DĚLAT
DOBRÝ SOFTWARE
NÁS BAVÍ

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Spark

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Agenda

1. What is it (for)
2. How to learn it
3. How to work with it
4. How it works
   - logical / technical level
   - transformations, actions, caching
   - examples
   - architecture, sources

Later:

› Spark SQL

› Spark streaming

What is Spark

(For) what is Spark

- framework for distributed computations
- improved map-reduce – by 2 orders
  - **in-memory processing** – less I/O operations, good for iterations and data analysis
  - **operation optimisation** before processing
  - enhanced by **SQL-like** commands
- API for Scala, Java, Python, R
- on Hadoop (using HDFS, YARN) or standalone
- written in Scala
- processing in JVM
- the most active (2017) opensource Big Data project

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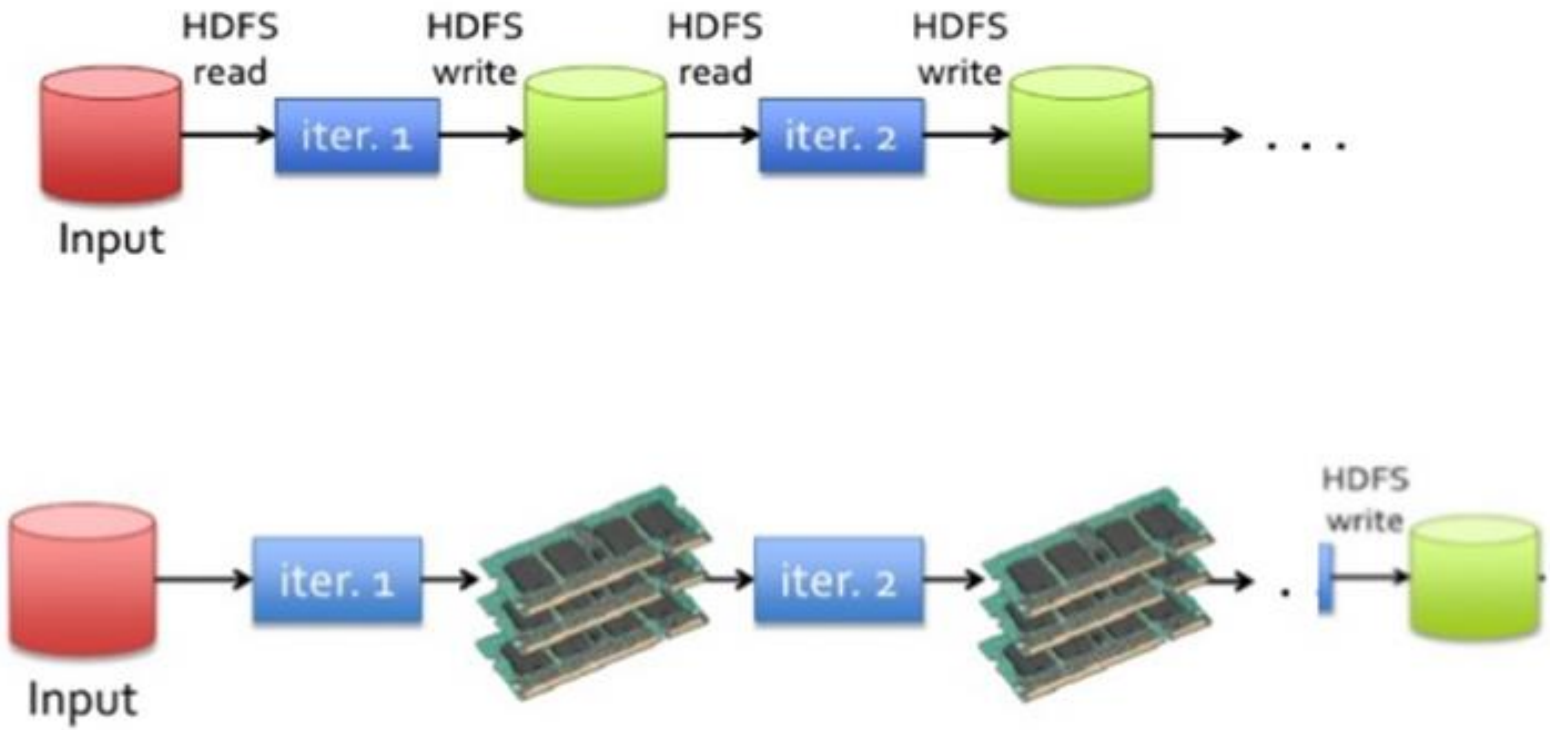
Spark vs. map-reduce



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Suitable tasks

- big enough, but not extreme
- able to be parallelized
- iterative
- not resolvable by traditional technologies

E. g.

1. sophisticated client features (risk score)
2. complicated SQL tasks for DWH
3. compute once (night), use many (day)
4. graph/network analysis
5. text-mining

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Not suitable tasks

- too small
- with extreme memory demands
- custom-tailored for other technologies (SQL, Java)
- unable to be parallelized
- strictly real-time

E. g.

1. small data modelling
2. median computation, random skipping in the file
3. JOIN of really big tables

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How to learn it

- http://spark.apache.org
- basics of Python | Scala | Java | R
- **self-practice**
- advice of experienced, StackOverflow etc.

