

# Big Data – Challenges of Distributed Data-Systems: Partitioning

Cooperative State University Baden-Wuerttemberg

# Agenda – 22.10.2018



01

**Presentation and Discussion: Exercise Of Last Lecture**  
HiveQL, HDFS/Hive Partitioning, HiveServer2

02

**Introduction To The Challenges Of Distributed Data-Systems: Partitioning**  
Basics of Partitioning, Key-Range and Hash Partitioning, Partitioning of Secondary Indices, Rebalancing and Lookup of Partitions

03

**HandsOn – Spark, Scala, PySpark and Jupyter**  
A quick Introduction to Spark, Scala, PySpark and Jupyter

04

**Exercise – Working with Spark, Scala, PySpark and Jupyter on IMDb dataset.**  
Install and configure Spark, Scala, PySpark and Jupyter as well as some practical exercises on IMDb dataset.

# Schedule

	<i>Lecture Topic</i>	<i>HandsOn</i>
01.10.2018 16:00-19:30 Ro. 0.11	About This Lecture, Introduction to Big Data	Hadoop
08.10.2018 16:00-19:30 Ro. 0.11	(Non-)Functional Requirements Of Distributed Data-Systems, Data Models and Access	MapReduce, Hive, HiveQL
15.10.2018 16:00-19:30 Ro. 0.11	Challenges Of Distributed Data Systems: Replication	Hive/HDFS Partitioning, HiveServer2
<b>22.10.2018 16:00-19:30 Ro. 0.11</b>	<b>Challenges Of Distributed Data Systems: Partitioning</b>	<b>Spark, Scala and PySpark/Jupyter</b>
29.10.2018 16:00-19:30 Ro. 0.11	Batch and Stream Processing	MongoDB or Spark Streaming or Flink
05.11.2018 16:00-19:30 Ro. 0.11	ETL Workflow And Automation	PDI/Airflow
12.11.2018 16:00-19:30 Ro. 0.11	Work On Practical Examination	
19.11.2018 16:00-19:30 Ro. 0.11	Presentation Of Practical Examination	



# Solution – Exercise 03

HiveQL, HDFS/Hive Partitioning, HiveServer2



# Solution

## Prerequisites:

- Download, Install and Setup Hadoop, YARN and Hive (previous lectures)
- Download, Install and Setup Apache HiveServer2
- Start HDFS, YARN and HiveServer2
- Download, Install and Configure JDBC Rich-client:
  - e.g. DBeaver,
  - SquirrelSQL,
  - ...
- Execute all preparation and example tasks of previous HandsOn slides of last lecture



# Solution

## Exercise 2:

2.1 Create table `imdb_actors_partitioned` partitioned by column `partition_is_alive`:

```
hive > CREATE EXTERNAL TABLE IF NOT EXISTS imdb_actors_partitioned(
    nconst STRING,
    primary_name STRING,
    birth_year INT,
    death_year STRING,
    primary_profession STRING,
    known_for_titles STRING
) PARTITIONED BY (partition_is_alive STRING)
STORED AS ORCFILE LOCATION '/user/hadoop/imdb/actors_partitioned';
```



# Solution

## Exercise 2:

2.2 Use **static** partitioning to create and fill partition ‘alive’

```
hive >     INSERT OVERWRITE TABLE imdb_actors_partitioned
          partition(partition_is_alive='alive')
          SELECT
              a.nconst,
              a.primary_name,
              a.birth_year,
              a.death_year,
              a.primary_profession,
              a.known_for_titles
          FROM imdb_actors a WHERE a.death_year IS NULL
```



# Solution

## Exercise 2:

### 2.3 Use static partitioning to create and fill partition 'dead'

```
hive >     INSERT OVERWRITE TABLE imdb_actors_partitioned
          partition(partition_is_alive='dead')
          SELECT
                  a.nconst,
                  a.primary_name,
                  a.birth_year,
                  a.death_year,
                  a.primary_profession,
                  a.known_for_titles
          FROM  imdb_actors a WHERE a.death_year IS NOT NULL
```



# Solution

## Exercise 2:

### 2.4 Check Results:

```
'hadoop fs -ls /user/hadoop/imdb/actors_partitioned
drwxr-xr-x  - hadoop supergroup          0 2018-10-09 20:48 /user/hadoop/imdb/actors_partitioned/
partition_is_alive=alive
drwxr-xr-x  - hadoop supergroup          0 2018-10-09 20:54 /user/hadoop/imdb/actors_partitioned/
partition_is_alive=dead'
```



# Solution

## Exercise 2:

### 2.4 Check Results:

The screenshot shows a database query results table. The query is:select \* FROM imdb\_actors\_partitioned where partition\_is\_alive = 'dead' LIMIT 100

```
Result
```

	imdb_actors_partitioned	imdb_actors_partitioned.primary_name	imdb_actors_partitioned.birth_year	imdb_actors_partitioned.death_year	imdb_actors_partitioned.primary_profession	imdb_actors_partitioned.known_for_titles
6	nm0000006	Ingrid Bergman	1.915	1982	actress,soundtrack,producer	tt0038109,tt0034583,tt0038787,tt0071877
7	nm0000007	Humphrey Bogart	1.899	1957	actor,soundtrack,producer	tt0034583,tt0043265,tt0037382,tt0033870
8	nm0000008	Marlon Brando	1.924	2004	actor,soundtrack,director	tt0047296,tt0078788,tt0070849,tt0068646
9	nm0000009	Richard Burton	1.925	1984	actor,producer,soundtrack	tt0061184,tt0059749,tt0087803,tt0057877
10	nm0000010	James Cagney	1.899	1986	actor,soundtrack,director	tt0029870,tt0031867,tt0035575,tt0055256
11	nm0000011	Gary Cooper	1.901	1961	actor,soundtrack,producer	tt0027996,tt0052876,tt0034167,tt0044706
12	nm0000012	Bette Davis	1.908	1989	actress,soundtrack,make_up_department	tt0056687,tt0035140,tt0031210,tt0042192
13	nm0000015	James Dean	1.931	1955	actor,miscellaneous	tt0049261,tt0045458,tt0048028,tt0048545
14	nm0000016	Georges Delerue	1.925	1992	composer,soundtrack,music_department	tt0079477,tt0069946,tt0096320,tt0091763
15	nm0000017	Marlene Dietrich	1.901	1992	soundtrack,actress,music_department	tt0055031,tt0052311,tt0040367,tt0051201
16	nm0000019	Federico Fellini	1.920	1993	writer,director,assistant_director	tt0053779,tt0071129,tt0056801,tt0047528
17	nm0000020	Henry Fonda	1.905	1982	actor,producer,soundtrack	tt0032551,tt0050083,tt0064116,tt0082846
18	nm0000021	Joan Fontaine	1.917	2013	actress,soundtrack,producer	tt0032976,tt0039504,tt0036969,tt0034248
19	nm0000022	Clark Gable	1.901	1960	actor,soundtrack,producer	tt0052278,tt0025316,tt0026752,tt0031381



# Solution

## Exercise 3:

3.1 Create table `imdb_movies_and_ratings_partitioned` partitioned by column `partition_year` using fields of table `imdb_movies` and `imdb_ratings`:

```
hive > CREATE TABLE IF NOT EXISTS imdb_movies_and_ratings_partitioned(
          tconst STRING,
          title_type STRING,
          primary_title STRING,
          original_title STRING,
          is_adult DECIMAL(1,0),
          start_year DECIMAL(4,0),
          end_year STRING,
          runtime_minutes INT,
          genres STRING,
          average_rating DECIMAL(2,1),
          num_votes BIGINT
      ) PARTITIONED BY (partition_year int) STORED AS ORCFILE LOCATION '/user/hadoop/imdb/
movies_and_ratings_partitioned';
```



# Solution

## Exercise 3:

3.2 Use **dynamic** partitioning to create and fill partition `partition_year`:

```
hive > SET hive.exec.dynamic.partition.mode=nonstrict;
        INSERT OVERWRITE TABLE imdb_movies_and_ratings_partitioned partition(partition_year)
        SELECT
            m.tconst,
            m.title_type,
            m.primary_title,
            m.original_title,
            m.is_adult,
            m.start_year,
            m.end_year,
            m.runtime_minutes,
            m.genres,
            r.average_rating,
            r.num_votes,
            m.start_year
        FROM imdb_movies m JOIN imdb_ratings r ON (m.tconst = r.tconst)
```



# Solution

## Exercise 3:

### 3.3 Check Results:

```
'hadoop fs -ls /user/hadoop/imdb/movies_and_ratings_partitioned
[...]
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2012
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2013
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2014
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2015
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2016
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2017
drwxr-xr-x  - hadoop supergroup
partitioned/partition_year=2018
0 2018-10-09 21:14 /user/hadoop/imdb/movies_and_ratings_
```



# Solution

## Exercise 3:

### 3.3 Check Results:

select \* FROM imdb\_movies\_and\_ratings\_partitioned mrp where mrp.partition\_year = '2018' LIMIT 100

Result

select \* FROM imdb\_movies\_and\_ratings\_partitioned| Enter a SQL expression to filter results (use Ctrl+Space)

abc mrp.title	abc mrp.primary_title	abc mrp.original_title	123 mrp.is	123 mrp.start	abc mrp	123 mrp.	abc mrp.genres	123 mrp.a	123 mrp.num	123 mrp.partition_year
movie	The Other Side of the Wind	The Other Side of the Wind	0	2.018	[NULL]	122	Comedy,Drama	7,5	174	2.018
movie	In Memoriam Alfons Vranckx	Le Saigneur est avec nous	0	2.018	[NULL]	90	Action,Adventure,Comedy	6,4	13	2.018
tvMovie	The Patchwork Girl of Oz	The Patchwork Girl of Oz	0	2.018	[NULL]	[NULL]	Adventure,Animation,Famil	5,1	14	2.018
movie	Nappily Ever After	Nappily Ever After	0	2.018	[NULL]	98	Comedy,Drama,Romance	6,5	2.354	2.018
movie	A Million Little Pieces	A Million Little Pieces	0	2.018	[NULL]	113	Drama	8,2	79	2.018
movie	Duel of Legends	Duel of Legends	0	2.018	[NULL]	[NULL]	Action,Drama,Sport	5,9	34	2.018
movie	Dukun	Dukun	0	2.018	[NULL]	108	Horror,Thriller	6,9	238	2.018
movie	Suspiria	Suspiria	0	2.018	[NULL]	152	Fantasy,Horror,Mystery	6,5	673	2.018
movie	Farming	Farming	0	2.018	[NULL]	107	Drama	7,5	40	2.018
movie	Death Wish	Death Wish	0	2.018	[NULL]	107	Action,Crime,Drama	6,4	37.212	2.018
movie	Beautiful Boy	Beautiful Boy	0	2.018	[NULL]	112	Biography,Drama	7,2	412	2.018
movie	Where Hands Touch	Where Hands Touch	0	2.018	[NULL]	122	Drama,Romance,War	5,1	101	2.018
movie	Den of Thieves	Den of Thieves	0	2.018	[NULL]	140	Action,Crime,Drama	7,0	52.408	2.018
movie	London Fields	London Fields	0	2.018	[NULL]	118	Crime,Mystery,Thriller	5,4	101	2.018
movie	The Guernsey Literary and Pot	The Guernsey Literary and Pota	0	2.018	[NULL]	124	Drama,History,Romance	7,4	12.586	2.018





