# HDFS

## The Hadoop Distributed File System

Bernard Lee Kok Bang

# Installing mrjob on HDP 2.6.5

- ***Install PIP***
  - yum-config-manager --save --setopt=HDP-SOLR-2.6-100.skip_if_unavailable=true
  - curl -O https://bootstrap.pypa.io/pip/2.7/get-pip.py
  - python get-pip.py

- ***Install MRJob***
  - pip install pathlib
  - pip install mrjob==0.7.4
  - pip install PyYAML==5.4.1

- ***Download u.data***
  - wget http://media.sundog-soft.com/hadoop/ml-100k/u.data

# Handles big files

- optimized for handling very large files
- distributed and broken up across an entire cluster
- e.g., big logs of information from sensors, or web servers, etc.

**e.g. health sensor, Netflix**

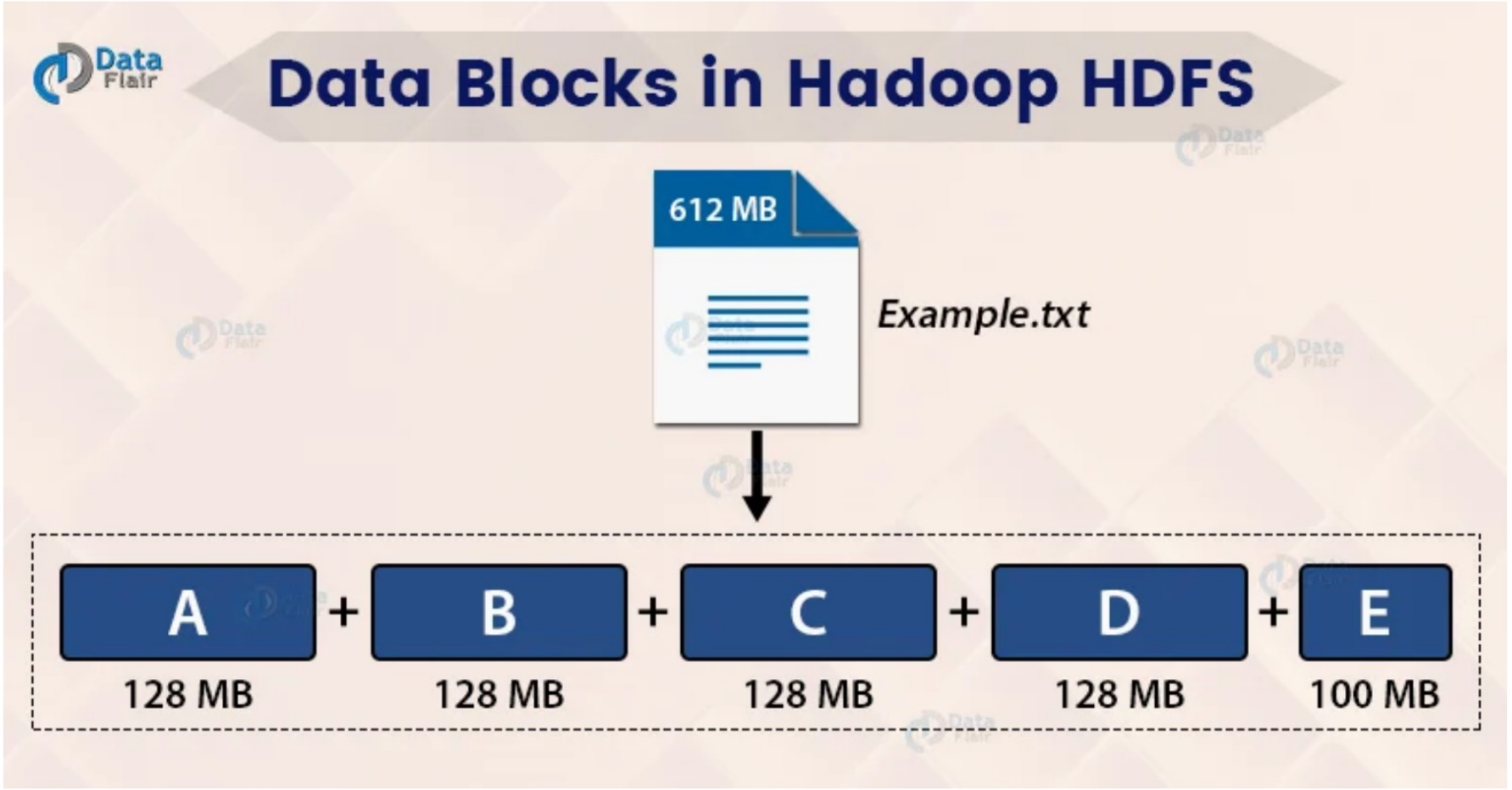
# By breaking into blocks

partitioned

- input data files are divided into **blocks of a particular size** (**128 mb** by default)
- these blocks of data are stored on different **DataNodes**
- Each block's information (its **address** on which data node is stored) is placed in **NameNode**
- if the block size is **too small**, then there will be **many blocks** to be stored on DataNodes
  - also a **large amount of metadata** information needs to be stored on NameNode
- if the block size **too large, parallelism** can't be achieved

*https://bit.ly/419z4RM*

# Data Blocks in Hadoop HDFS




**broken up / partitioned**

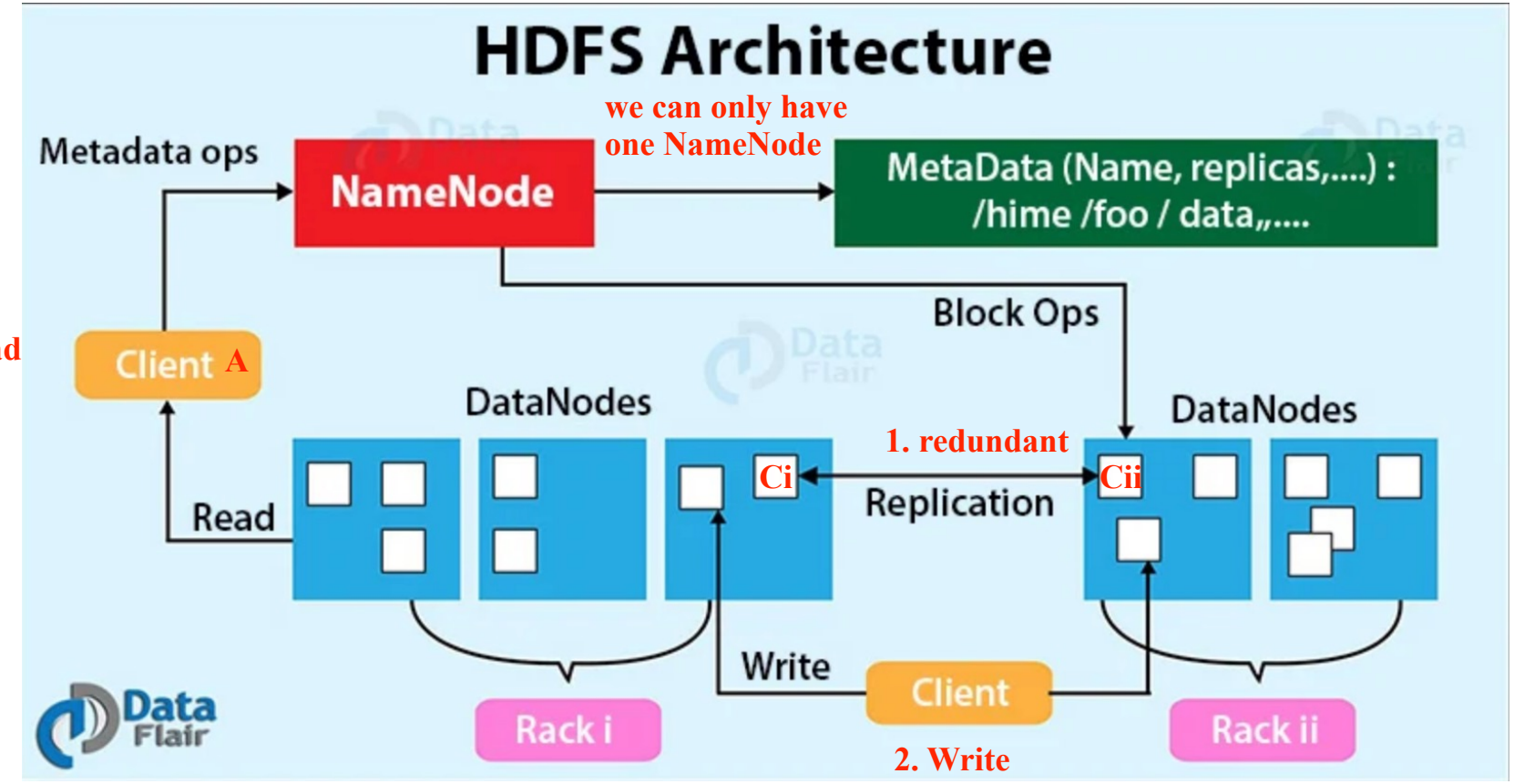
*https://bit.ly/2BpJ5jb*

# Stored Across Several Commodity Computers

- Blocks can be **stores across several commodity computers**
- Store **more than one copy** of each block to handle failure
- HDFS **retrieve information from back up copy** of that block in the event failure happened
- **not a big deal** if one single computer goes down