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How to work with it

- interactively
  - command line (shell for Python and Scala)
  - Zeppelin/Jupyter notebook
- batch / application
  - compiled .jar file
  - Python script

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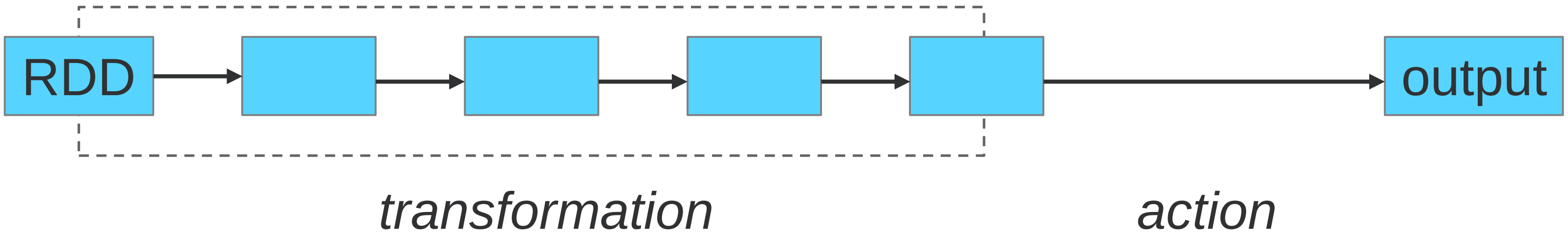
How Spark works

Logical level (high)

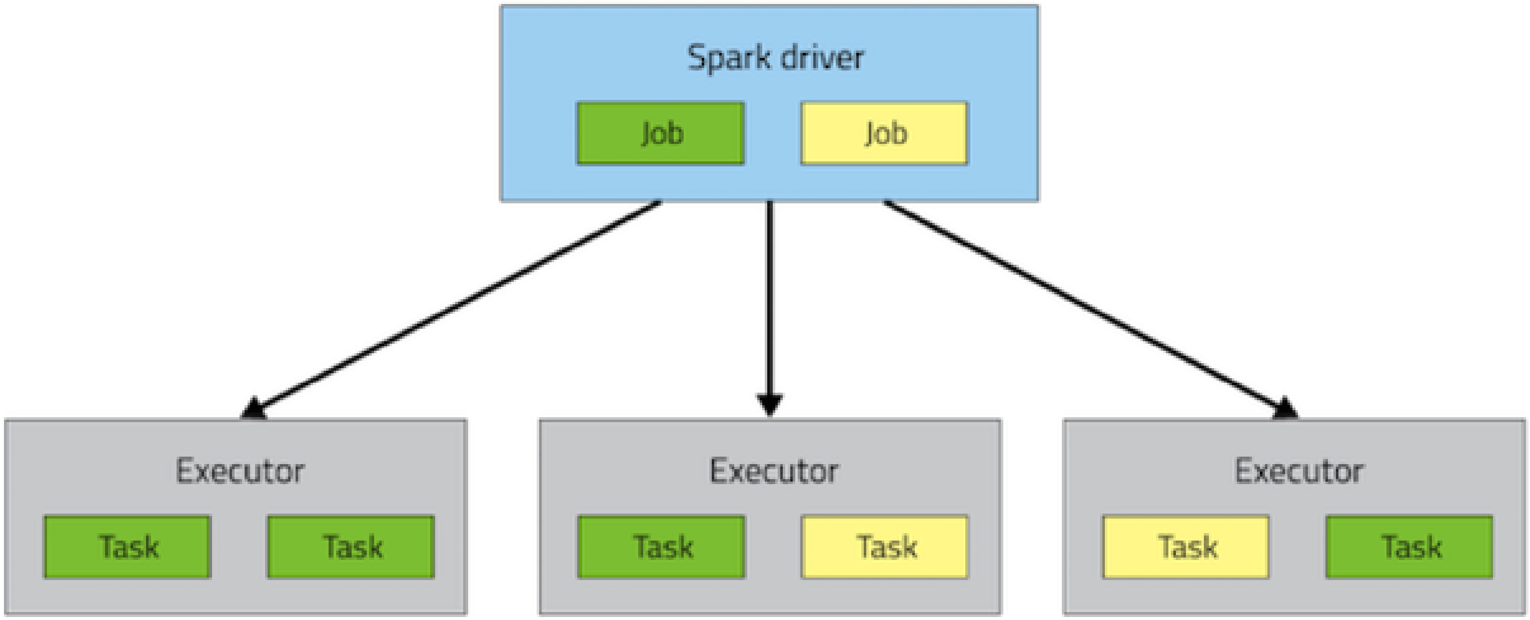


- series of transformations finished by action
- transformation are **planned** and **optimized**, but **not made**
- **lazy evaluation:** action starts all process

What is RDD?

- resilient distributed dataset
- item collections (line of a text file, files in a direktory, data matrix, etc.)
- must be divisible to parts – Spark does the division itself

Technical level (mid)



- creates JVM on nodes (=executors)
- application → jobs; job → tasks
- task (and data) distribution to nodes
- process control
- **more later – Spark architecture**

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Spark RDD – transformations

RDD1 ⇨ RDD2, item by item („row by row“)

- **map** (item ⇨ transforming function ⇨ new item)
- **flatMap** (item ⇨ transforming function ⇨ 0 až N new items)
- **filter**, **distinct** (only items meeting condition / unique items)
- **join** (joining other RDD by key)
- **union**, **intersection**
- **groupByKey**, **reduceByKey** (items agregation by key)
- ... and many others

How to get „key“?

"tuple"
(Scala, Python)

- first member of *tuple* = key
- result of transformation: word ⇨ (word, 1)

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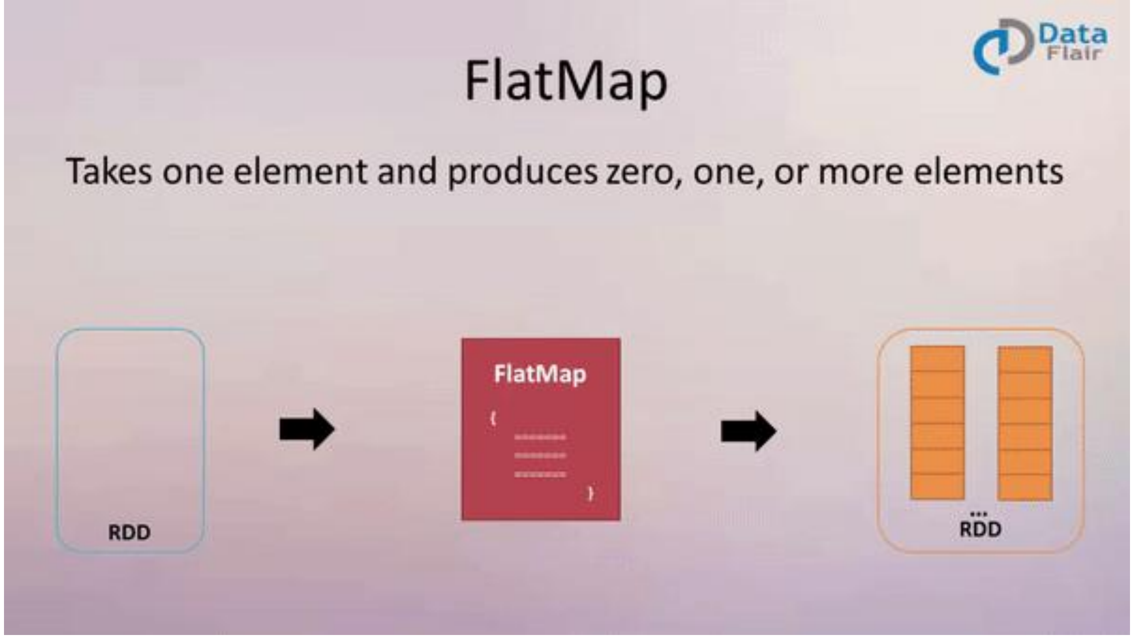
map a flatMap



