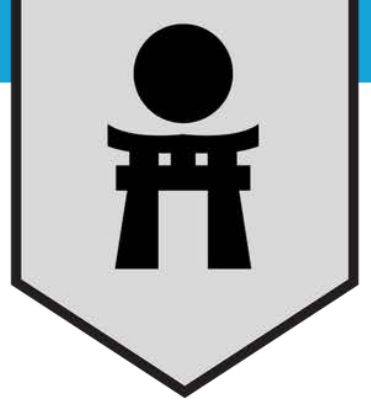


Data Science Dojo

Big Data Engineering with Distributed Systems

datasciencedojo
data science for everyone

Agenda

- **Introduction:**
  - Data engineering for data scientists
  - The "5 Vs" of Big Data
- **A key problem – machine learning at scale**
- **Distributed computing with Apache Hadoop & Hive**
- **Hadoop in the Azure cloud**
- **Machine learning at scale with Apache Mahout**
- **Distributed computing v2.0 – Apache Spark**

Data Engineering for Data Scientists

Driving a car

vs

Servicing a car

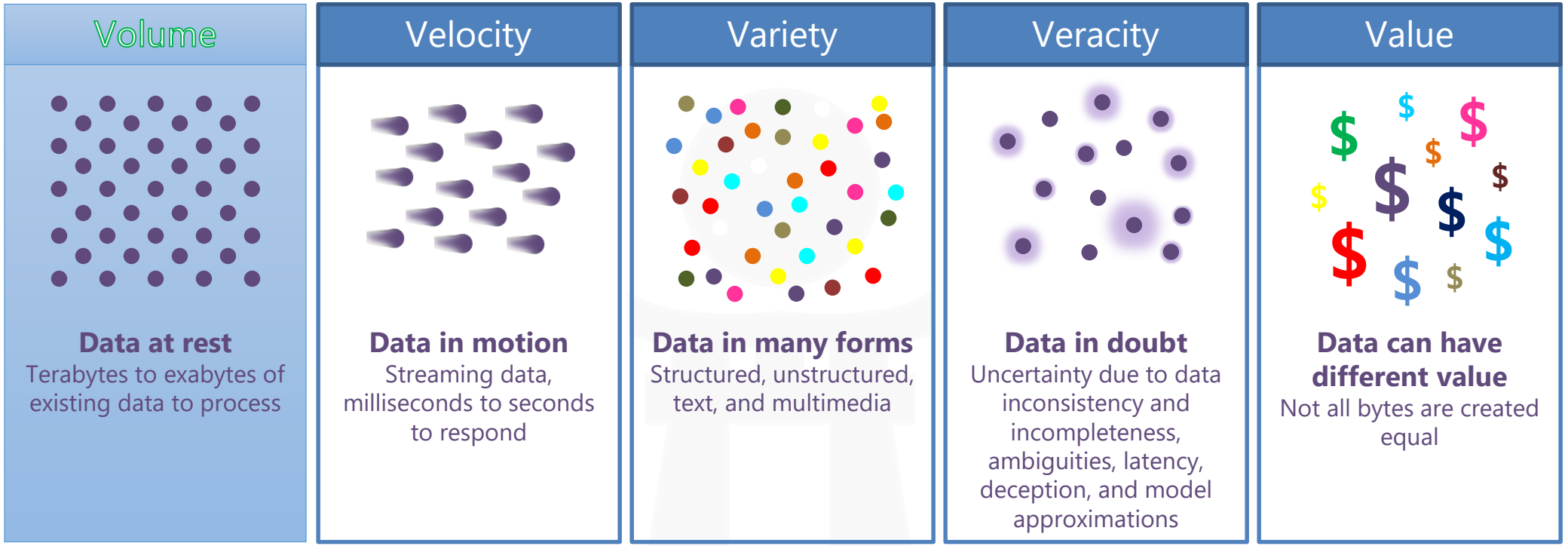
Goals:

- Teach you about data engineering topics/concepts

Non goals:

- Managing or administering a Hadoop cluster

5 Vs of Big Data

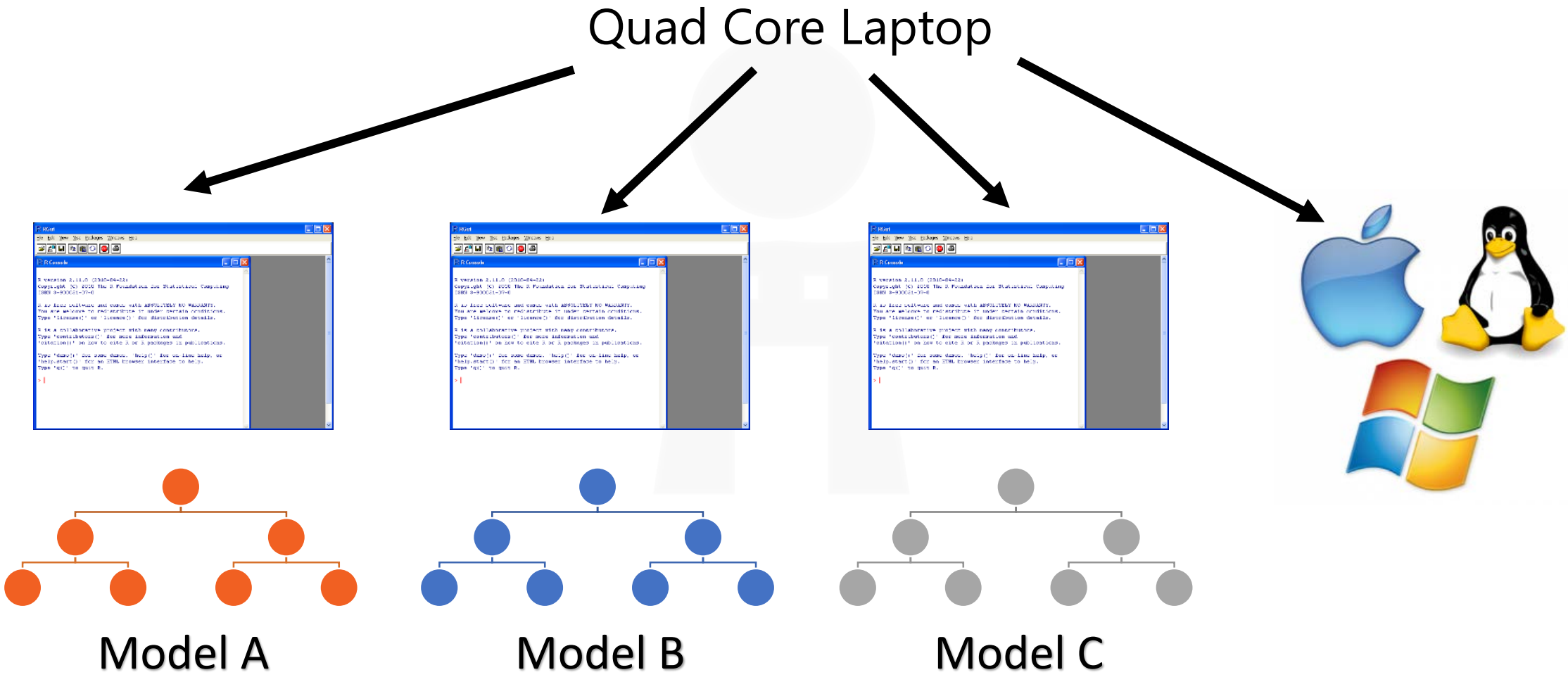


- **Goal:** As data scientists we want cost-effective access to the raw materials for our data products!

MACHINE LEARNING AT SCALE

OSS R Limits

- Single core
- Single threaded



OSS R Limits

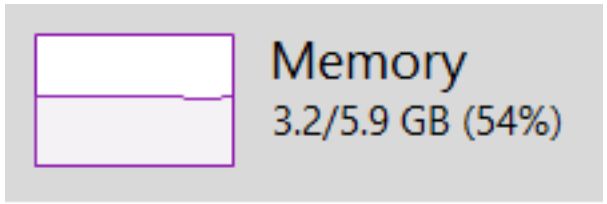
- Single core
- Single threaded
- All in memory (RAM)
- Vectors & Matrices capped at 4,294,967,295 elements (rows) if 32-bit version; 2^32 - 1

OSS R Limits: RAM

- All in memory (RAM)

$$Max\ Data\ Limit = (\ Total\ RAM\ Access\ x\ 80\%) - Normal\ RAM\ Usage$$

Laptop Example:



$$Max\ Data\ Limit = (\ 5.9\ gb\ x\ 80\%)\ - 3.2\text{gb}$$
$$Max\ Data\ Limit = \sim 1.52gb$$

*R data frames actually bloats data files by ~3x

$$R\ Data\ Limit = \sim 1.52gb\ \div 3 = \sim 506.7mb$$

OSS R Limits: RAM

INSTANCE	CORES	RAM	DISK SIZES [1]	PRICE
M64MS	64	1,750.00 GiB	**2,000** GB	$10.34/hr
M128S	128	2,000.00 GiB	**4,000** GB	$13.34/hr

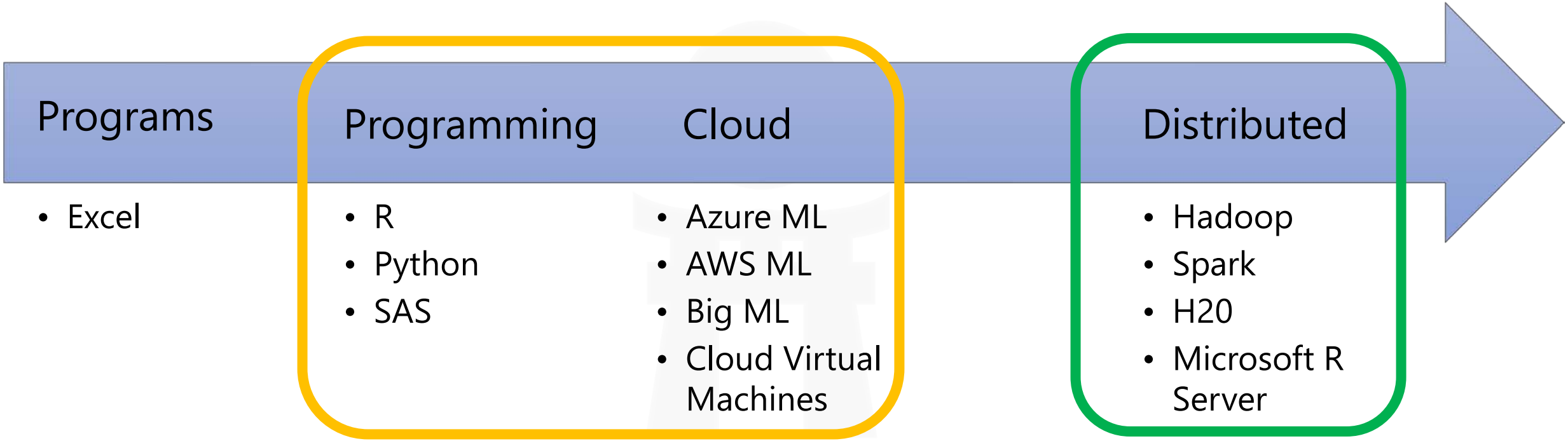
Azure's VM with largest RAM*:

$$Max\ Data\ Limit = (\ 2000gb\ x\ 80\%\ ) - 1gb$$
$$Max\ Data\ Limit = \sim 1600gb$$
$$R\ Data\ Limit = \sim 1600gb\ \div 3 = \sim 533.33\ gb$$

24x7x52 Annual Cost: $116,938.44!

*Data collected 06/07/2017

Machine Learning Scaling



This only gets us so far!

