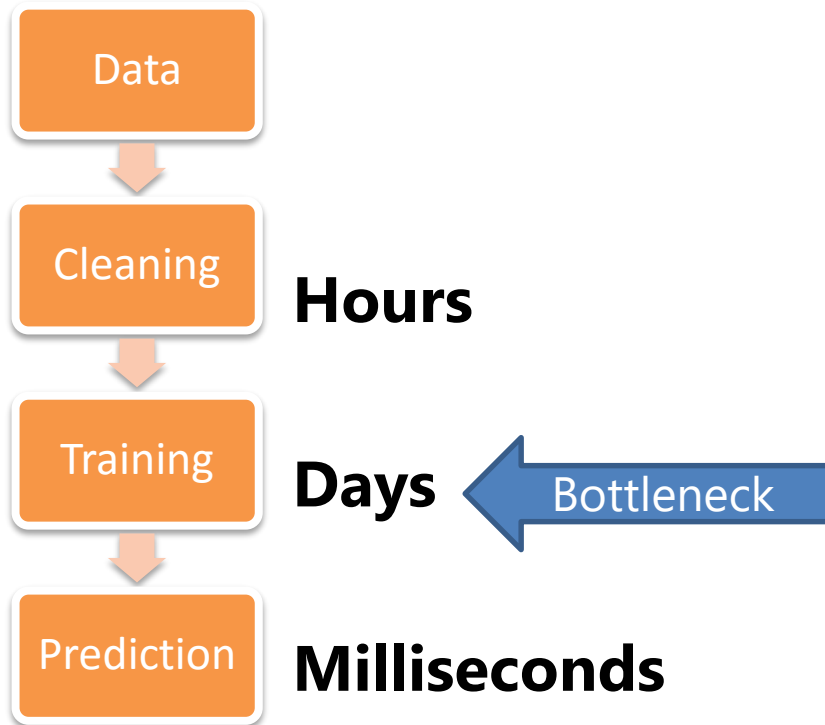


Big Data Engineering with Distributed Systems

Data Science Dojo

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

Machine Learning Scaling

Programs

- Excel

Programming

- Python
- R
- SAS

Cloud

- Azure ML
- AWS ML
- Watson Analytics
- Big ML
- Cloud Virtual Machines

Distributed

- Hadoop
- Spark
- H2O
- Revolution R

Excel: Cell Meta Data

	A	B	C	D	E
1	Sepal. Leng	Sepal. Wid	Petal. Leng	Petal. Wid	Species
2	5.1	3.5	1.4	0.2	setosa
3	4.9	3	1.4	0.2	setosa

E2 Cell = Application, Address, AllowEdit, Areas, Borders, BottomPadding, Comment, Column, ColumnIndex, Creator, **Font**, FitText, Height, HeightRule, ID, Interior, LeftPadding, NestingLevel, RightPadding, Row, RowIndex, Shading, Tables, TopPadding, VerticalAlignment, **Value**, Width, WordWrap

"Value": "Setosa"

"Font":{
 "Application": "Microsoft Excel",
 "Background": None,
 "Bold": True,
 "Color": 0,
 "ColorIndex": 5,
 "Creator": "XCEL",
 "FontStyle": "Bold Italic",
 "Italic": True,
 "Name": "Comic Sans MS",
 "OutlineFont": True,
 "Parent": None,
 "Shadow": False,
 "Size": 12,
 "Strikethrough": False,
 "Subscript": False,
 "ThemeColor": 12,
 "ThemeFont": 2,
 "TintAndShade": 1,
 "Superscript": False,
 "Underline": False,
}

R Limits

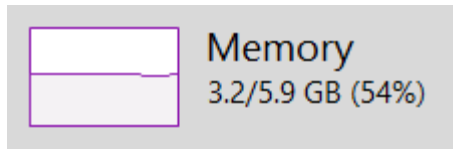
- Single core
- Single threaded
- All in memory (RAM)
- Vectors & Matrices capped at 4,294,967,295 elements; $2^{32} - 1$

R Limits: RAM

- All in memory (RAM)

$$\text{Max Data Limit} = (\text{Total RAM Access} - \text{Normal RAM Usage}) \times 80\%$$

Phuc's Laptop Example:



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

$$\text{Max Data Limit} = \sim 2.16\text{gb}$$

R Limits: RAM

INSTANCE	CORES	RAM	DISK SIZES	PRICE
G1	2	28 GB	384 GB	\$0.67/hr (~\$498/mo)
G2	4	56 GB	768 GB	\$1.34/hr (~\$997/mo)
G3	8	112 GB	1,536 GB	\$2.68/hr (~\$1,994/mo)
G4	16	224 GB	3,072 GB	\$5.36/hr (~\$3,988/mo)
G5	32	448 GB	6,144 GB	\$9.65/hr (~\$7,180/mo)

Azure's Biggest Virtual Machine

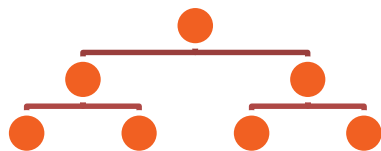
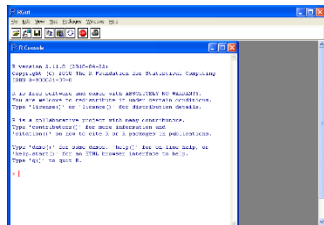
Max Data Limit = (448gb – 1gb) x 80%

Max Data Limit = ~357.6gb

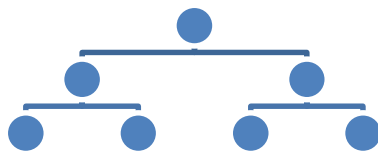
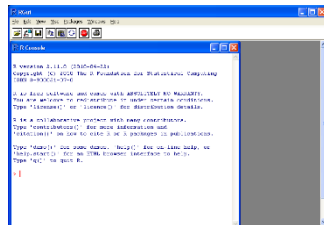
R Limits: Single Core

- Single core
- Single threaded

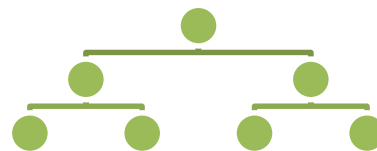
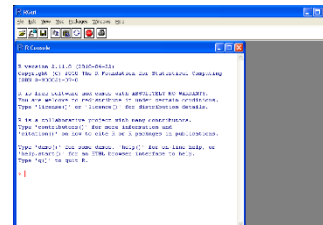
Quad Core Laptop



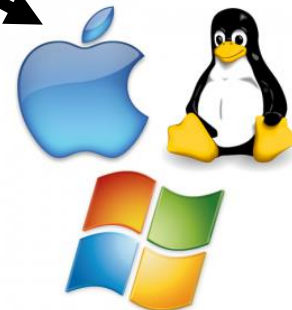
Model A



Model B



Model C



Machine Learning Scaling

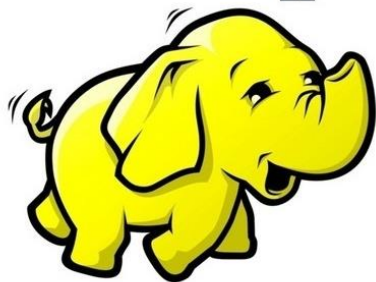
Programs	Programming	Cloud	Distributed
<ul style="list-style-type: none">• Excel	<ul style="list-style-type: none">• Python• R• SAS	<ul style="list-style-type: none">• Azure ML• AWS ML• Watson Analytics• Big ML• Cloud Virtual Machines	<ul style="list-style-type: none">• Hadoop• Spark• H2O• Revolution R

Distributed R Solutions:

<https://cran.r-project.org/web/views/HighPerformanceComputing.html>

Agenda

hadoop



From a Data Scientist's Perspective



Goals:

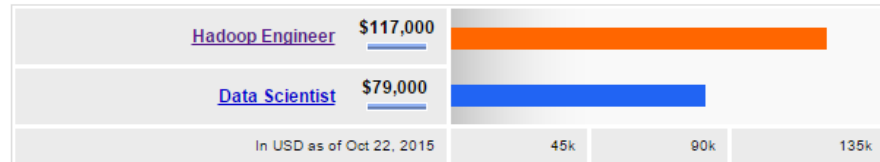
- Teach you how to leverage an existing Hadoop cluster, self-service data query

Not goals:

- Managing or administering a Hadoop cluster

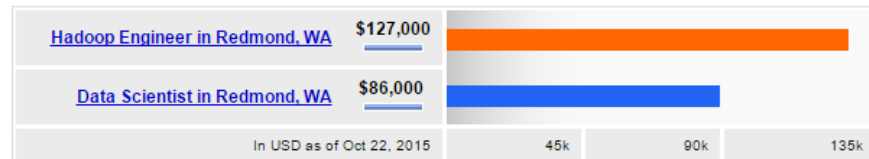
Hadoop Engineers

Average Salary of Jobs Matching Your Search



Average Hadoop Engineer salaries for job postings nationwide are 47% higher than average Data Scientist salaries for job postings nationwide.

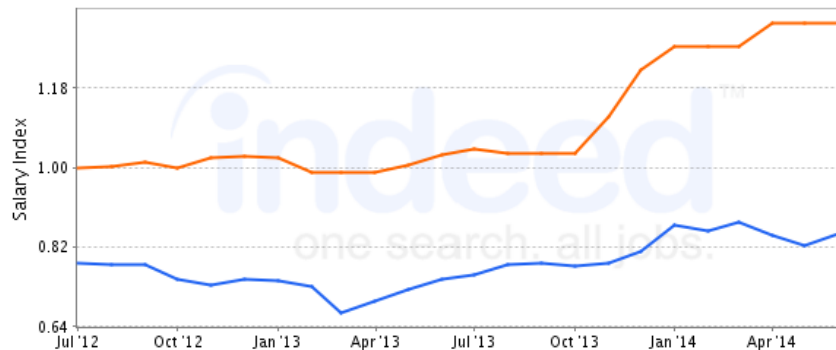
Average Salary of Jobs Matching Your Search



Average Hadoop Engineer salaries for job postings in Redmond, WA are 47% higher than average Data Scientist salaries for job postings in Redmond, WA.