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Example 1 – word count

- Task: count frequency of words in document
- Input: text file divided to lines
- Output: RDD with items (word, frequency)
- Workflow:
  - import text file as RDD
  - lines transformation: line ⇨ words ⇨ tuples (word, 1)
  - grouping items with same key, summing ones = count

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How to launch the interactive shell

pyspark (Python) **| spark-shell** (Scala)

- from Linux shell in console
- Spark on master node (local) or on YARN:
  - `pyspark --master local`
  - `pyspark --master yarn`
- creates important objects: `sc` (SparkContext), `sqlContext`
- many parameters – later
- closed by `exit()`

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Example 1 – word count

- Task: count frequency of words in document
- Input: text file divided to lines
- Workflow:
- import text file as RDD
```
lines = sc.textFile("/user/pascepet/bible.txt")
```
- lines transformation: line ⇨ words
```
words = lines.flatMap(lambda line: line.split(" "))
```
- lines transformation: words ⇨ tuples (word, 1)
```
pairs = words.map(lambda word: (word, 1))
```
- grouping items with same key, summing ones = count
```
counts = pairs.reduceByKey(lambda a, b: a + b)
```

to be or not to be	to be or not to be	(to, 1) (be, 1) (or, 1) (not, 1) (to, 1) (be, 1)	(to, 2) (be, 2) (or, 1) (not, 1)

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Why does it not count anything?

Because we have done no action so far.

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Spark RDD – actions

- **count**
- **take** (gets first *n* RDD items)
- **collect** (gets all items in RDD)
- **reduce** (aggregation of all RDD items with function provided)
- **saveAsTextFile**
- ... and others

- Action starts all chain from the beginning!
  - After run, all results are „forgotten“.
  - **If we don‘t want this, we have to cache some RDD.**

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Caching

- Caching: RDD is not forgotten but saved into memory / on disk.
- **Caching methods:**
  - **cache** (try to save in memory)
  - **persist** (more general – can control serialization, disk/memory)
  - **unpersist** (release RDD from memory/disk)
- **Caching types:**
  - MEMORY_ONLY
  - MEMORY_AND_DISK
  - MEMORY_ONLY_SER
  - MEMORY_AND_DISK_SER
- SER = serialization – less memory, high computation demands
  - Useful only for Java and Scala; Python makes serialization always
- Caching is not an action!

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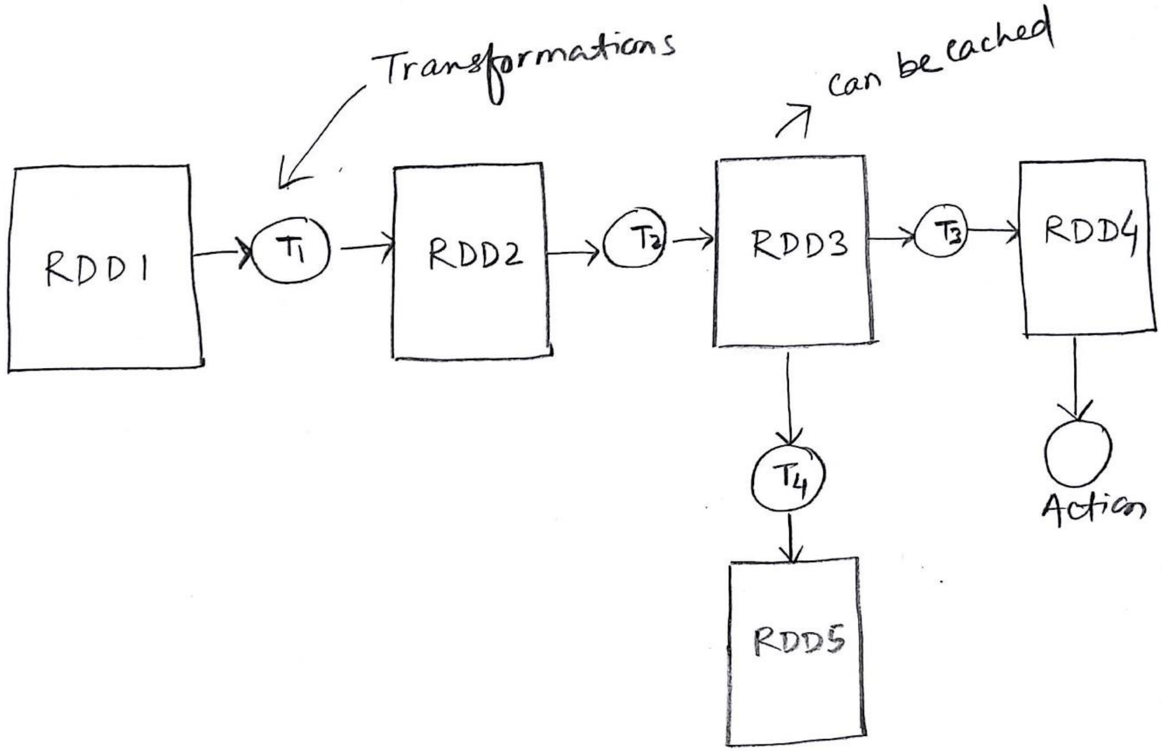
Spark program as a graph