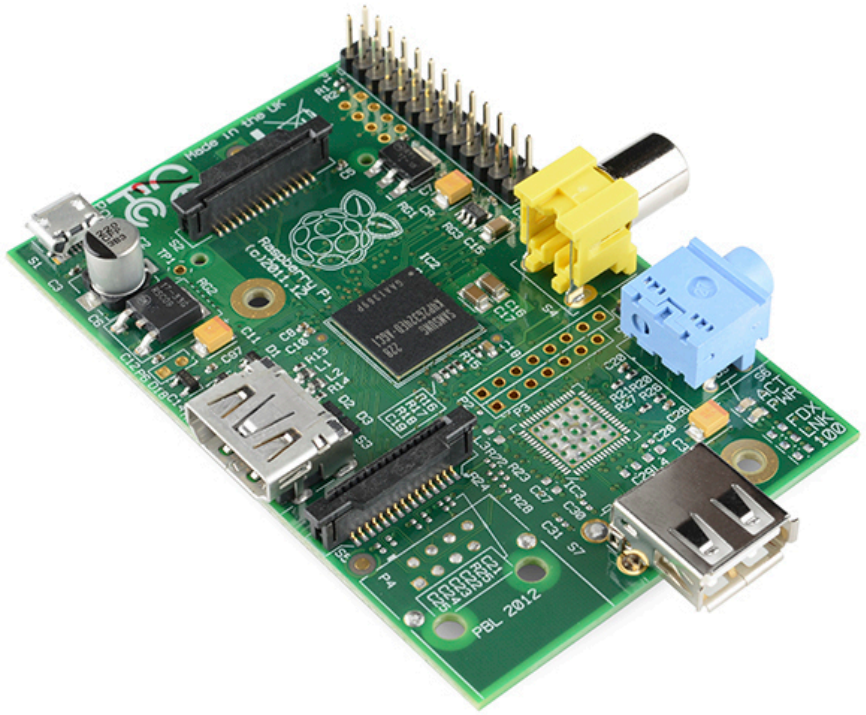
Big data scale!

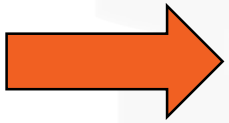
DISTRIBUTED COMPUTING WITH APACHE HADOOP

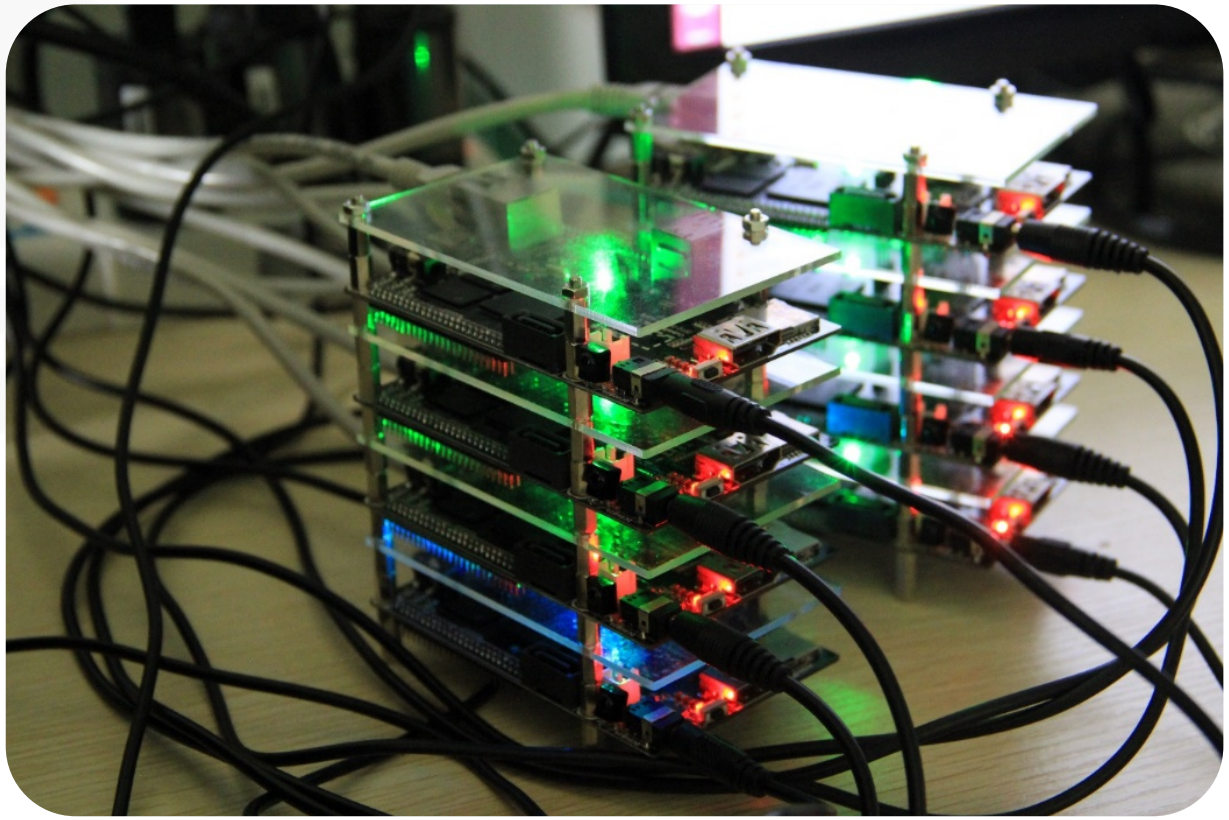
Turn Back The Clock, The Mainframe

- “Big Iron”
- Backbone of computing for decades.
- Still widely used.
- “Scale-up” model of shared computing.
- Core platform is cost effective, ecosystem is not (e.g., software licensing).
- The original VM host!

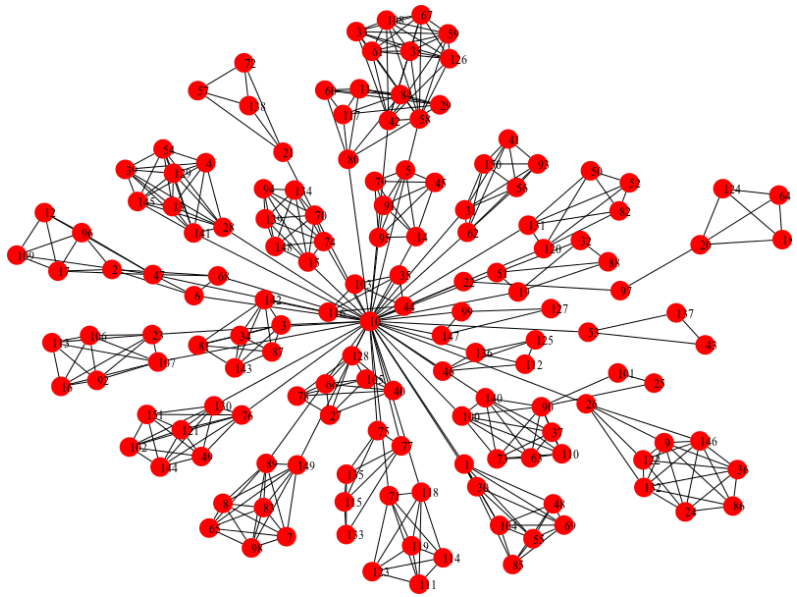
Distributed Computing





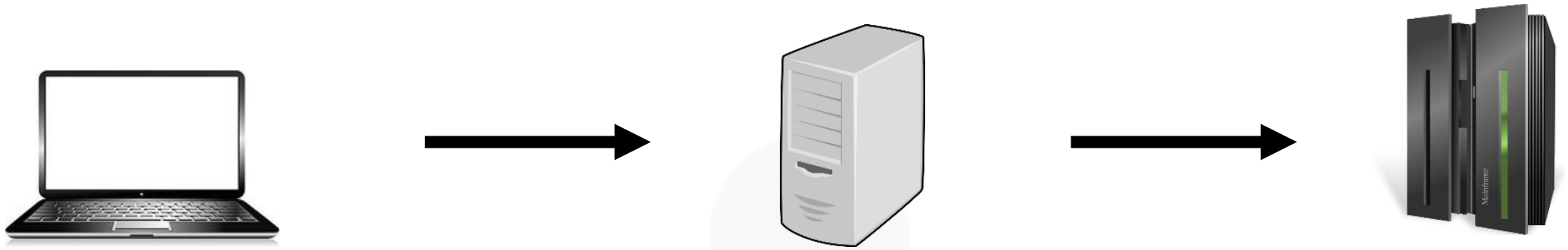


Cloud Computing



- Conceptually – a combination of mainframe and distributed computing.
- VM hosts are now the “Big Iron”.
- Many VMs work together to distribute workloads.
- Some workloads on dedicated HW (e.g., SAP HANA).

Scaling Computational Power



Old Scaling:

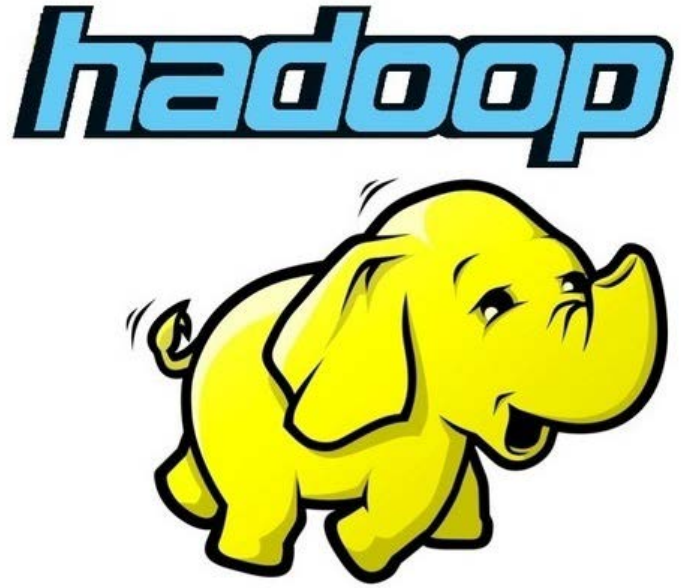
- Vertical Scaling, Scaling UP
- High performance computers

New Scaling:

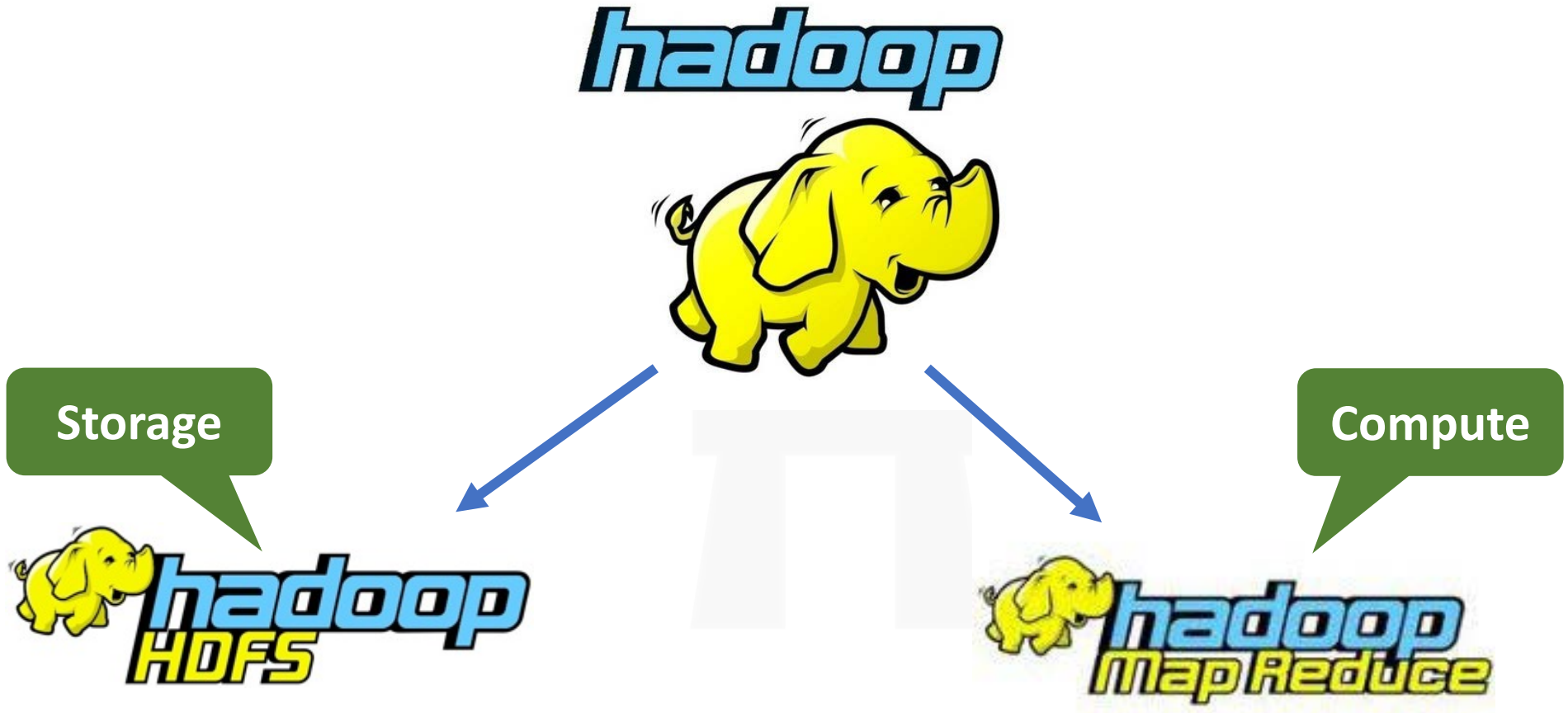
- Horizontal Scaling, Scaling OUT
- Commodity hardware, distributed

What is Hadoop?

