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

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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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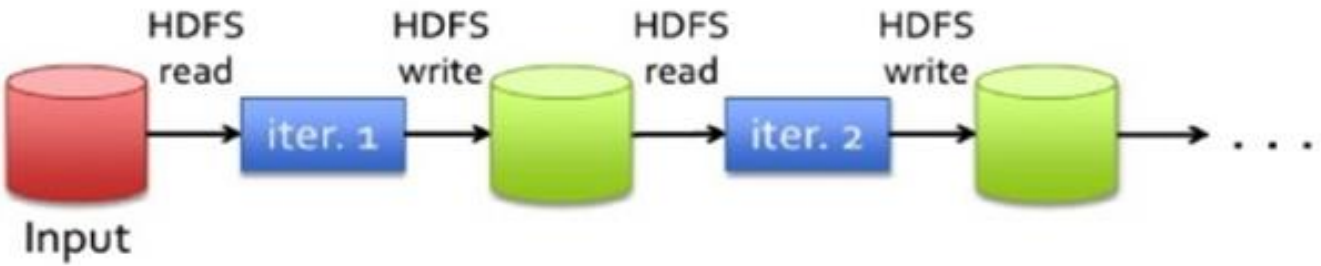
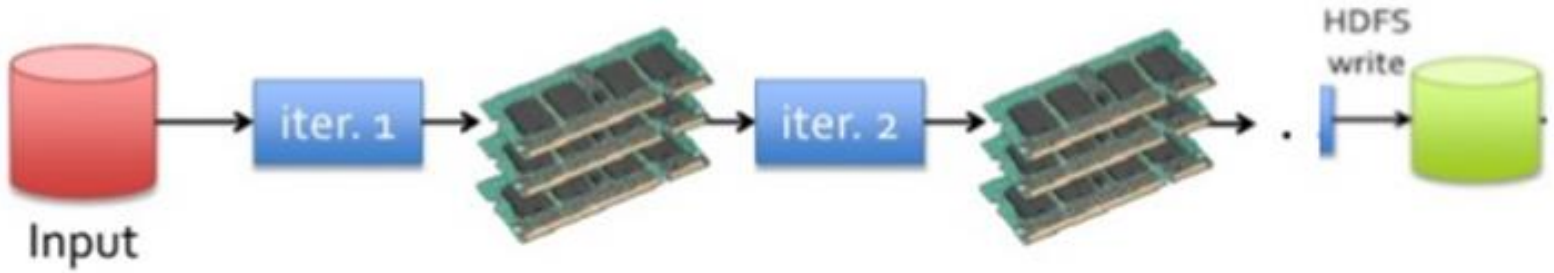
Spark vs. map-reduce





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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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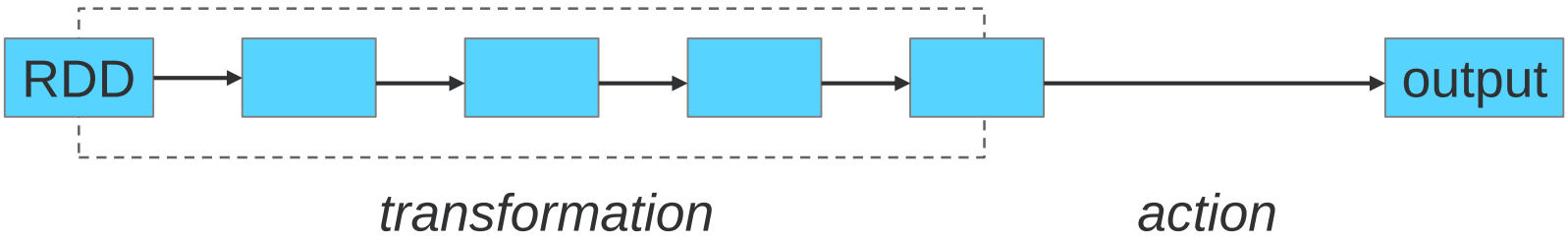
How Spark works