**horizontal scaling vs vertical scaling**

# HDFS Architecture




https://bit.ly/2z3g50p

- master node
- hold metadata

**Master-Slave architecture**

- single master node NameNode
- multiple slave nodes DataNode

**Master node [NameNode]**

- stores and manages the file system namespace metadata
- information about blocks of files like block locations, permissions, edit logs

**Slave nodes [DataNodes]**

- store data blocks of files

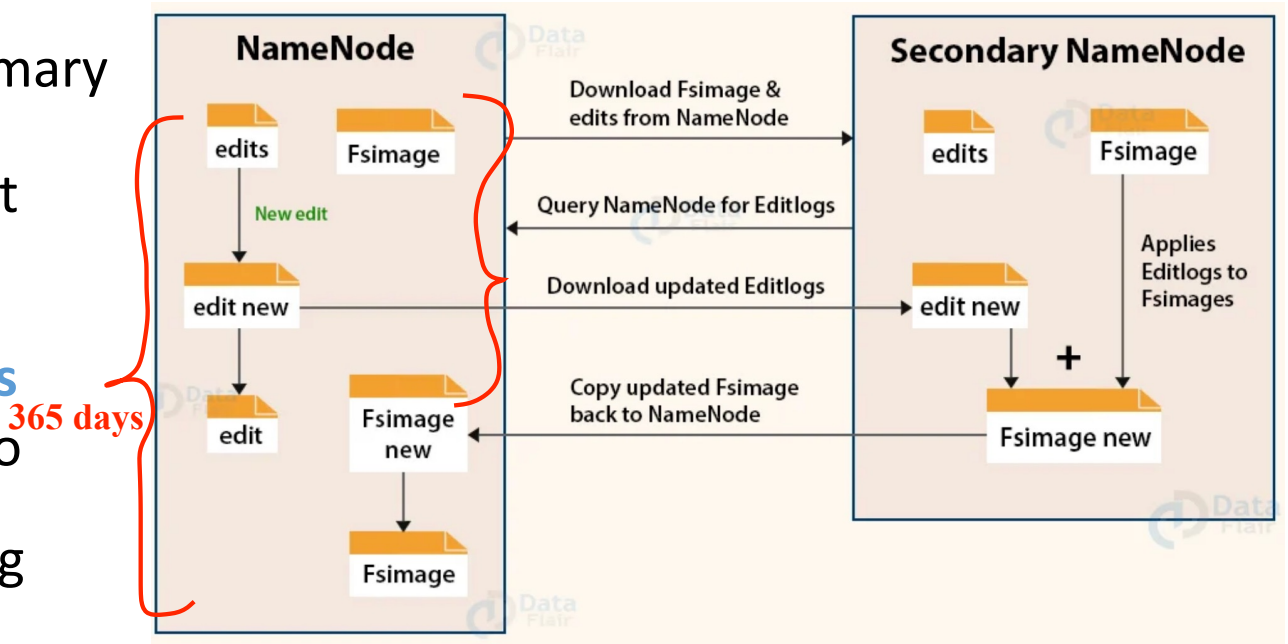
# What happens if NameNode goes down?

- very important to have **one NameNode active** at a given time
- NameNode is very resilience:
- 1. Back up Metadata
  - writes the edit logs to local disk and Network File System (NFS) [in different rack or data centre]
    - NFS → a network file sharing protocol that defines the way files are stored and retrieved from storage devices across networks
  - **might have some lag** when writing out the back up data [still have something to start from] **in the event of failure happened**

# What happens if NameNode goes down? [cont...]

- 2. Secondary Namenode
  - works as a **helper node** to primary NameNode but doesn't replace primary NameNode -> in sleeping mode
  - downloads the Fsimage (file system image) file and edit logs file from NameNode
  - **periodically applies edit logs to Fsimage and refreshes the edit logs**
  - The updated Fsimage is then sent to the NameNode so that NameNode doesn't have to re-apply the edit log records during its restart
  - keeps the **edit log size small** and **reduces the NameNode restart time**

primary node
[meant to run 24/7/365];
never shut down




1. edit logs would be super long
   - say NameNode crashed on 364th day
   - don't need refresh the edit logs from day 0

https://bit.ly/2z3g50p

# What happens if NameNode goes down? [cont…]

- each NameNode **manages a specific namespace volume**
  - especially when NameNode reach their breaking points of handling too much small files
  - separate NameNode responsible for **different namespace volume**
  - only lose a portion of the data if one of those NameNodes went down
  - namespace → a file or directory which is handled by NameNode [information about files, metadata, directories, etc…]

# What happens if NameNode goes down? [cont…]

- 4. High availability

**not an inherent part of the HDFS architecture**

- Hot standby NameNode using shared edit log [**not part of HDFS**]
- Zookeeper tracks active NameNode
- Use **extreme measures** to ensure **only one NameNode is used** at a time [such as physically cut off the power to a NameNode if Zookeeper thinks an active NameNode is down]

# Fsimage in HDFS

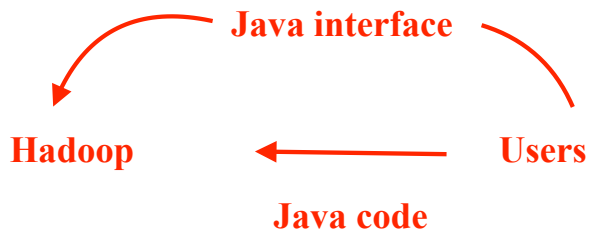
- Fsimage (File System Image) in Hadoop Distributed File System (HDFS) represents a ***snapshot of the file system's metadata***
- Contains metadata such as ***file names, directory structure, permissions, modification times, and file sizes***
- Periodically created by the NameNode as ***part of the checkpointing process***
- ***Merges latest edits from edit logs*** to create an updated snapshot of metadata
- NameNode ***loads fsimage into memory and applies edit logs*** since last checkpoint instead of replaying all edit logs
- Stored on NameNode's disk along with edit logs to ***enable recovery of NameNode's state in case of failure***.

# Edit Logs in HDFS

- Edit logs in Hadoop Distributed File System (HDFS) are ***sequential records of metadata changes*** in ***chronological order*** since the last checkpoint
- Record operations like ***file creations, deletions, modifications, and directory changes***
- Each entry in edit log corresponds to a ***single transaction or operation***
- Used with fsimage to restore metadata after NameNode failure or restart
- Edit log replayed to ***reconstruct file system state*** since last checkpoint
- Kept until merged into new fsimage during checkpoint
- After merge, can be truncated to reclaim storage space

# Using HDFS

- UI (Ambari) [copy files, view files…]
- Command-Line interface
- HTTP / HDFS Proxies
- **Java interface [Hadoop is written in Java under the hood; doesn't mean you need to write Java code ☺; you can still use R, Python…]**



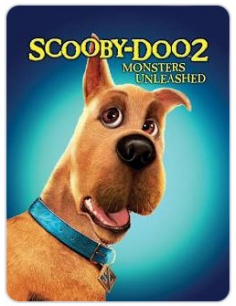

**Hive, pig latin ….. are actually Java interface**

# MapReduce Fundamental Concept

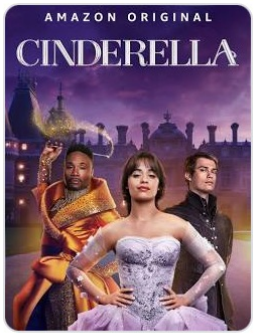
- Why MapReduce?
  - Distributes the processing of data on the cluster
  - Divides our data into partitions that are **MAPPED (transformed)** and **REDUCED (aggregated)** by mapper and reducer functions
  - **Resilient to failure** – an application master monitors mappers and reducers on each partition
- **Mapper** transforms the data as it comes in one line at a time
  - Extracting and organizing the data as **key/value pair**
- **Reducer** aggregates data together