- OSS Platform for distributed computing over Internet-scale data.
- Originally built at Yahoo!
- Implementation of ideas (e.g., MapReduce) published by Google.
- The de facto standard big data platform.
- Named after a stuffed animal belonging to Doug Cutting's son.



Hadoop at Base



Distributed batch processing engine for big data.

HDFS & MapReduce

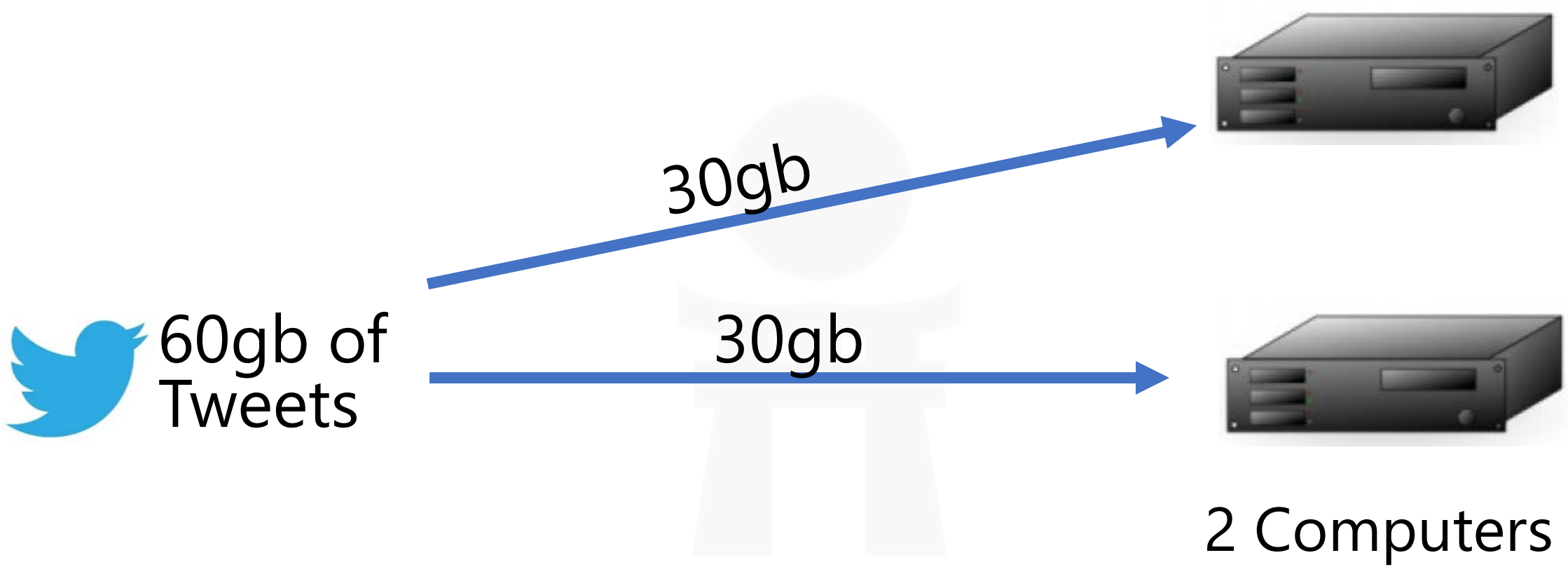
60gb of Tweets

60gb

1 Computer

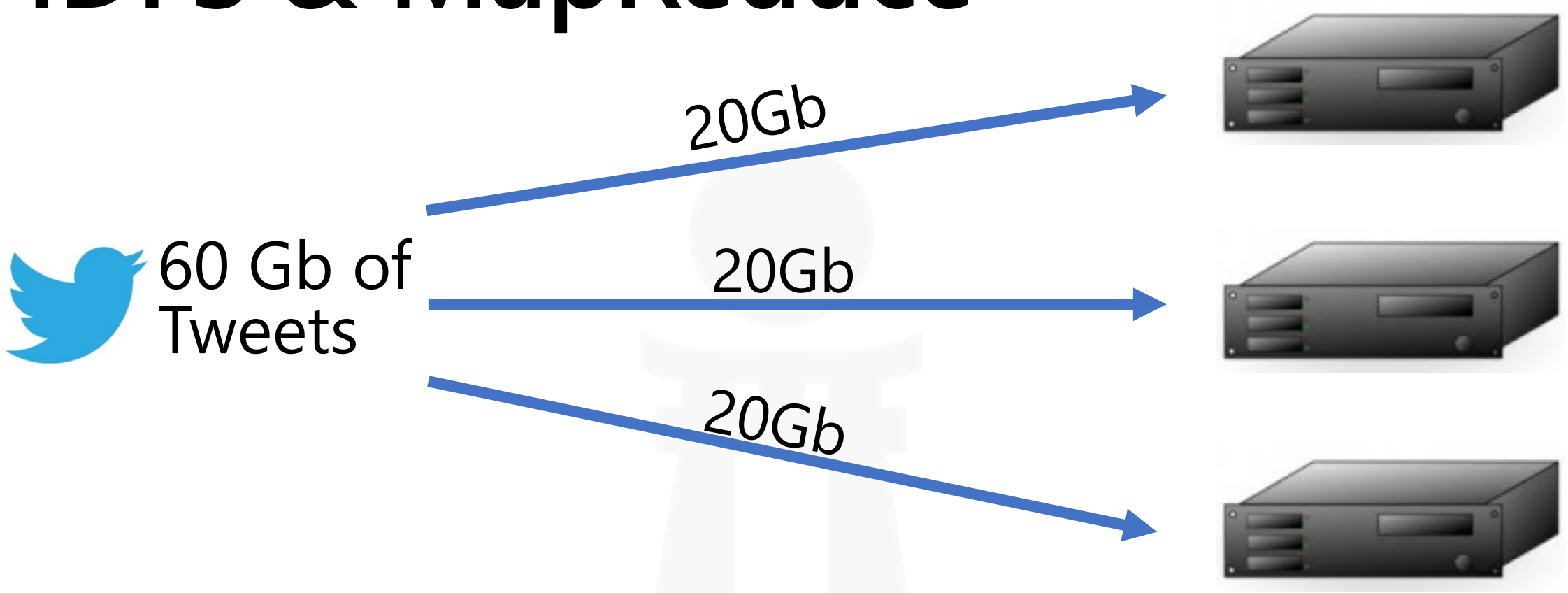
Processing: 30 hours

HDFS & MapReduce



Processing: 15 hours

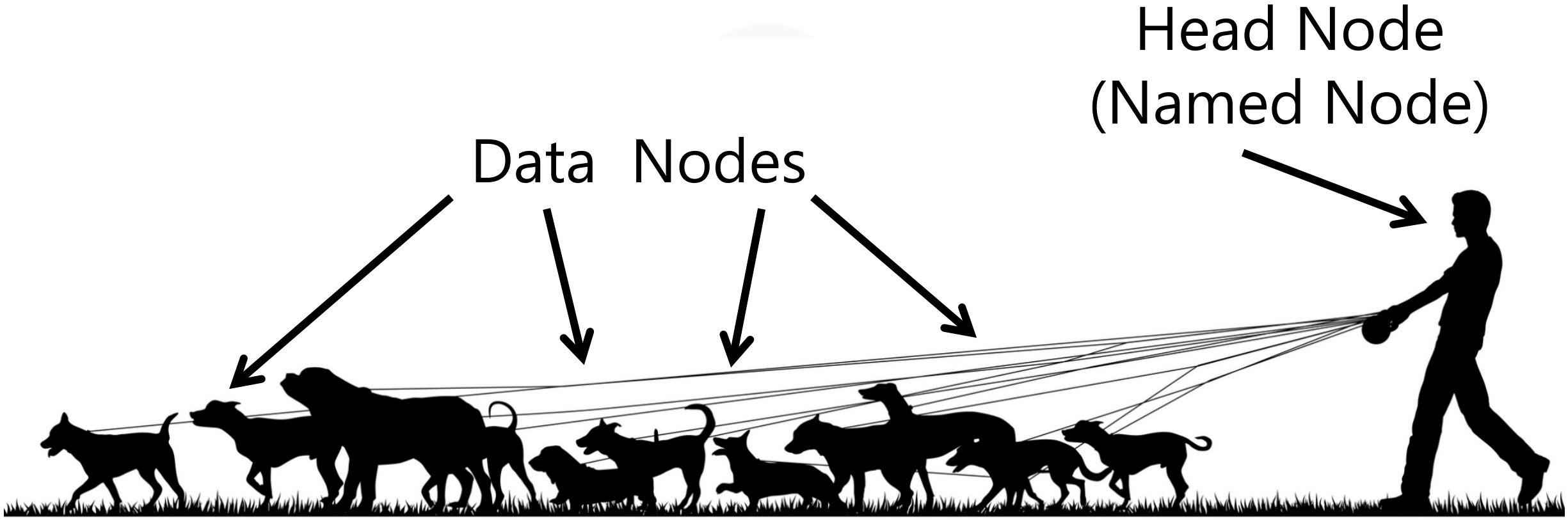
HDFS & MapReduce



Most Cases, Linear Scaling Of Processing Power

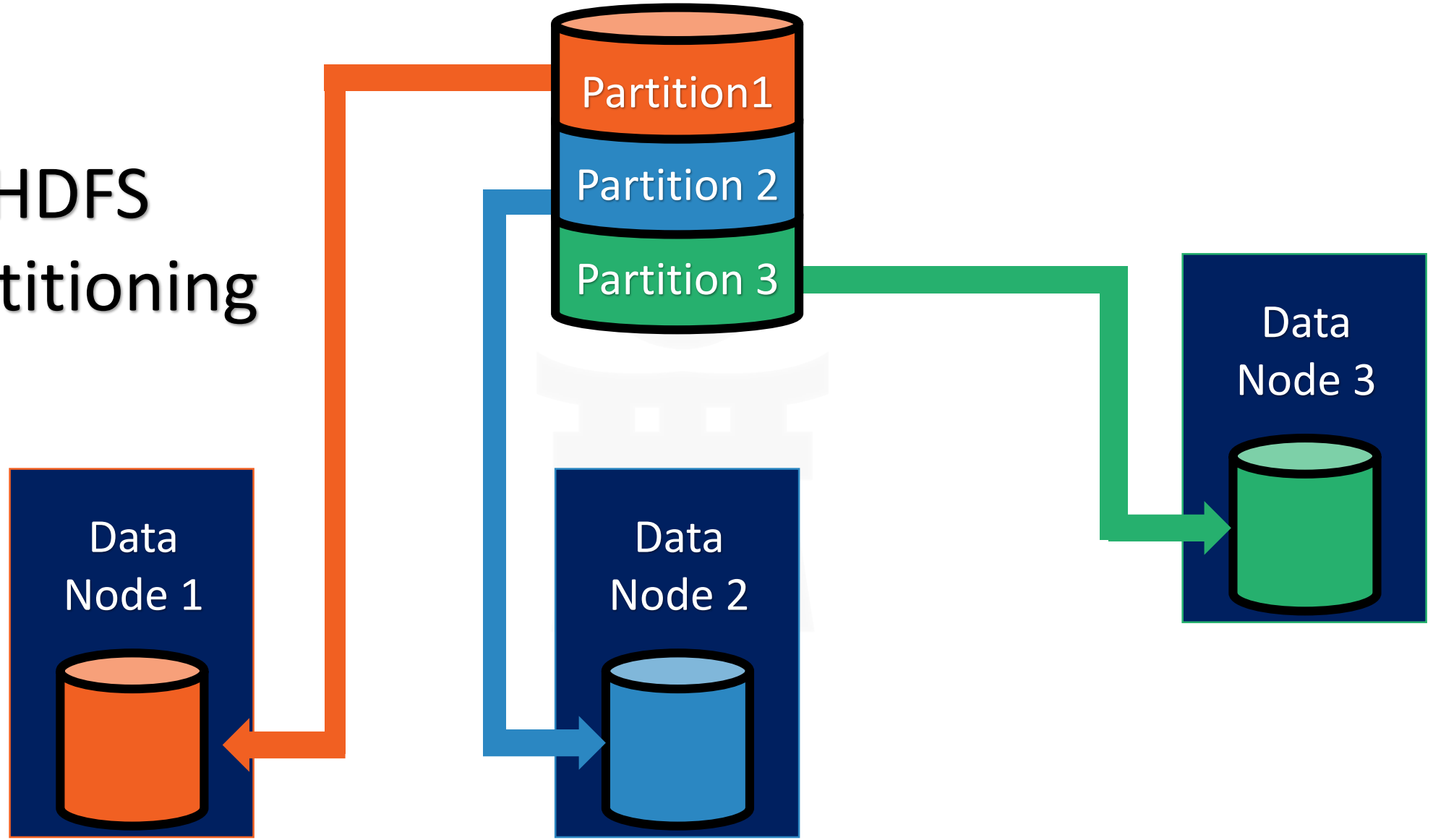
Number of Computers	Processing Time (hours)
1	30
2	15
3	10
4	7.5
5	6
6	5
7	4.26
8	3.75
9	3.33

If dogs were servers…

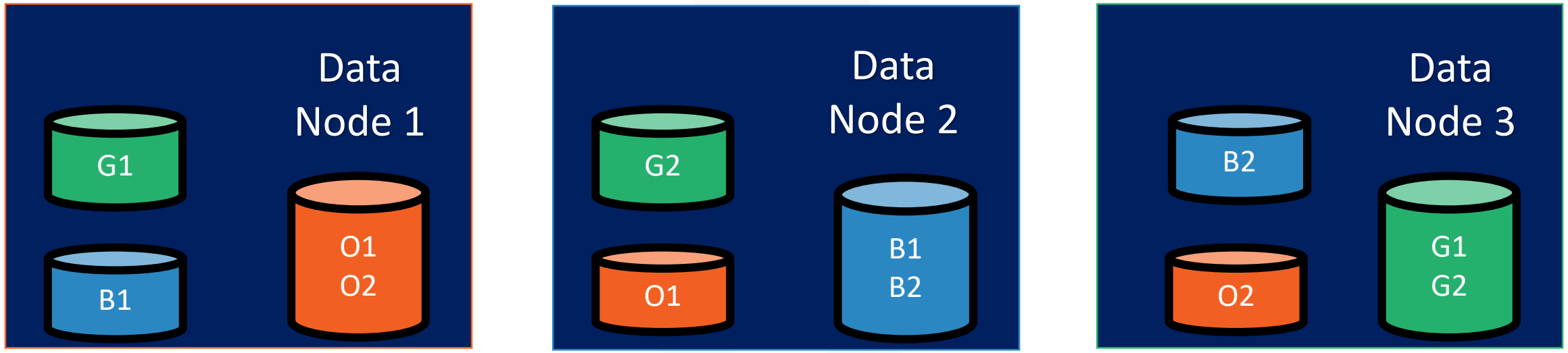


HDFS

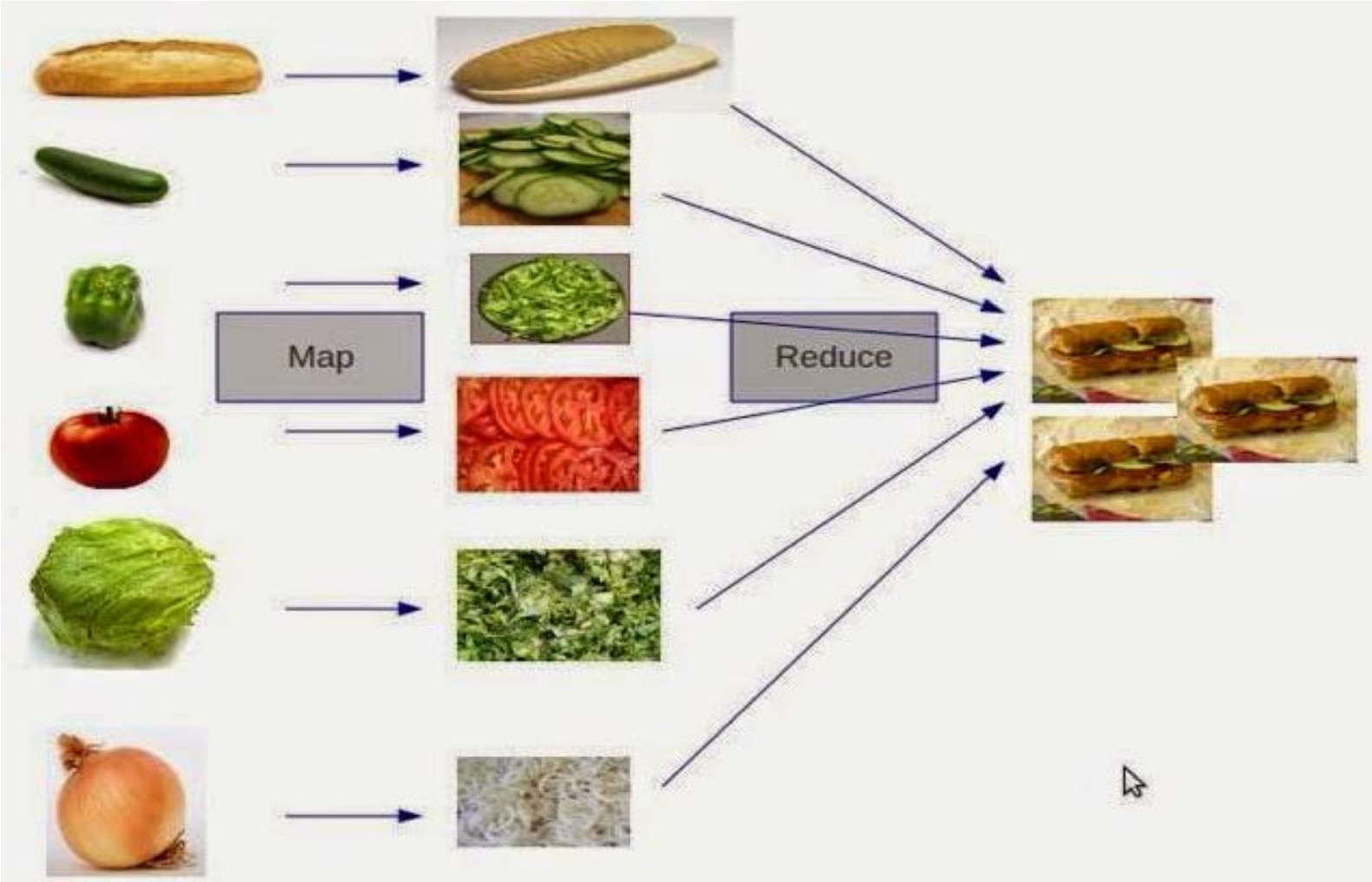
HDFS Partitioning



HDFS Redundancy



MapReduce – Sandwich Analogy



Limitations with MapReduce

- Lot of code to perform the simplest task
- Slow
- Troubleshooting multiple computers
- Good devs are scarce
- Expensive certifications

```java
package org.apache.hadoop.examples;

import java.io.IOException;
import java.util.StringTokenizer;

import org.apache.hadoop.conf.Configuration;
import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Job;
import org.apache.hadoop.mapreduce.Mapper;
import org.apache.hadoop.mapreduce.Reducer;
import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;
import org.apache.hadoop.mapreduce.lib.output.FileOutputFormat;
import org.apache.hadoop.util.GenericOptionsParser;

public class WordCount {

  public static class TokenizerMapper