Example 2 – similarity of images

- Task: evaluate similarity in pairs of images
- Input: b&w BMP files (4×4px, 256 colors) – RDD items
- Workflow:
  - parsing: binary BMP ⇨ sequence of 16 bits (0/1)
  - generating list of image pairs
  - evaluating similarity in pairs
- Result:
  RDD with items (file1, file2, similarity)
  save as text file

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Example 2 – similarity of images

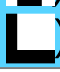
Task: evaluate similarity in pairs of images

Input: b&w BMP files (4×4px, 256 colors) – RDD items

```
files = sc.binaryFiles("/user/pascepet/pismena/*.bmp")
```

Workflow:

- parsing: binary BMP ⇨ sequence of 16 bits (0/1)
  ```
  filesParsed = files.map(parseBMP)
  ```
- generating list of image pairs
  ```
  filesPairs = filesParsed.cartesian(filesParsed) \
      .filter(lambda f: f[0][0]<f[1][0])
  ```
- evaluating similarity in pairs
  ```
  simil = filesPairs.map(similPair)
  ```

(N, )
(J, )
(L, )

(N, 1001101111011001)
(J, 0110100100010001)
(L, 1111100010001000)

(N, 1001...), (J, 0110...)
(N, 1001...), (L, 1111...)
(J, 0110...), (L, 1111...)

(N, J, 0.5)
(N, L, 0.6)
(J, L, 0.3)

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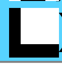
Example 2 – parsing

(N, )
(J, )
(L, )

```
def parseBMP(file):
    name = file[0]
    bytes = file[1]
    bytesLast = bytes[-16:]
    bits = []
    for z in bytesLast:
        if z=='\x00':
            bits.append(1)
        elif z=='\xff':
            bits.append(0)
        else:
            pass
    return (name, bits)
```

(N, 1001101111011001)
(J, 0110100100010001)
(L, 1111100010001000)

Example 2 – similarity

```
((N, 1001101111011001), (J, 0110100100010001))
```

```
def similPair(pair):
    file1 = pair[0]
    file2 = pair[1]
    return (file1[0],file2[0],
            similarity(file1[1],file2[1])
           )


def similarity(bits, pattern=[0]*16):
    sum = 0
    for i in range(0, len(bits)):
        sum += (bits[i]==pattern[i])
    return sum*1.0/len(bits)
```

```
(N, J, 0.5)
```

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Other Spark RDD operations

https://training.databricks.com/visualapi.pdf

Essential Core & Intermediate Spark Operations

TRANSFORMATIONS

General

- map
- filter
- flatMap
- mapPartitions
- mapPartitionsWithIndex
- groupBy
- sortBy

Math / Statistical

- sample
- randomSplit

Set Theory / Relational

- union
- intersection
- subtract
- distinct
- cartesian
- zip

Data Structure / I/O

- keyBy
- zipWithIndex
- zipWithUniqueID
- zipPartitions
- coalesce
- repartition
- repartitionAndSortWithinPartitions
- pipe

ACTIONS

General

- reduce
- collect
- aggregate
- fold
- first
- take
- forEach
- top
- treeAggregate
- treeReduce
- forEachPartition
- collectAsMap

Math / Statistical

- count
- takeSample
- max
- min
- sum
- histogram
- mean
- variance
- stdev
- sampleVariance
- countApprox
- countApproxDistinct

Set Theory / Relational

- takeOrdered

Data Structure / I/O

- saveAsTextFile
- saveAsSequenceFile
- saveAsObjectFile
- saveAsHadoopDataset
- saveAsHadoopFile
- saveAsNewAPIHadoopDataset
- saveAsNewAPIHadoopFile

https://training.databricks.com/visualapi.pdf

Essential Core & Intermediate PairRDD Operations

TRANSFORMATIONS

General

- flatMapValues
- groupByKey
- reduceByKey
- reduceByKeyLocally
- foldByKey
- aggregateByKey
- sortByKey
- combineByKey

Math / Statistical

- sampleByKey

Set Theory / Relational

- cogroup (=groupWith)
- join
- subtractByKey
- fullOuterJoin
- leftOuterJoin
- rightOuterJoin

Data Structure

- partitionBy

ACTIONS

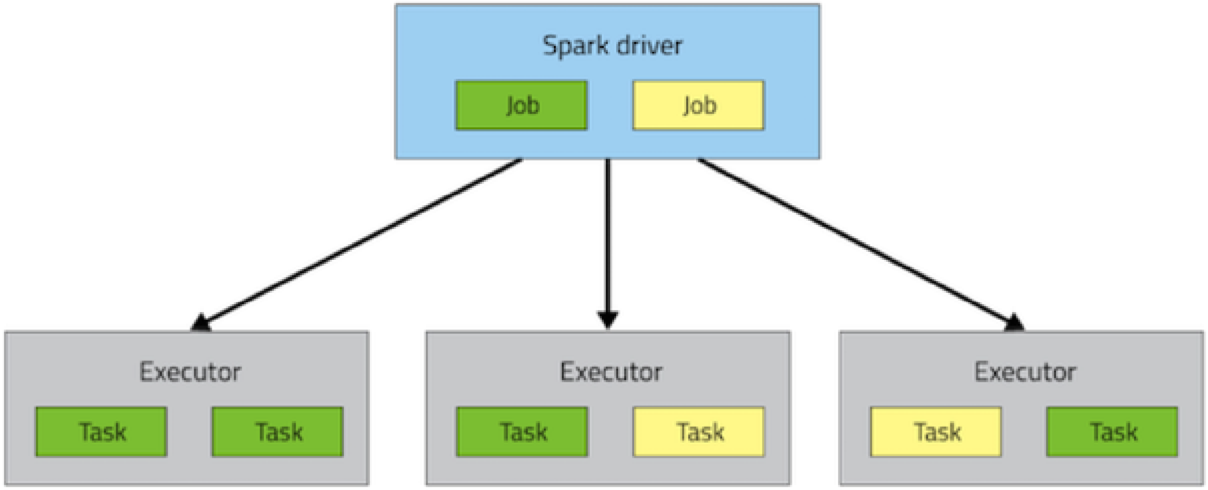
- keys
- values

- countByKey
- countByValue
- countByValueApprox
- countApproxDistinctByKey
- countApproxDistinctByKey
- countByKeyApprox
- sampleByKeyExact