**MapReduce -> Fundamental building blocks of Hadoop**

# Illustrate with an example




Scooby Doo 2: …

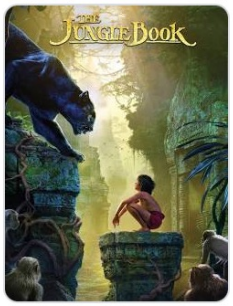



Cinderella


Hotel Transylvan…


Alice in Wonderl…


Kung Fu Panda

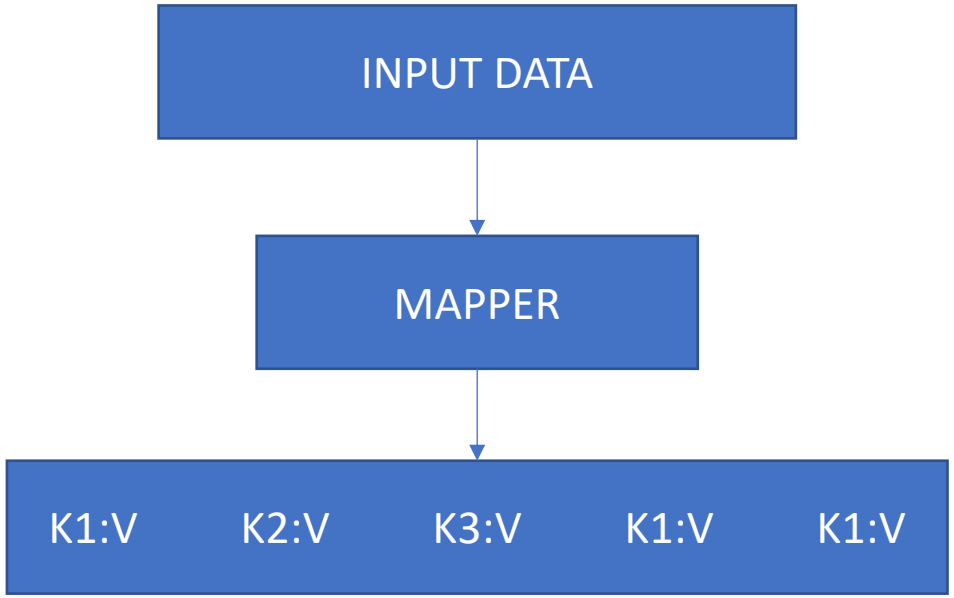



The Jungle Book

**How many movies did each user rate in the MovieLens data set?**

# How MapReduce Works: Mapper

- The MAPPER converts raw source data into **key/value pair**

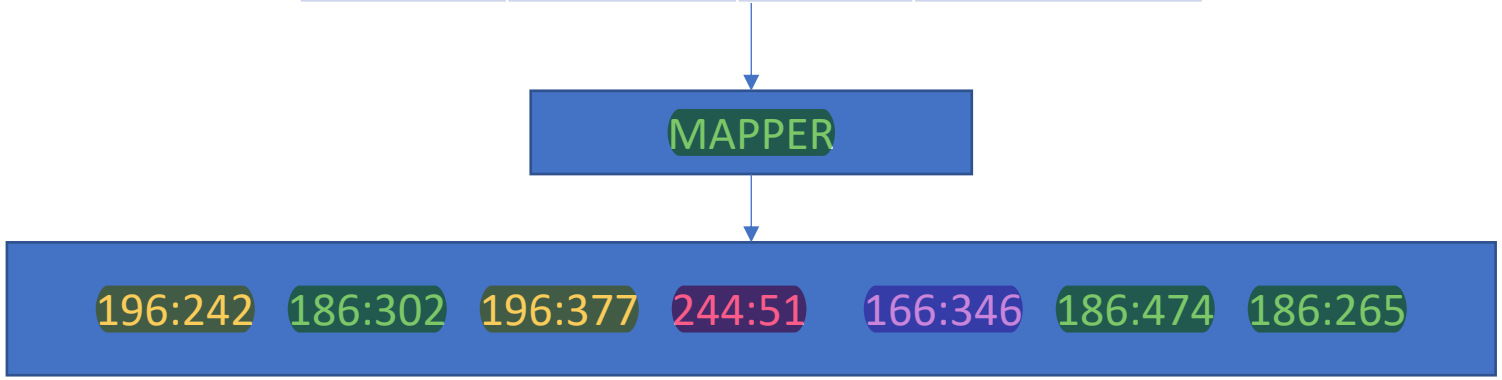



Key [K] = user ID
Value [V] = movie name

**Row by Row**

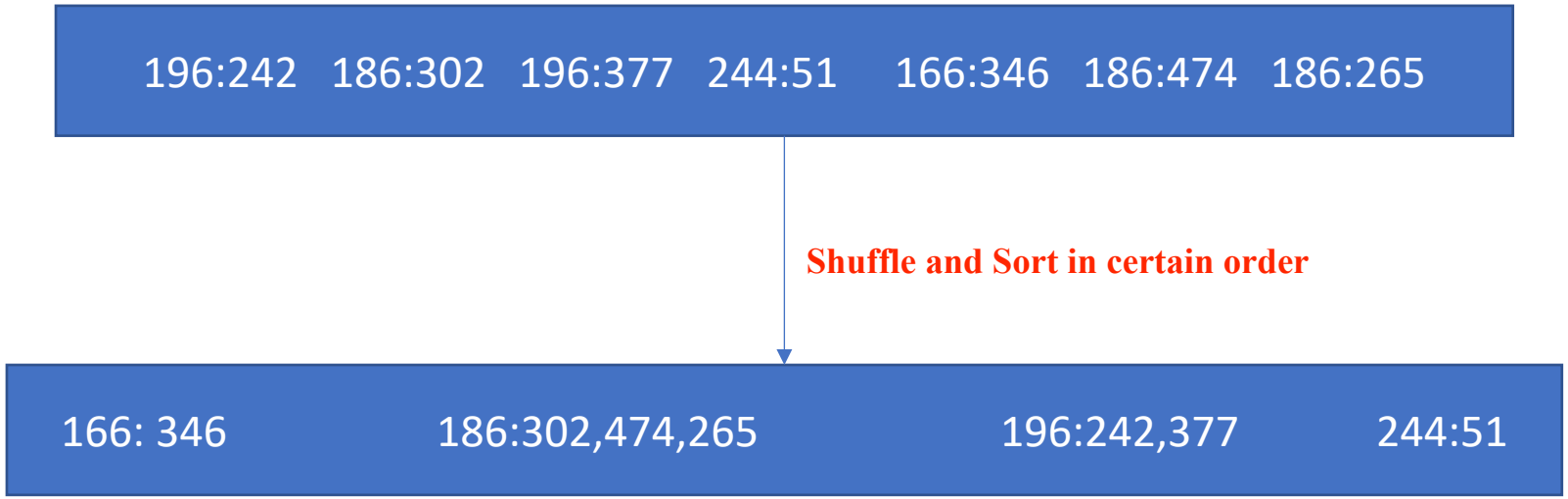
# Example: MovieLens data (u.data)

| USER ID | MOVIEID | Rating | TIMESTAMP |
|---|---|---|---|
| 196 | 242 | 3 | 881250949 |
| 186 | 302 | 3 | 891717742 |
| 196 | 377 | 1 | 878887116 |
| 244 | 51 | 2 | 880606923 |
| 166 | 346 | 1 | 886397596 |
| 186 | 474 | 4 | 884182806 |
| 186 | 265 | 2 | 881171488 |