       extends Mapper<Object, Text, Text, IntWritable>{

    private final static IntWritable one = new IntWritable(1);
    private Text word = new Text();

    public void map(Object key, Text value, Context context
                    ) throws IOException, InterruptedException {
      StringTokenizer itr = new StringTokenizer(value.toString());
      while (itr.hasMoreTokens()) {
        word.set(itr.nextToken());
        context.write(word, one);
      }
    }
```

DISTRIBUTED COMPUTING WITH APACHE HIVE

What is Hive?

- Abstraction built on top of MapReduce & HDFS.
- Makes Hadoop look like an RDBMS (e.g., coding in SQL).
- Developed by Facebook to democratize Hadoop.
- Applies structure to data at runtime ("schema on read").

Hive Jobs

Word Count Revisited

```java
package org.apache.hadoop.examples;

import java.io.IOException;
import java.util.StringTokenizer;

import org.apache.hadoop.conf.Configuration;
import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapreduce.Job;
import org.apache.hadoop.mapreduce.Mapper;
import org.apache.hadoop.mapreduce.Reducer;
import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;
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      StringTokenizer itr = new StringTokenizer(value.toString());
      while (itr.hasMoreTokens()) {
        word.set(itr.nextToken());
        context.write(word, one);
      }
    }
  }
```

vs.

```sql
SELECT word,
       COUNT(*) AS word_count
FROM words
GROUP BY word;
```

Caution:

SELECT * FROM ANYTHING: This brings back everything. Everything doesn't fit on a single computer.

JOIN: Join will take hours or days to perform and eat up all cluster bandwidth for everyone else trying to use it in the queue.