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

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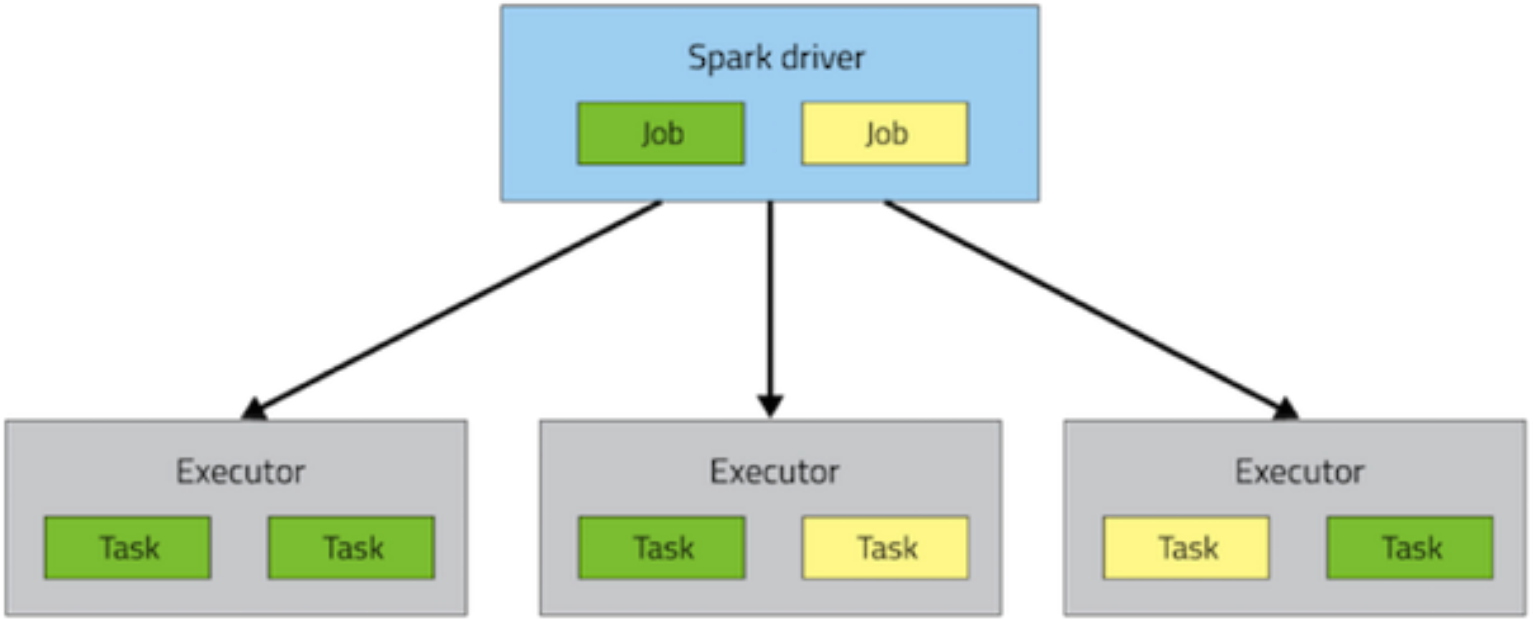
Technical level (mid)



- 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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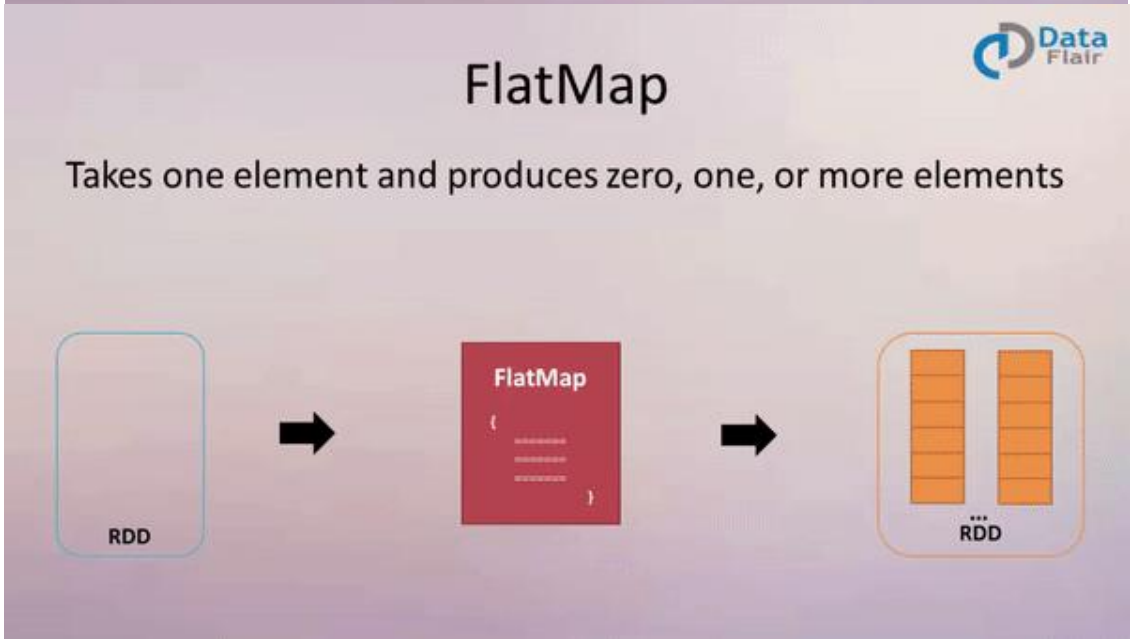
map a flatMap