Spark architecture

Important terms 1

- **Application master**
  - process for negotiation of sources
- **Driver**
  - main process
  - workflow planning
  - distributing work to executors
- **Executor**
  - process running on a node – JVM
  - doing tasks (possibly in parallel if it has multiple cores)



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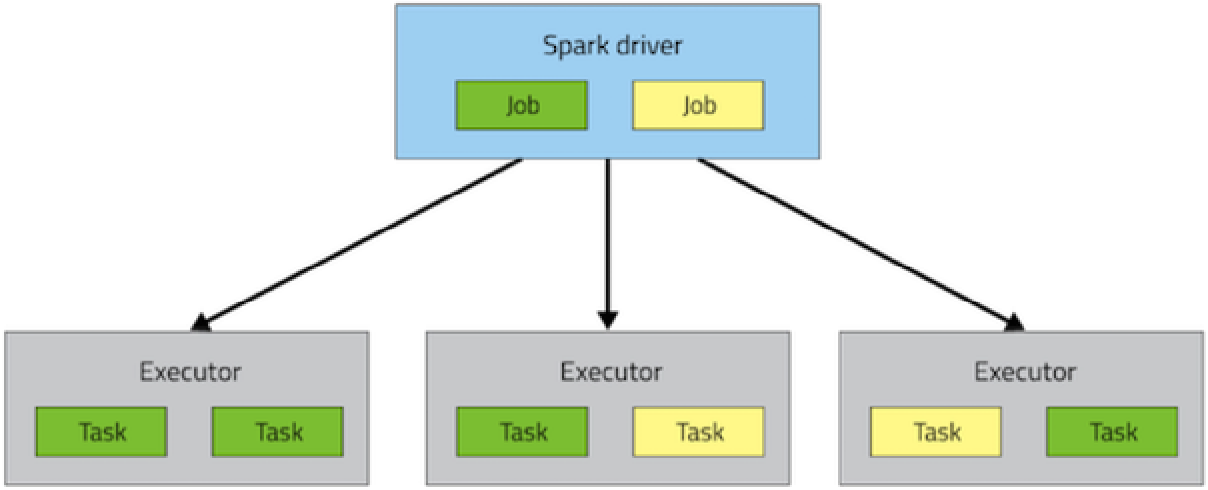
Important terms 2

- **Job**
  - part of application, driven by driver
- **Stage**
  - set of transformations which can be done without a shuffle
- **Task**
  - unit of work which is carried out by executor on some pice of data



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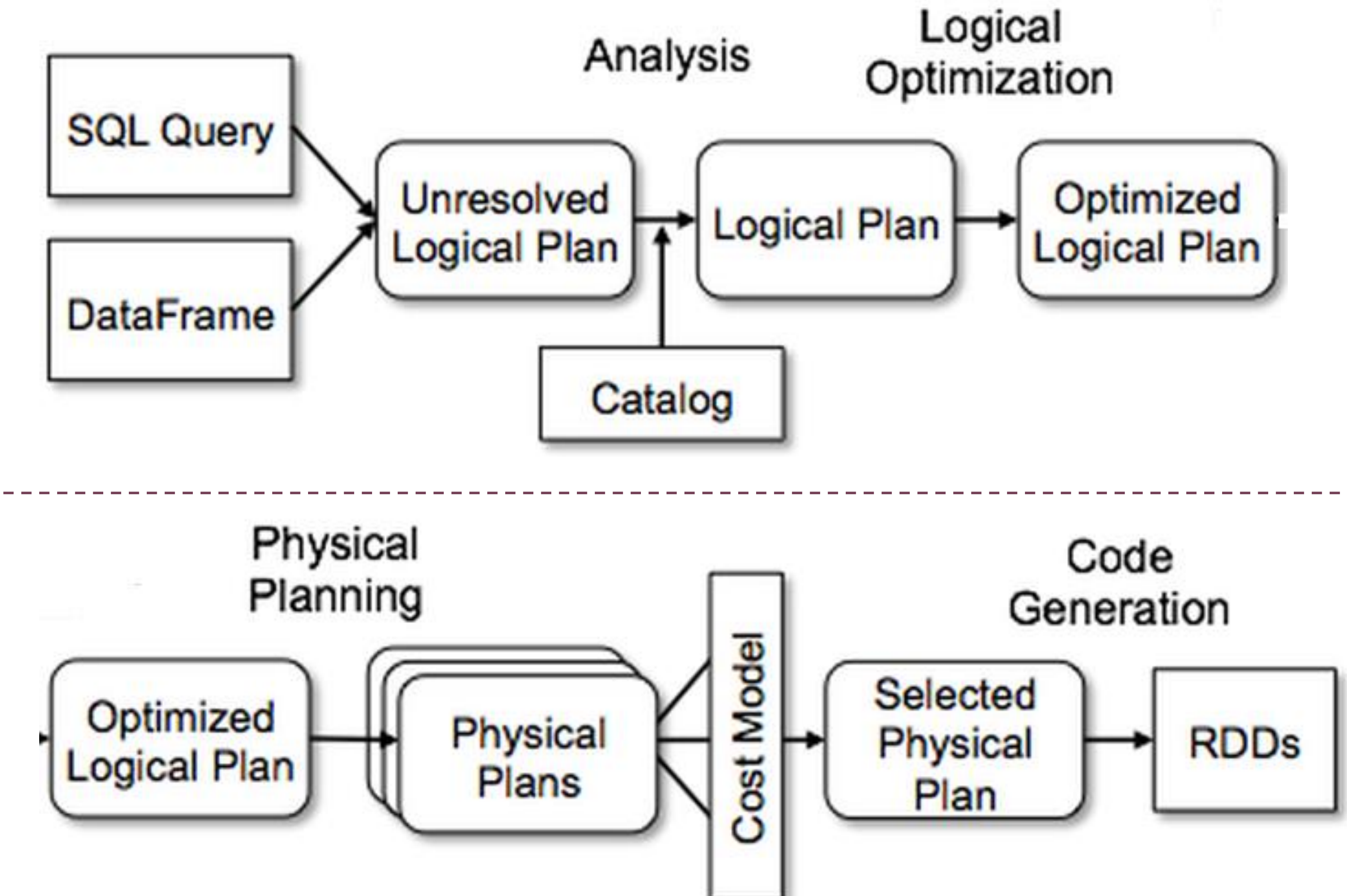
Planning and optimization