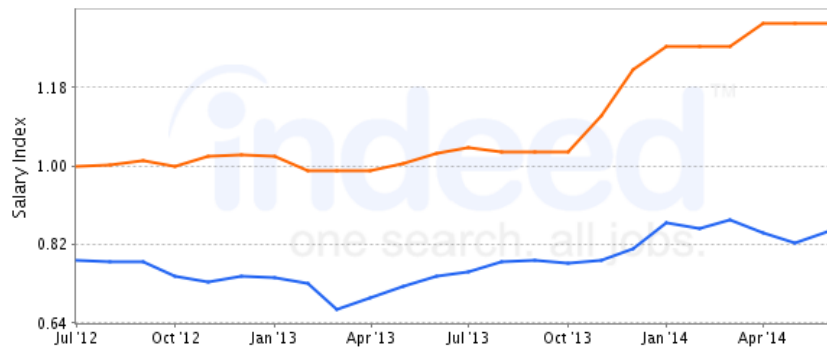
National Salary Trend from Indeed.com

— Hadoop Engineer — Data Scientist



National Salary Trend from Indeed.com

— Hadoop Engineer — Data Scientist



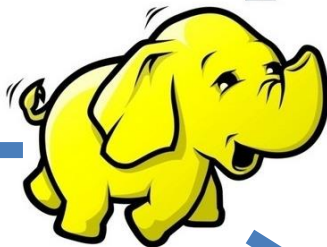
Source: Ineed.com

Hadoop Implementations

hadoop



HDInsight

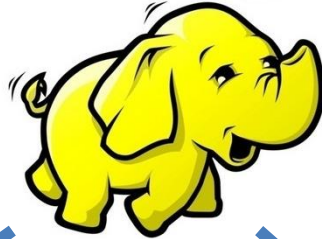


Amazon Elastic
MapReduce

datascience**dojo**
unleash the data scientist in you

(Vanilla/Base) Hadoop

hadoop

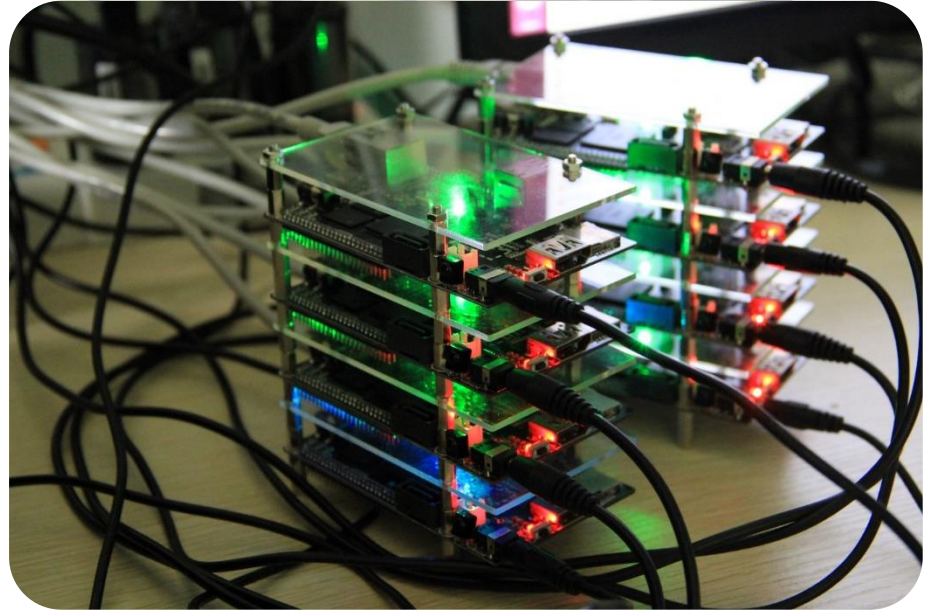
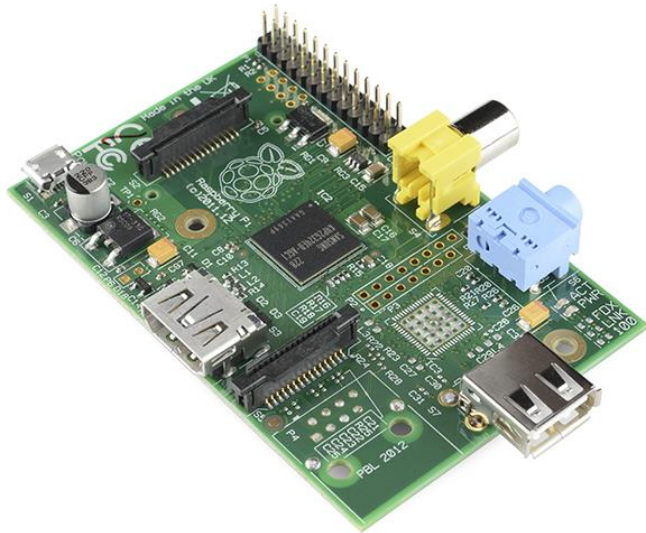


Processing engine for distributed batch processing.

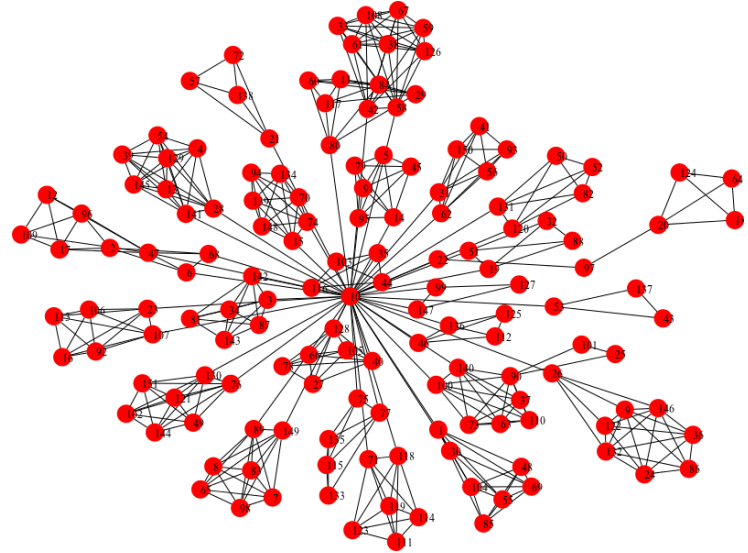
Turn Back The Clock, The Mainframe



Distributed Computing



Cloud Computing

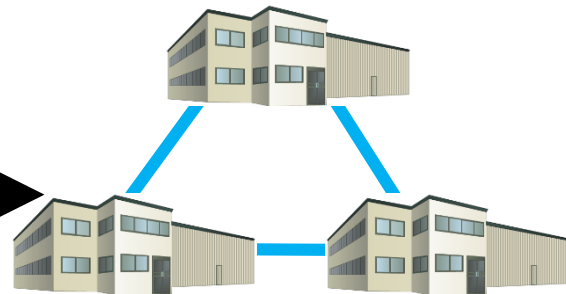


Scaling Computational Power



Old Scaling:

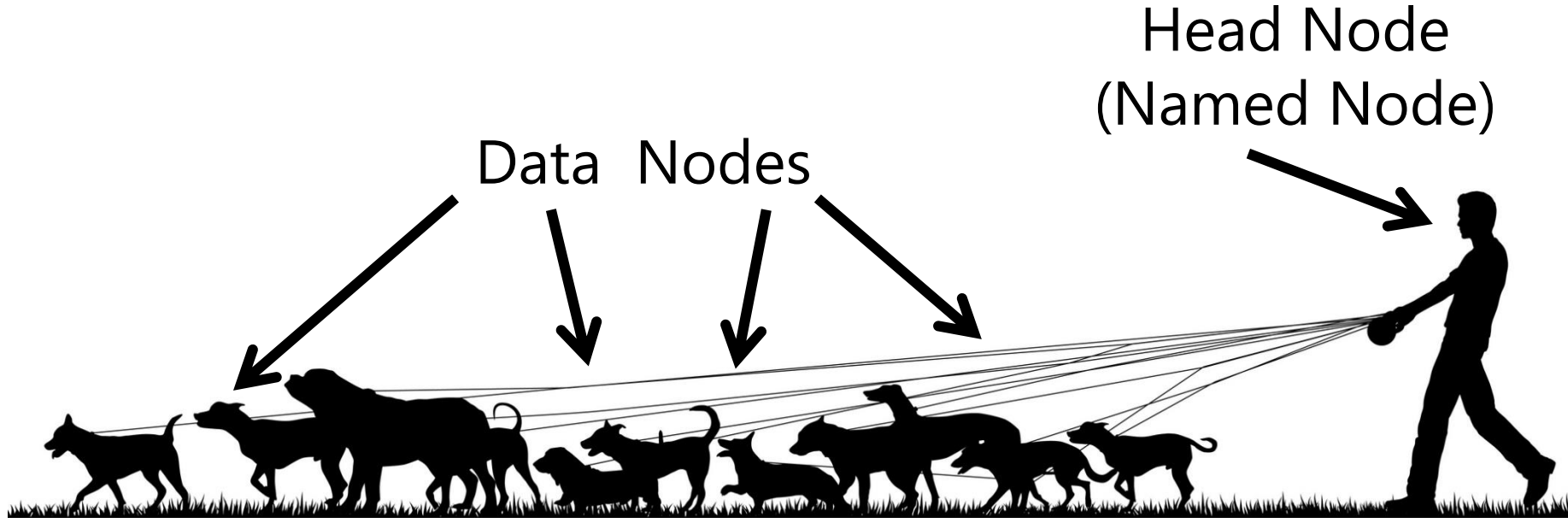
- Vertical Scaling, Scaling UP
- High performance computers



New Scaling:

- Horizontal Scaling, Scaling OUT
- Commodity hardware, distributed

If dogs were servers...