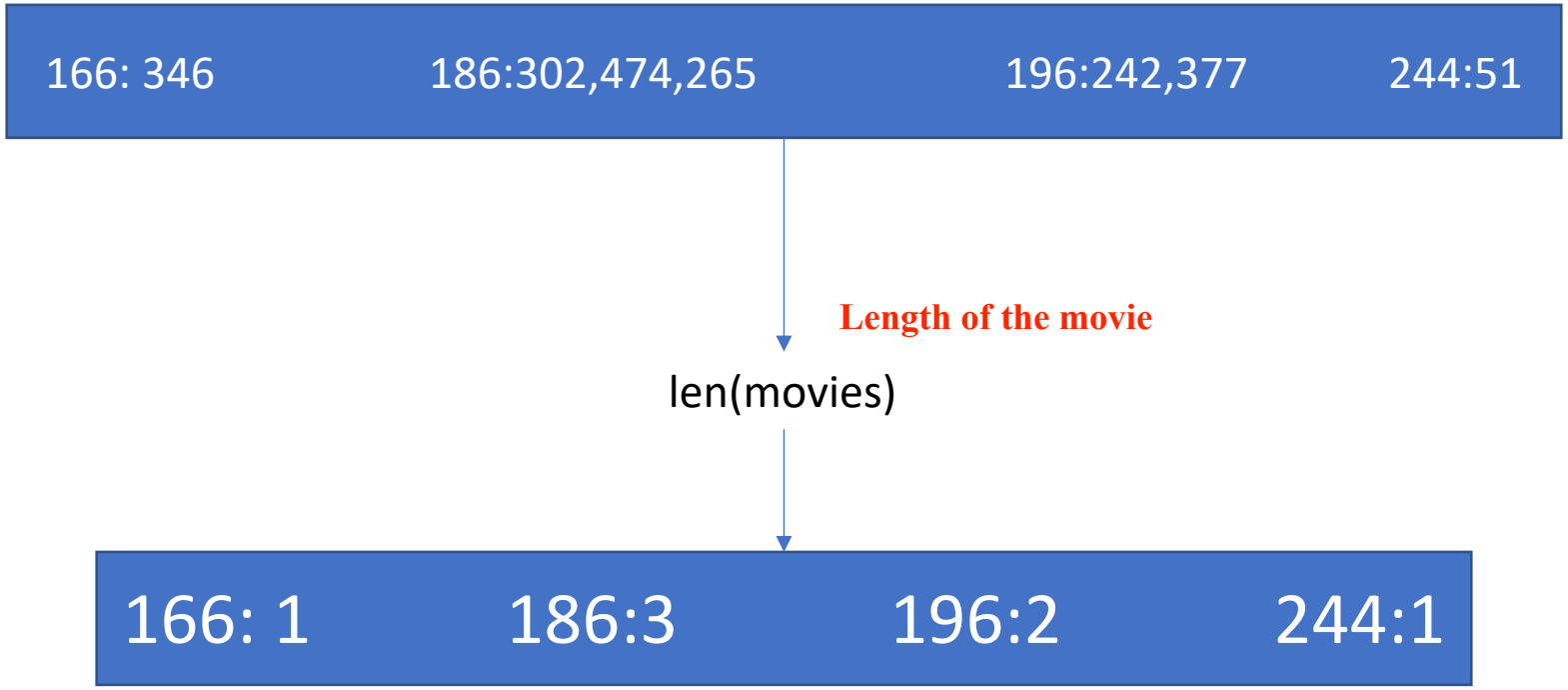

key:value pair

# MapReduce Sorts and Groups the Mapped Data ("Shuffle and Sort")




- 1. Aggregate all given values for each unique key
- 2. Sort all given keys

# The REDUCER Processes Each Key's Value




**How many movies did each user rate?**

# Putting it All Together

**HDFS**
- **data would be distributed / broken up / partitioned**
- **data be reduced**
- **data would be replicated / redundant**
- **from back up copy**

**MapReduce, NameNode, DataNode….**
**They always have back up copy**

| USER ID | MOVIEID | Rating | TIMESTAMP |
|---|---|---|---|
| 196 | 242 | 3 | 881250949 |
| 186 | 302 | 3 | 891717742 |
| 196 | 377 | 1 | 878887116 |
| 244 | 51 | 2 | 880606923 |
| 166 | 346 | 1 | 886397596 |
| 186 | 474 | 4 | 884182806 |
| 186 | 265 | 2 | 881171488 |