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()`

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

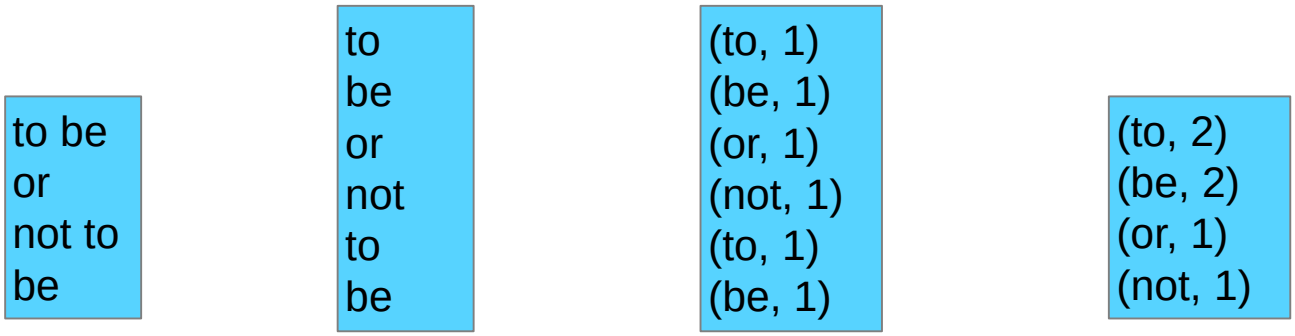
```
words = lines.flatMap(lambda line: line.split(" "))
```