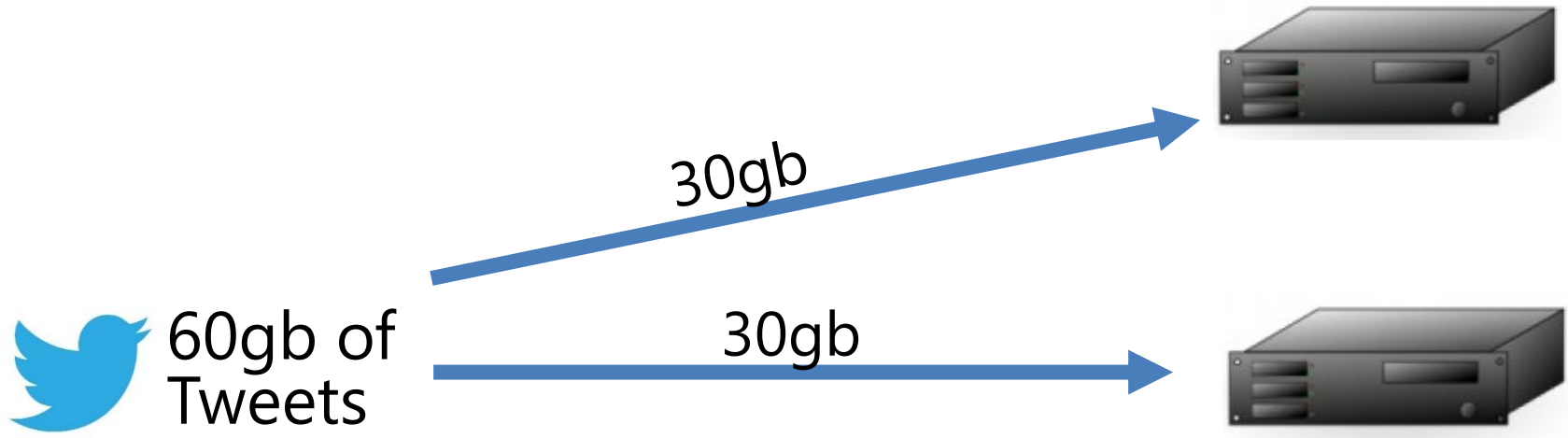


HDFS & MapReduce



Processing: 30 hours

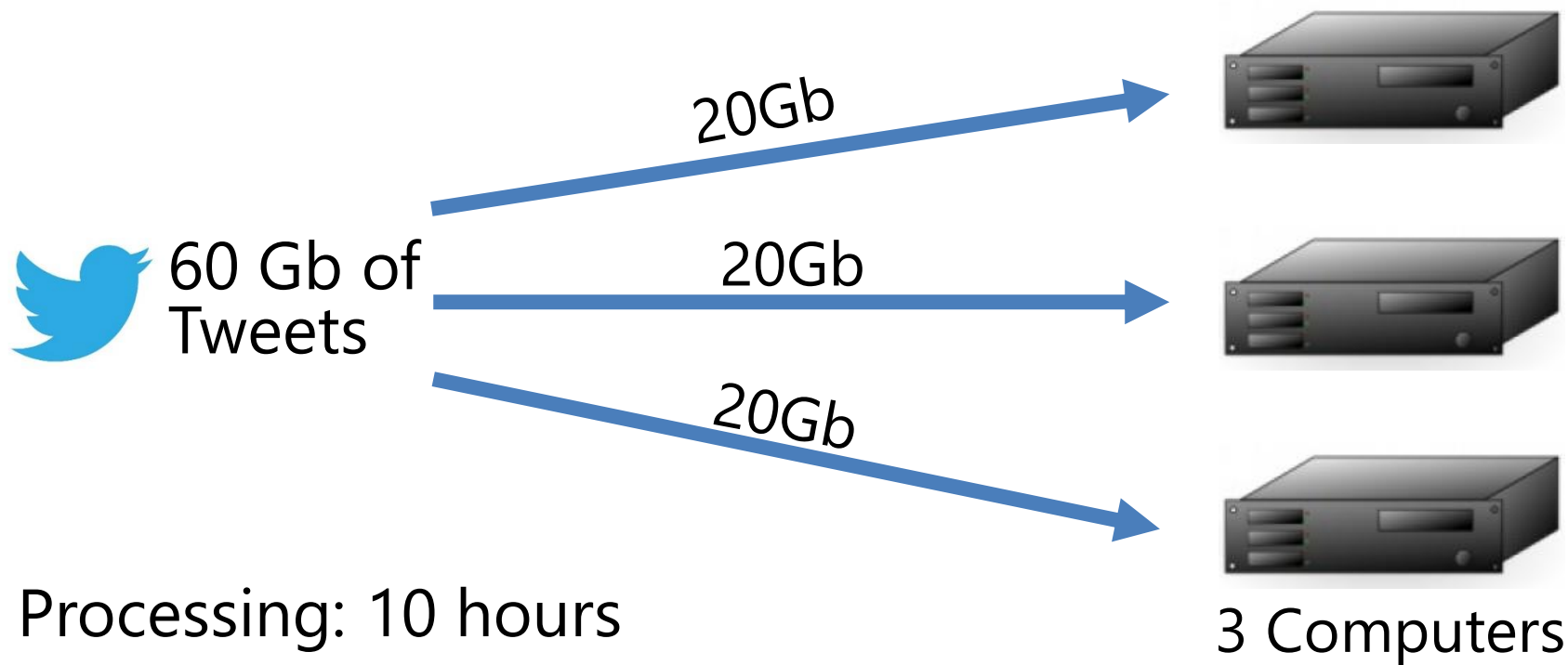
HDFS & MapReduce



2 Computers

Processing: 15 hours

HDFS & MapReduce

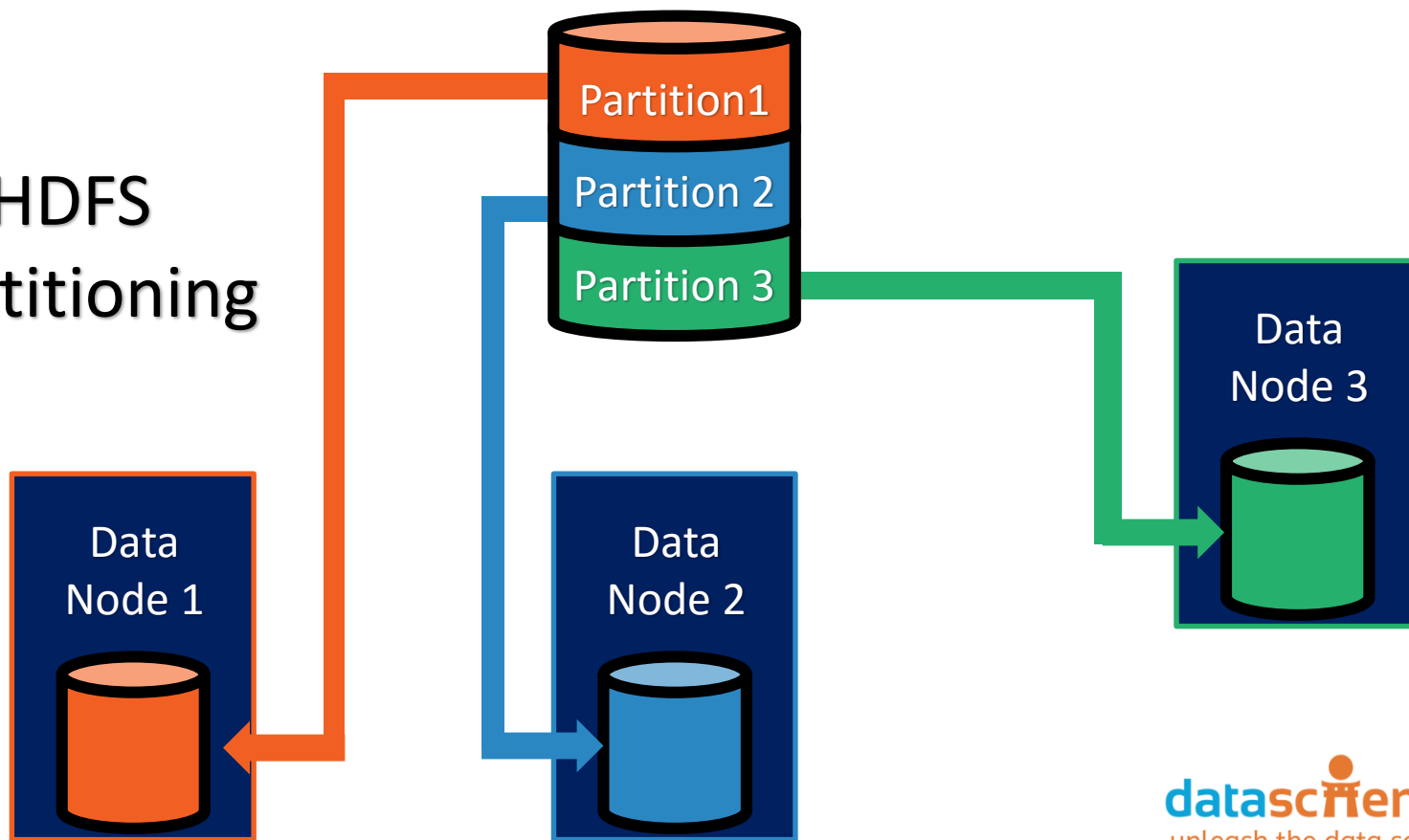


Most Cases, Linear Scaling Of Processing Power

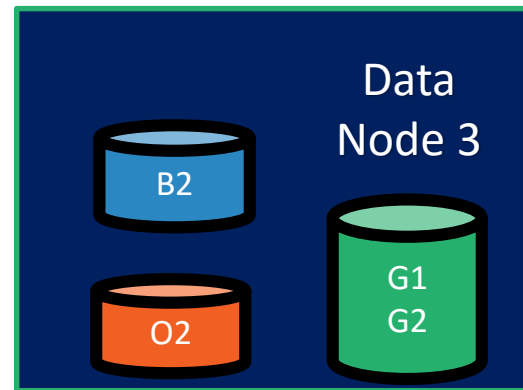
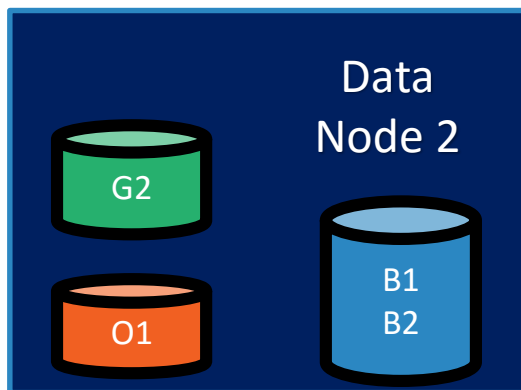
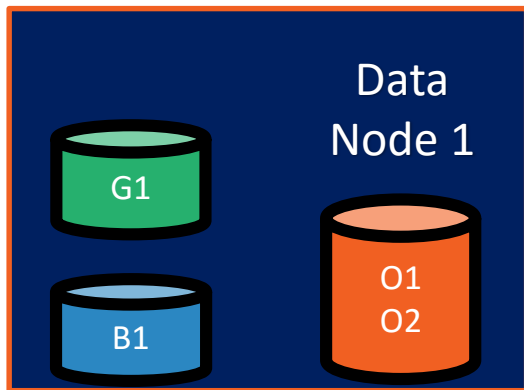
Number of Computers	Processing Time (hours)
1	30
2	15
3	10
4	7.5
5	6
6	5
7	4.26
8	3.75
9	3.33

HDFS

HDFS Partitioning



HDFS Redundancy



Limitations with MapReduce

- ~70 lines of code to do anything
- Slow
- Troubleshooting multiple computers
- Good devs are scarce
- Expensive certifications

```
1 package org.apache.hadoop.examples;
2
3 import java.io.IOException;
4 import java.util.StringTokenizer;
5
6 import org.apache.hadoop.conf.Configuration;
7 import org.apache.hadoop.fs.Path;
8 import org.apache.hadoop.io.IntWritable;
9 import org.apache.hadoop.io.Text;
10 import org.apache.hadoop.mapreduce.Job;
11 import org.apache.hadoop.mapreduce.Mapper;
12 import org.apache.hadoop.mapreduce.Reducer;
13 import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;
14 import org.apache.hadoop.mapreduce.lib.output.FileOutputFormat;
15 import org.apache.hadoop.util.GenericOptionsParser;
16
17 public class WordCount {
18
19     public static class TokenizerMapper
20         extends Mapper<Object, Text, Text, IntWritable>{
21
22         private final static IntWritable one = new IntWritable(1);
23         private Text word = new Text();
24
25         public void map(Object key, Text value, Context context
26             ) throws IOException, InterruptedException {
27             StringTokenizer itr = new StringTokenizer(value.toString());
28             while (itr.hasMoreTokens()) {
29                 word.set(itr.nextToken());
30                 context.write(word, one);
31             }
32         }
33     }
```



Ambari: Cluster provisioning, management, and monitoring



Avro (Microsoft .NET Library for Avro): Data serialization for the Microsoft .NET environment