**raw files**

**MAPPER** **reads the data one line at one time to become key/value pair**

196:242 186:302 196:377 244:51 166:346 186:474 186:265

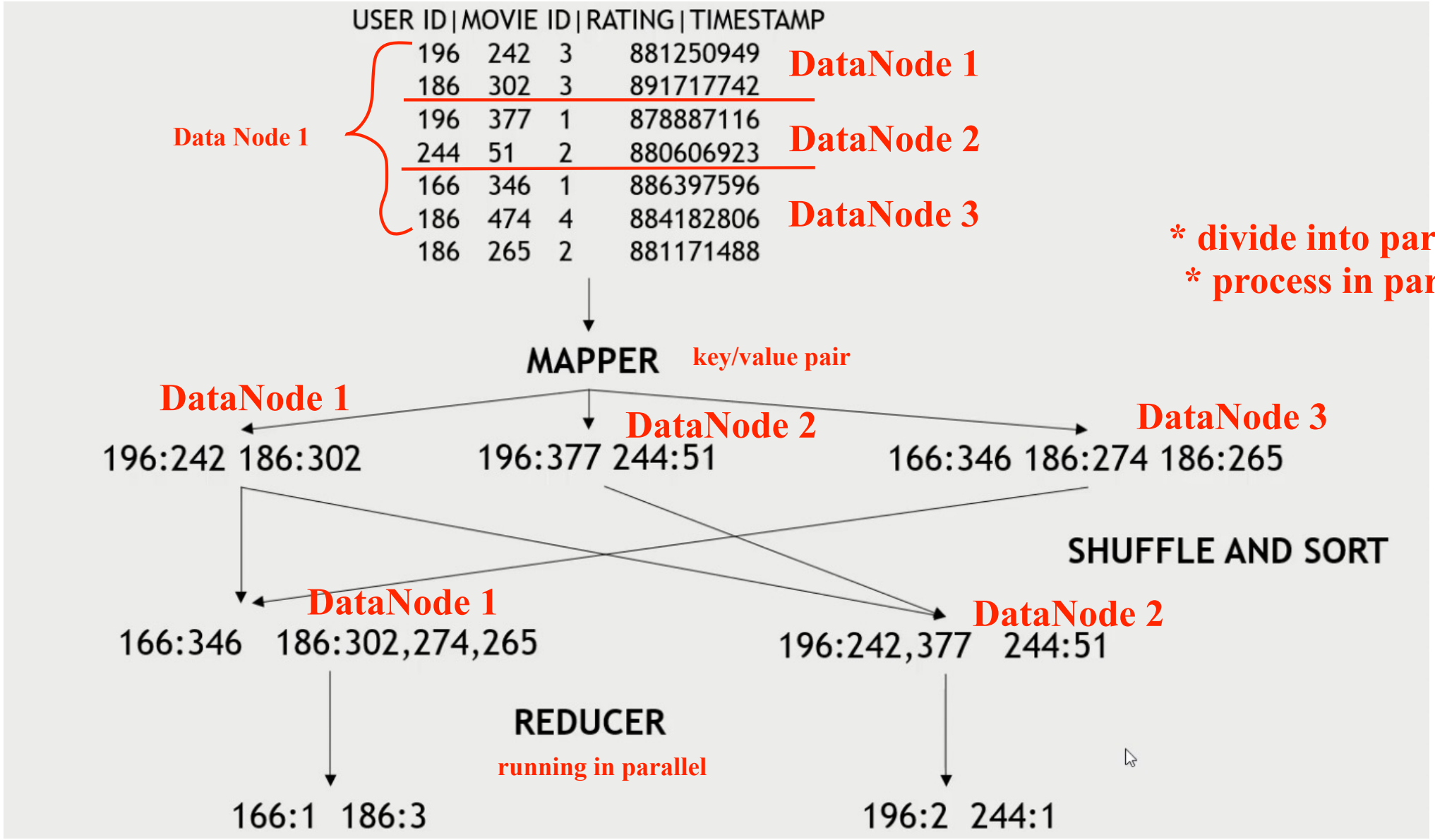
**Shuffle & Sort**

166: 346 186:302,474,265 196:242,377 244:51

**Reducer**

166: 1 186:3 196:2 244:1

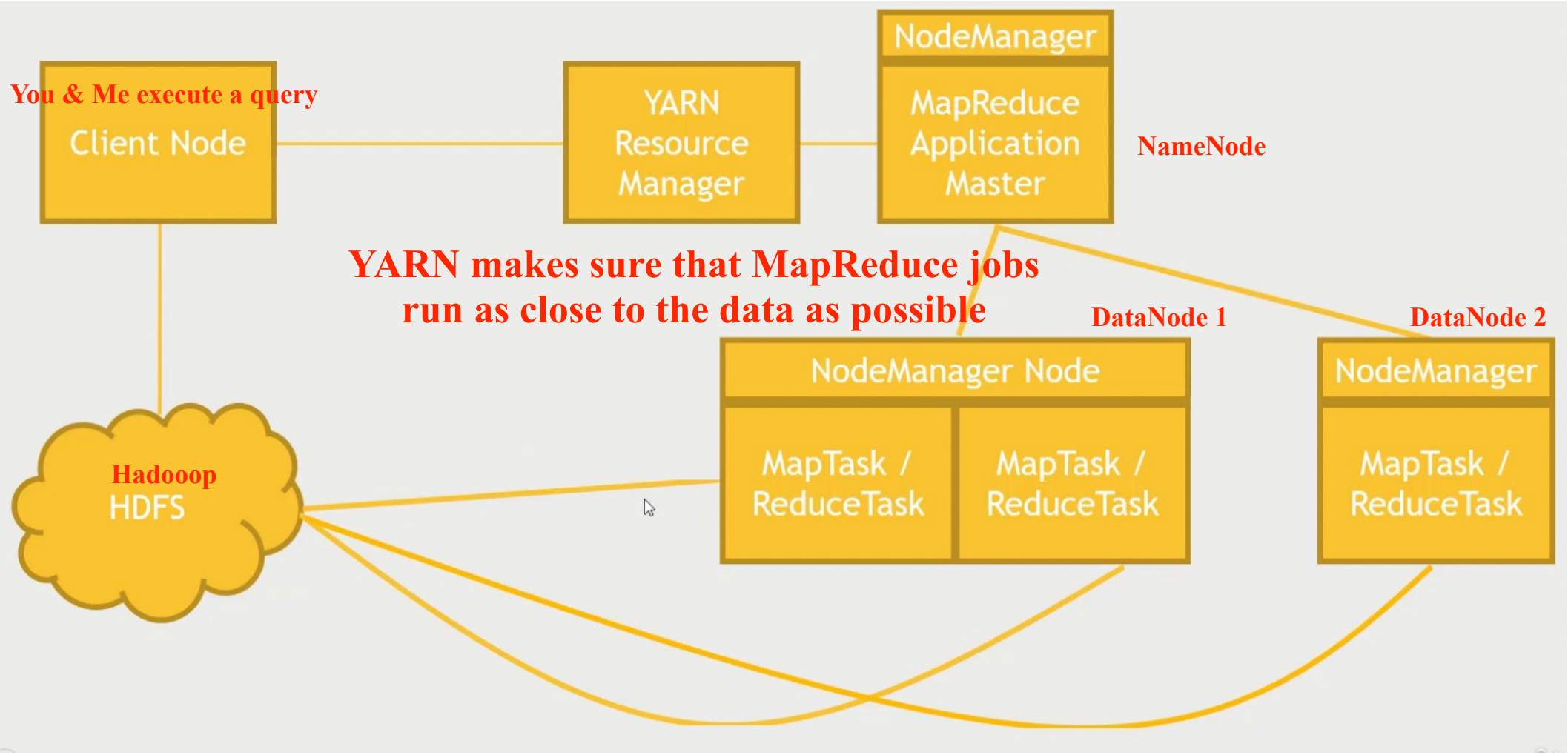
# MapReduce - if you understand this messy figure




* divide into partition
* process in parallel

# What's happening

Handling failure



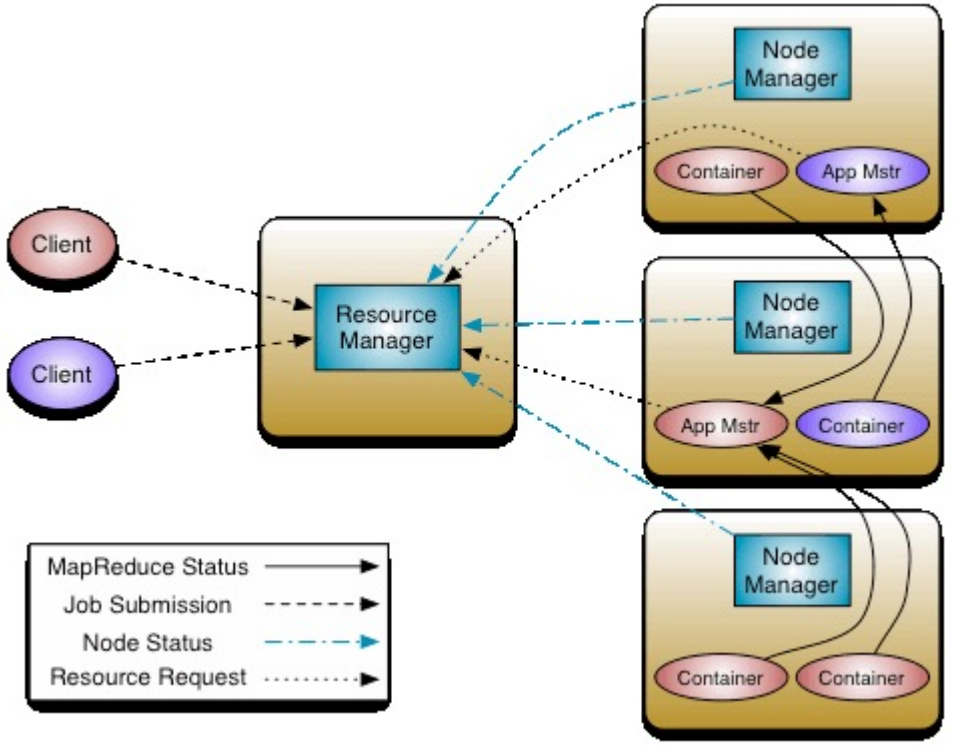
# Handling Failure

- Application master monitors worker tasks for errors or hanging
  - *Restart as needed*
  - *Preferably on a different node*
- What if the application master goes down?
  - *YARN can try to restart it*
- What if entire Node goes down?
  - *This could be the application master*
  - *The resource manager will try to restart it*
- What if the resource manager goes down?
  - *Can set up "high availability" (HA) using Zookeeper to have a hot standby*

**Overwatch of the watch**

# YARN – Yet Another Resource Negotiator

- employs a master-slave model and includes several components
- The global **Resource Manager** is the ultimate authority that arbitrates resources among all applications in the system.
- The per-application **Application Master** negotiates resources from the Resource Manager and works with the Node Managers to execute and monitor the component tasks.
- The per-node slave **Node Manager** is responsible for launching the applications' containers, monitoring their resource usage and reporting to the Resource Manager.




*https://bit.ly/3vqVPmX*

# MapReduce: An example

- How many of each rating type exist [from MovieLens dataset]?