- 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)
```



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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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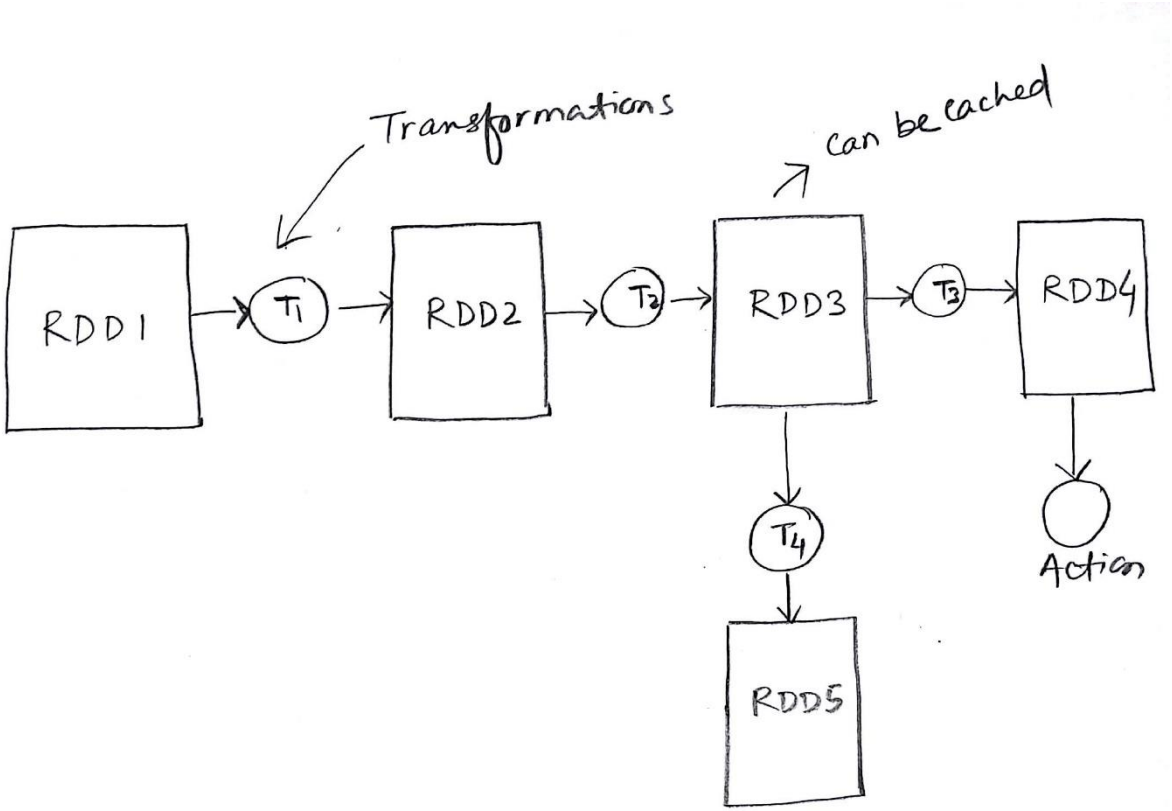
Caching

- 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!

Spark program as a graph



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Příklad 2 – podobnost obrázků

- Úkol: spočítat podobnosti mezi dvojicemi obrázků
- Vstup: čb soubory BMP (4×4, 256 barev) – prvky RDD
- Postup:
  - parsing: binární BMP ⇨ posloupnost 16 čísel 0/1
  - vytvoření dvojic obrázků
  - výpočet podobnosti dvojic obrázků
- Výsledek transformace:
  RDD s prvky (soubor1, soubor2, podobnost)
- Akce na konci – např. uložení do textového souboru

Příklad 2 – podobnost obrázků

Úkol: spočítat podobnosti mezi dvojicemi obrázků

Vstup: čb soubory BMP (4×4, 256 barev) – prvky RDD

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

Postup:

- parsing: binární BMP ⇨ posloupnost 16 čísel 0/1

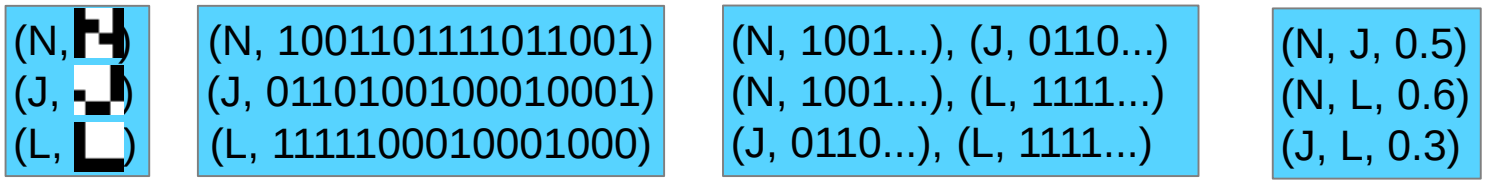
```
filesParsed = files.map(parseBMP)
```

- vytvoření dvojic obrázků

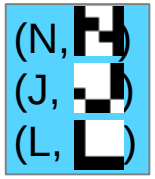
```
filesPairs = filesParsed.cartesian(filesParsed) \
    .filter(lambda f: f[0][0]<f[1][0])
```

- výpočet podobnosti dvojic obrázků

```
simil = filesPairs.map(similPair)
```



Příklad 2 – parsing



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

```
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)
```

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Příklad 2 – podobnost