# Introduction To The Challenges Of Distributed Data-Systems: Partitioning

Basics of Partitioning, Key-Range and Hash Partitioning,  
Partitioning of Secondary Indices, Rebalancing and Lookup of  
Partitions



# Why Partitioning (and Replication)?

Partitioning is the process of continuously **dividing data into subsets** and **distributing it to several nodes** within a data-system. Usually **each record or document** within a partitioned data-system is distributed and **directly assigned to certain partition**. Partitioning serves the purpose of, e.g.:

**Scalability and Performance:** Distributing data to multiple nodes, for instance increases read/write performance and throughput as read/write queries can be distributed to multiple nodes and handled concurrently. In this way it is possible parallelize IO (disk), computing power (CPU) as well as scale the memory usage needed to run a certain operation on a part of the dataset.

**Low Latency:** Using partitioning it is possible to place data close to where it is used (user or consumer applications).

**Availability:** Even if some nodes fail, only parts of the data are offline.



# Replication vs Partitioning

	Replication	Partitioning
stores:	<b>copies of the same data on multiple nodes</b>	<b>subsets (<i>partitions</i>) on multiple nodes</b>
introduces:	<b>redundancy</b>	<b>distribution</b>
scalability:	<b>parallel IO</b>	<b>memory consumption</b> , certain parallel IO
availability:	<b>nodes can take load of failed nodes</b>	node <b>failures affect only parts of the data</b>

**Different purposes, but usually used together**



# Partitioning – Avoid Confusion On Terms

To avoid confusion on the term partition or partitioning, let's list some other terms, you might have heard and which are frequently used synonymously:

- **shards/sharding** - (e.g. *MongoDB*, *ElasticSearch* or *RethinkDB*)
- **Vnodes/Virtual Nodes** - (e.g. *Riak* or *Cassandra*)
- **region** - (e.g. *HBase*)
- **tablet** - (e.g. *BigTable*)
- **vBucket** - (e.g. *Couchbase*)

**Partitioning** and **Replication** are usually used together, especially when building data-intensive applications, as datasets are too big to be stored on a single server or replica, and benefits of replication are required (e.g. redundancy, fault-tolerance or high read/write throughput). This can be achieved by storing partitions of a data set on multiple replica nodes.

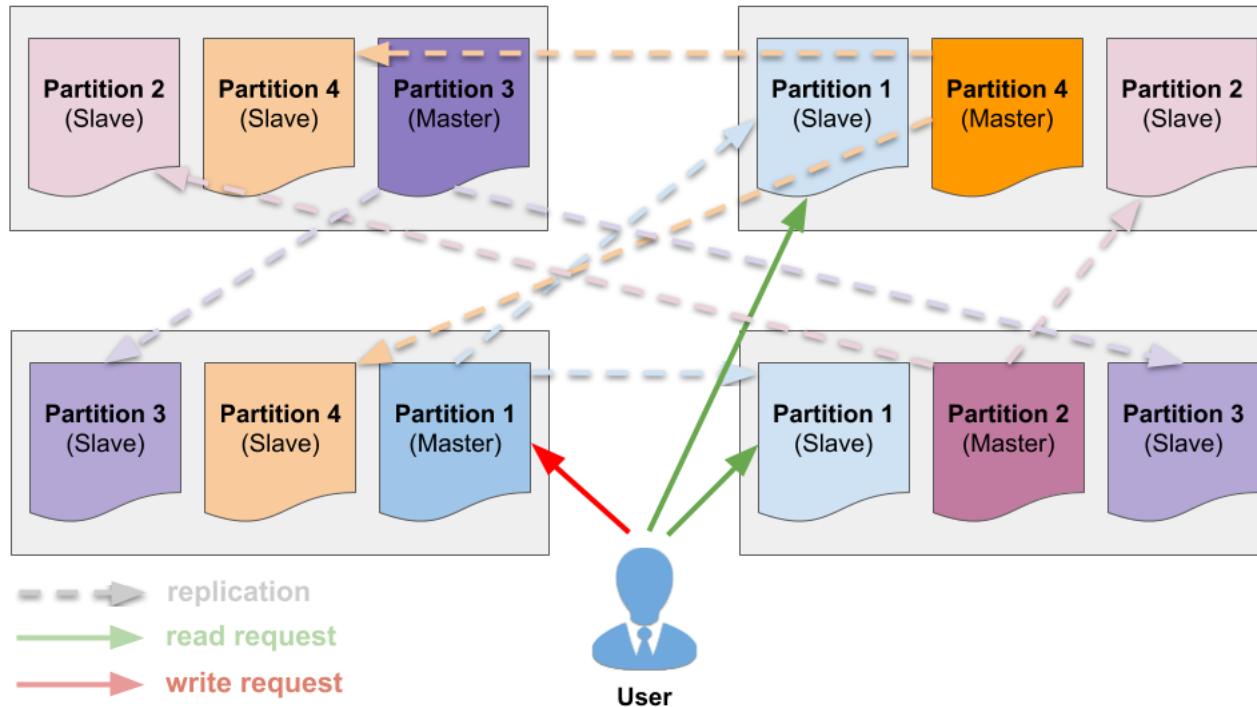


# Partitioning – Avoid Confusion On Terms



As **horizontal** and **vertical partitioning** are mixed up sometimes, it is important to notice: when we speak about **partitioning** within this lecture, we mean **horizontal partitioning**. **Vertical partitioning** is an **approach of traditional relational databases**, usually done by splitting datasets into multiple entities (e.g. tables or databases) and using references (e.g. to achieve normalization).

# Partitioning – An Example



- Partitioning and Replication
  - Using Master-based Replication
  - Each node is master for a certain partition
  - Each partition has 2 slave nodes
- Ensure HA

# Partitioning – Key-Value Data

## 2 Purposes of Partitioning:

- **distributing a dataset,**
- more important: **distribute related load** (read/write queries) evenly among several nodes of a data-system

## This requires:

- a **wise way of determining the partition** of a certain row or document → as it **directly affects the performance of a data-system**
- an **improper chosen distribution key** may cause:
  - **some nodes** to be **idle and/or empty** and
  - a **single node** to be the **processing bottleneck** and hitting its space limitations as all read/write requests end up on that single node
- an **appropriate distribution key** will **distribute the data evenly** and enable the data-system to (theoretically) scale linearly in terms of space utilization and request throughput.



# Partitioning – Key-Value Data (Approaches)

**Key Range Partitioning:** Derive a partition by determining whether a key is inside a certain value range.  
→ More details on next slides.

**Partitioning By Hash Value Of A Key:** Derive a partition by a certain hash of a given key to achieve a more even data distribution. → More details on next slides.

**Partitioning By List:** Every partition to be used has an assigned list of values. A related partition is derived from the input dataset by checking whether it contains one of those values. For instance all rows containing iPhone, Samsung Galaxy and HTC One within a column `device_type` are assigned to partition Smartphone. → As no data-intensive system makes use of partitioning by list (as it is very improper to provide even data distribution), we wont discuss this approach in detail.

**Round-Robin Partitioning:** A very simple approach, which ensures even data distribution. For instance assignment to a partition can be achieved by  $n \text{ modulo } p$  ( $n = \text{number of incoming data records}$ ,  $p = \text{number of partitions}$ ). → As no data-intensive system makes use of round-robin partitioning (as for instance the direct access to an individual data record or subset usually requires accessing the whole dataset), we wont discuss this approach in detail.



# Partitioning – Key-Range Partitioning



**Key Range partitioning** is done by:

- defining continuous ranges of keys
  - assigning each range to a certain partition
- If you are aware of the boundaries of each key range, you can easily derive a partition belonging to a certain data record (and in this way node of a data-system) just by using the key of the record.

- This approach can be compared with an encyclopedia, which is partitioned into books, of which everyone stores a certain range of articles partitioned by the first letters of the name of the article.
- For instance the article “Arsenal F.C.” will be found in partition 863 “ARS” - “ART”.
- For instance used by: **RethinkDB** (called *ranged sharding*)

# Partitioning – Key-Range Partitioning

## Strengths:

- Simple
- Range Lookups

## Weaknesses:

- **Datasets Are Changing:** A *key range* partitioning which was suitable in the past might not be appropriate in the future. Expensive rebalancing or even repartitioning might be needed somewhere. For instance web server log files partitioned per ranges of the URL (`/products/[A-B]`, `/products/[C-D]` ... `/products/[Y-Z]`) maybe improper in the future, as some products will have heavier traffic than other products over time (*load skew*).
- **Hotspots:** Keys that seem very appropriate in terms of even distribution at first sight, e.g. partitioning of webserver logfiles over time (by using timestamp of data record), create hotspots as all write requests end up on the same partition (e.g. *today*), a single partition (and node(-s)) will underly heavy load whereas other partitions or rather nodes are idle (*load skew*).
- **Query Performance:** As you do not know the size of a partition beforehand, query performance is unpredictable as well as partition pruning and partitionwise joins are more complex and less efficient.



# Partitioning – Hash Partitioning

**Hash partitioning** is used to spread data efficiently and evenly among several certain partitions. This is achieved by:

- splitting data in a randomized way
  - rather than by using information provided within the dataset (e.g. IDs) or
  - derived by arbitrary factors (e.g. time of data receival)
- The hash value itself is derived by a hash function (on a certain key of a data record) and is used to determine the partition a data records should be saved on.



**Hash Function** is a function which takes input data of arbitrary size and usually provides an output of fixed size. The output of a hash function is called hash, hash value or digest. A hash function needs to be deterministic and uniform. Common use cases for hash functions are cryptography, checksums and partitioning.

# Partitioning – Hash Partitioning (Hash Functions)

**Hash functions** are commonly used for partitioning, as they are:

- **deterministic** - as we need to be able to find records to be saved later on and
- **uniform** - as we want to distribute the data as evenly as possible among the set of available partitions and nodes, even if the inputs of the hash function (e.g. data record key) are very similar.