HBase: Non-relational database for very large tables



HDFS: Hadoop Distributed File System



Hive: SQL-like querying



Mahout: Machine learning

MapReduce and YARN: Distributed processing and resource management



Oozie: Workflow management



Pig: Simpler scripting for MapReduce transformations



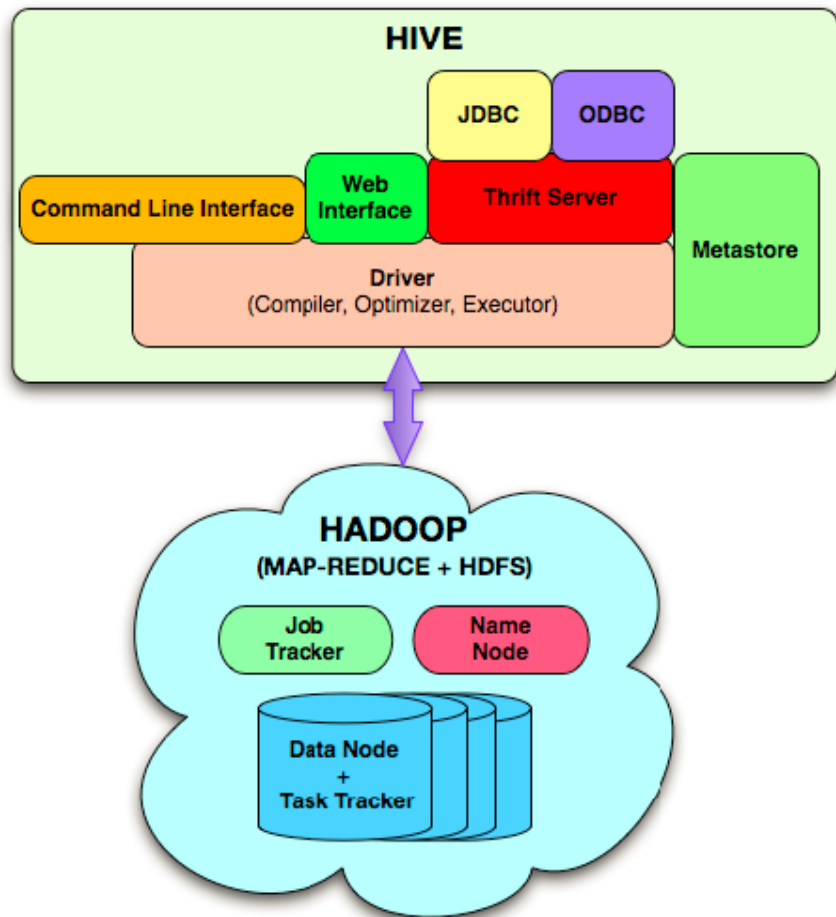
Sqoop: Data import and export



Storm: Real-time processing of fast, large data streams



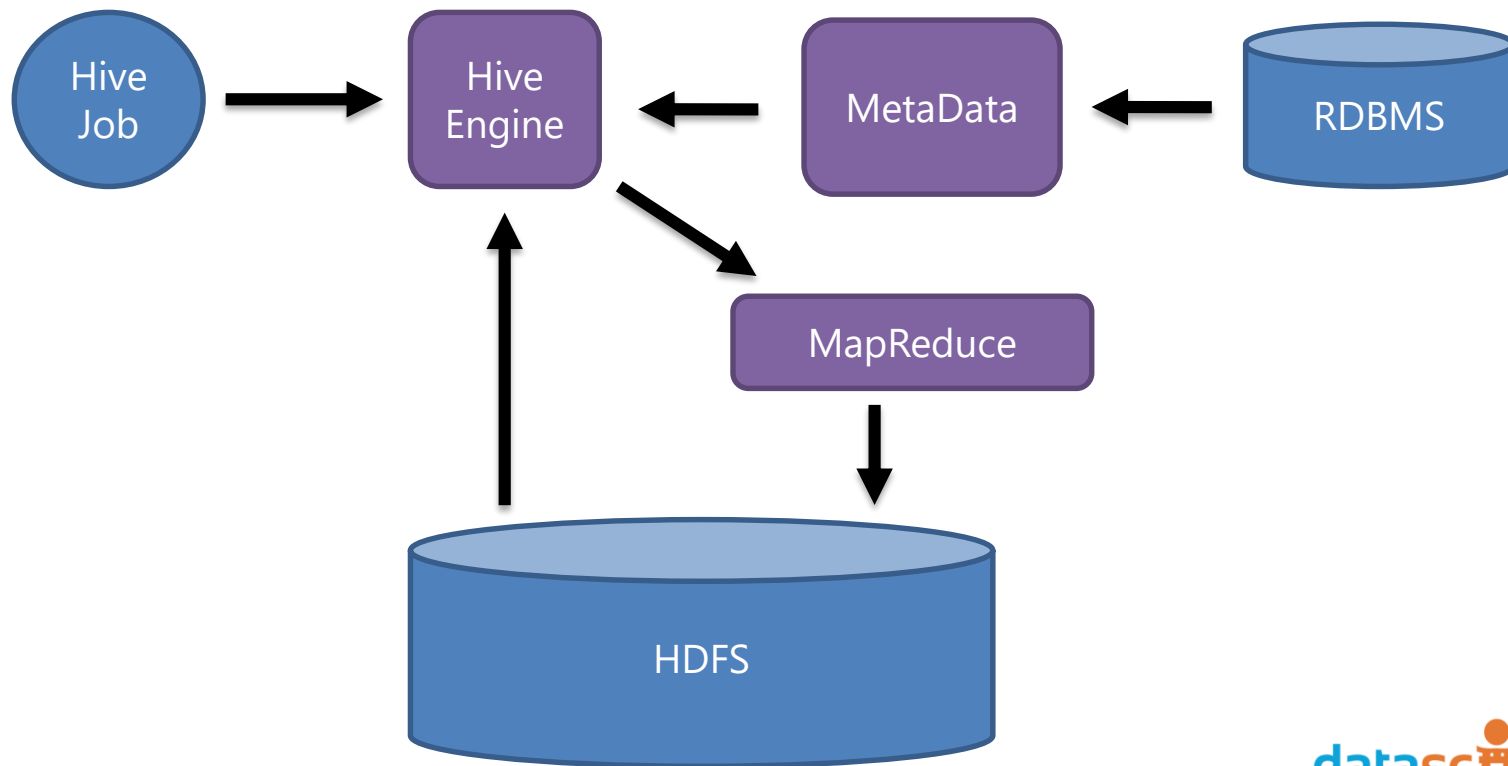
Zookeeper: Coordinates processes in distributed systems



Hive Jobs



Hive Architecture





Data File



Unstructured
Data



Data File



Metadata File/DB



Structured
Data

Semi Structured Data

Self Describing Flat Files

- XML
- JSON
- CSV
- TSV

```
[  
  {  
    "created_at": "Thu May 07 18:06:23 +0000 2015",  
    "id": 596375540631646210,  
    "id_str": "596375540631646210",  
    "text": "Expert usable tips differently the press",  
    "source": "<a href='\"http://twitterfeed.com\"' rel",  
    "truncated": 0,  
    "in_reply_to_status_id": null,  
    "in_reply_to_status_id_str": null,  
    "in_reply_to_user_id": null,  
    "in_reply_to_user_id_str": null,
```


Why Hive?

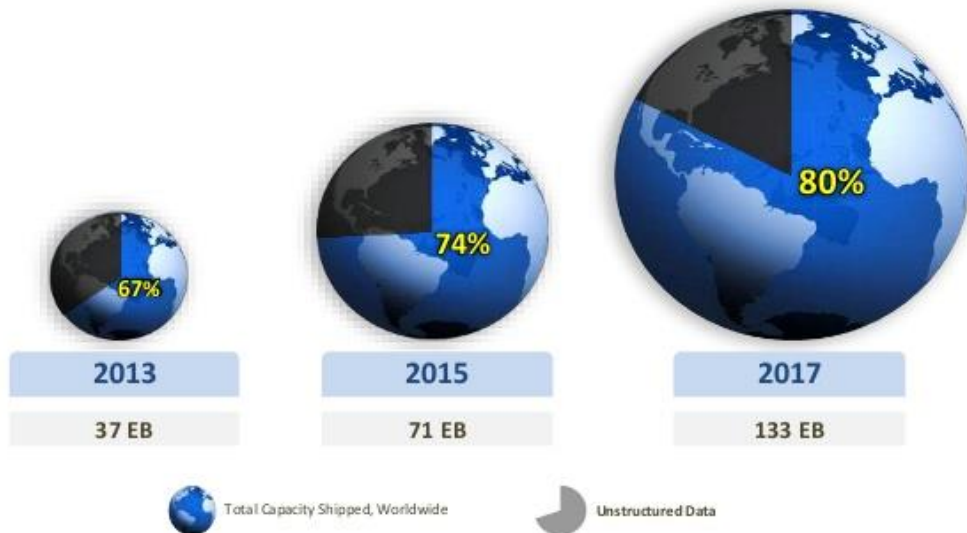


- SQL spoken here (HiveQL)
- ODBC driver
- BI Integration
- Supports only Structured Data

Limitations



Structured vs. Unstructured Data Growth

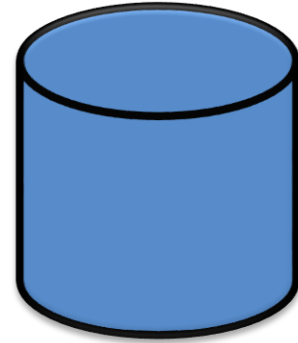
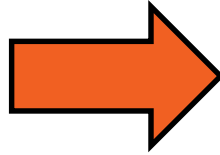