```
((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

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

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

- takeOrdered

- 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

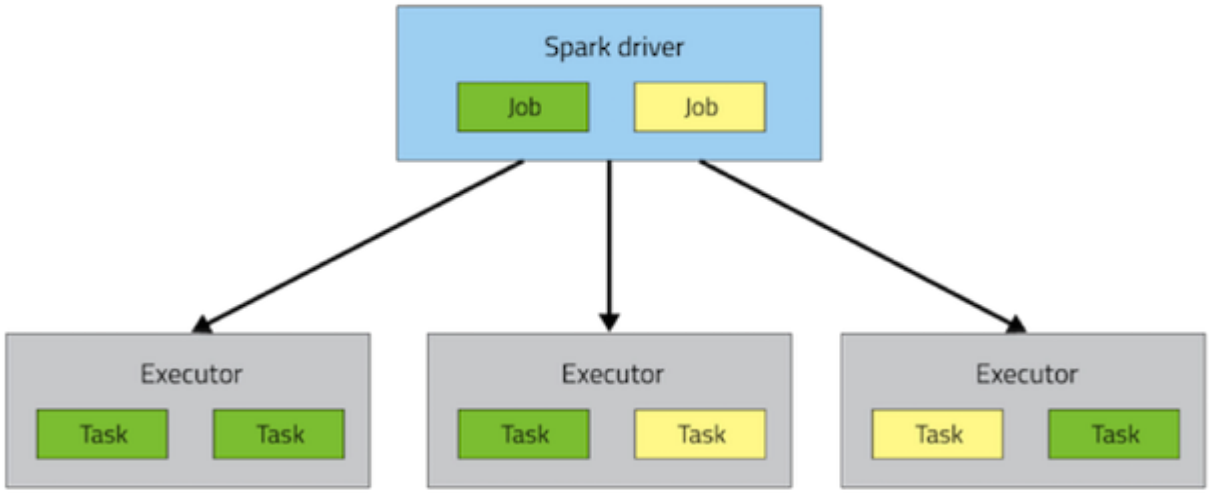
- keys
- values

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

Spark architecture

Důležité pojmy 1

- **Application master**
  - proces zodpovědný za vyjednání výpočetních zdrojů od res. manageru
- **Driver**
  - hlavní proces
  - plánuje workflow
  - distribuuje práci do exekutorů
- **Executor**
  - proces běžící na některém z nodů (ideálně na každém)
  - provádí tasky (může i několik paralelně)



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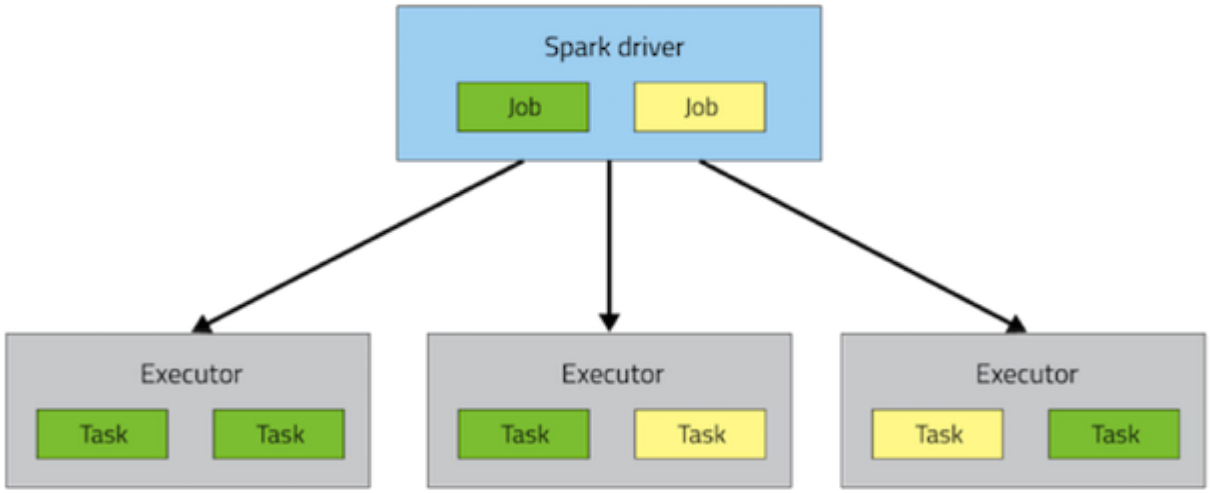
Důležité pojmy 2