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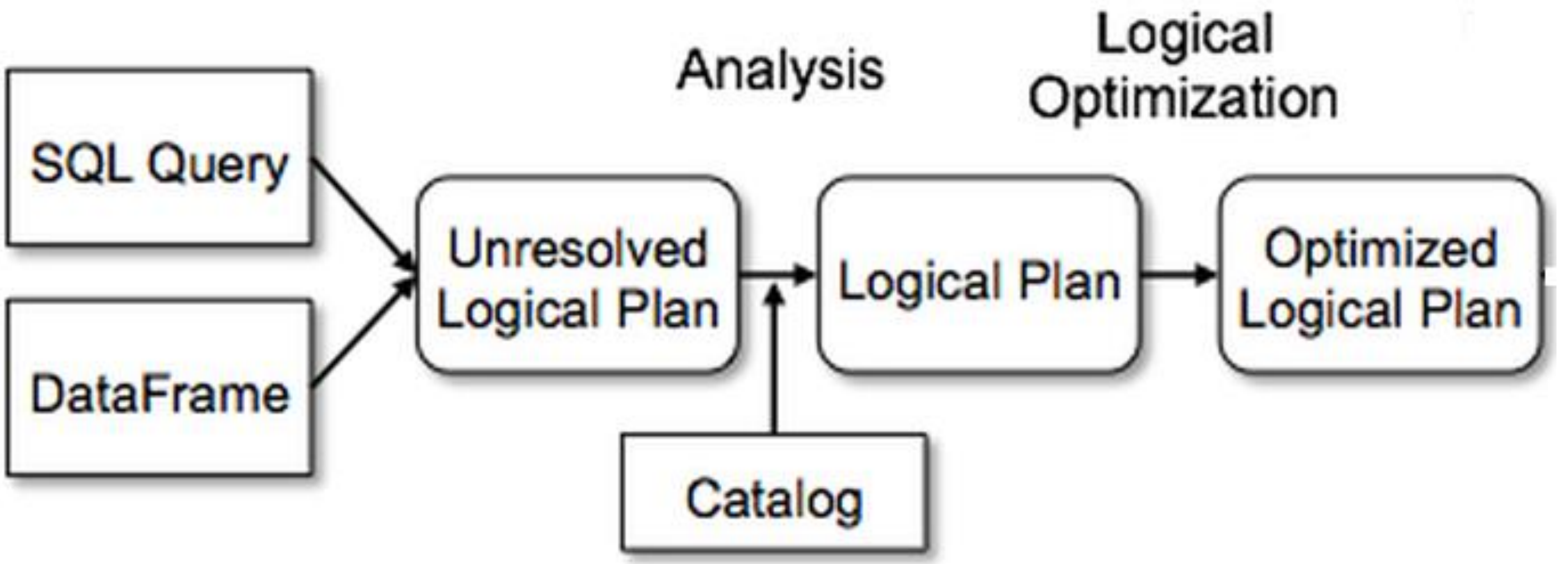
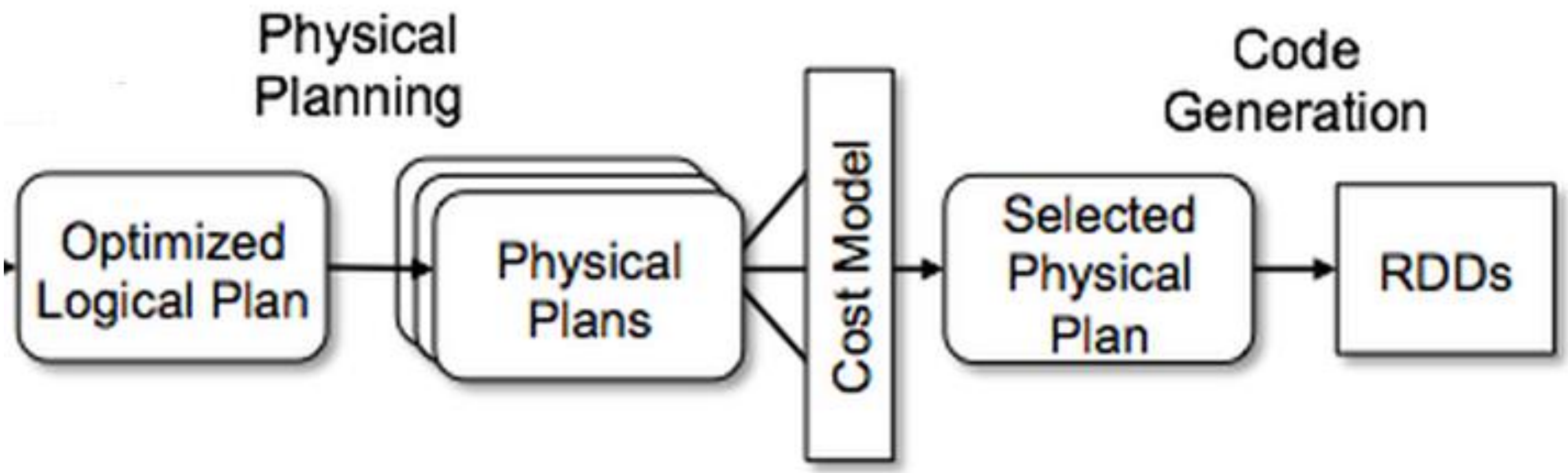
Planning and optimization