Source: IDC

Azure Blob Storage

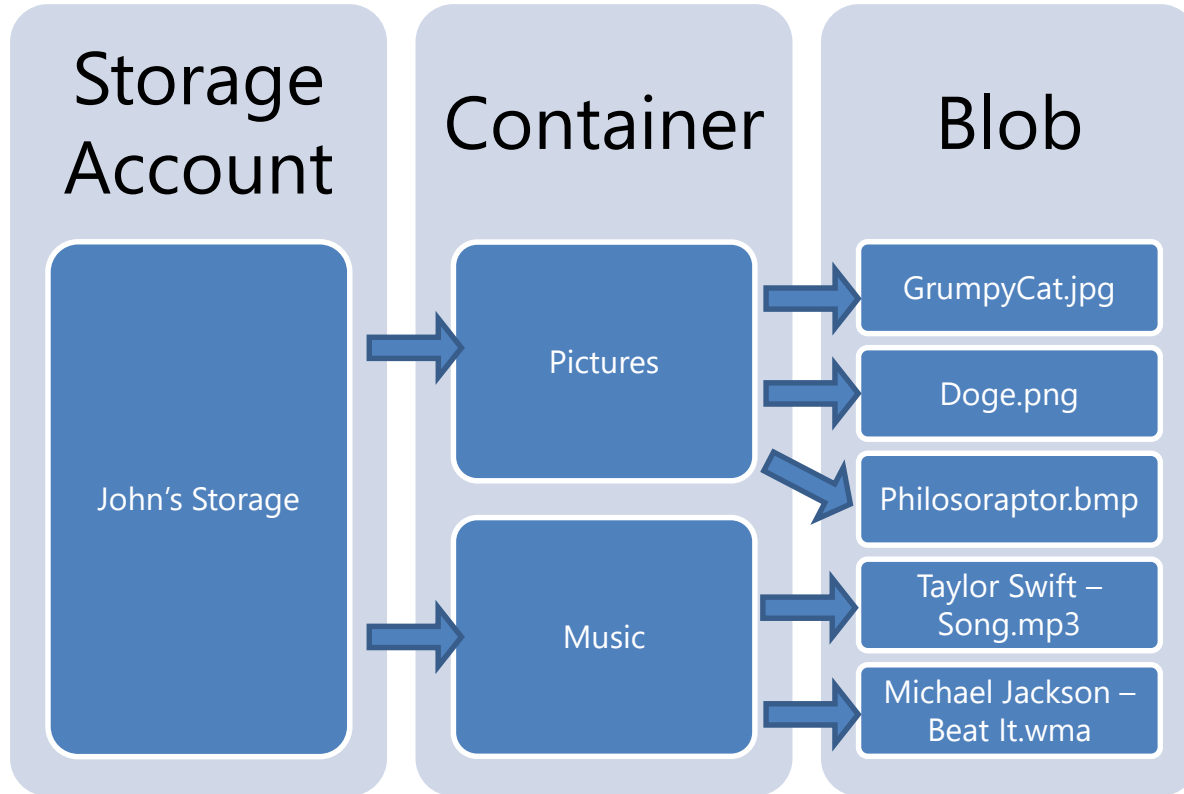


HDInsight

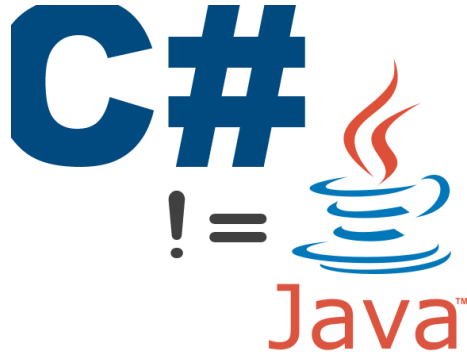


Blob Storage

Azure Blob Storage



When to Use Each



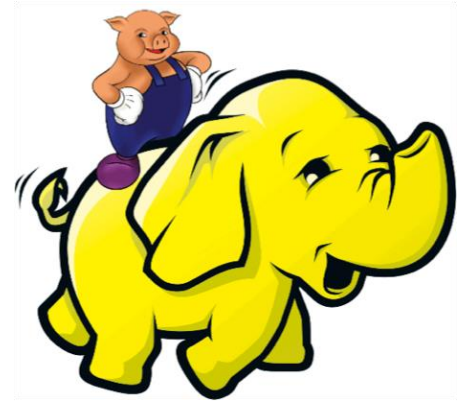
C#
Java
MapReduce

VS



Hive

VS



Pig

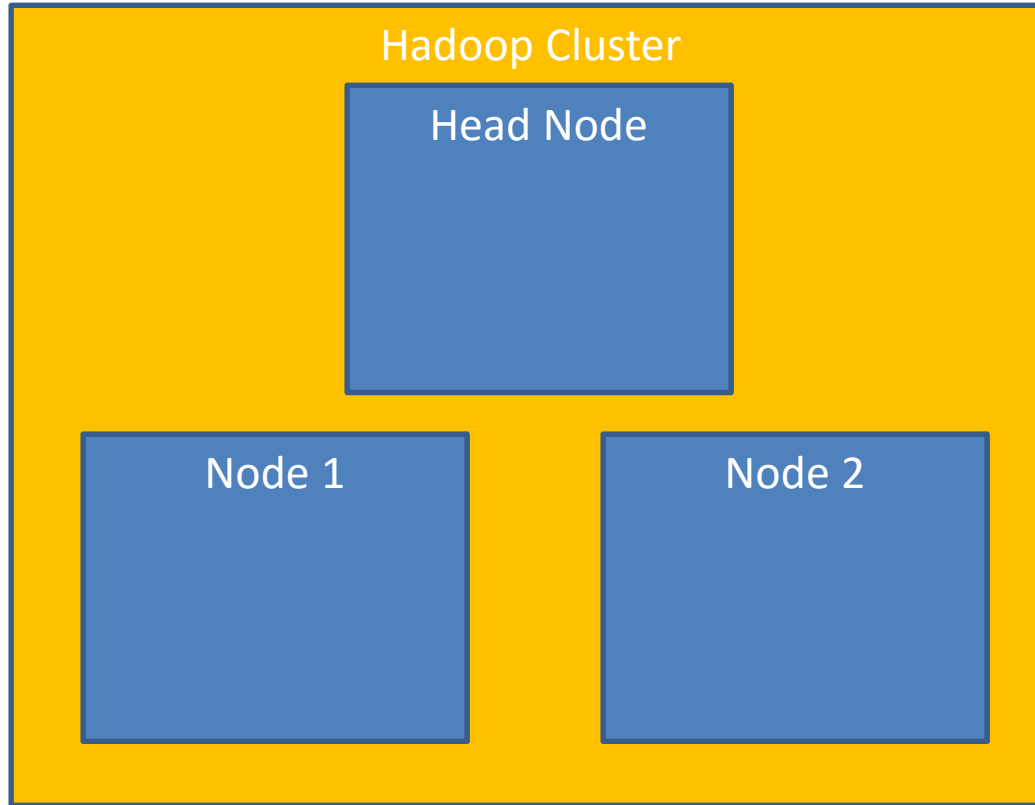
MapReduce, via Playing Cards



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

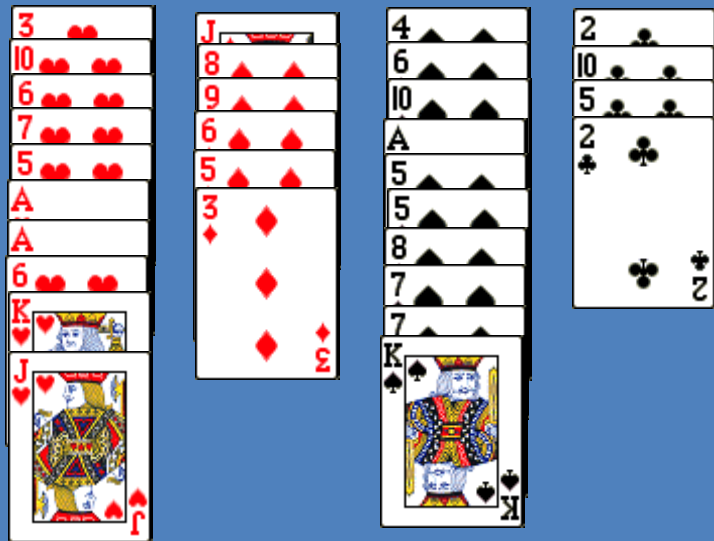
- Each card represents a row of data
- Each suit & number represents an attribute of the data