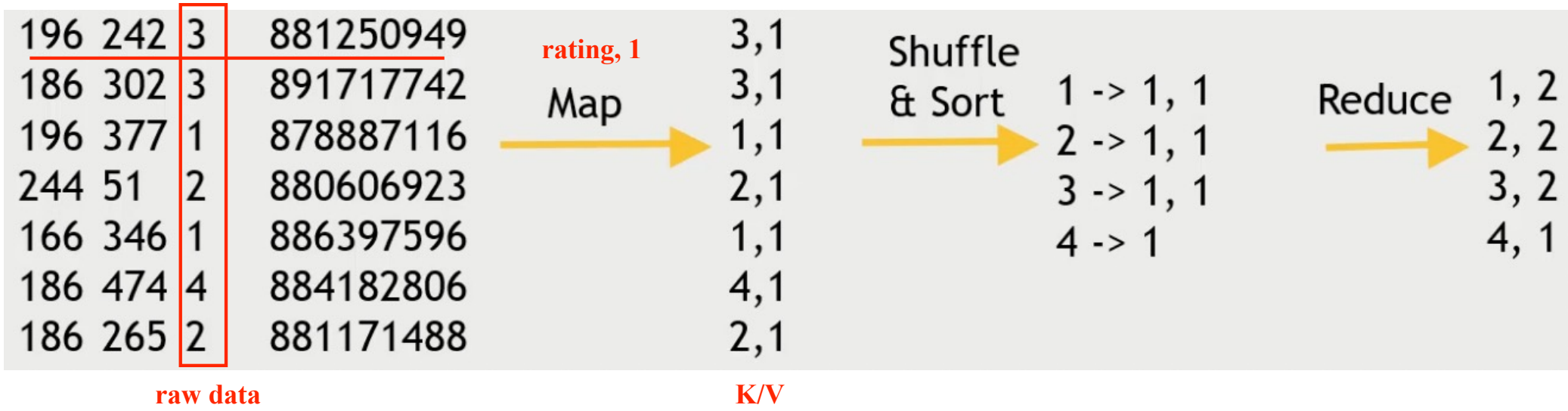
How many people give ratings of 5

…
…
…
…
…
…
…
…

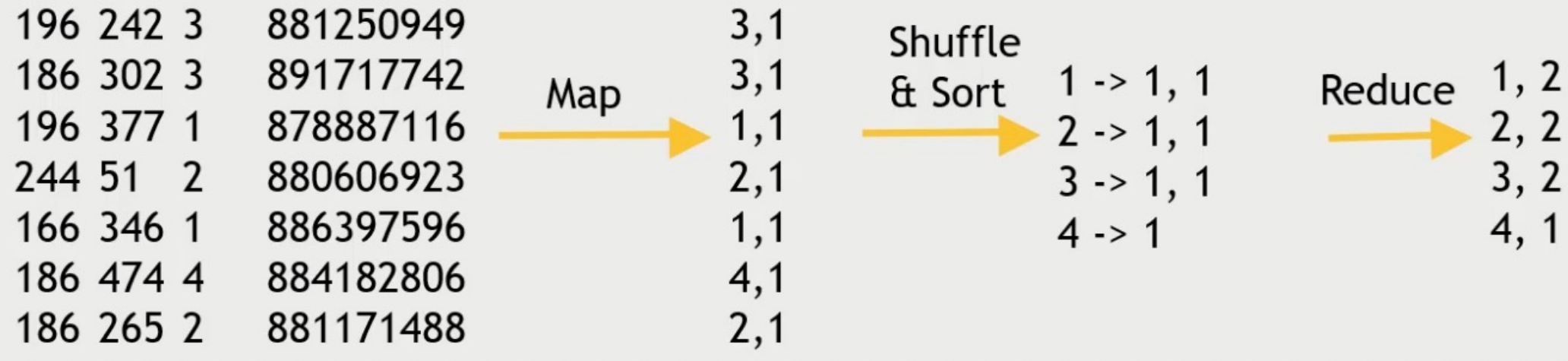
How many people give ratings of 1

# Turning it into a MapReduce Problem

- **MAP** each input line to (***rating, 1***)
- **REDUCE** each rating with the sum of all the 1's



# Writing the Mapper



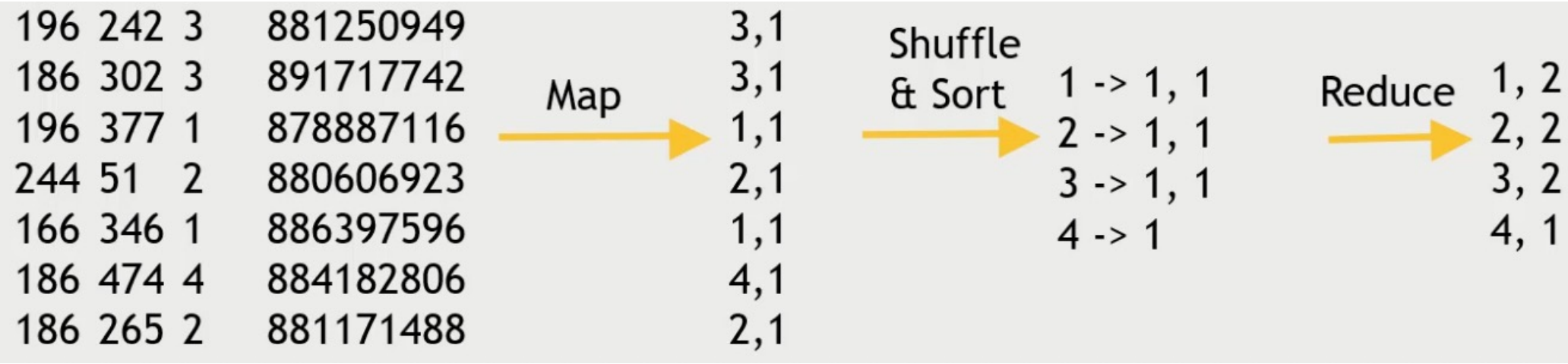

Python function

3 parameters "_" -> used to hold redundant data / data that we don't need

```
def mapper_get_ratings(self, _, line):
    (userID, movieID, rating, timestamp) = line.split('\t')
    yield rating, 1
```

output

# Writing the Reducer




Pyton function

3 parameters

```
def reducer_count_ratings(self, key, values):
    yield key, sum(values)
```

# Putting all together

**Save as:**
**MapReducer.py**

```
from mrjob.job import MRJob
from mrjob.step import MRStep

class RatingsBreakdown(MRJob):
    def steps(self):
        return [
            MRStep(mapper=self.mapper_get_ratings,
                   reducer=self.reducer_count_ratings)
        ]

    def mapper_get_ratings(self, _, line):
        (userID, movieID, rating, timestamp) = line.split('\t')
        yield rating, 1

    def reducer_count_ratings(self, key, values):
    yield key, sum(values)

if __name__ == '__main__':
    RatingsBreakdown.run()
```