Unlike cryptography, **partitioning makes use of hash functions** that are **not cryptographilly strong** (as this is not needed) but fast and less CPU consuming.  
Examples of commonly used hash function for distributed data-systems are:

- **MD5** - For instance used and supported by *MySQL* and *Cassandra*.
- **MurmurHash** - For instance supported by *Cassandra*.
- **SHA1** - For instance used and supported by *Riak*.
- **CRC32** - For instance used and supported by *Couchbase*.



# Partitioning – Hash Partitioning (Hash Functions)

As an example for **determinism** and **uniformity** let's take a quick look at **MD5** and how the hash value changes:

- when a single **character is added** to the input value,
- when just a single **character** of the input value is **changed** or
- the **same input** value is **hashed twice**

```
1 marcel$ md5 -s abc
2 MD5 ("abc") = 900150983cd24fb0d6963f7d28e17f72
3 // add a single character ("d")
4 marcel$ md5 -s abcd
5 MD5 ("abcd") = e2fc714c4727ee9395f324cd2e7f331f
6 // change a single character ("d" to "e")
7 marcel$ md5 -s abce
8 MD5 ("abce") = b9c4fe92c2a30ef69833ac8f53eebcec
9 // hash again with same input value
10 marcel$ md5 -s abce
11 MD5 ("abce") = b9c4fe92c2a30ef69833ac8f53eebcec
```

Code Snippet 2.7: Bash Output - *MD5 Hash For Several Input Values*



# Partitioning – Hash Partitioning (Hash Modulo)

**Hash Modulo Partitioning** = take the calculated *hash value V* and calculate  $V \text{ modulo } N$  (*number of partitions*).

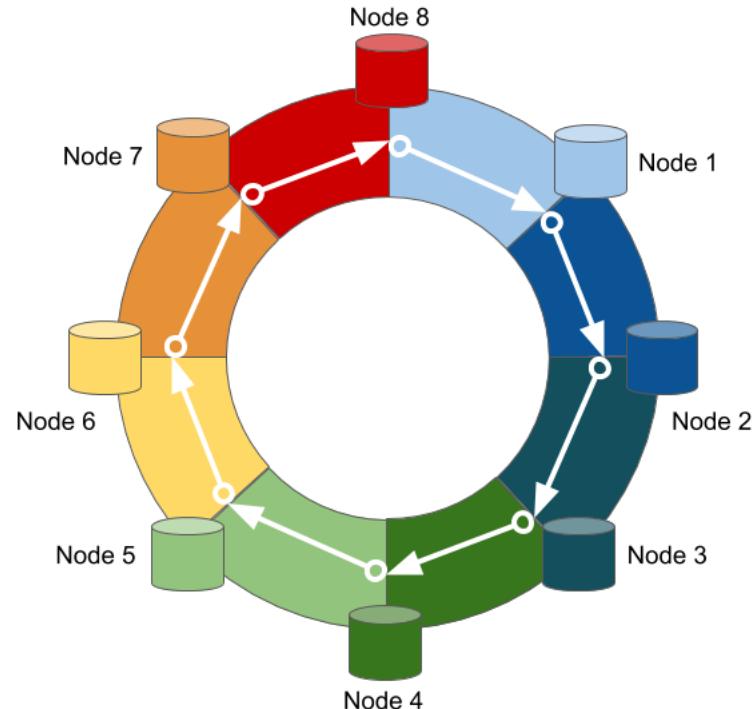
- This allows the data-system to easily distribute and receive records to and from a given number of partitions.
- Major disadvantage in terms of **scalability** and **operability**.
  - Adding nodes results in different partition assignments for a lot of records (depending on size of N), which will require to **shuffle and reassign already saved data again** among all partitions.
- Nevertheless for instance **elasticsearch** makes use of it, a partition (called shard) is derived by: ***shard = hash(routing) % number\_of\_primary\_shards***
- The number of shards for an *index* can increased (by *\_split*) or decreased (by *\_shrink*) some time after creation but this is not a trivial task and will usually require recreating the same or even creating a new index.



# Partitioning – Hash Partitioning (Consistent Hashing)

- assign a *range of hashes* to every partition (and in this way node)
- every record will be stored and read from the partition in charge for a given *range of hash values*.
- imagine **consistent hashing** as a *ring of keys*
- each node ( $N_i$ ) is in charge for serving all hash values  $v$  in between:
  - $i$  and
  - the position  $j$  of its clockwise predecessor  $N_j$

$$j < v < i$$



# Partitioning – Hash Partitioning (Consistent Hashing)

## Strengths:

- Adding/Removing a node → only  $c/N$  keys need to be re-distributed
  - $c$  is the **count of hash values** and
  - $N$  is the **number of nodes** within the data-system

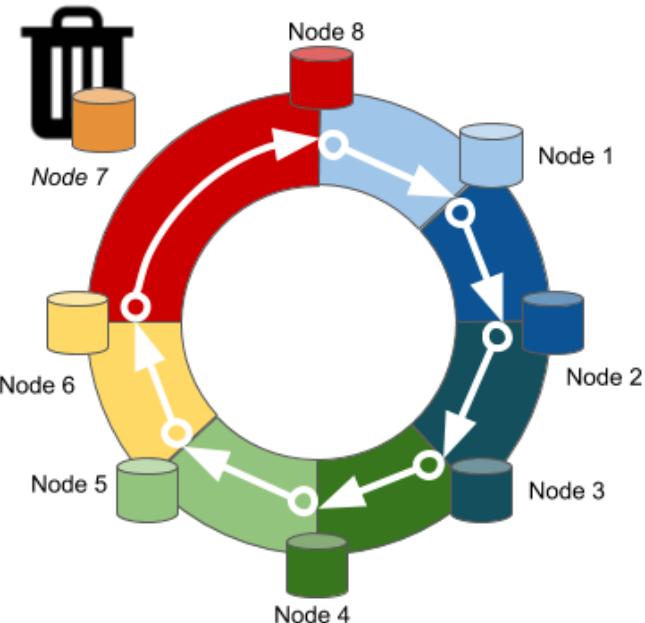
## Weaknesses:

- Range Queries (as keys are randomly distributed among data system)
- e.g. MongoDB provides *key-range partitioning* as well as *hash partitioning* to efficiently serve both use cases

## Used by e.g.:

- Cassandra
- Riak
- VoldemortDB
- DynamoDB

## Example: Removing a Node



# Partitioning – Partitioning Of Secondary Indices

**Secondary Index** = Index in addition to primary index, which:

- is used to accelerates queries
- may not identify records uniquely
- used to lookup records with a certain value/attribute
- **needs to be partitioned as well**

→ Remember previous Facebook Profile example (Primary Key = User ID)  
→ What if you want to acclerate the lookup of cities and comanies? Add a secondary index!



# Partitioning – Local Secondary Indices

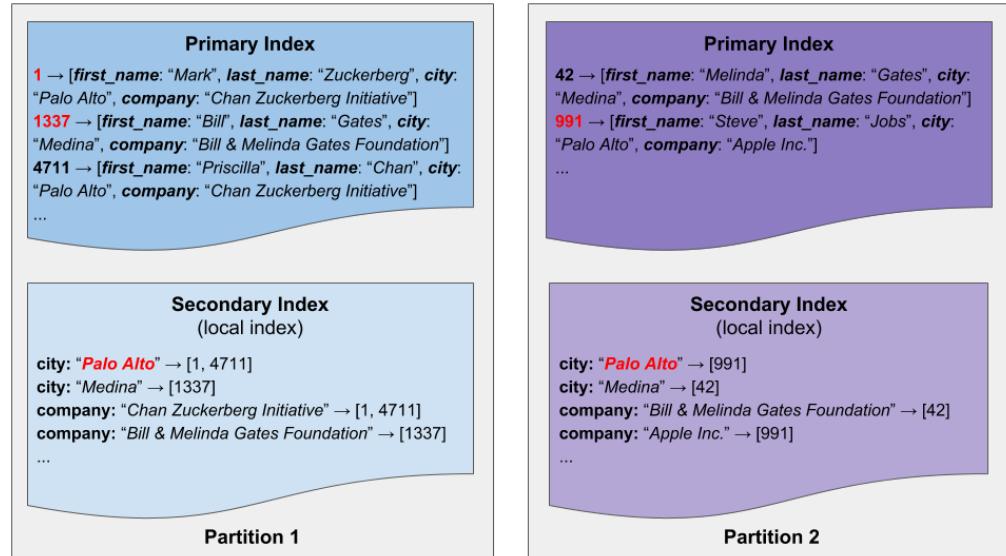
- **LSI = Local Secondary Index**
- every partition manages its own index
- all pointers reference only to local data items

## Strengths:

- maintaining *local index* requires less overhead than *global index*
- INSERT/DELETE/UPDATE performed locally

## Weaknesses:

- maintaining *local index* will compete with *local workload* and affect throughput
- expensive `SELECT: scattering and gathering` as well as related overhead will probably affect read request performance



## E.g. provided by:

- Riak
- Cassandra
- DynamoDB



# Partitioning – Global Secondary Indices

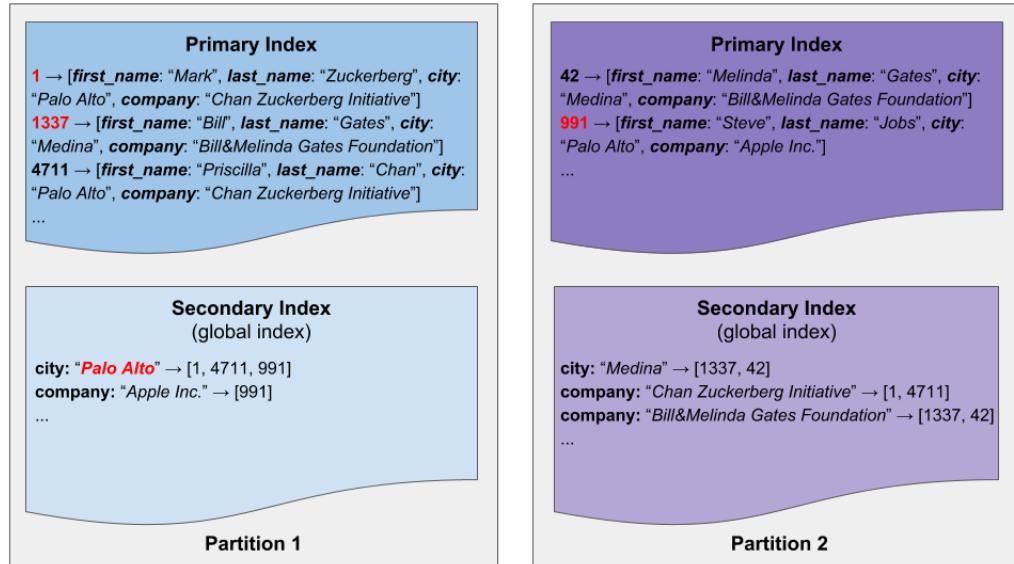
- **GSI = Global Secondary Index**
- Index is partitioned, distributed and stored among several nodes independently of local data records
- pointers reference to local but also remote data records

## Strengths:

- SELECT statements need to query only one index partition
- No scattering and gathering (like using LSI)

## Weaknesses:

- maintaining *global index* requires more overhead than a *local index* → *INSERT/DELETE/E/UPDATE* statements require remote updates
- usually weakens read-consistency as indices update take more time → DynamoDB **eventual consistency**



## E.g. provided by:

- Oracle
- MS SQL Server
- Couchbase
- DynamoDB



# Partitioning – Rebalancing Partitions

## Why?

- Node Failure → other nodes need to take over
- Query load increases → more CPUs and RAM required
- Data Size increases → more RAM and disk space required

## Goals:

- **Minimal Data Shuffle:** Move as less data as possible around nodes during rebalancing
- **Evenly Distribution:** Data distribution should be even after rebalancing.
- **No Availability Impact:** Rebalancing should have as less impact as possible on a running data-system, requiring no downtime.