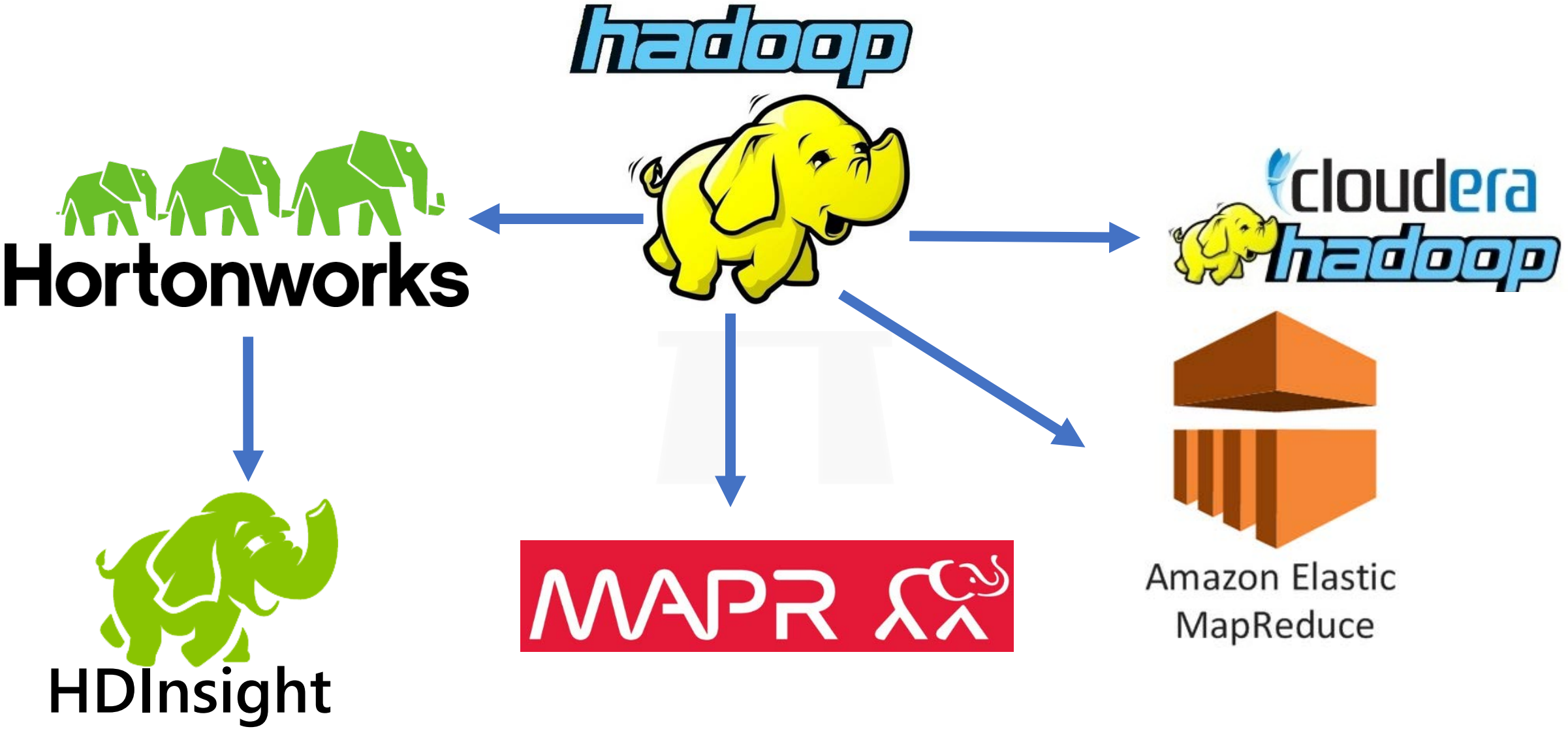
ORDER BY: Sorting is very computationally expensive.

Sub Queries: A sub query essentially creates a secondary table, which will be huge in HIVE.

Interactivity: SQL in DBMS is interactive because it's almost instantaneous.

HADOOP IN THE AZURE CLOUD

Hadoop Implementations



Hadoop in Azure

HDInsight

Compute

HDFS

Azure Data Lake Store

Blob Storage

Storage

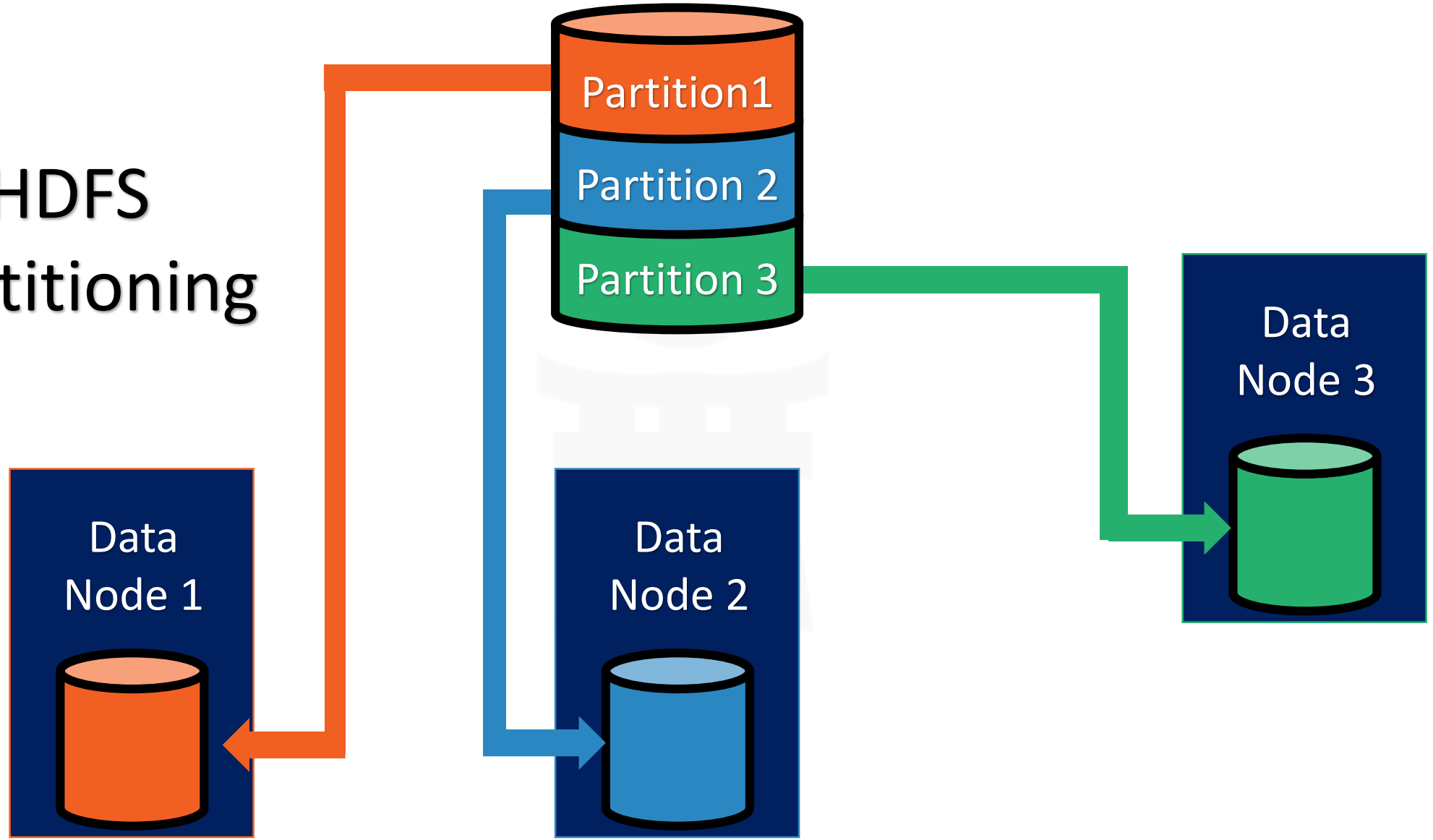
MACHINE LEARNING AT SCALE - REVISITED

What is Mahout?

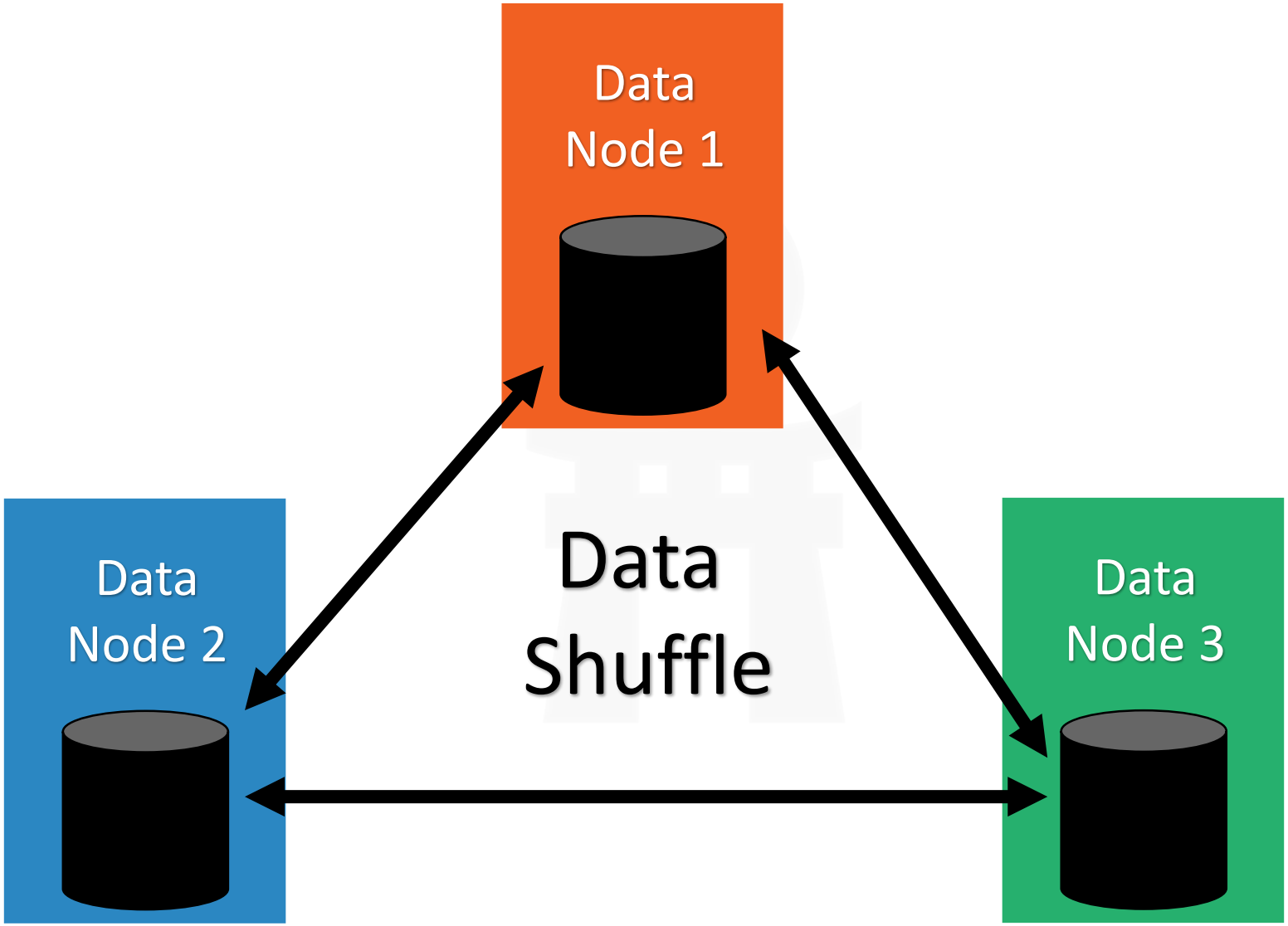
- Distributed Machine Learning platform.
- Built on top of MapReduce and HDFS.
- Script-based and command line interfaces.
- R-like language implementation.