Using a 2 Data Node Cluster

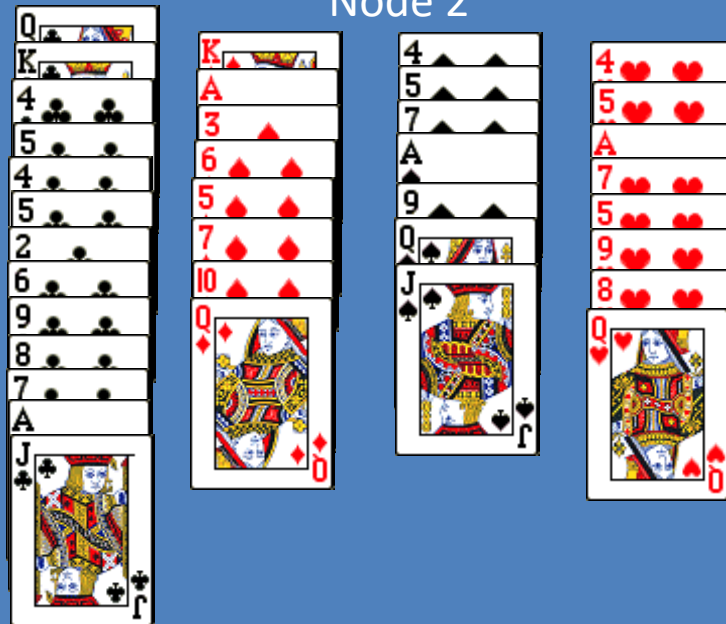


Mapping: Node Sorting

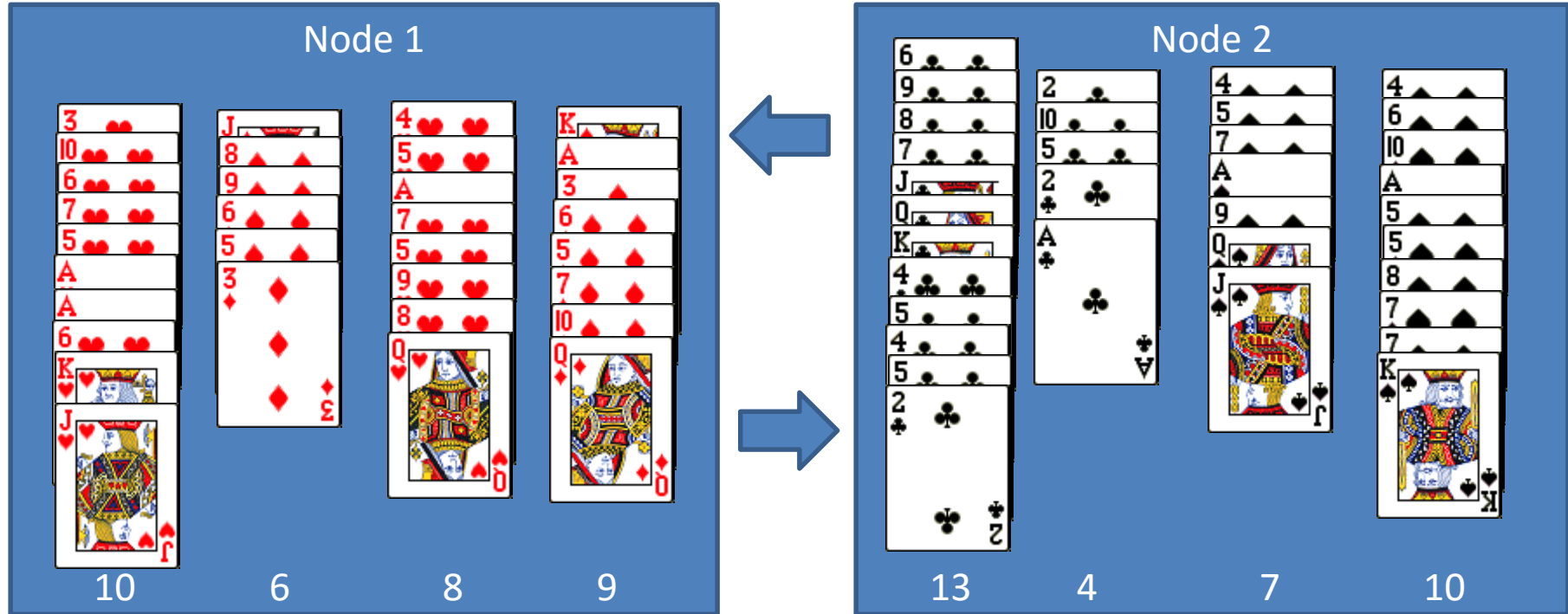
Node 1



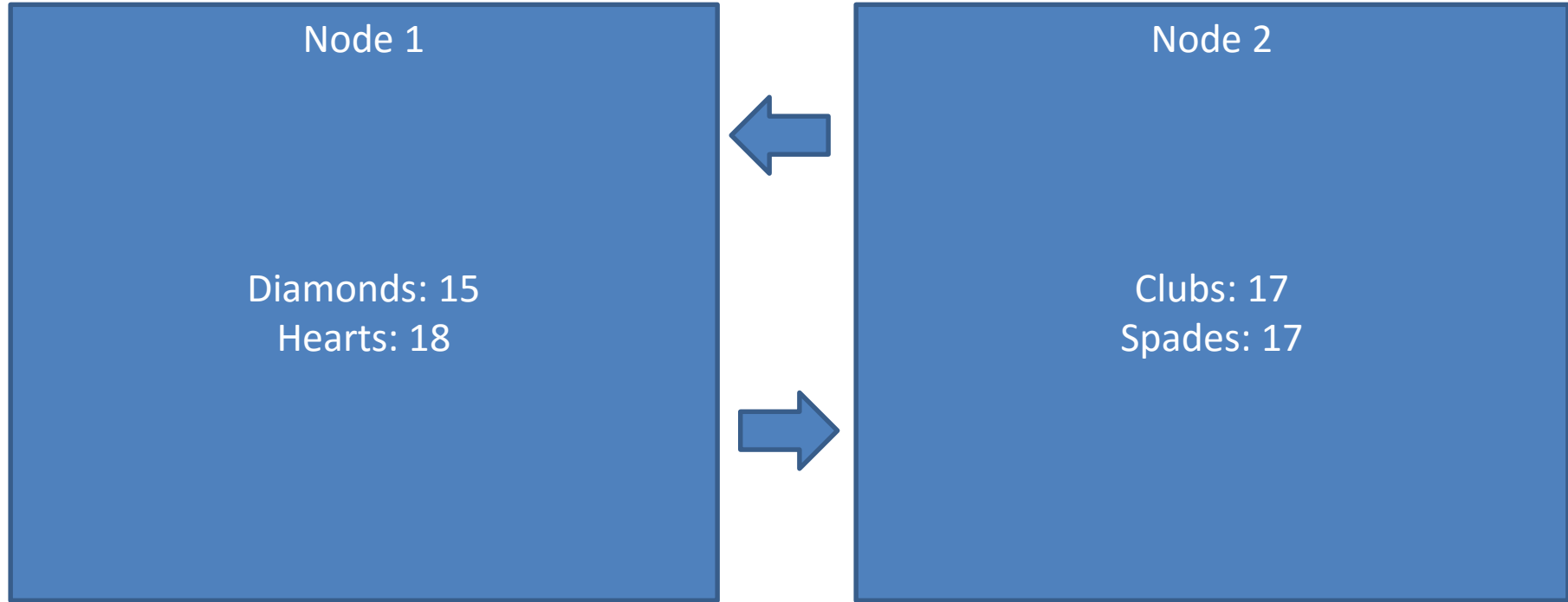
Node 2



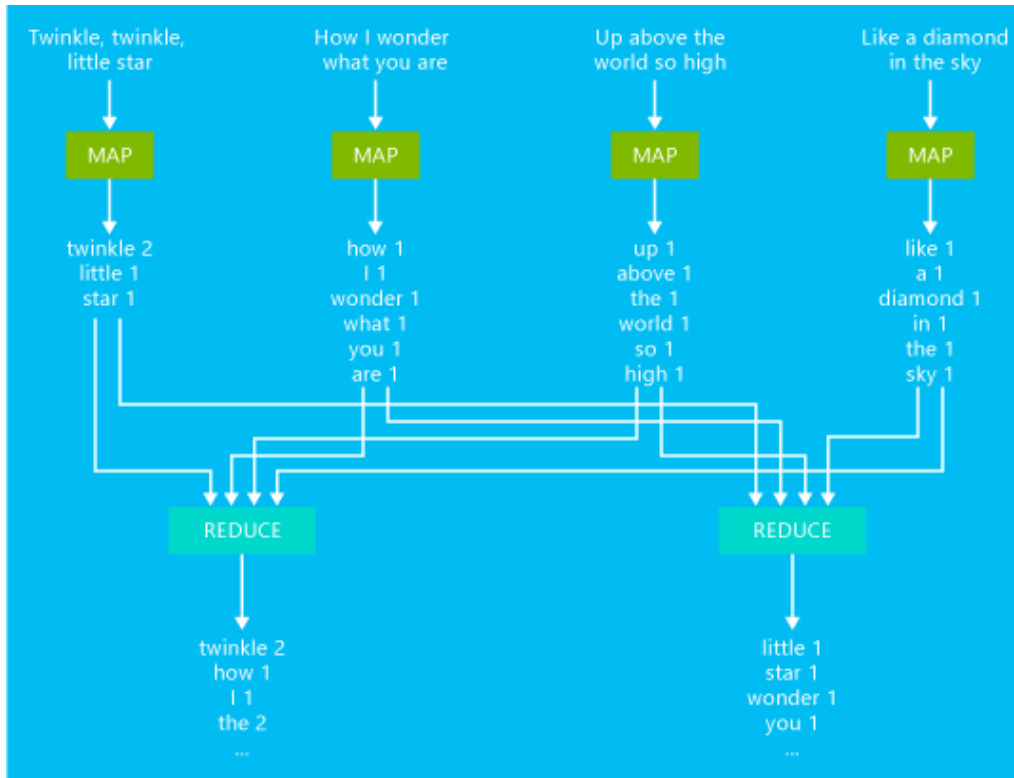
Mapping: Node Shuffle, Data Transfer



Mapping: Node Shuffle, Data Transfer



Word Count, via MapReduce()



Source: <https://azure.microsoft.com/en-us/documentation/articles/hdinsight-use-mapreduce/>

Databases

Rank & Title	IMDB Rating
 1. The Shawshank Redemption (1994)	★ 9.2
 2. The Godfather (1972)	★ 9.2
 3. The Godfather: Part II (1974)	★ 9.0
 4. The Dark Knight (2008)	★ 8.9
 5. 12 Angry Men (1957)	★ 8.9

movie	year	rating	director
Aliens	1986	8.2	James (I) Cameron
Animal House	1978	7.5	John (I) Landis
Apollo 13	1995	7.5	Ron Howard
Batman Begins	2005	NULL	Christopher Nolan
Braveheart	1995	8.3	Mel (I) Gibson
Fargo	1996	8.2	Ethan Coen
Fargo	1996	8.2	Joel Coen
Few Good Men, A	1992	7.5	Rob Reiner
Fight Club	1999	8.5	David Fincher

Normalization, joining

```
SELECT
  m.name AS movie,
  m.year AS year,
  m.rank AS rating,
  CONCAT(d.first_name, " ", d.last_name)
  AS director
FROM movies AS m
JOIN movies_directors AS md
  ON m.id = md.movie_id
JOIN directors AS d
  ON md.director_id = d.id
;
```

Movie Information

movie	year	rating	director
Aliens	1986	8.2	James (I) Cameron
Animal House	1978	7.5	John (I) Landis
Apollo 13	1995	7.5	Ron Howard
Batman Begins	2005	NULL	Christopher Nolan
Braveheart	1995	8.3	Mel (I) Gibson
Fargo	1996	8.2	Ethan Coen
Fargo	1996	8.2	Joel Coen
Few Good Men, A	1992	7.5	Rob Reiner
Fight Club	1999	8.5	David Fincher

Database = Normalization

director

id	first_name	last_name
24758	David	Fincher
66965	Jay	Roach
72723	William	Shatner

movie_directors

director_id	movie_id
24758	112290
66965	209658
72723	313398

movies

id	name	year	rank
112290	Fight Club	1999	8.5
209658	Meet the Parents	2000	7
210511	Memento	2000	8.7

Data Warehouse = Denormalization

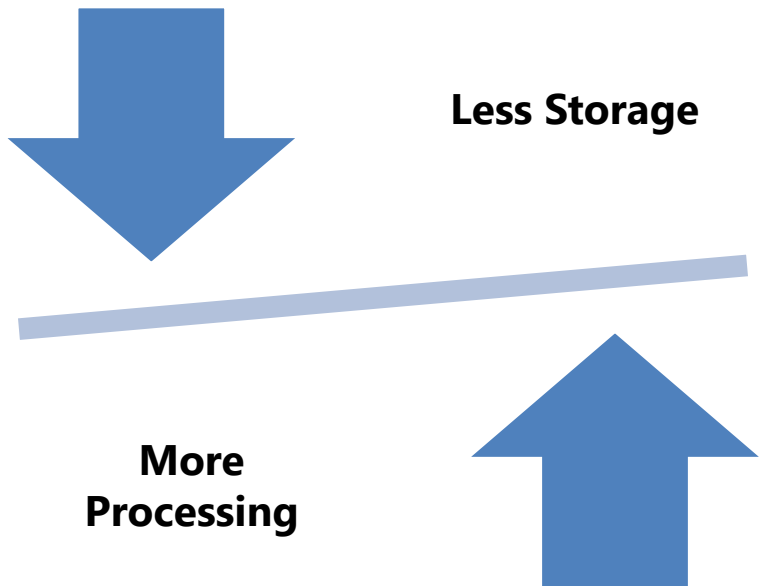
student	course	grade
Bart	Computer Science 142	B-
Milhouse	Computer Science 142	B+
Bart	Computer Science 143	C
Lisa	Computer Science 143	A+
Milhouse	Computer Science 143	D-
Ralph	Computer Science 143	B
Lisa	Computer Science 154	A+
Nelson	Computer Science 154	D+
Ralph	Informatics 100	D+

Tables:

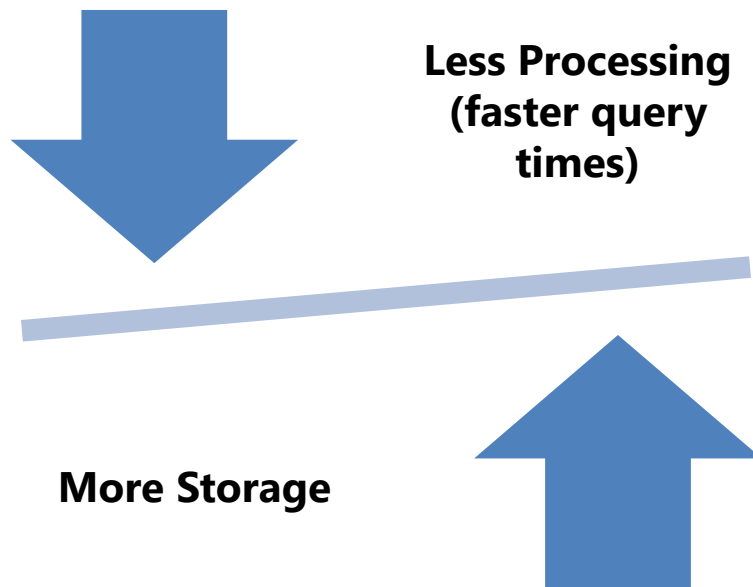
- Students Table
- Courses Table
- Roster Table