- **Job**
  - akce volaná uvnitř programu driveru
- **Stage**
  - sada transformací, které mohou být vykonány bez shuffle
- **Task**
  - jednotka práce, kterou provádí exekutor na nějakém kousku dat



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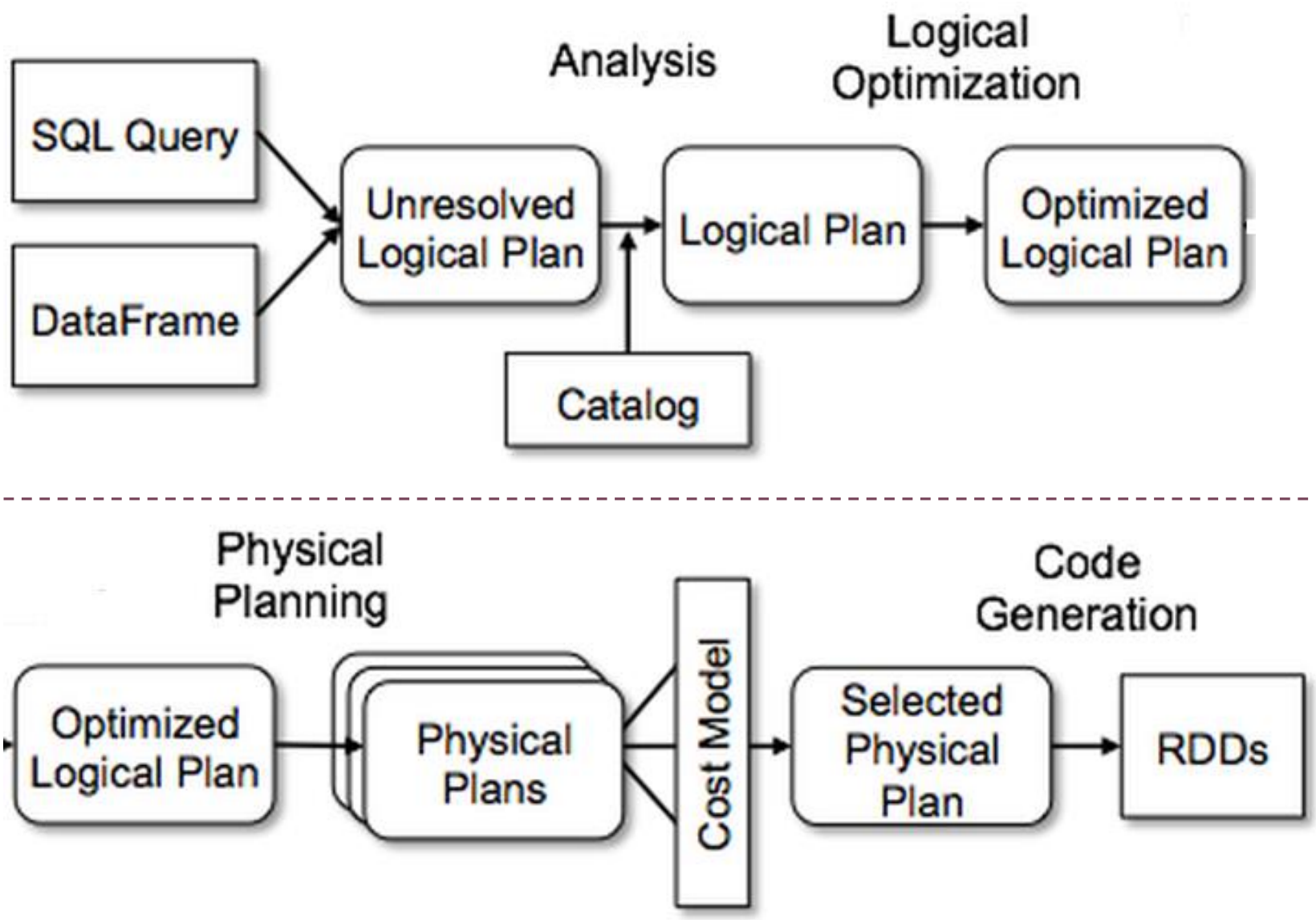
Plánování a optimalizace



