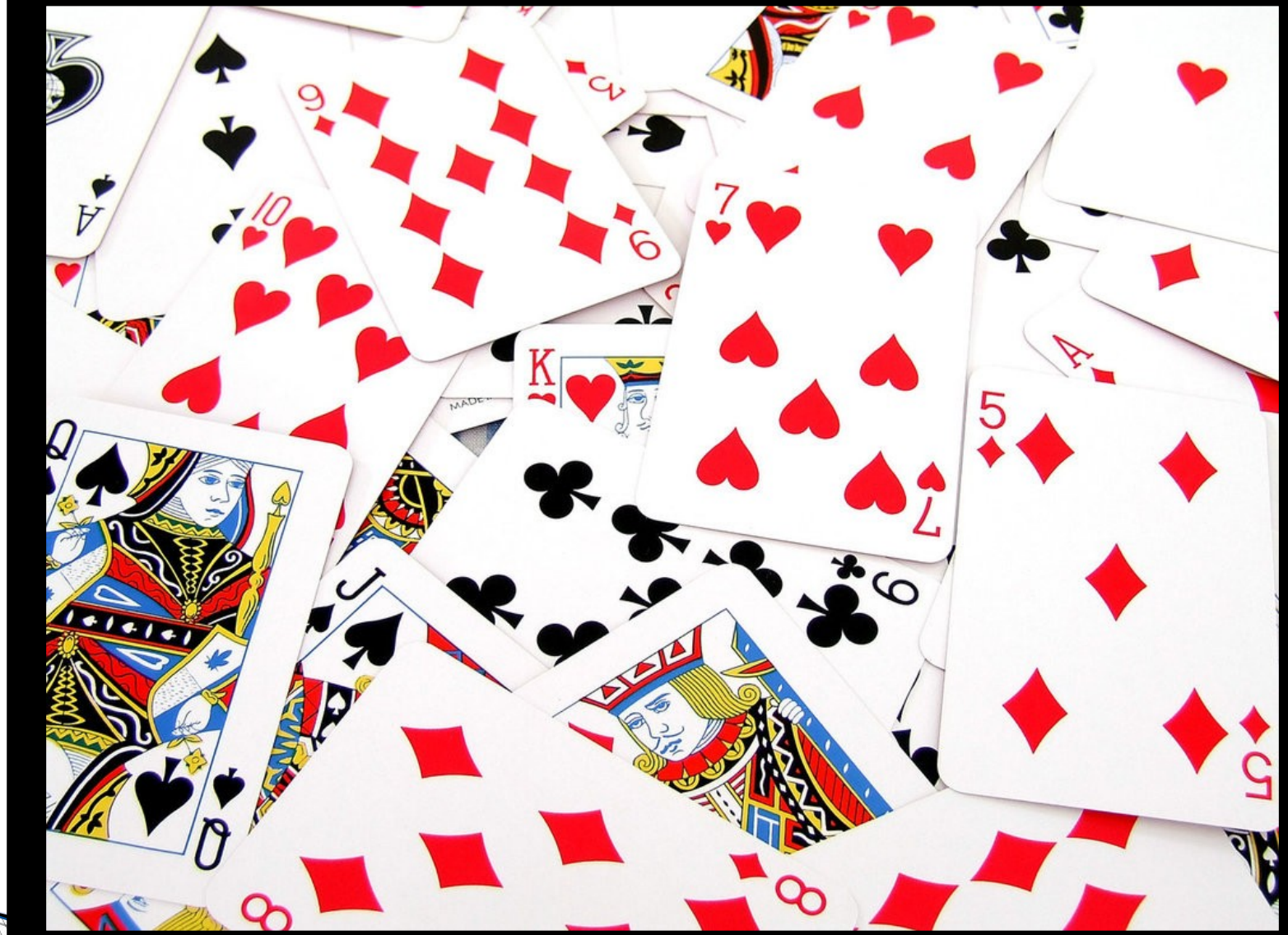
- Distributing computation across nodes

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

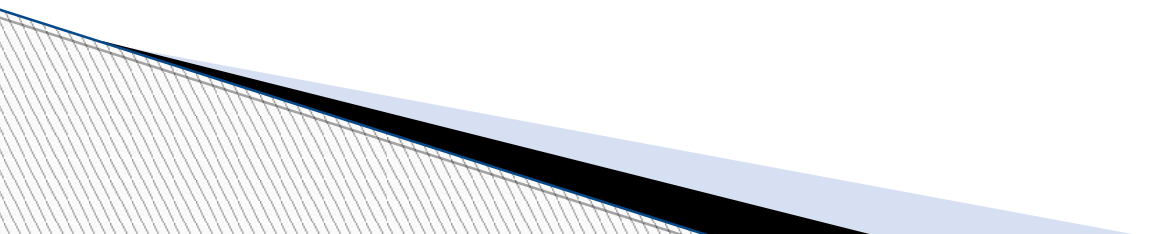


The Mapper

- Reads data as key/value pairs
  - The key is often discarded
- Outputs zero or more key/value pairs