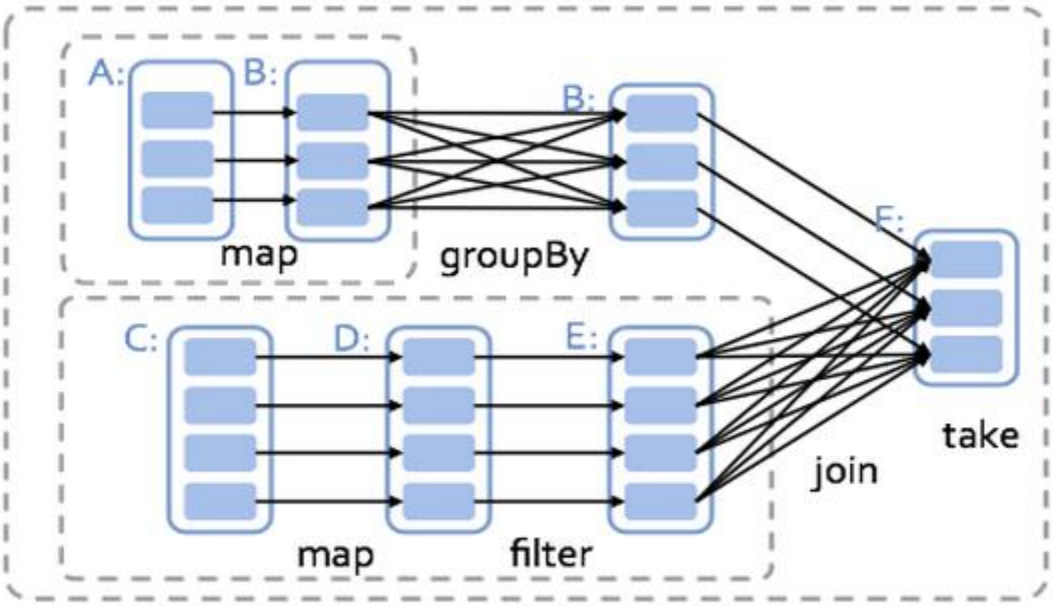
- typecasting
- rearranging of transformations (e. g. swap FILTER and JOIN)
- JOIN type selection, exploiting clustering, partitions, data skew
- etc.

Planning and optimization



- partitioninga and data distribution
- translating of transformations and actions to JVM language
- etc.

Example of graphic planning



- DAG – directed acylic graph
- describes computation flow
- dependencies (X must be done before Y)
- optimisation with respect to dependencies

Data partitioning

- **partition** – piece of data processed in one task
- by default 1 partition = 1 HDFS block = 1 task = 1 core
- partition processed on the node where is saved
- more partitions ⇨ more tasks ⇨ higher parallelism ⇨ smaller partition ⇨ lower efficiency ⇨ higher overhead
- ... and the other way around

Is it possible to set? And how?

- data input: ***`sc.textFile(file, partition_number`***`)`
- at run: ***`coalesce, repartition, partitionBy`***
- Every repartitioning causes a shuffle!

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Launching and configuration

Spark launching

```
pyspark | spark-shell | spark-submit --param value
```

Where and how it runs

- on the cluster – full parallelism
  - mode client
  - mode cluster
- locally – parallel run on multiple cores
- determined by parameters –master, --deploy-mode