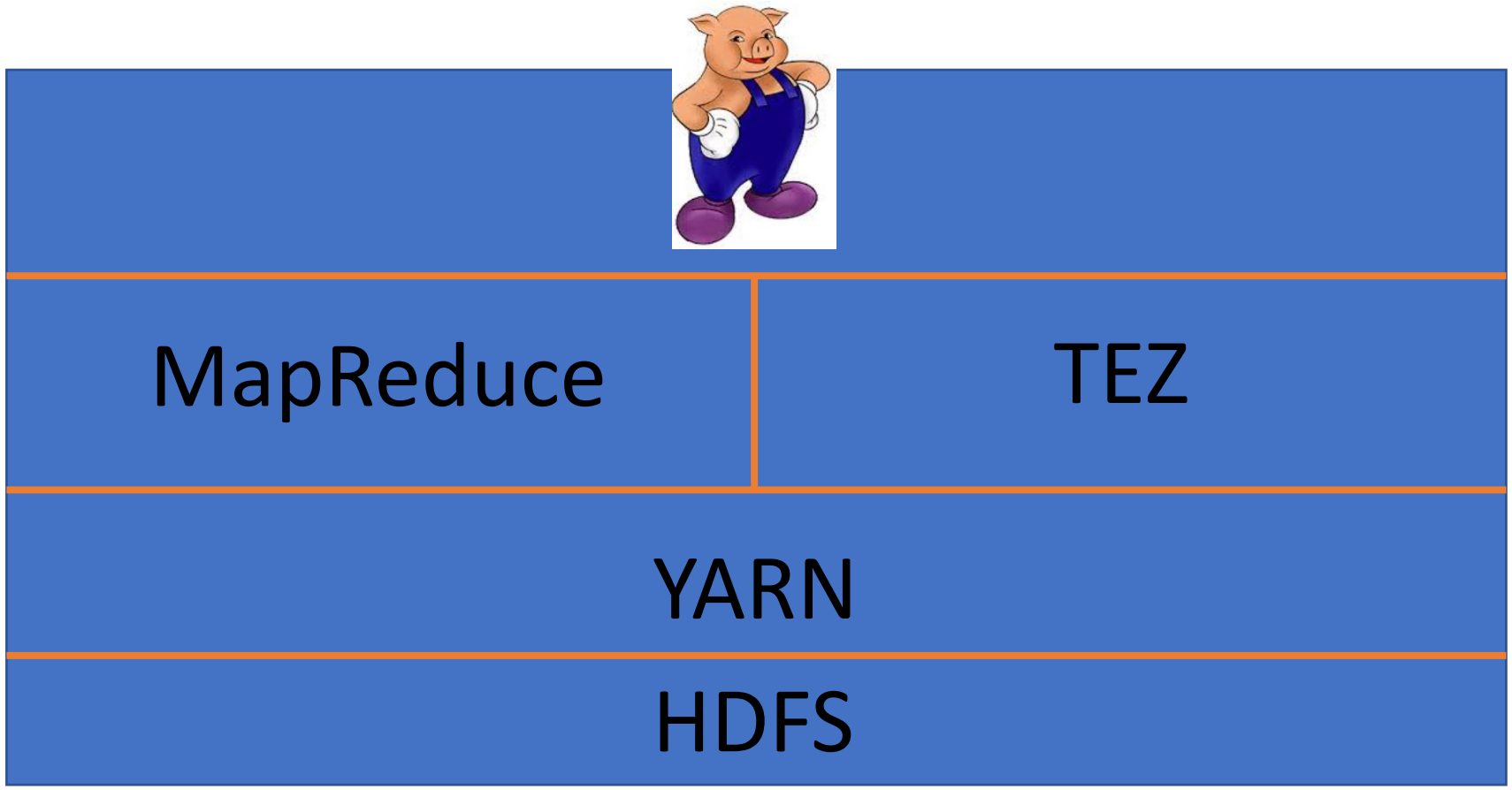
*to run:*
*python MapReduce.py u.data*

Mapper functioin

Reducer function

→ runs from command-line

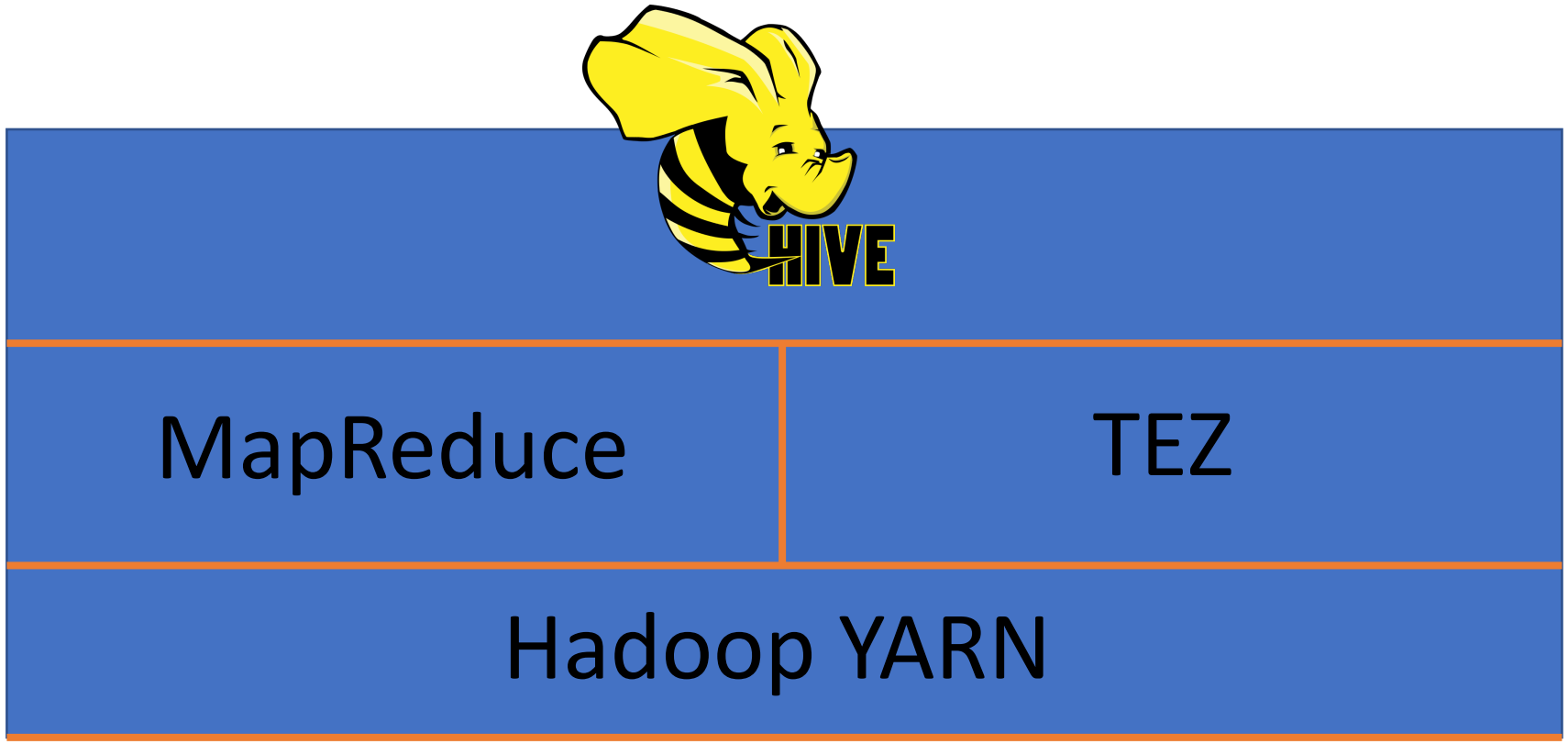
# Pig Architecture



# Why Pig?

- Writing mappers and reducers by hand takes a long time
- Pig introduces Pig Latin, a scripting language that lets us use SQL-like syntax to define the map and reduce steps

# Hive Architecture




- **Translates SQL queries to MapReduce or TEZ jobs on Hadoop clusters**
- **Hive will break down the SQL queries into Mappers and Reducers**

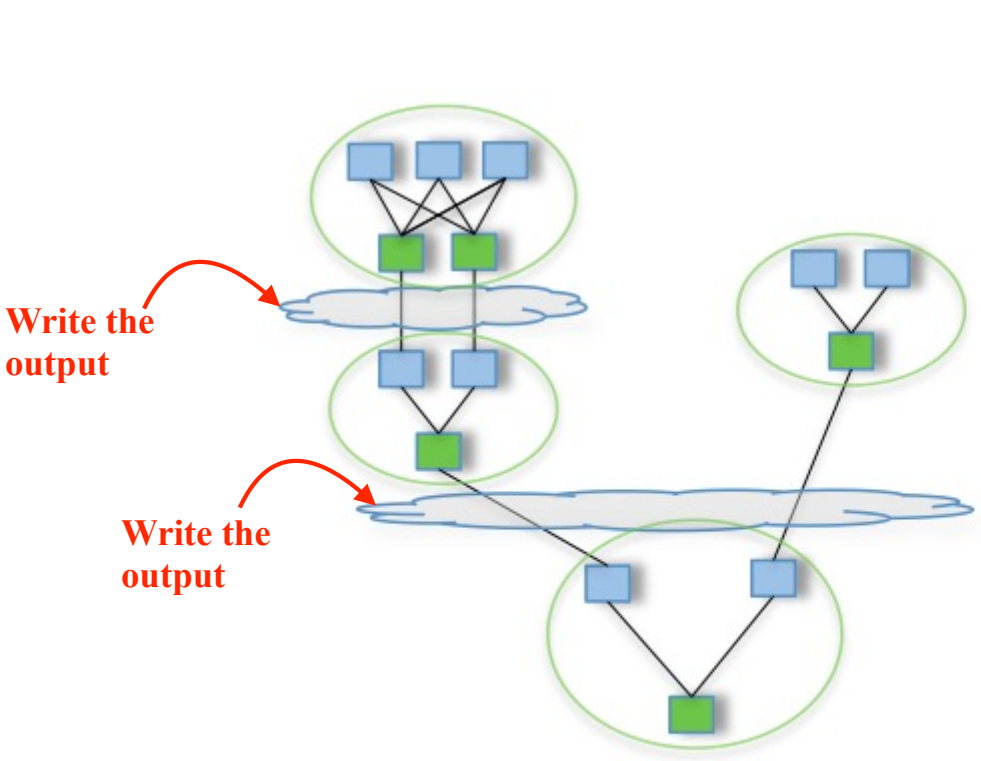
# Why Hive

- Use familiar SQL syntax (**HiveQL**)
- Interactive
- Scalable – works with “big data” on a cluster
  →Appropriate for data warehouse application
- Easy Online Analytics processing (OLAP) – much easier than writing MapReduce in Java

# TEZ

**Once client execute a function, Tez will evaluate what's the final output; then work backward to get the most optimal pathway**

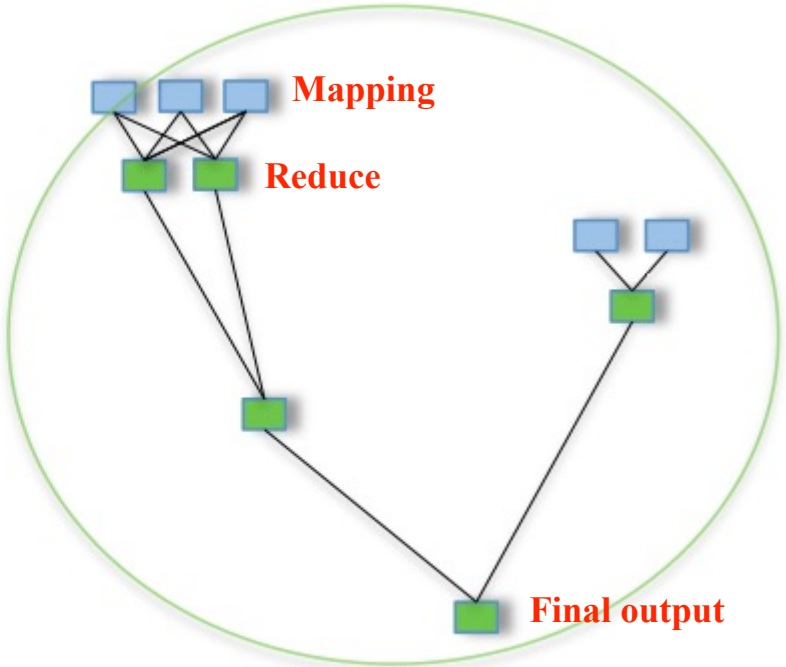
- an application framework which allows for a complex directed-acyclic-graph (DAG) of tasks for processing data.