# Partitioning – Rebalancing Partitions (Hash Modulo)

## Approach:

- hash % n

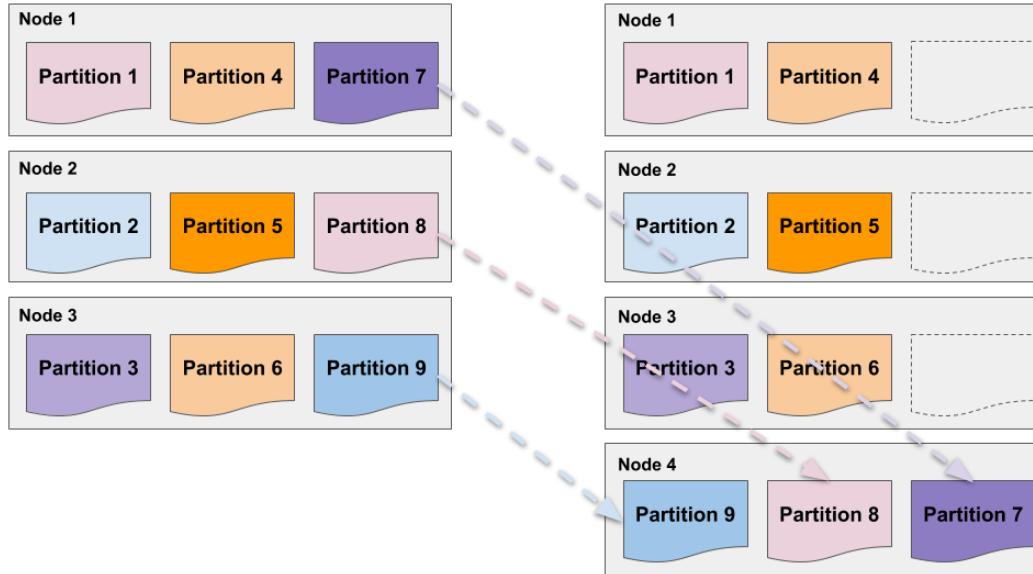
## Contra:

- stupid
- requires shuffling a lot of data, as assignment of partitions to nodes changes significantly

## Used by e.g.:

- shouldn't be used

# Partitioning – Rebalancing Partitions (Fixed Number of Partitions)



## Approach:

- Create more partitions than there are nodes on initial setup
- new nodes „steal“ partitions from old ones

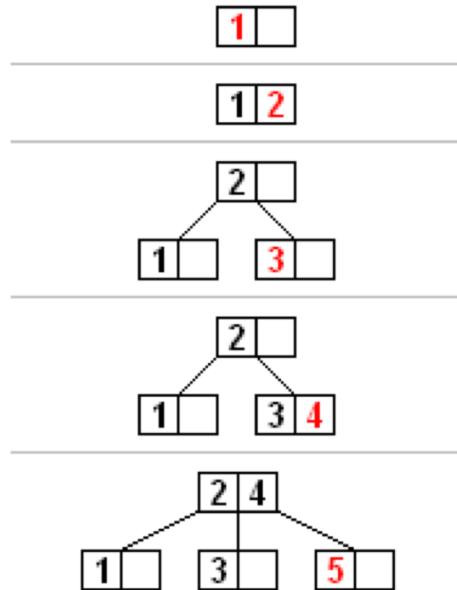
## Pro/Contra:

- partition/node mappings change
- but for less partitions  
→ only partial rewrite of partitions

## Used by e.g.:

- Voldemort
- Riak
- ElasticSearch
- Couchbase

# Partitioning – Rebalancing Partitions (Dynamic No. Of Partitions)



## Approach:

- Create certain number of initial partitions
- Idea similar to B-Trees
- If a partition exceeds a threshold in size, it gets split
- If a partition falls below a threshold in size, merge it with another
- new nodes „steal“ partitions from old ones

## Pro/Contra:

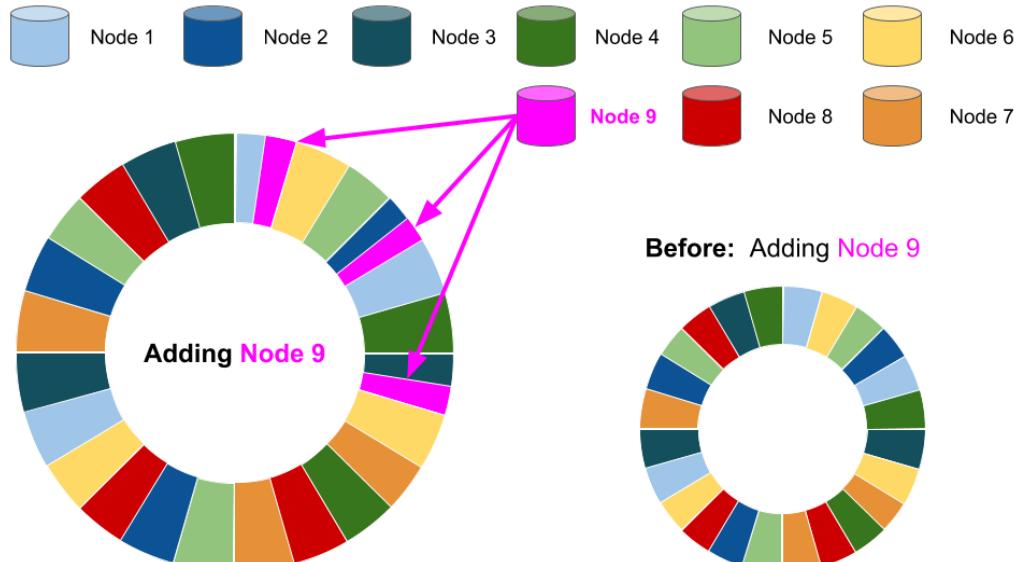
- evenly distribution
- continues overhead during runtime

## Used by e.g.:

- MongoDB
- RethinkDB



# Partitioning – Rebalancing Partitions (Fixed Partition No. Per Node)



## Approach:

- create fixed number of partitions at initial setup
  - new nodes randomly split partitions of old nodes
- steal half of partitions of old nodes

## Pro/Contra:

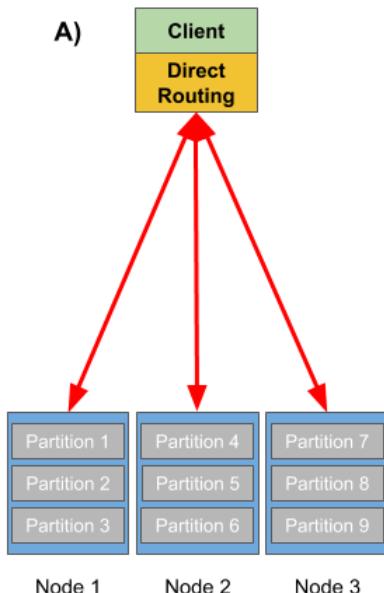
- works well for range partitioning (hash or keys)
- load may be temporarily unbalanced but will be even again over time

## Used by e.g.:

- Cassandra

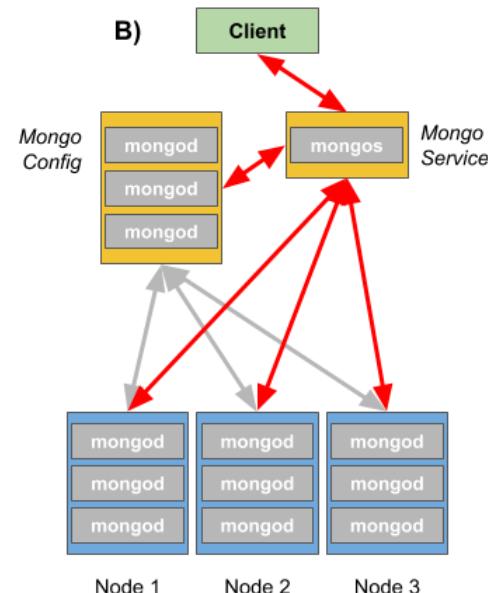
# Partitioning – Partition Lookup

Direct Routing



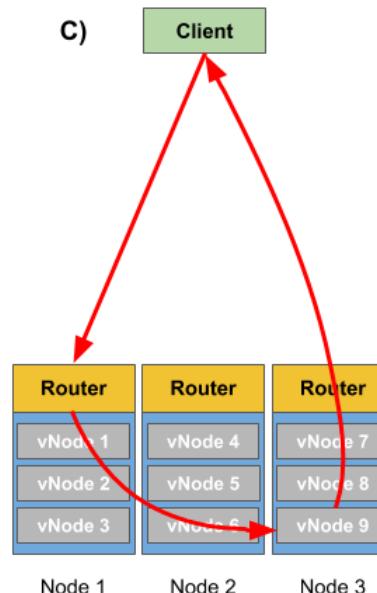
e.g. Microsoft SQL Server

Dedicated Routing Tier



e.g. MongoDB

Ask-Any-Node



e.g. Riak, Cassandra

Legend:

Client Tier

Routing Tier

Data Tier

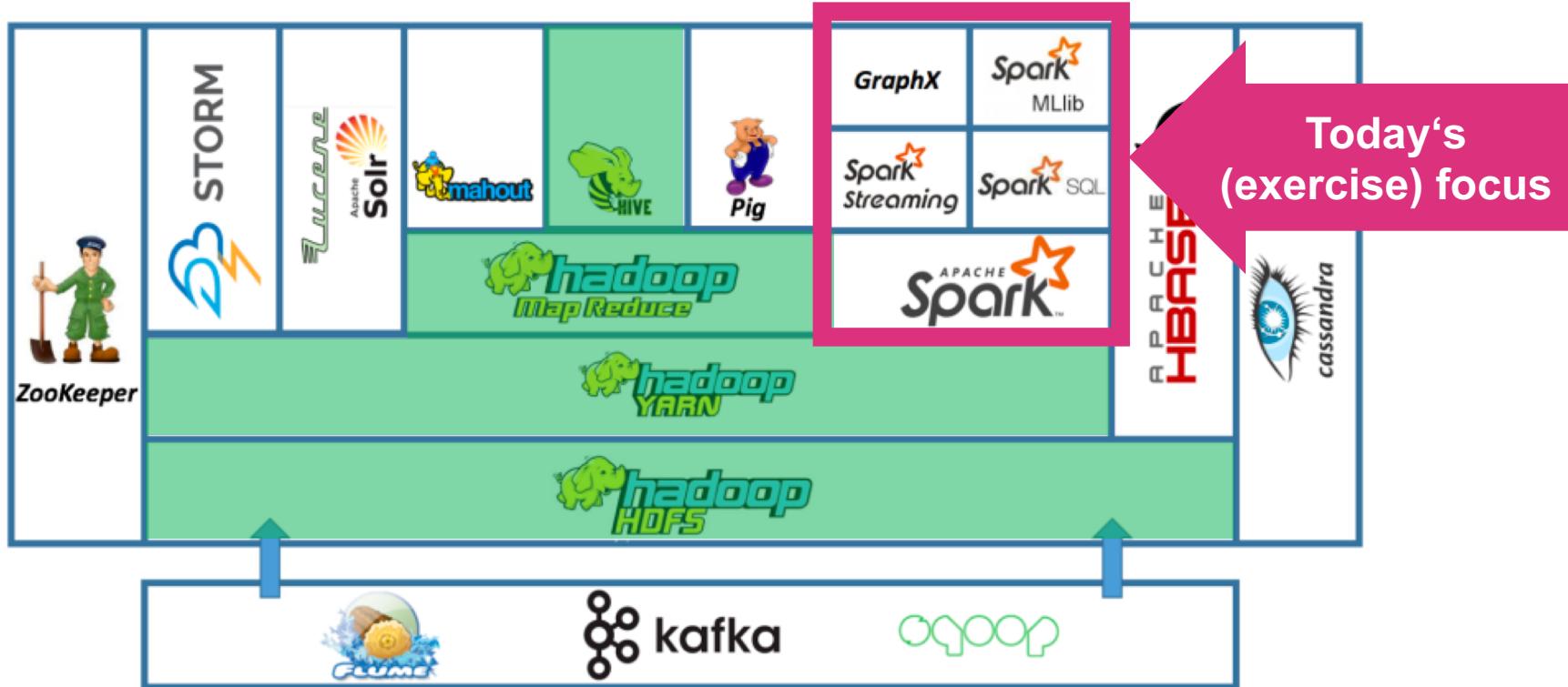
# HandsOn – Spark, Scala, PySpark and Jupyter

A quick Introduction to Spark, Scala, PySpark and  
Jupyter

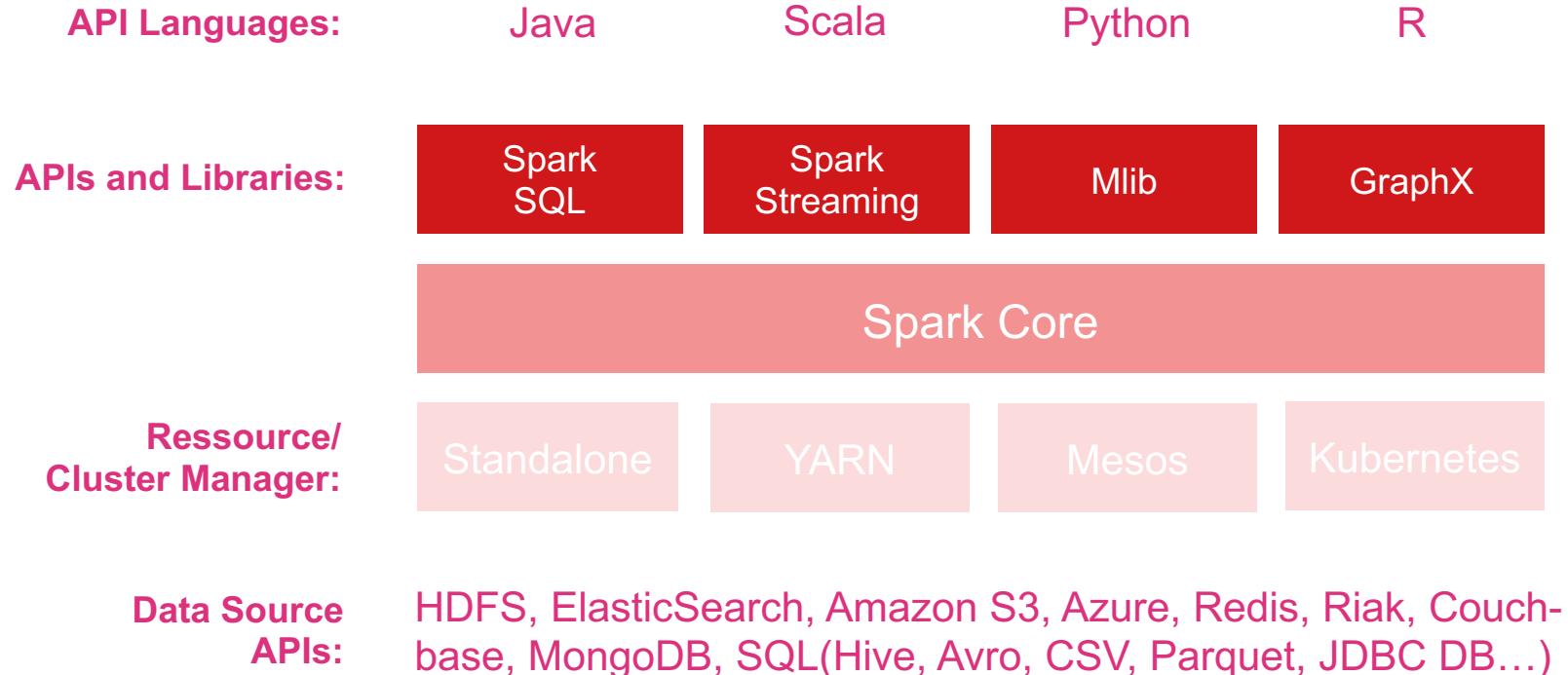


[www.marcel-mittelstaedt.com](http://www.marcel-mittelstaedt.com)

# The Hadoop Ecosystem

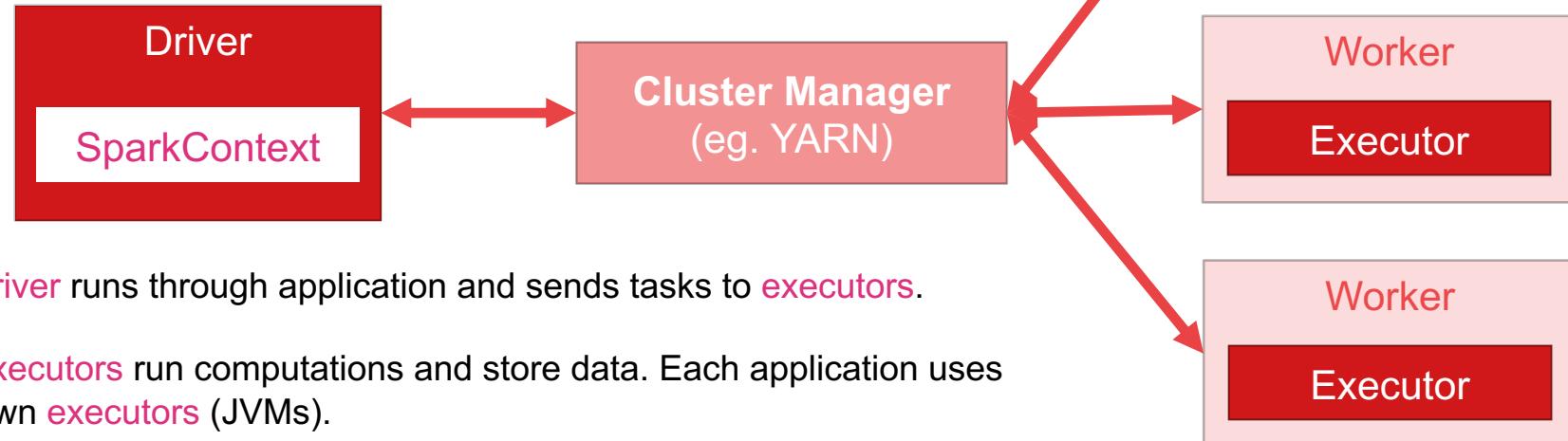


# Spark



# Spark – Execution Process

1. Spark applications starts and instantiates **SparkContext** (JVM process).
2. Spark acquires **executors** on worker nodes from cluster manager.
3. Cluster manager launches **executors**.



4. **Driver** runs through application and sends tasks to **executors**.
5. **Executors** run computations and store data. Each application uses its own **executors** (JVMs).
6. If any worker crashes, ist tasks will be send to another **executor**.