Shuffle and Sort

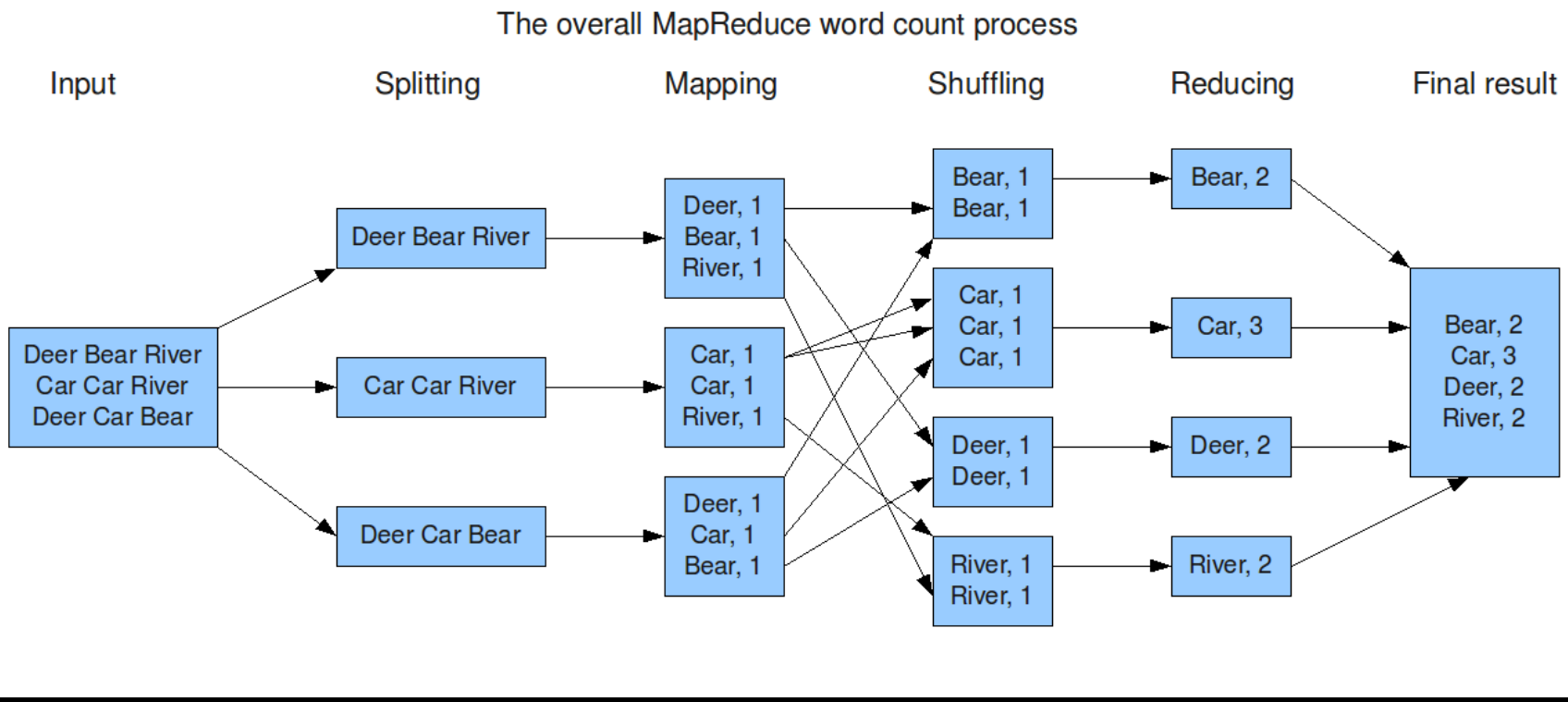
- Output from the mapper is sorted by key
- All values with the same key are guaranteed to go to the same machine



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



Anatomy of a Cluster

- What parts actually make up a Hadoop cluster

Overview

- 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

The NameNode

- Stores the HDFS file system information in a fsimage
- Updates to the file system (add/remove blocks) do not change the fsimage file
  - They are instead written to a log file
- When starting the NameNode loads the fsimage file and then applies the changes in the log file

The Secondary NameNode

- **NOT** a backup for the NameNode
- Periodically reads the log file and applies the changes to the fsimage file bringing it up to date
- Allows the NameNode to restart faster when required

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

Hadoop Ecosystem

- Other available tools

Why do these tools exist?

- MapReduce is very powerful, but can be awkward to master
- These tools allow programmers who are familiar with other programming styles to take advantage of the power of MapReduce

Other Tools

- Hive
  - Hadoop processing with SQL
- Pig
  - Hadoop processing with scripting
- Cascading
  - Pipe and Filter processing model
- HBase
  - Database model built on top of Hadoop
- Flume
  - Designed for large scale data movement