Pig/Hive - MR

**MapReduce algorithm**

**backward workflow**




Pig/Hive - Tez

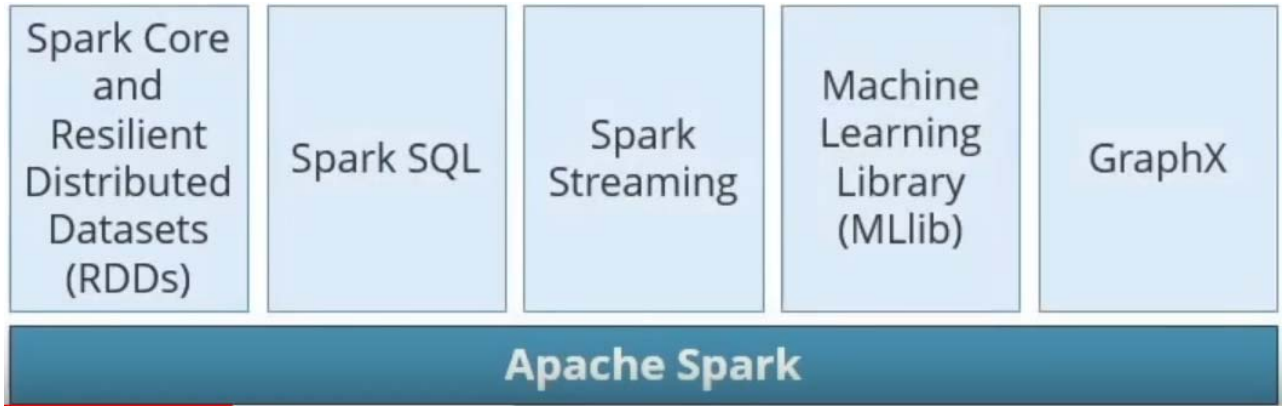
**Tez algorithm**

**Lazy evaluation**

*https://bit.ly/3vqVPmX*

# Introduction to Spark

- Spark is an open-source cluster computing Framework
  - It is suitable for **real-time** processing, trivial operations, and processing large data on network.
  - Provides up to 100 times faster performance for a few applications with in-memory primitives, as compared to the two-stage disk-based MapReduce paradigm of Hadoop.
  - Is suitable for machine learning algorithms, as it allows programs to load and query data repeatedly



# Application of In-Memory Processing

With column-centric database coming, the similar information can be stored together. The working of in-memory processing can be explained as below:

- The entire information is loaded into memory, eliminating the need for indexes, aggregates, optimized databases, star schemas, and cubes.
- Compression algorithms are used by most of the in-memory tools, thereby reducing the in-memory size.

  →reduce the number of bytes required to represent data and the amount of memory required to store images
- With in-memory tools, the analysis of data can be flexible in size and can be accessed within seconds by concurrent users with an excellent analytics potential.

# Row-based vs column-centric database

| Name | | | City | | | Age | | |
|---|---|---|---|---|---|---|---|---|
| Matt | Dave | Tim | Los Angeles | San Francisco | Oakland | 27 | 30 | 33 |

**Normal Table**

Facebook_Friends

| Name | City | Age |
|---|---|---|
| Matt | Los Angeles | 27 |
| Dave | San Francisco | 30 |
| Tim | Oakland | 33 |

**Hadoop is about partitioned data; distributed processing**

Row-based

Column-based

| Matt | Los Angeles | 27 | Dave | San Francisco | 30 | Tim | Oakland | 33 |
|---|---|---|---|---|---|---|---|---|

*** Same type of Data**

*** Mapped new data easier**

| Disk 1 | | |
|---|---|---|
| Name | City | Age |
| Matt | Los Angeles | 27 |

| Disk 2 | | |
|---|---|---|
| Name | City | Age |
| Dave | San Francisco | 30 |

| Disk 3 | | |
|---|---|---|
| Name | City | Age |
| Tim | Oakland | 33 |

**Names that is age ≥ 30 years**

| Disk 1 | | |
|---|---|---|
| Name | | |
| Matt | Dave | Tim |

| Disk 2 | | |
|---|---|---|
| City | | |
| Los Angeles | San Francisco | Oakland |

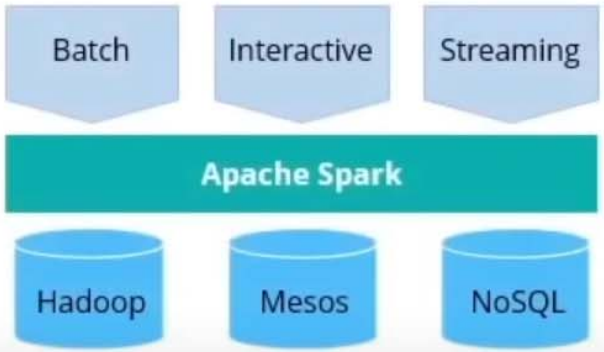
| Disk 3 | | |
|---|---|---|
| Age | | |
| 27 | 30 | 33 |

**Names that is age ≥ 30 years**

*https://bit.ly/3OvlPVN*

# Spark Advantages

- **Speed**: Extending the MapReduce model to support computations like stream processing and interactive queries.
- **Combination**: Covering various workloads that used to require different distributed systems, which makes combining different processing types and allows easy tools management
- **Hadoop Support**: Allowing to create distributed datasets from any file stored in the Hadoop Distributed File System (HDFS) or any other supported storage systems.

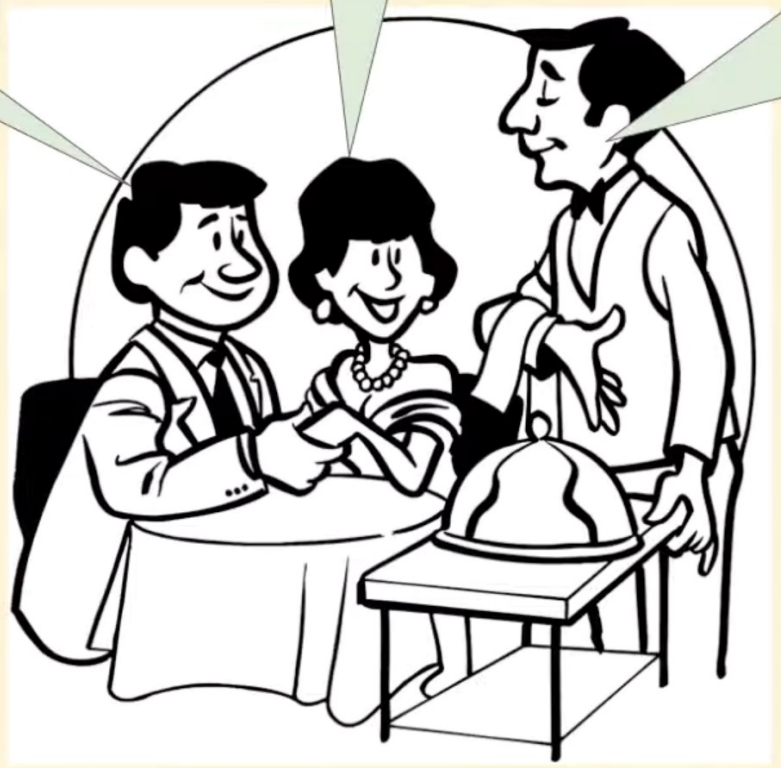
# A good programmer is a super lazy person :)

## Lazy Evaluation Example - The waiter takes orders patiently

Cheese burger, soup and a Plate of Noodles please

Soup and A Plate of Noodles for me

Ok.
One cheese burger
Two soups
Two plates of Noodles
Anything else, sir?



The chef is able to optimize because of clubbing multiple order together

**Final output**

**Final order**

*https://bit.ly/3Mp7Hey*