# Spark – RDDs, DataFrame and DataSet

**Supported by:**

**RDD**  
(2011)

Scala, Java, Python

**Idea:**

- RDD = immutable **distributed** collection of data
- **partitioned across nodes** of cluster
- can be **operated in parallel** with a low-level API

**Typed:** typed, no schema

**Use for:** unstructured data

**DataFrame**  
(2013)

Scala, Java, Python

- based on RDD
- immutable **distributed** collection of data
- but **organized into columns**
- higher level abstraction

untyped, schema

semi-structured and structured data

**DataSet**  
(2015)

Scala, Java

- based on DataFrame API, but type-safe
- immutable **distributed** collection of data
- high-level API
- converted into optimized RDD

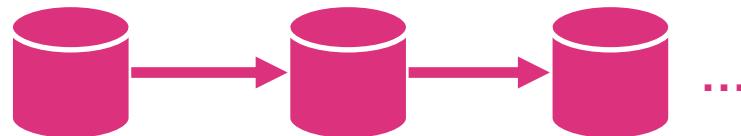
typed, schema

structured data



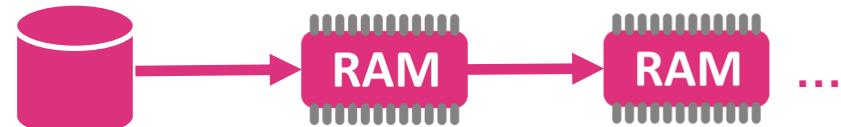
# Hadoop MapReduce vs Spark

## Hadoop MapReduce



- performs **read** from **HDFS (HDD)** before **every computation**
- performs **write** on **HDFS (HDD)** after **every computation**
- using distributed **disk space**

## Spark



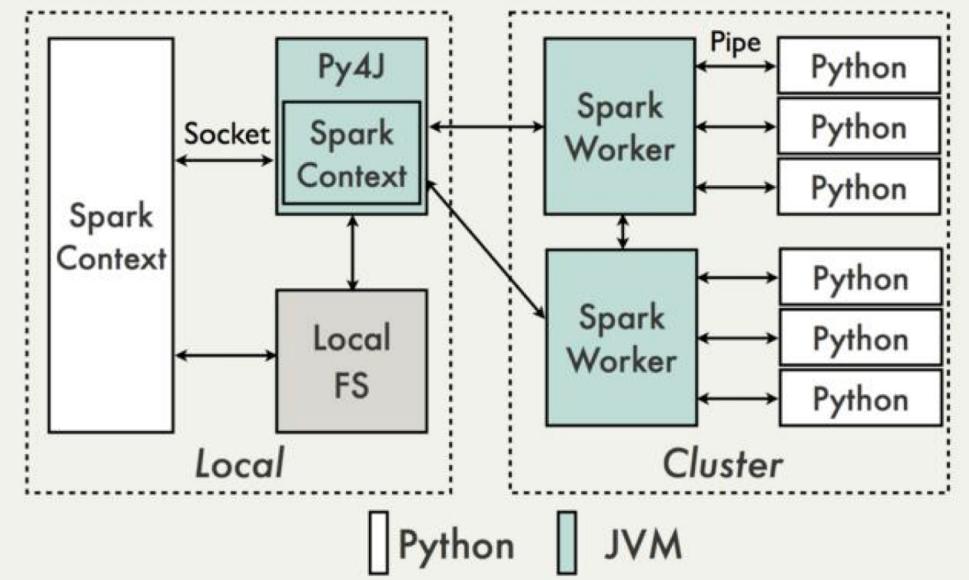
- performs **read** from **RAM** before **every computation (except first)**
- performs **write** on **RAM** after **every computation**
- using distributed **memory**



# PySpark

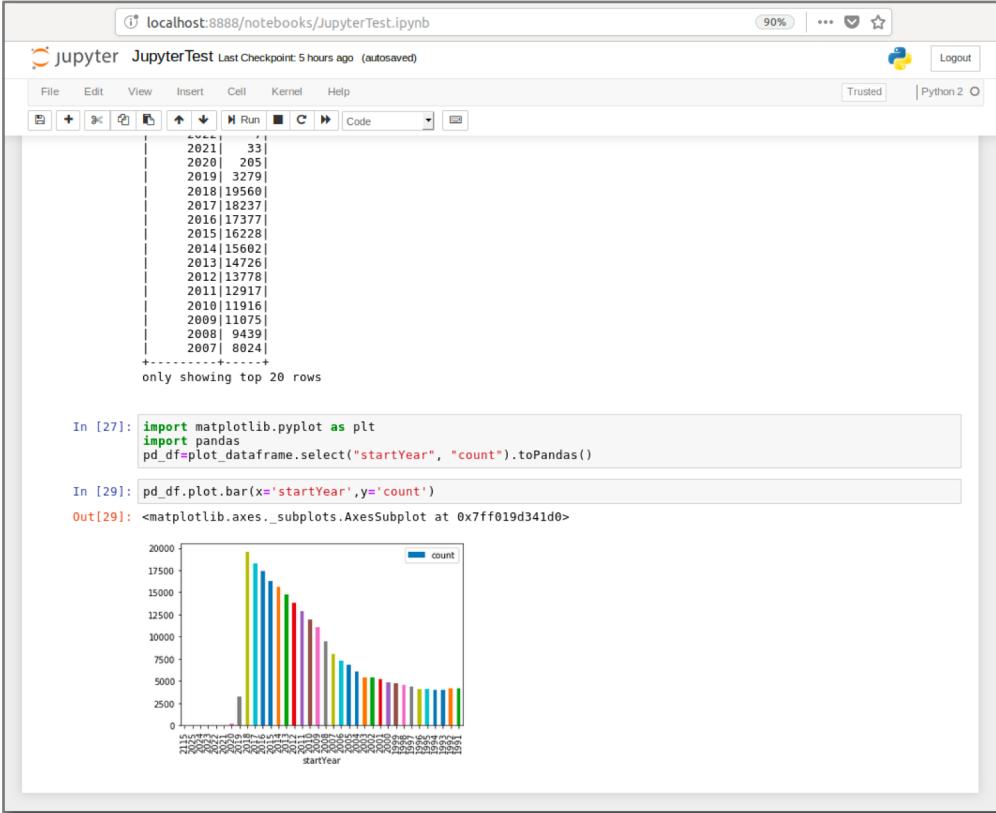


## Data Flow



- built on-top of Spark's Java API
- data is processed in Python and cached/shuffled within the JVM
- Spark executors on the cluster start Python interpreter to execute user code
- A Python RDD corresponds to an RDD in the local JVM
- e.g. `sc.textFile()` in Python will call JavaSparkContext `textFile()`

# Jupyter (Notebooks)



The screenshot shows a Jupyter Notebook interface running on localhost:8888/notebooks/JupyterTest.ipynb. The notebook has a Python 2 kernel and is set to Trusted mode. The top cell displays a table of data:

startYear	count
2021	33
2020	205
2019	3279
2018	19560
2017	18237
2016	17377
2015	16228
2014	15602
2013	14726
2012	13778
2011	12917
2010	11916
2009	11075
2008	9439
2007	8024

only showing top 20 rows

In [27]:

```
import matplotlib.pyplot as plt
import pandas
pd_df=plt_dataframe.select("startYear", "count").toPandas()
```

In [29]:

```
pd_df.plot.bar(x='startYear',y='count')
```

Out[29]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff019d341d0>
```

A bar chart titled 'startYear' with 'count' on the y-axis (0 to 20000) and 'startYear' on the x-axis (labeled with years from 2007 to 2021). The bars are colored in a gradient.



- Interactive Web IDE
- Kernel-based Notebooks
- Open-source
- Create and share:
  - code,
  - visualizations and
  - narrative text like documentation
- Supports:
  - Python
  - R
  - Scala
  - ...
- Works well with Spark

# Exercises Preparation I

Install and Setup Spark



[www.marcel-mittelstaedt.com](http://www.marcel-mittelstaedt.com)

# Download And Install Spark

## 1. Download Spark 2.3.2 (for Hadoop 2.7++)

```
wget http://mirror.funkfreundelandshut.de/apache/spark/spark-2.3.2/spark-2.3.2-bin-hadoop2.7.tgz
```

## 2. Extract and Move:

```
tar -xzf http://mirror.funkfreundelandshut.de/apache/spark/spark-2.3.2/spark-2.3.2-bin-hadoop2.7.tgz
```

```
mv spark-2.3.2-bin-hadoop2.7/ spark
```



# Configure Spark

## 1. Setup spark-env.sh

```
cp spark/conf/spark-env.sh.template spark/conf/spark-env.sh
```

```
vi spark/conf/spark-env.sh
```

```
export SPARK_MASTER_IP=localhost
export SPARK_WORKER_CORES=1
export SPARK_WORKER_MEMORY=800m
export SPARK_WORKER_INSTANCES=1
export HADOOP_CONF_DIR=$HADOOP_HOME/etc/hadoop
SPARK_LOCAL_IP="localhost"
```



# Configure Spark

## 2. Setup slave

```
cp spark/conf/slaves.template spark/conf/slaves
```

```
vi spark/conf/slaves
```

```
# A Spark Worker will be started on each of the machines listed below.  
localhost
```



# Configure Spark

## 3. Setup Environment Variables

```
vi .bashrc
```

```
export SPARK_HOME=/home/hadoop/spark  
export PATH=$SPARK_HOME/bin:$PATH
```

```
source .bashrc
```



# Configure Yarn (Yarn Java 8 Bug)

<https://issues.apache.org/jira/browse/YARN-4714>

<https://stackoverflow.com/questions/38988941/running-yarn-with-spark-not-working-with-java-8>

## 1. Setup yarn-site.xml

```
vi hadoop/etc/hadoop/yarn-site.xml
```

```
<property>
    <name>yarn.nodemanager.pmem-check-enabled</name>
    <value>false</value>
</property>
<property>
    <name>yarn.nodemanager.vmem-check-enabled</name>
    <value>false</value>
</property>
```



# Configure Yarn

## 2. Restart HDFS and Yarn

```
stop-all.sh
```

```
start-dfs.sh
```

```
start-yarn.sh
```



# Start Spark (on Yarn)

## 1. Start Spark Shell:

```
spark-shell --master yarn
```

```
Spark context Web UI available at http://localhost:4040
Spark context available as 'sc' (master = yarn, app id = application_1539278841328_0001).
Spark session available as 'spark'.
Welcome to
```

Using Scala version 2.11.8 (OpenJDK 64-Bit Server VM, Java 1.8.0\_181)  
Type in expressions to have them evaluated.  
Type :help for more information.

scala>



# Start Spark (on Yarn) – Test Install

## 2. Create Scala Collection `dummy_data` of Numbers 1 – 100:

```
scala> val dummy_data = 1 to 100
dummy_data: scala.collection.immutable.Range.Inclusive = Range(1, 2, 3, 4, 5, 6
, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26,
27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46,
47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66,
67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86,
87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100)
```

## 3. Create a Scala RDD `dummy_RDD` of previous collection:

```
scala> val dummy_RDD = sc.parallelize(dummy_data)
dummy_RDD: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[0] at parallel
ize at <console>:26
```



# Start Spark (on Yarn) – Test Install

4. Run simple filter transformation and `collect()` to calculate results:

```
scala> dummy_RDD.filter(_ < 10).collect()
res0: Array[Int] = Array(1, 2, 3, 4, 5, 6, 7, 8, 9)
```

5. Now you should see a completed stage in Spark Shell UI (`localhost:4040`):

The screenshot shows the Spark Shell application UI at `marcel-virtualbox:8088/proxy/application_1539278841328_0002/`. The UI displays the following information:

- Spark Version:** 2.3.2
- User:** hadoop
- Total Uptime:** 11 min
- Scheduling Mode:** FIFO
- Completed Jobs:** 1
- Event Timeline:** (link)
- Completed Jobs (1):**

Job Id	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
0	collect at <console>:26 collect at <console>:26	2018/10/11 20:17:22	0.8 s	1/1	2/2




# Start Spark (on Yarn) – Test Install

6. As well as the whole time the Spark Shell Container Running on Yarn:

The screenshot shows the Hadoop YARN web interface at `localhost:8088/cluster/apps/RUNNING`. The page title is "RUNNING Applications". On the left, there's a sidebar with navigation links like Cluster Metrics, Cluster Nodes Metrics, Scheduler Metrics, and a table of cluster metrics. The main content area displays the "RUNNING Applications" table.

ID	User	Name	Application Type	Queue	Application Priority	StartTime	FinishTime	State	FinalStatus	Running Containers	Allocated CPU VCores	Allocated Memory MB	Reserved CPU VCores	Reserved Memory MB	% of Queue	% of Cluster	Progress
application_1539278841328_0002	hadoop	Spark shell	SPARK	default	0	Thu Oct 11 20:08:57 +0200 2018	N/A	RUNNING	UNDEFINED	3	3	5120	0	0	62.5	62.5	<div style="width: 62.5%;"></div>

Showing 1 to 1 of 1 entries



# Start Spark (Standalone) – Test Install

## 1. Start Spark Shell:

## spark-shell

```
Spark context Web UI available at http://localhost:4040
Spark context available as 'sc' (master = local[*], app id = local-1539282394656)
Spark session available as 'spark'.
```

Welcome to

Using Scala version 2.11.8 (OpenJDK 64-Bit Server VM, Java 1.8.0 181)

Type in expressions to have them evaluated.

Type :help for more information.

scala>



# Start Spark (Standalone) – Test Install

## 2. Run previous example:

```
scala> val dummy_data = 1 to 100
dummy_data: scala.collection.immutable.Range.Inclusive = Range(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100)
```

```
scala> val dummy_RDD = sc.parallelize(dummy_data)
dummy_RDD: org.apache.spark.rdd.RDD[Int] = ParallelCollectionRDD[0] at parallelize at <console>:26
```

```
scala> dummy_RDD.filter(_ < 10).collect()
res0: Array[Int] = Array(1, 2, 3, 4, 5, 6, 7, 8, 9)
```



# Start Spark (Standalone) – Test Install

3. Now you should see a completed stage in Spark Shell UI (*localhost:4040*):

The screenshot shows the Spark shell application UI at `localhost:4040/jobs/`. The UI has a header with a back arrow, forward arrow, refresh button, and a search bar. Below the header, there's a navigation bar with tabs for **Jobs**, **Stages**, **Storage**, **Environment**, and **Executors**. The **Jobs** tab is selected. On the right side of the header, it says "Spark shell application UI". The main content area is titled "Spark Jobs (?)". It displays the following information:

- User: hadoop
- Total Uptime: 6.2 min
- Scheduling Mode: FIFO
- Completed Jobs: 1

Below this, there's a link to "Event Timeline". The "Completed Jobs (1)" section contains a table with one row. The table columns are: Job Id, Description, Submitted, Duration, Stages: Succeeded/Total, and Tasks (for all stages): Succeeded/Total. The data in the table is:

Job Id	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
0	collect at <console>:26 collect at <console>:26	2018/10/11 20:27:30	0.3 s	1/1	3/3



# Start Spark (Standalone) – Test Install

4. And see, nothing Running On Yarn:

The screenshot shows the Hadoop YARN web interface at [localhost:8088/cluster/apps/RUNNING](http://localhost:8088/cluster/apps/RUNNING). The title bar includes the Hadoop logo and the text "RUNNING Applications". The left sidebar has sections for Cluster Metrics, Cluster Nodes Metrics, Scheduler Metrics, and Tools. The main content area displays various metrics tables and a large table for "Running Applications". The "Running Applications" table has the following columns: ID, User, Name, Application Type, Queue, Application Priority, StartTime, FinishTime, State, FinalStatus, Running Containers, Allocated CPU VCores, Allocated Memory MB, Reserved CPU VCores, Reserved Memory MB, % of Queue, % of Cluster, Progress, Tracking UI, and Blacklisted Nodes. Below the table, a message says "No data available in table". At the bottom, there are links for "Showing 0 to 0 of 0 entries", "First", "Previous", "Next", and "Last".



# Exercises Preparation II

Install and Setup PySpark



[www.marcel-mittelstaedt.com](http://www.marcel-mittelstaedt.com)

## Start and Use PySpark (on Yarn) – Test Install

1. As PySpark is already installed, start PySpark Shell and execute previous example as Python code:

```
pyspark --master yarn
```

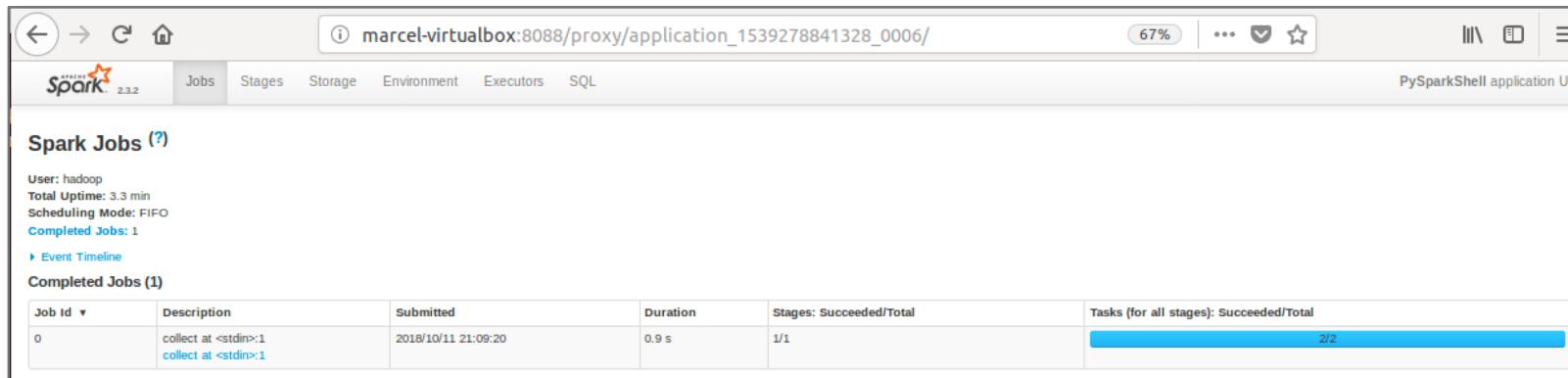
*Python 2.7.15rc1 (default, Apr 15 2018, 21:51:34)  
Welcome to*

Using Python version 2.7.15rc1 (default, Apr 15 2018 21:51:34)  
SparkSession available as 'spark'.

```
>>> dummy_data = range(1, 100)
>>> dummy_rdd = sc.parallelize(dummy_data)
>>> print(dummy_rdd.filter(lambda x: x<10).collect())
[1, 2, 3, 4, 5, 6, 7, 8, 9]
>>>
```

# Start and Use PySpark (on Yarn) – Test Install

2. Now you should see a completed stage in **PySpark UI** (*localhost:4040*):



The screenshot shows the PySpark UI interface at `marcel-virtualbox:8088/proxy/application_1539278841328_0006/`. The top navigation bar includes links for Spark 2.3.2, Jobs, Stages, Storage, Environment, Executors, and SQL. On the right, it says "PySparkShell application UI". The main area is titled "Spark Jobs (?)". It displays user information (User: hadoop, Total Uptime: 3.3 min, Scheduling Mode: FIFO), a completed job count (Completed Jobs: 1), and an "Event Timeline" link. Below this, a table titled "Completed Jobs (1)" lists one job:

Job Id	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
0	collect at <stdin>:1 collect at <stdin>:1	2018/10/11 21:09:20	0.9 s	1/1	2/2



# Start and Use PySpark (on Yarn) – Test Install

3. As well as the related **PySpark** Container Running on Yarn:

The screenshot shows the Hadoop YARN web interface at `localhost:8088/cluster/apps/RUNNING`. The page title is "RUNNING Applications". On the left, there's a sidebar with cluster metrics (6 submitted, 0 pending, 1 running, 5 completed), cluster nodes metrics (1 active, 0 decommissioning, 0 decommissioned, 0 lost, 0 unhealthy, 0 rebooted), and scheduler metrics (Capacity Scheduler). The main table lists one application: "application\_1539278841328\_0006" by user "hadoop" with name "PySparkShell" and type "SPARK". It's in the "default" queue, priority 0, started on Thu Oct 11 21:08:28 +0200 2018, and is currently RUNNING with 3 containers, allocated 5120 CPU Vcores, and 0 memory MB.

ID	User	Name	Application Type	Queue	Application Priority	StartTime	FinishTime	State	FinalStatus	Running Containers	Allocated CPU Vcores	Allocated Memory MB	Reserved CPU Vcores	Reserved Memory MB	% of Queue	% Clus
application_1539278841328_0006	hadoop	PySparkShell	SPARK	default	0	Thu Oct 11 21:08:28 +0200 2018		RUNNING	UNDEFINED	3	3	5120	0	0	62.5	62.5



# Exercises Preparation III

Install and Setup Jupyter (on PySpark)



[www.marcel-mittelstaedt.com](http://www.marcel-mittelstaedt.com)

# Install and Setup Jupyter

## 1. Install Python

```
sudo apt-get install python
```

## 2. Install pip for Python

```
sudo apt-get install python-pip
```

## 3. Install Jupyter

```
pip2 install jupyter
```



# Install and Setup Jupyter

4. As Jupyter is installed under `~/.local/bin/jupyter` add path to **\$PATH**:

```
vi .bashrc
```

```
export PATH=$PATH:~/.local/bin
```

```
source .bashrc
```

5. Start Jupyter Notebook

```
jupyter notebook
```



# Start and Use Jupyter (on PySpark on Yarn)

6. Open Jupyter Notebook and execute previous example as Python code:

```
jupyter notebook
```

The screenshot shows a Jupyter Notebook window with two code cells. The first cell (In [1]) contains PySpark setup code to initialize a SparkContext and set up the environment for running on Yarn. The second cell (In [2]) contains a simple filter operation on a RDD, printing the result [1, 2, 3, 4, 5, 6, 7, 8, 9].