Distributed Random Forest

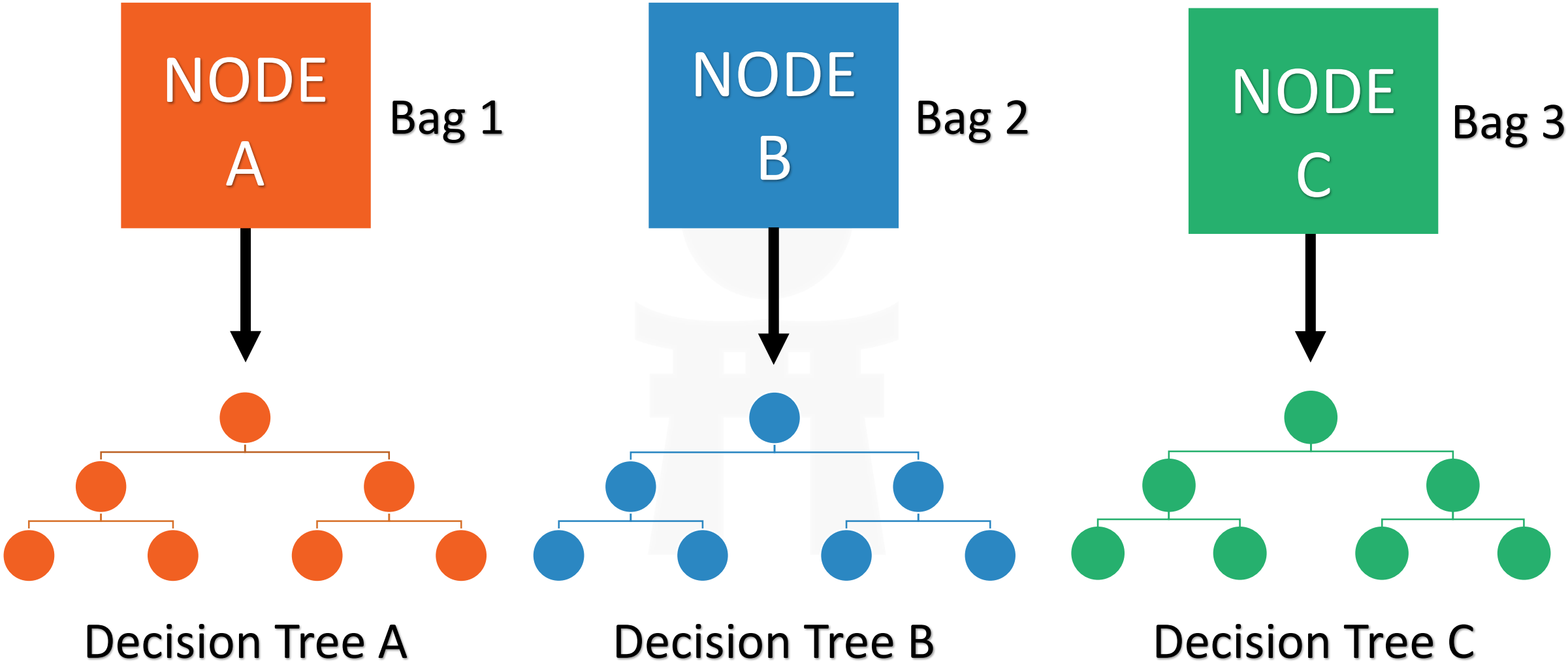
HDFS Partitioning



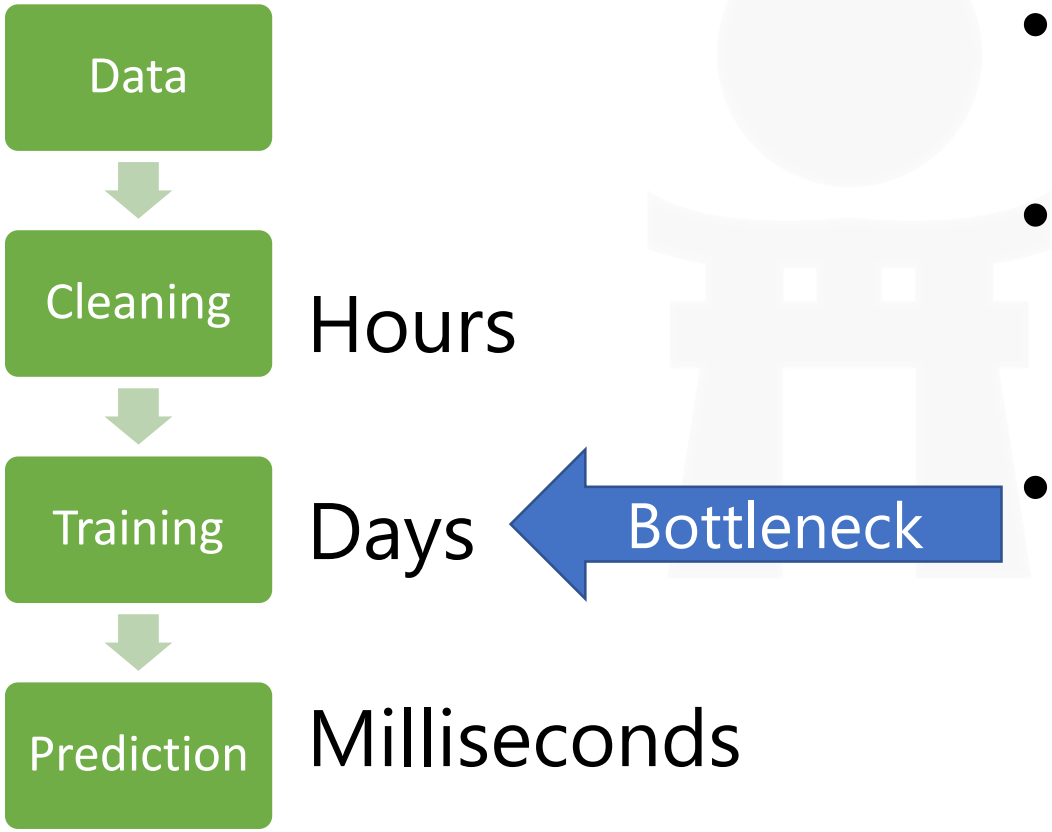
Distributed Random Forest



Distributed Random Forest



Processing Times - Machine Learning



- Large scale systems are only needed for training
- Phones can use models outputted by mahout to predict new data
- After a model is trained, save the model to any IO file type and reload it where you want

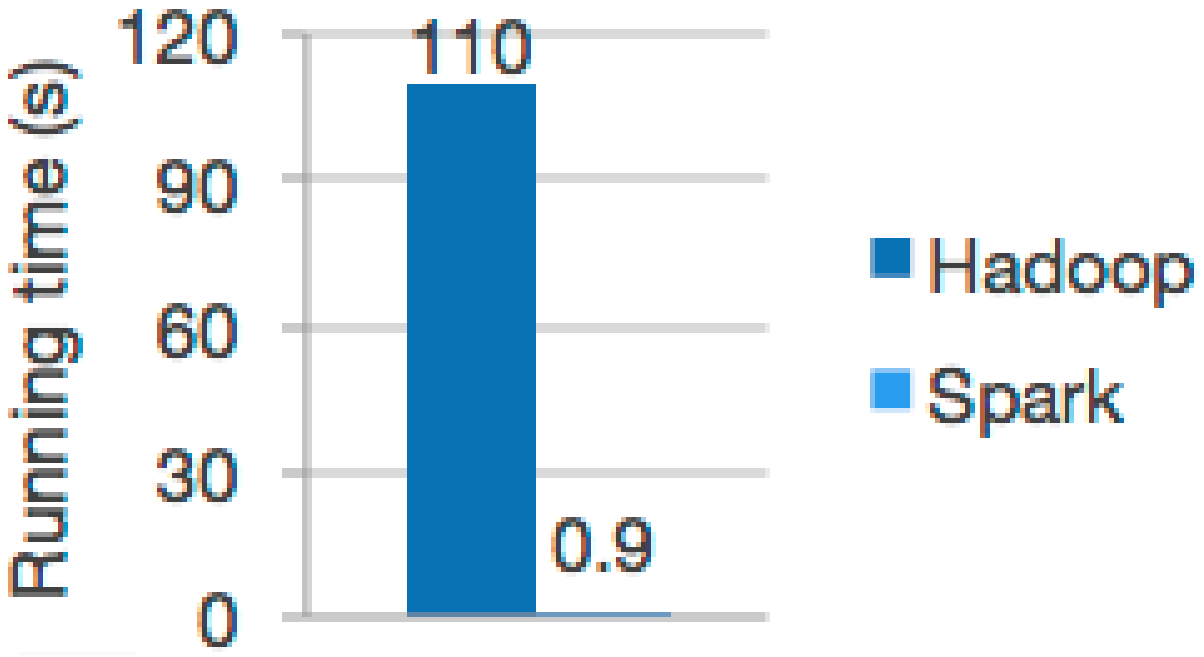
DISTRIBUTED COMPUTING V2.0 – APACHE SPARK

What is Spark?

- "A fast and general engine for large-scale data processing."
- Designed to incorporate the goodness of Hadoop and address Hadoop's shortcomings.
- Can complement Hadoop via integration with both HDFS and Hive.

Why Spark? Improved Perf!

- Up to 10x faster than Hadoop working with data from disk.*
- Up to 100x faster working with data stored in memory!*



* benchmark is without Apache Yarn

Big Data, Faster!

3x faster on 10x fewer machines!

Daytona GraySort Contest: Sort 100 TB of data!

Previous World Record:

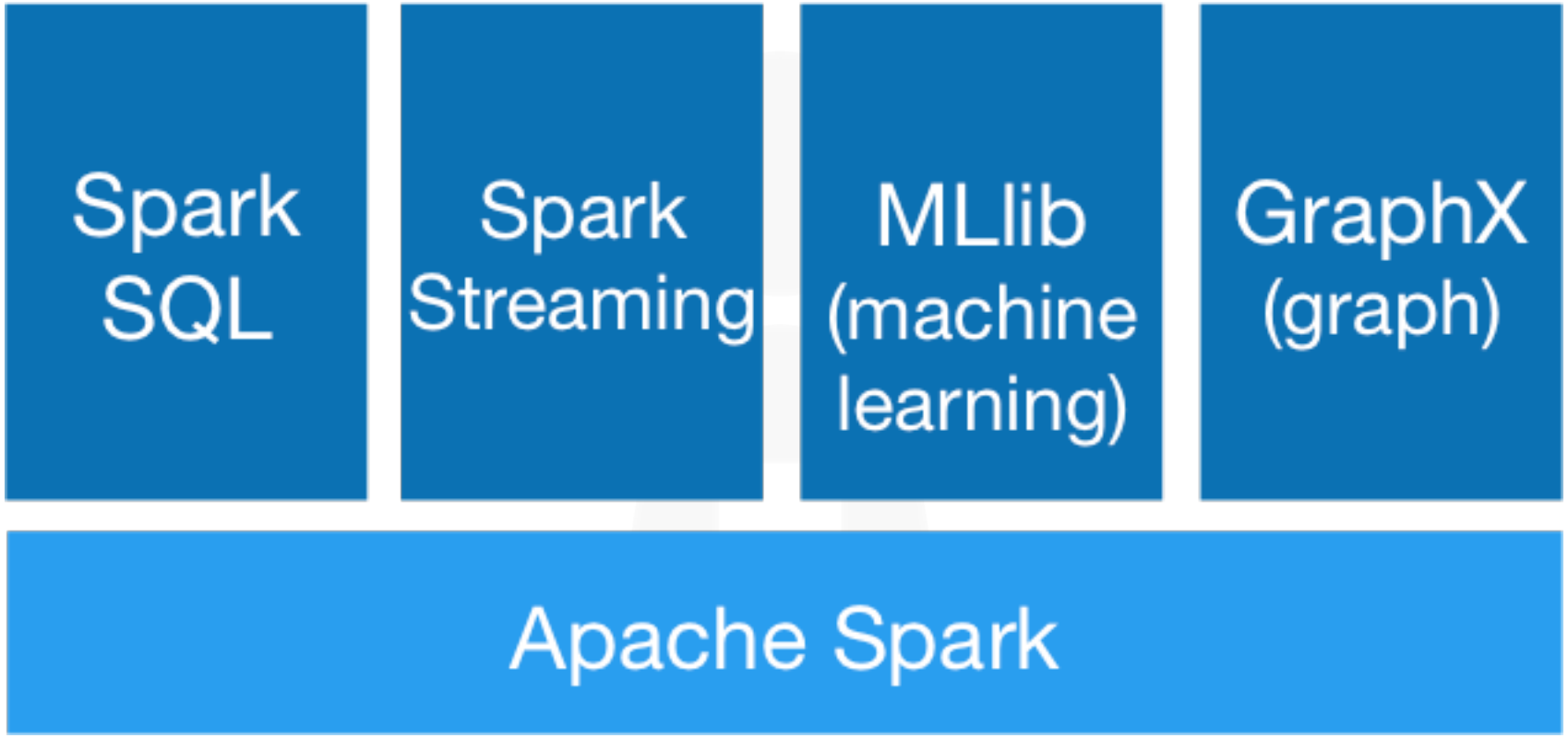
- Method: Hadoop
- Yahoo!
- 72 Minutes
- 2100 Nodes

2014:

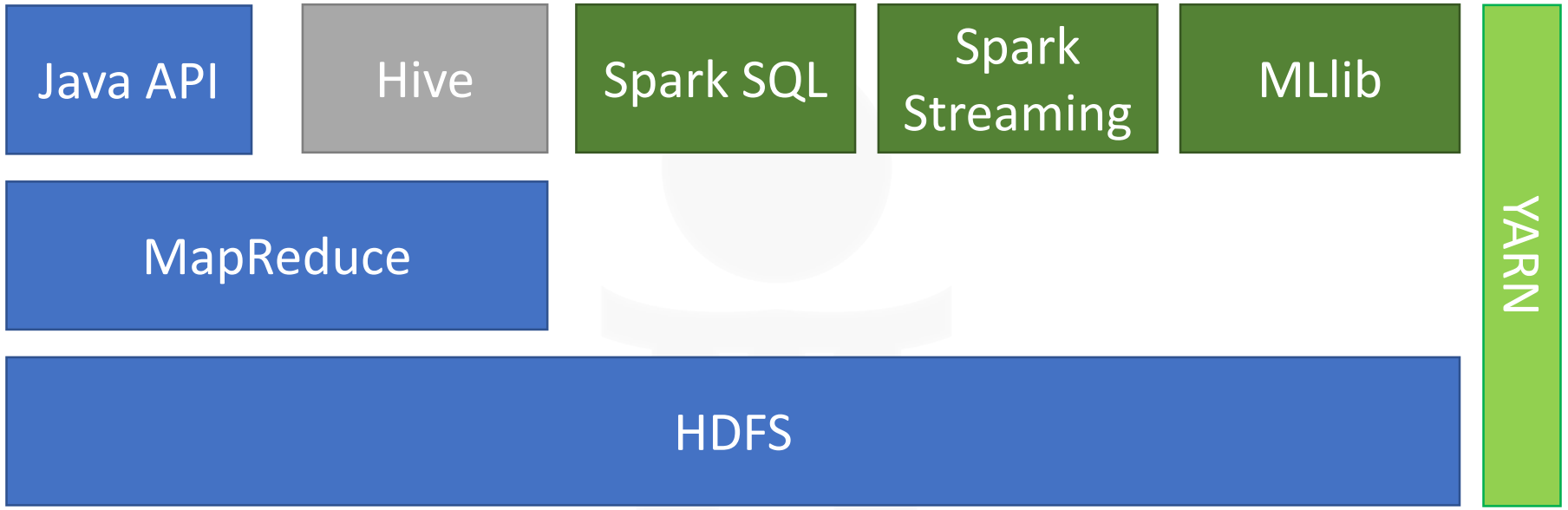
- Method: Spark
- Databricks
- 23 Minutes
- 206 Nodes

Source: https://databricks.com/blog/2014/10/10/spark-petabyte-sort.html

Conceptual Architecture



Spark and Hadoop



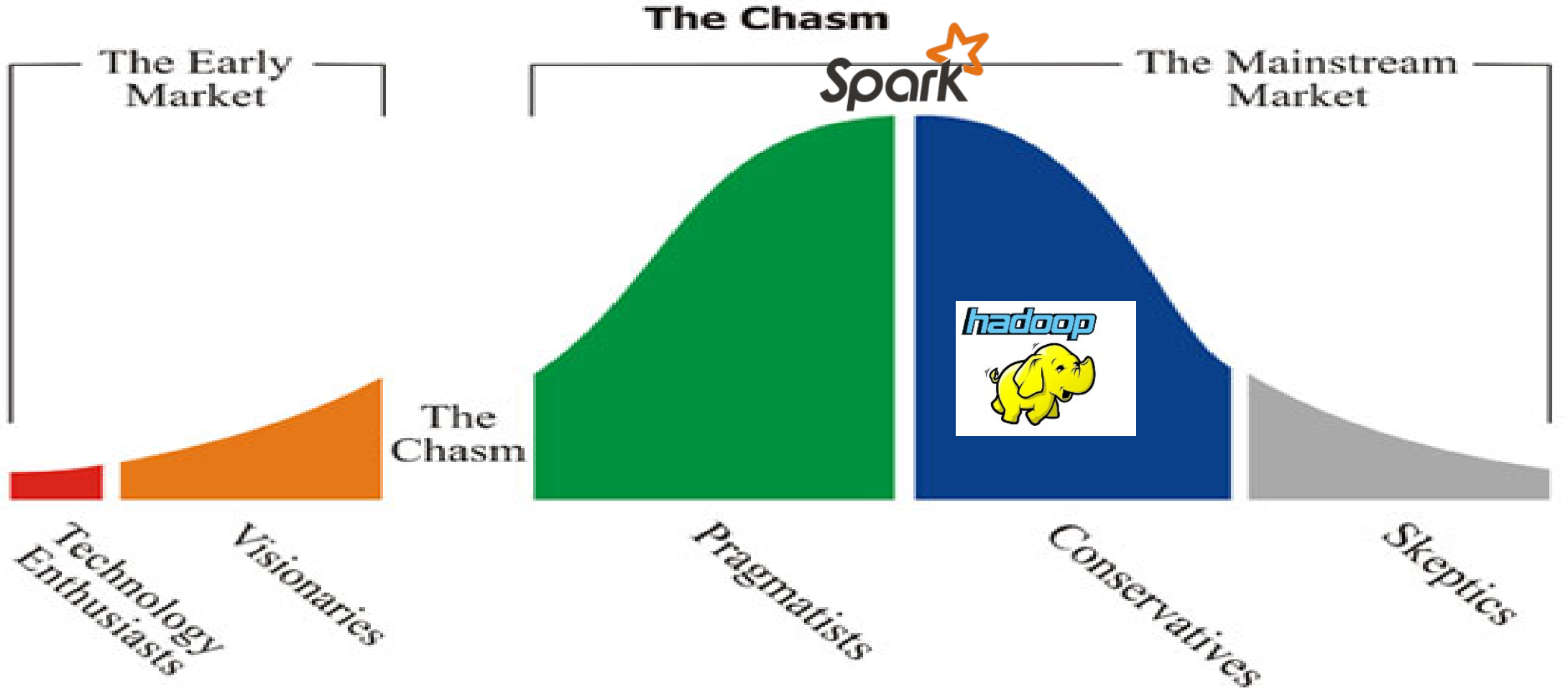
- Spark can be deployed on a Hadoop cluster and share cluster resources via YARN.
- Spark, however, does not require Hadoop!

Why is Spark Faster?

- First, Spark processing implements *lazy execution*:
  - Data operations are either *transformations* or *actions*.
  - Transformations are not executed immediately, but are stored.
  - When an action is issued, Spark evaluates all stored transformations and optimizes processing before executing.

- Second, Spark performs most processing in-memory:
  - RAM is far faster than using disk storage – even SSD drives.
  - More RAM in the cluster allows Spark to processes data faster.