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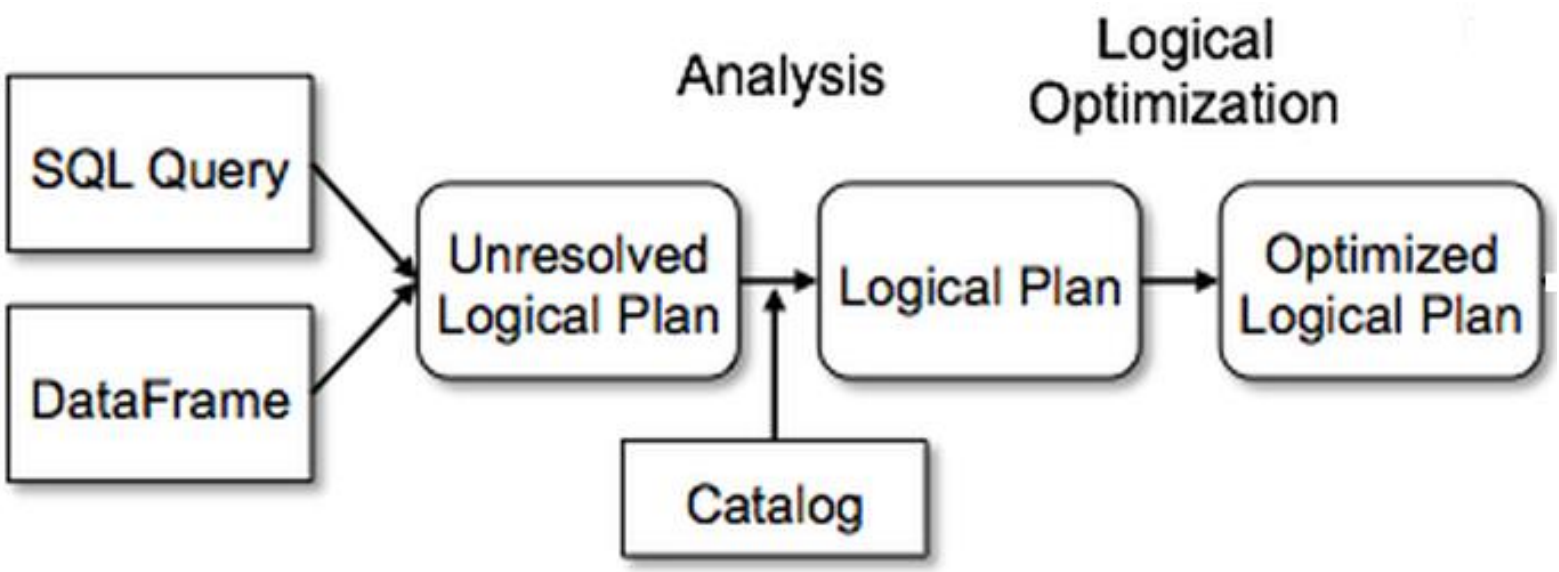
Plánování a optimalizace



- přetypování
- posloupnost transformací (např. přehození FILTER a JOIN)
- volba typu JOINu, využití clusterování, partitions, skew apod.
- atd.