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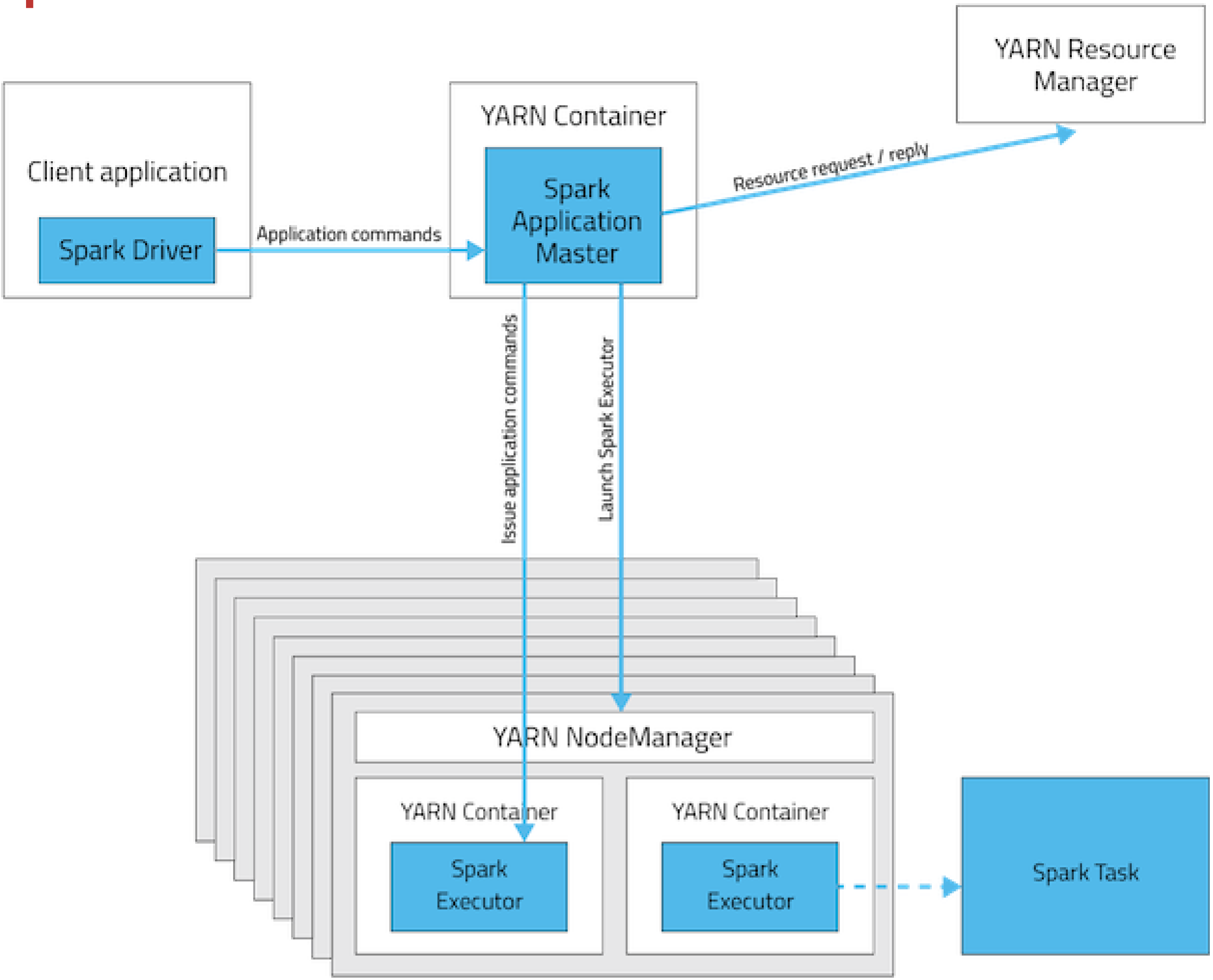
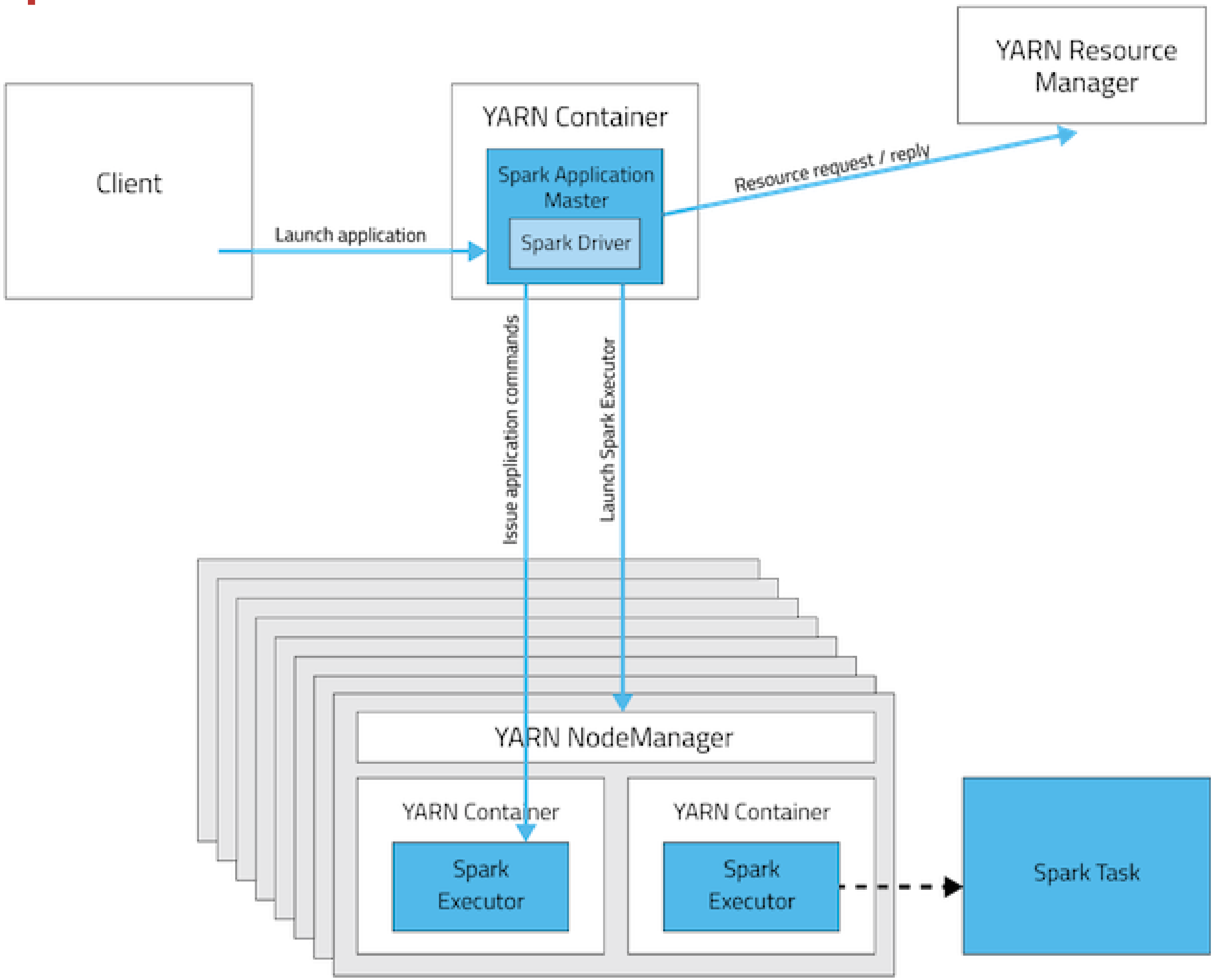
Spark on YARN client mode



Spark on YARN cluster mode



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Mode client and mode cluster

- default mode = client
- **client** – good for an interactive work and debugging (output to the local console)
- **cluster** – good for production

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Spark configuration – requirement of sources

- --name
- --driver-memory
- --num-executors
- --executor-cores
- --executor-memory

Example

- `pyspark --master yarn --deploy-mode client --driver-memory 1G --num-executors 3 --executor-cores 2 --executor-memory 3G`

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Source allocation plan – example

Generally:

- --num-cores <= 5
- --executor-memory <= 64 GB

Let‘s say… cluster of 6 nodes, each 16 cores and 64 GB RAM

- 1 core and 1GB per node → OS
  6 * 15 cores and 63 GB remaining
- 1 core for Spark Driver: 6 * 15 – 1 = 89 cores remaining
- 89 / 5 ~ 17 executors; each node approx. 3 executors
- 63 GB / 3 ~ 21 GB memory for an executor
- due to memory overhead → set 19 GB for an exekutor

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Thank for your attention

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