Technology adoption life cycle



Source: http://carlosmartinezt.com/2010/06/technology-adoption-life-cycle/

QUESTIONS

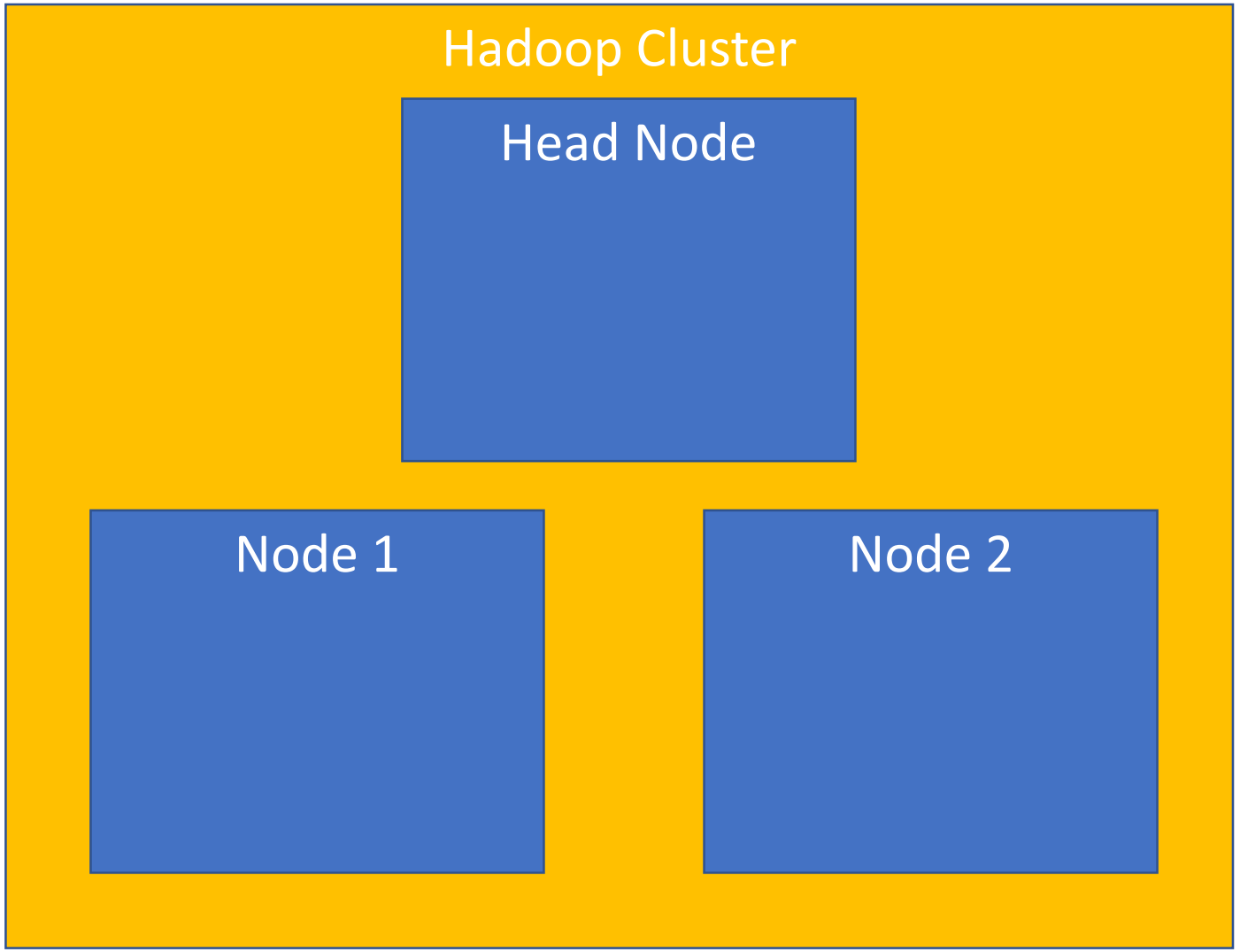
APPENDIX

MapReduce, via Playing Cards

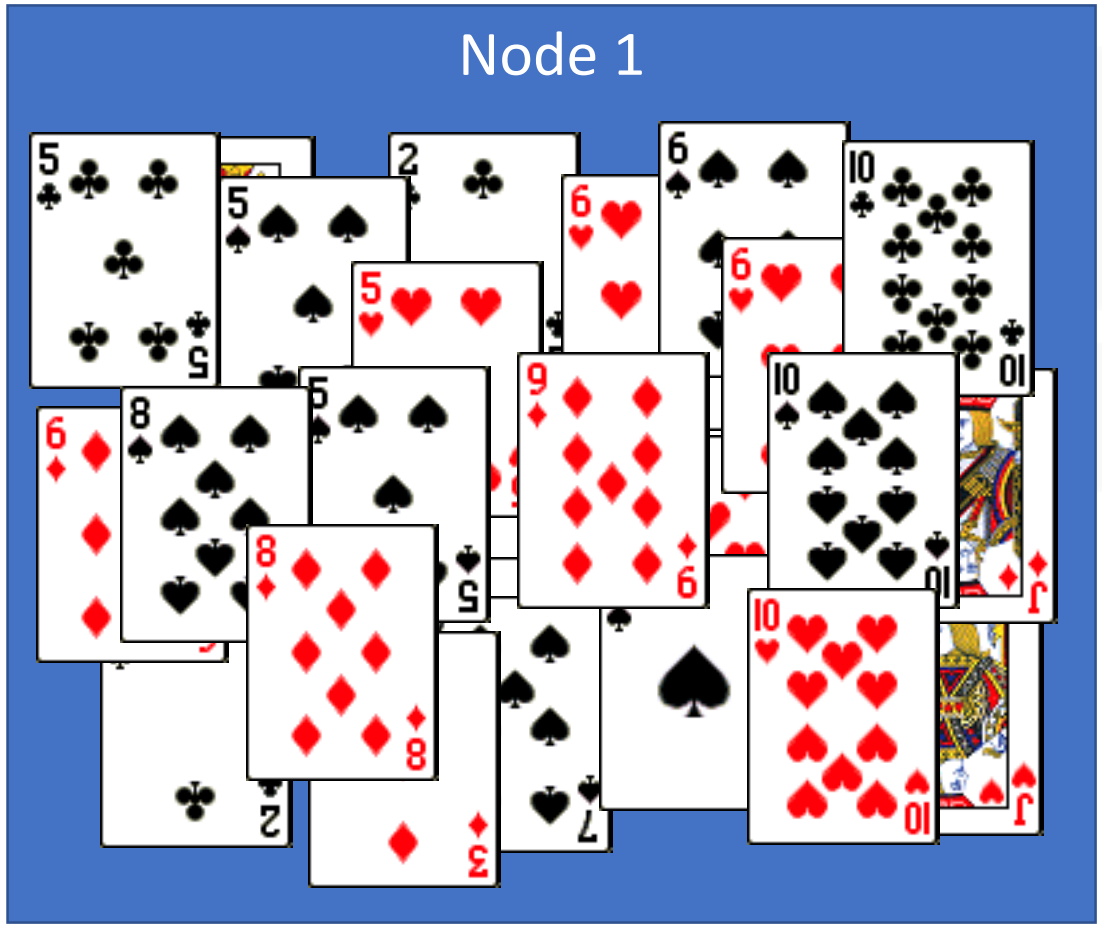
Let's count the number of spades, clubs, hearts, and diamonds in a stack of cards, the way map reduce would.

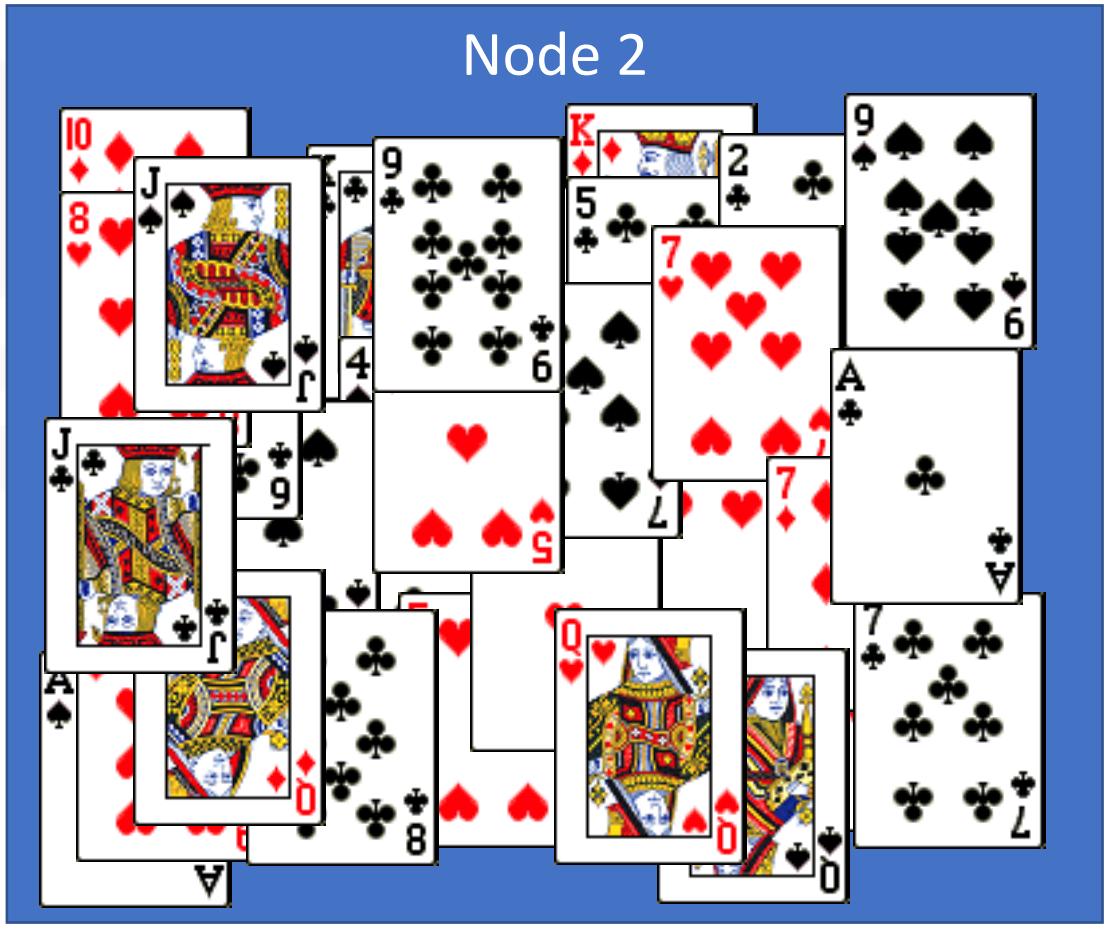
- Each card represents a row of data
- Each suit & number represents an attribute of the data

Using a 2 Data Node Cluster

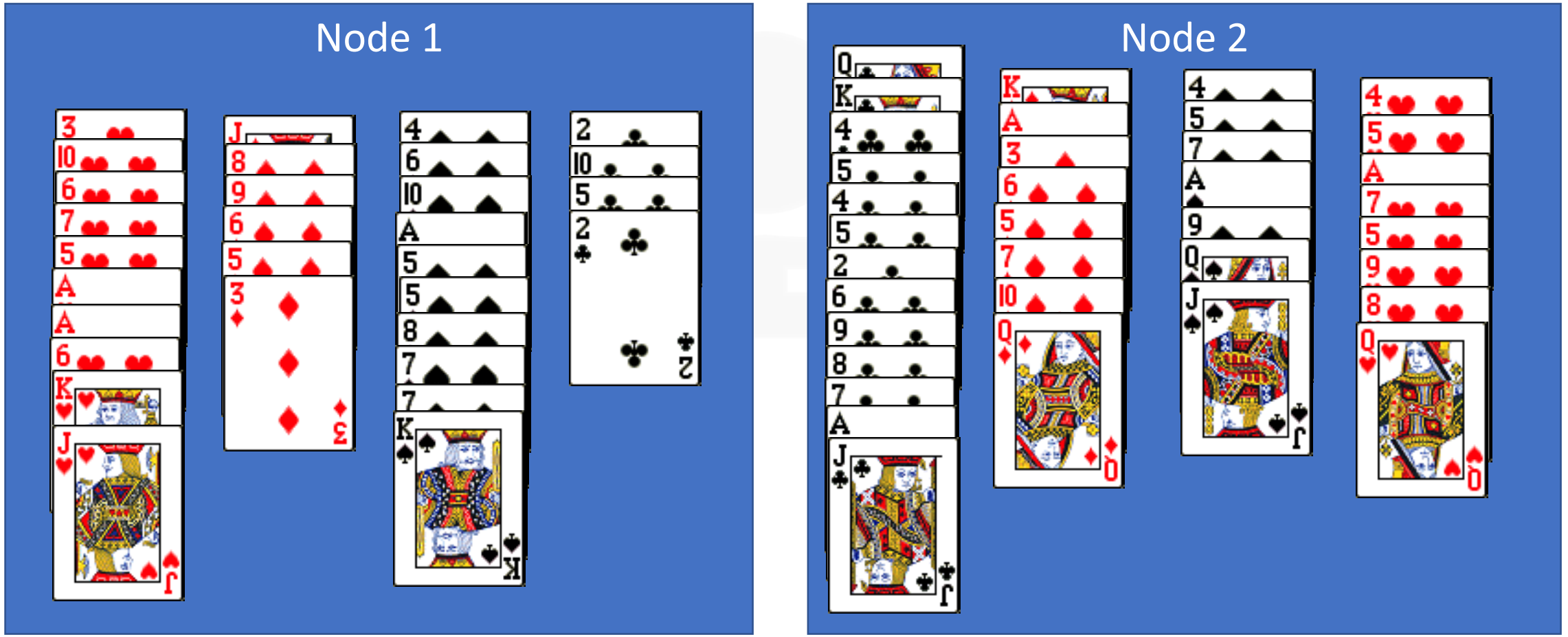


Mapping: Each Node's HDFS

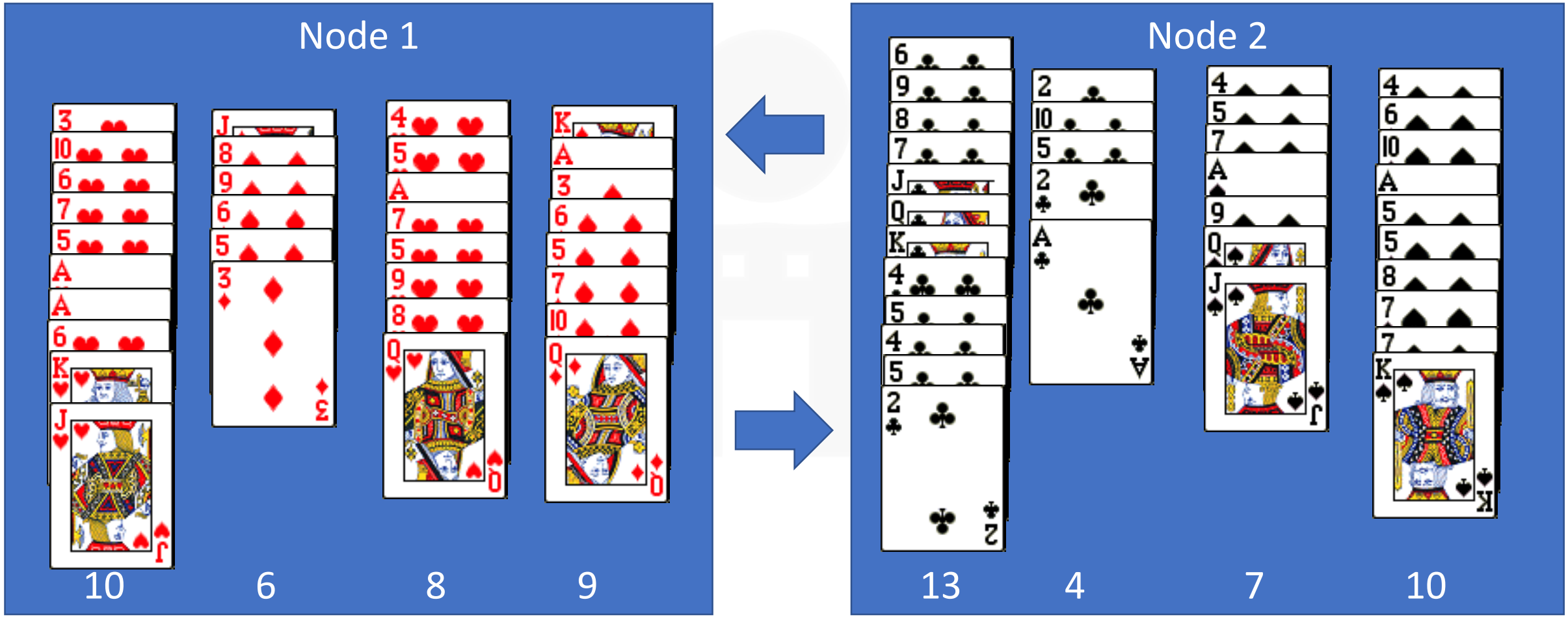




Mapping: Node Sorting



Shuffle Sort and Data Transfer



Mapping: Node Shuffle, Data Transfer