Trade-Offs

Normalization



Denormalization



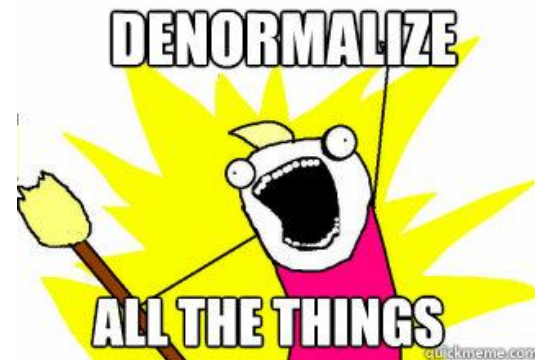
Costs, Storage vs Processing

Processing

US – N. Virginia	US – N. California	EU – Ireland
Standard On-Demand Instances	Linux/UNIX Usage	Windows Usage
Small (Default)	\$0.085 per hour	\$0.12 per hour
Large	\$0.34 per hour	\$0.48 per hour
Extra Large	\$0.68 per hour	\$0.96 per hour

Storage

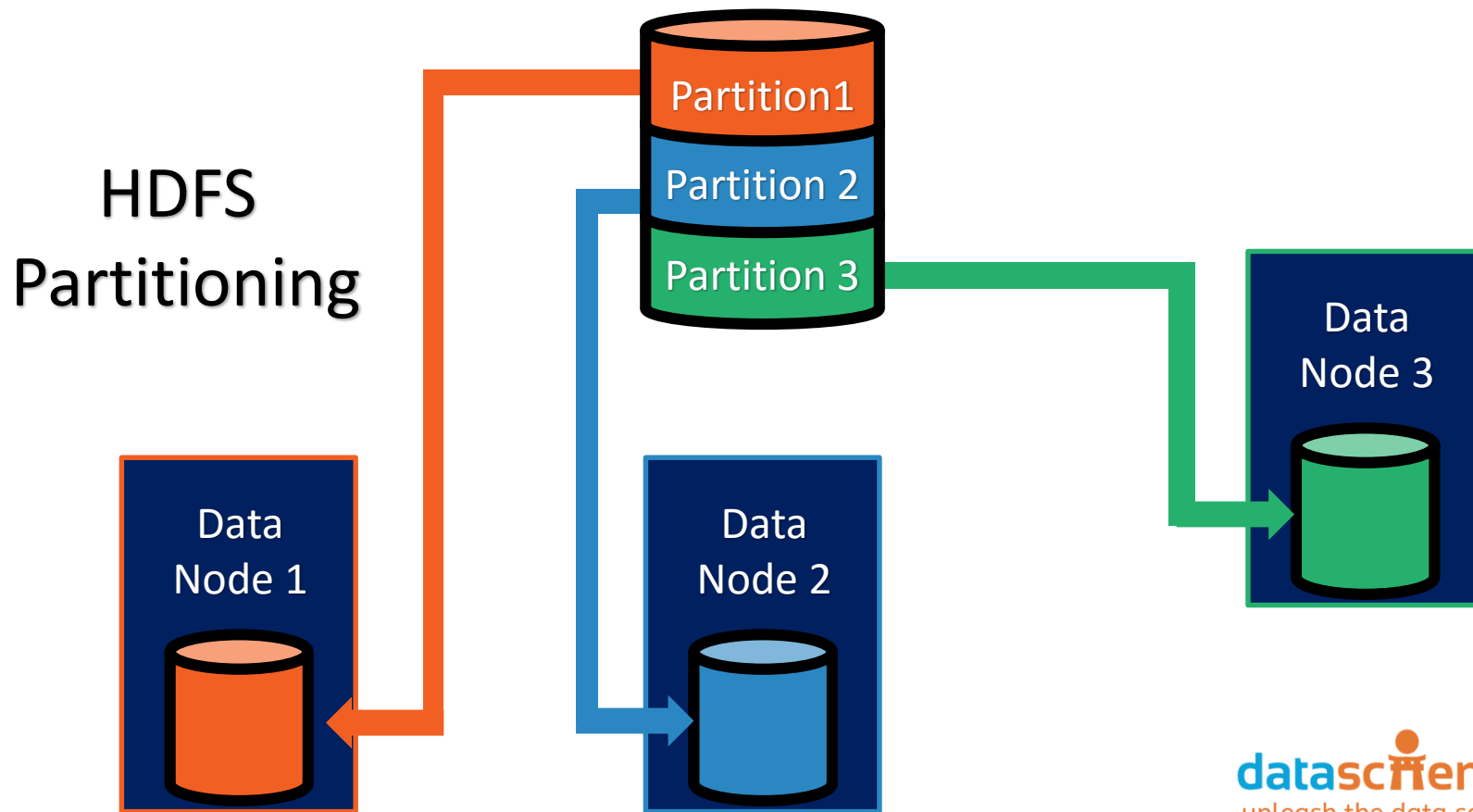
US – Standard	US –
Storage	
Tier	Pricing
First 50 TB / Month of Storage Used	\$0.150 per GB
Next 50 TB / Month of Storage Used	\$0.140 per GB
Next 400 TB /	\$0.130 per GB



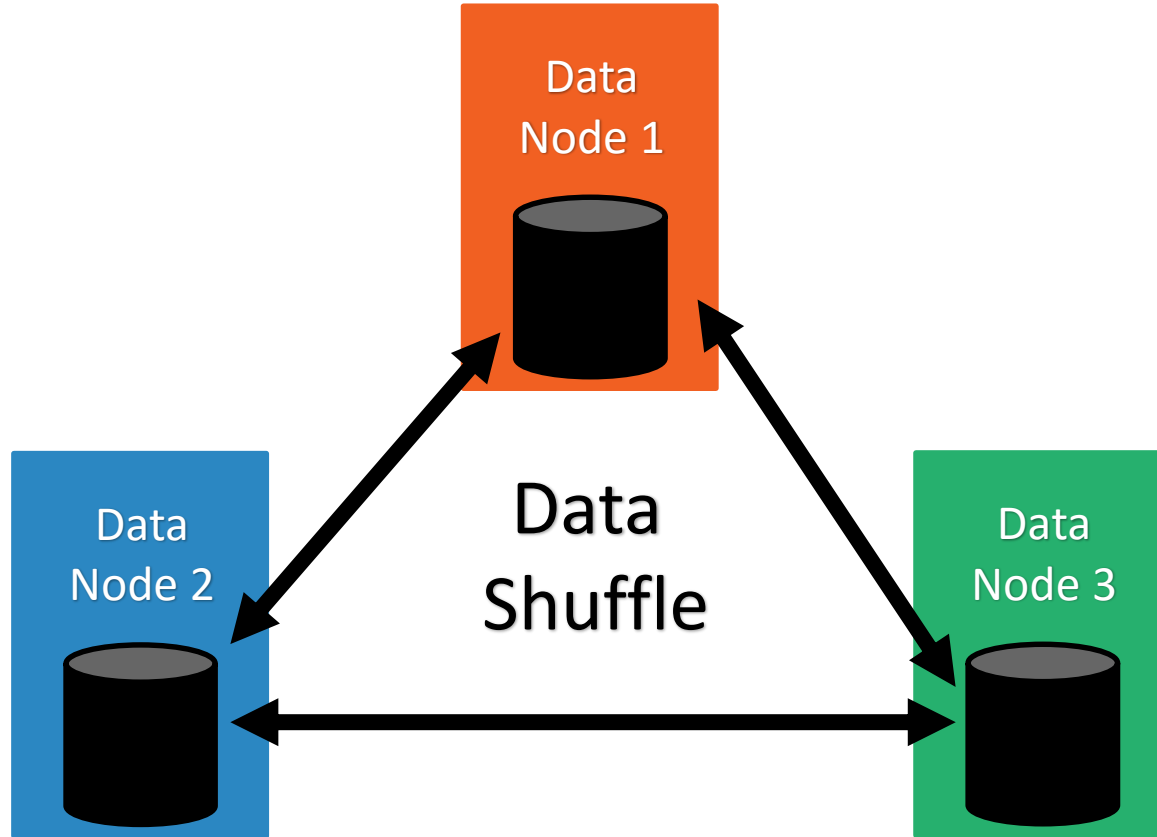


- Distributed Machine Learning
- Installed into Hadoop & Spark
- R-like language Implementation