```
In [1]:  
import findspark  
import os  
findspark.init('/home/hadoop/spark')  
from pyspark.conf import SparkConf  
from pyspark.context import SparkContext  
conf = SparkConf().setAppName('Jupyter PySpark Test')  
conf.set('spark.yarn.dist.files','file:/home/hadoop/spark/python/lib/pyspark.zip,file:/home/hadoop/spark/python/lib/py4j-0.10.7-src.zip')  
conf.setExecutorEnv('PYTHONPATH','pyspark.zip:py4j-0.10.7-src.zip')  
conf.setMaster('yarn') # Run on Yarn, not local  
sc = SparkContext(conf=conf)  
  
In [2]:  
dummy_data = range(1, 100)  
dummy_rdd = sc.parallelize(dummy_data)  
print(dummy_rdd.filter(lambda x: x<10).collect())  
[1, 2, 3, 4, 5, 6, 7, 8, 9]
```



# Use Jupyter (on PySpark on Yarn)

7. Now you should see a completed stage in **PySpark UI** (*localhost:4040*):

The screenshot shows the PySpark UI interface at `marcel-virtualbox:8088/proxy/application_1540030431225_0003/`. The top navigation bar includes links for Jobs, Stages, Storage, Environment, and Executors. The main content area is titled "Spark Jobs (?)". It displays the following information:

- User: hadoop
- Total Uptime: 3.9 min
- Scheduling Mode: FIFO
- Completed Jobs: 1

A link to "Event Timeline" is also present. Below this, a table titled "Completed Jobs (1)" lists one job:

Job Id	Description	Submitted	Duration	Stages: Succeeded/Total	Tasks (for all stages): Succeeded/Total
0	collect at <ipython-input-2-a93978b47ddd>.3 collect at <ipython-input-2-a93978b47ddd>.3	2018/10/20 13:41:46	0.9 s	1/1	2/2



# Use Jupyter (on PySpark on Yarn)

8. As well as the related **PySpark** Container Running on Yarn:

The screenshot shows the Hadoop YARN web interface at `localhost:8088/cluster/apps/RUNNING`. The page title is "RUNNING Applications". On the left, there's a sidebar with a "hadoop" logo and sections for Cluster Metrics, Cluster Nodes Metrics, Scheduler Metrics, and Tools. The main content area displays "Cluster Metrics" with values: Apps Submitted (3), Apps Pending (1), Apps Running (1), Apps Completed (1), Containers Running (3), Memory Used (5 GB), Memory Total (8 GB), Memory Reserved (0 B), Vcores Used (3), and Vcores Total (8). Below this are "Cluster Nodes Metrics" and "Scheduler Metrics" tables. The "Scheduler Metrics" table shows Capacity Scheduler details: Scheduling Resource Type [memory-mb (unit=Mi), vcores] <memory:1024, vCores:1> and Maximum Allocation <memory:8192, vCores:4>. A detailed table lists "Show 20 entries" of running applications. One entry is highlighted: "application\_1540030431225\_0003" by user "hadoop" with name "Jupyter PySpark Test". It's a SPARK application in the default queue with priority 0, running since Sat Oct 20 13:38:06 +0200 2018, with 3 containers, 5120 allocated CPU VCores, 0 reserved CPU VCores, and 62.5% progress.

ID	User	Name	Application Type	Queue	Application Priority	StartTime	FinishTime	State	FinalStatus	Running Containers	Allocated CPU VCores	Allocated Memory MB	Reserved CPU VCores	Reserved Memory MB	% of Queue	% of Cluster	Progress
application_1540030431225_0003	hadoop	Jupyter PySpark Test	SPARK	default	0	Sat Oct 20 13:38:06 +0200 2018	N/A	RUNNING	UNDEFINED	3	3	5120	0	0	62.5	62.5	62.5



# Use Jupyter (on PySpark on Yarn)

## 9. Basic PySpark operations: Read Files from HDFS into DataFrames:

```
In [3]: from pyspark.sql import SparkSession  
spark = SparkSession(sc)  
  
In [4]: imdb_ratings_dataframe = spark.read.format('com.databricks.spark.csv').options(delimiter = '\t',header ='true',nullValue ='null',inferSchema='true').load('hdfs://user/hadoop/imdb_raw/title_ratings/2018/12/7/title.ratings.tsv')  
  
In [5]: imdb_ratings_dataframe.show(5) # show first 5 lines of tsv file (now a spark dataframe)  
+-----+-----+-----+  
| tconst|averageRating|numVotes|  
+-----+-----+-----+  
|tt0000001|      5.8|     1418|  
|tt0000002|      6.4|      167|  
|tt0000003|      6.6|     1013|  
|tt0000004|      6.4|      100|  
|tt0000005|      6.2|     1712|  
+-----+-----+-----+  
only showing top 5 rows  
  
In [6]: imdb_ratings_dataframe.printSchema() # show schema of tsv file (now dataframe)  
root  
 |-- tconst: string (nullable = true)  
 |-- averageRating: double (nullable = true)  
 |-- numVotes: integer (nullable = true)
```

[https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04\\_spark\\_pyspark\\_jupyter/JupyterTest.html](https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04_spark_pyspark_jupyter/JupyterTest.html)



# Use Jupyter (on PySpark on Yarn)

## 9. Basic PySpark: Operations on DataFrames:

```
In [8]: imdb_ratings_dataframe.count() # show number of rows within dataframe
Out[8]: 872954

In [9]: from pyspark.sql.functions import col, avg
imdb_ratings_dataframe.agg(avg(col("averageRating"))).show() # calculate average movie rating
+-----+
|avg(averageRating)|
+-----+
| 6.929355269579343|
+-----+

In [11]: imdb_ratings_dataframe.filter(col('averageRating') > 9.5).show(5) # filter movie ratings > 9.5 and show first 5
+-----+-----+
| tconst|averageRating|numVotes|
+-----+-----+
|tt0015927|      9.7|      6|
|tt0041069|      9.7|      6|
|tt0050536|      9.7|      7|
|tt0053560|      9.6|      5|
|tt0055416|      9.7|     31|
+-----+-----+
only showing top 5 rows

In [16]: imdb_ratings_dataframe.write.format("csv").save("hdfs://user/hadoop/imdb_ratings")
# saved on HDFS as /user/hadoop/imdb_ratings/part-00000-ce6e8310-64c0-4fb9-b597-d66a92f5309b-c000.csv
```

[https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04\\_spark\\_pyspark\\_jupyter/JupyterTest.html](https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04_spark_pyspark_jupyter/JupyterTest.html)



# Use Jupyter (on PySpark on Yarn)

## 9. Basic PySpark: Join DataFrames:

```
In [16]: imdb_ratings_dataframe.write.format("csv").save("hdfs:///user/hadoop/imdb_ratings")
# saved on HDFS as /user/hadoop/imdb_ratings/part-00000-ce6e8310-64c0-4fb9-b597-d66a92f5309b-c000.csv

In [17]: imdb_movies_dataframe = spark.read.format('com.databricks.spark.csv').options(delimiter = '\t',header ='true',nullValue =
'null',inferSchema='true').load('hdfs:///user/hadoop/imdb_raw/title_basics/2018/12/7/title.basics.tsv')

In [18]: all_imdb_dataframe = imdb_ratings_dataframe.join(imdb_movies_dataframe, imdb_ratings_dataframe.tconst == imdb_movies_data-
frame.tconst)

In [19]: all_imdb_dataframe.select("primaryTitle", "startYear", "averageRating", "numVotes").show(5)

+-----+-----+-----+
| primaryTitle|startYear|averageRating|numVotes|
+-----+-----+-----+
|The Puppet's Nigh...| 1908|      6.5|     126|
|The Lighthouse Ke...| 1911|      7.1|       8|
| The Sands of Dee| 1912|      6.9|      51|
|Zigomar contre Ni...| 1912|      6.8|      10|
|His Favorite Pastime| 1914|      5.1|    814|
+-----+-----+-----+
only showing top 5 rows
```

[https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04\\_spark\\_pyspark\\_jupyter/JupyterTest.html](https://github.com/marcelmittelstaedt/BigData/tree/master/exercises/04_spark_pyspark_jupyter/JupyterTest.html)



# Use Jupyter (on PySpark on Yarn)

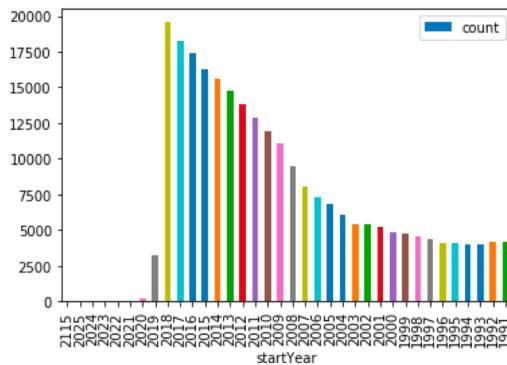
## 9. Basic Python: Plot results:

```
In [25]: plot_dataframe = imdb_movies_dataframe.filter(col('startYear') != '\N').filter(col('startYear') > 1990).filter(col('titleType') == 'movie').groupBy('startYear').count().sort(col("startYear").desc())
```

```
In [27]: import matplotlib.pyplot as plt
import pandas
pd_df=plot_dataframe.select("startYear", "count").toPandas()
```

```
In [29]: pd_df.plot.bar(x='startYear',y='count')
```

```
Out[29]: <matplotlib.axes._subplots.AxesSubplot at 0x7ff019d341d0>
```



# Exercises

Use PySpark Shell or Jupyter Notebooks on  
PySpark to solve exercises



# PySpark Exercises - IMDB

1. Execute Tasks of previous HandsOn Slides
2. Use PySpark or Jupyter on PySpark to answer following questions:
  - a) How many **movies** are within the IMDB dataset?
  - b) Who is the **oldest** actor/writer/... within the dataset?
  - c) Create a list (`tconst`, `original_title`, `start_year`, `average_rating`, `num_votes`) of movies which are:
    - equal or newer than year 2000
    - have an average rating better than 8
    - have been voted more than 100.000 timessave result (DataFrame) back to HDFS as CSV File.



# PySpark Exercises - IMDB

2. Use PySpark or Jupyter on PySpark to answer following questions:

d) How many movies are in list of c)?

e) create following plot with result of c)  
(plot visualizes the amount of good  
movies per year since 2001)