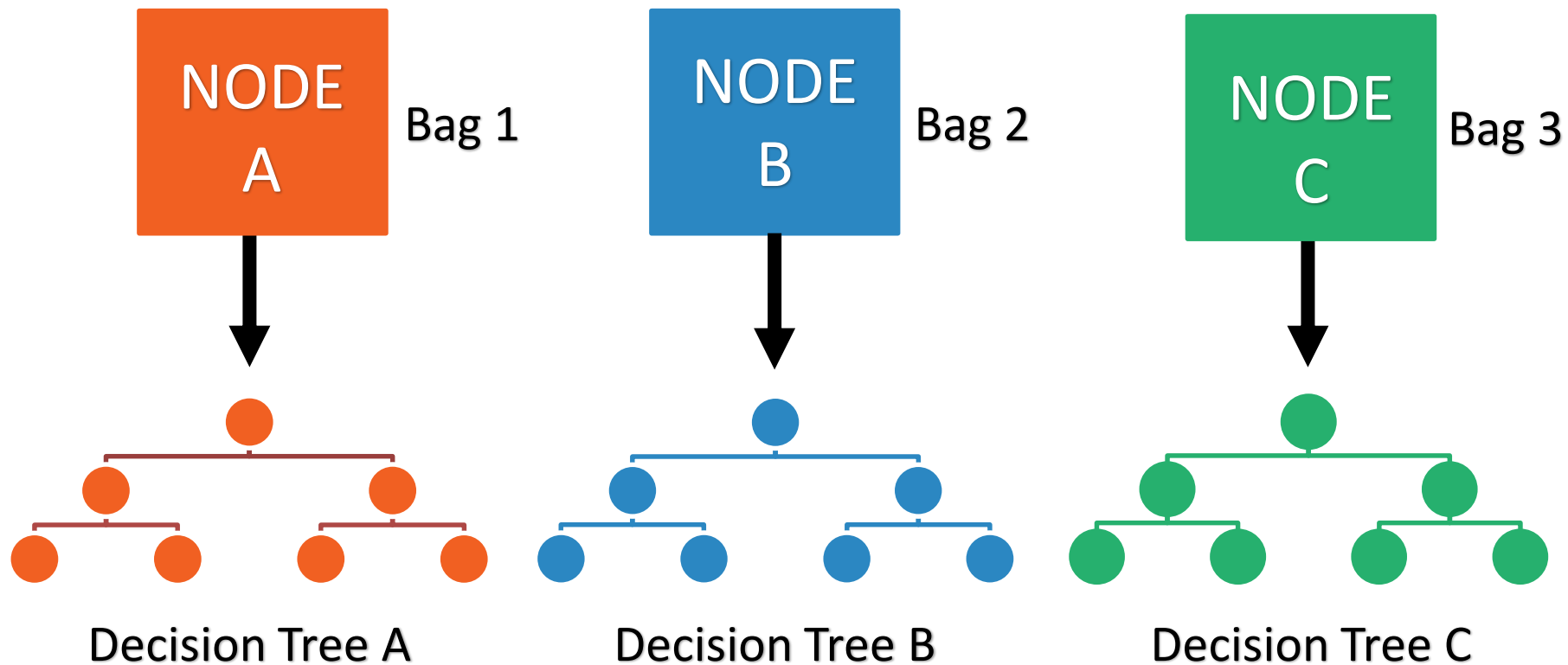
Distributed Random Forest



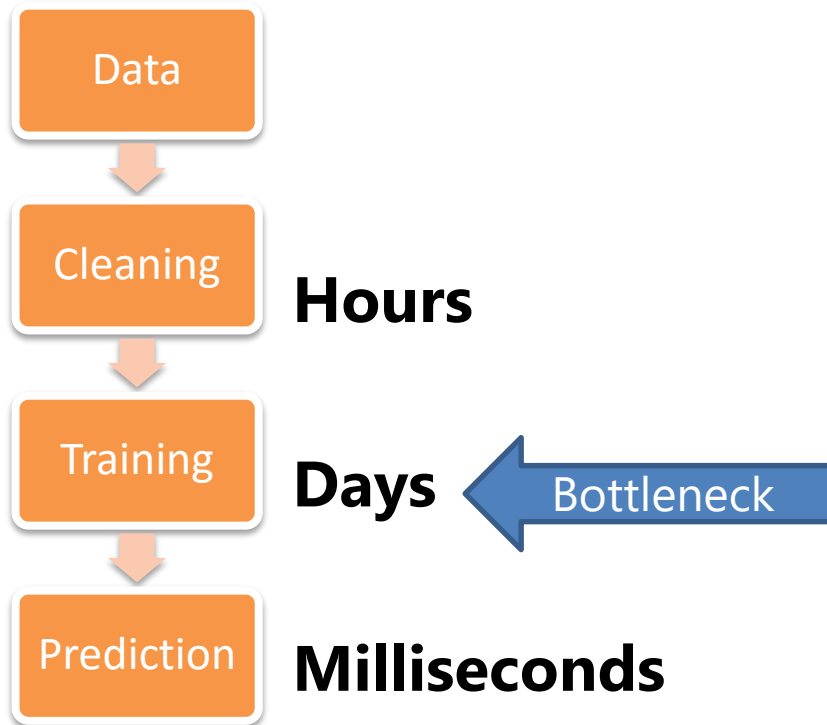
Distributed Random Forest



Distributed Random Forest

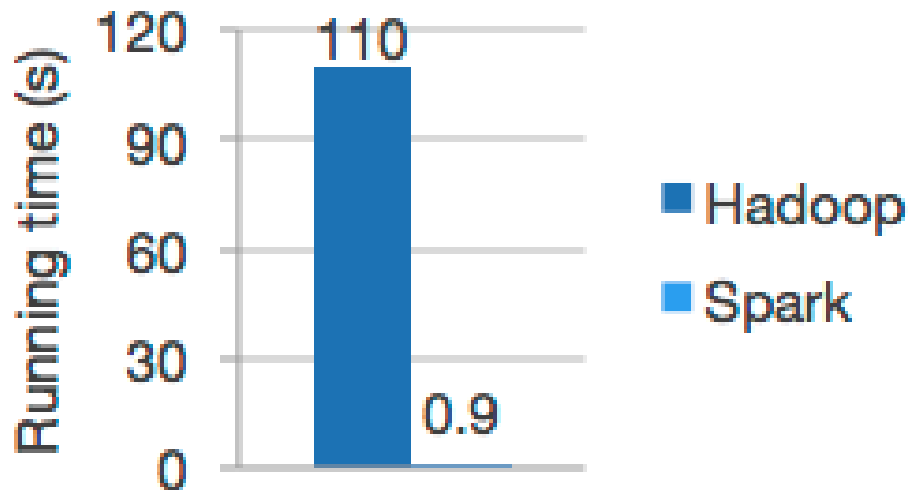


Processing Times - Machine Learning



- 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





In-Memory: 100x
times faster than
Hadoop



3x faster on 10x few machines

Datona GraySort Benchmark: Sort 100 TB of data

Previous World Record:

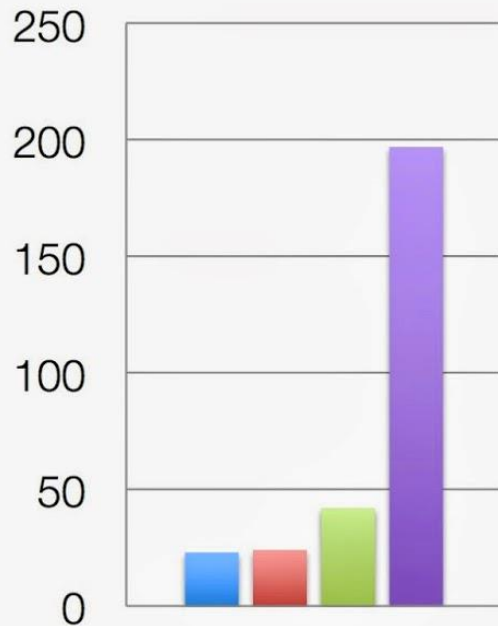
- Method: Hadoop
- Yahoo!
- 72 Minutes
- 2100 Nodes

2014:

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

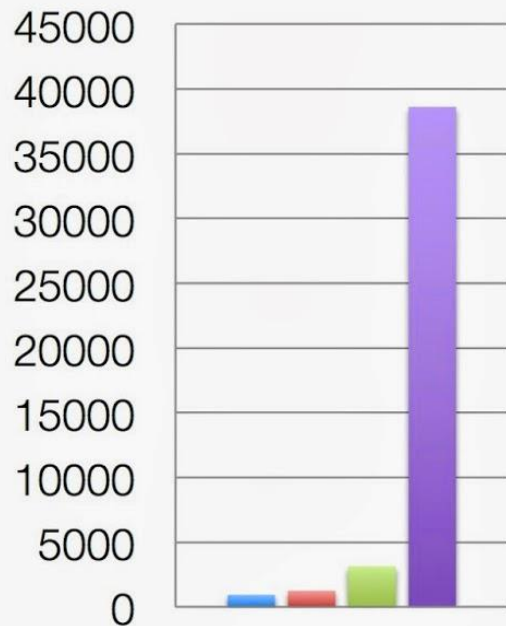
Source: <https://databricks.com/blog/2014/10/10/spark-petabyte-sort.html>

Activity in last 30 days



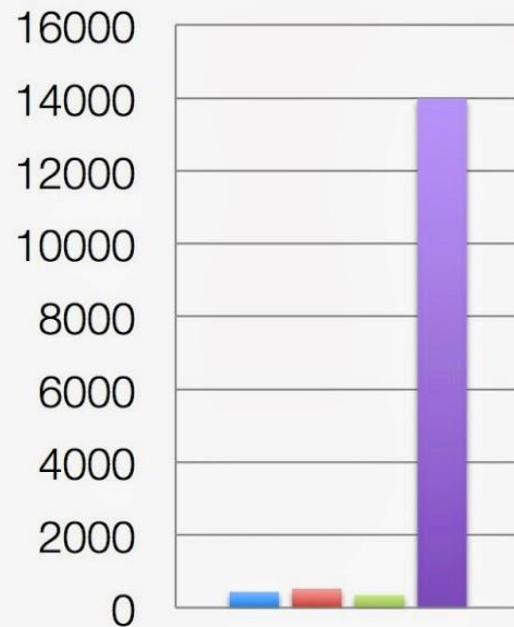
Patches

MapReduce Storm
Yarn Spark



Lines Added

MapReduce Storm
Yarn Spark



Lines Removed

MapReduce Storm
Yarn Spark

Source: Xiangrui Meng, Data Bricks



Spark
SQL

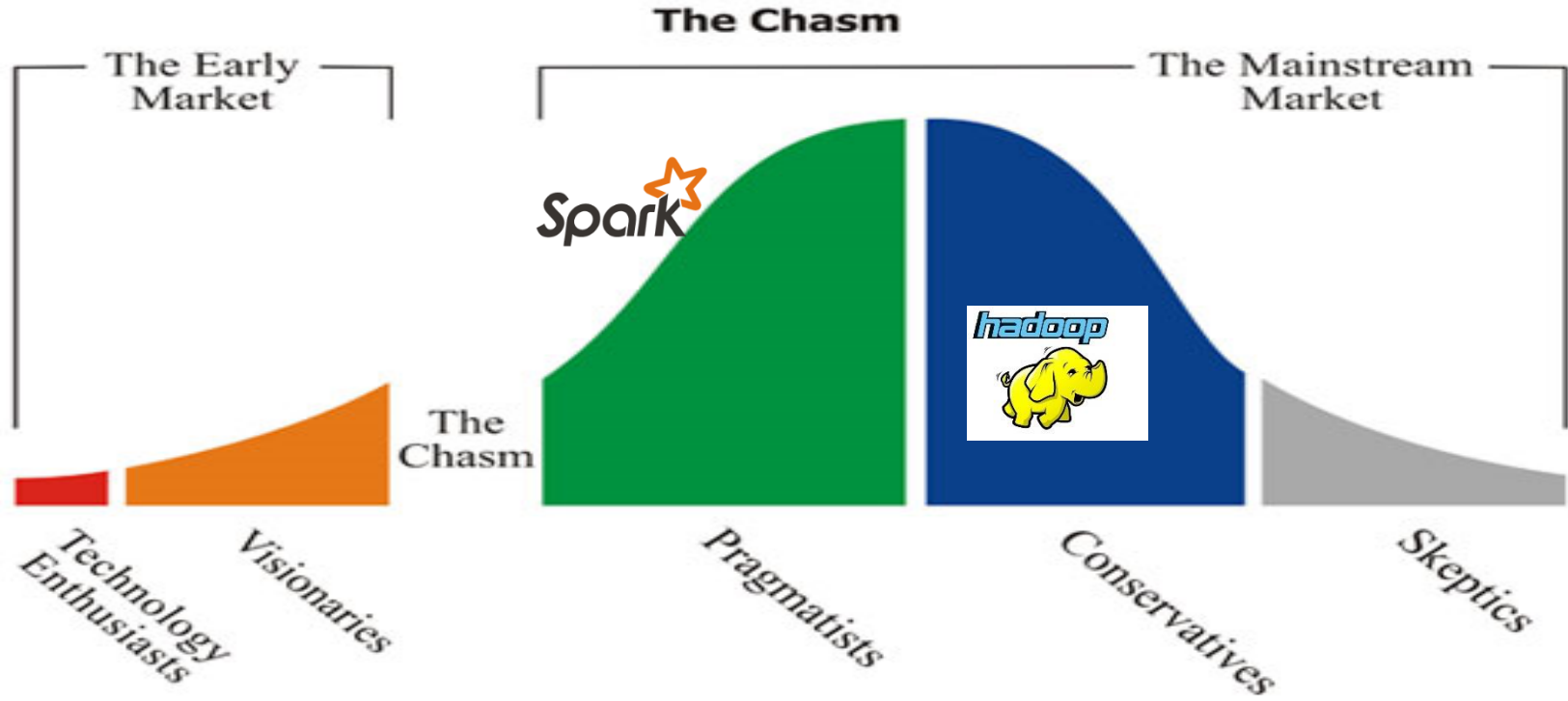
Spark
Streaming

MLlib
(machine
learning)

GraphX
(graph)

Apache Spark

Technology adoption life cycle



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

QUESTIONS

Enjoying the bootcamp?

We'd love it if you could write a short review of Data Science Dojo!

Switch Up (<https://www.switchup.org/bootcamps/data-science-dojo>)

Course Report (<https://www.coursereport.com/schools/data-science-dojo>)



Your reviews help other people find and attend our bootcamp.