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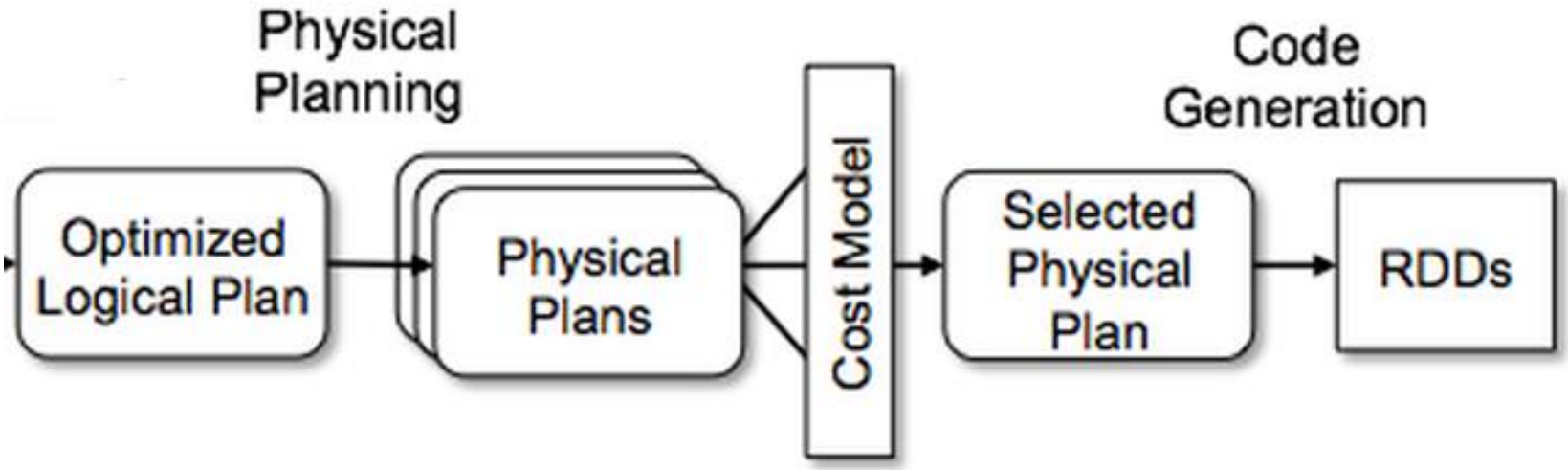
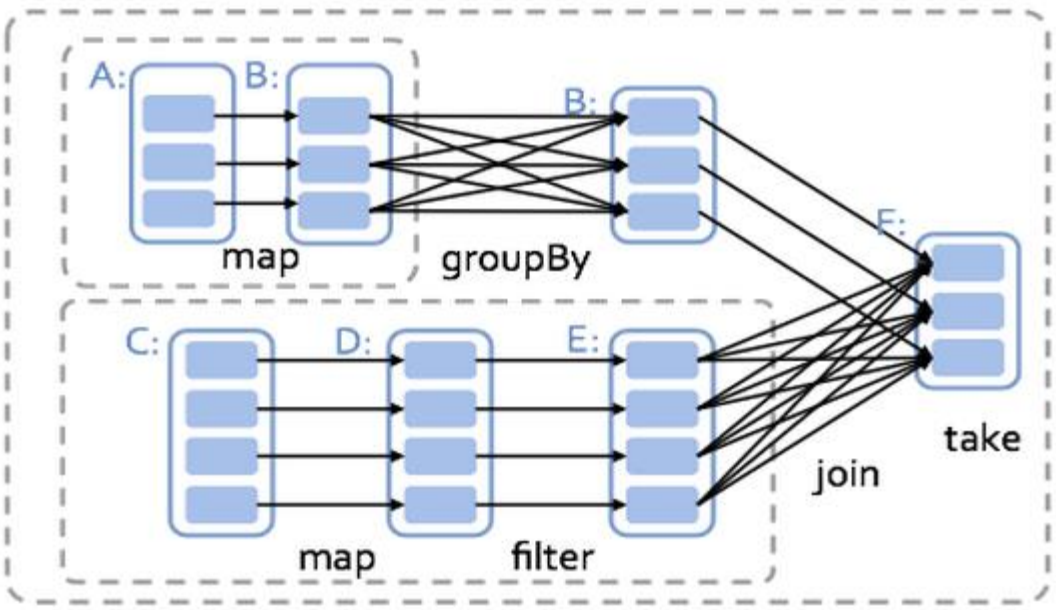
Plánování a optimalizace



- rozdělení a distribuce dat
- překlad transformací a akcí do příkazů pro JVM
- atd.

Ukázka



- DAG – graf popisující průběh výpočtu
- určení závislostí (X musí být uděláno před Y)
- optimalizace v rámci dodržení závislostí

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Rozdělení dat – partitions

- **partition** – část dat zpracovaná v jednom tasku
- defaultně 1 partition = 1 HDFS block = 1 task = 1 core
- partition se zpracuje na nodu, kde je uložená
- více partitions ⇨ víc tasků ⇨ vyšší paralelizace ⇨ menší velikost jedné partition ⇨ nižší efektivita ⇨ vyšší overhead
- ... a naopak

Lze ovlivnit? A jak?

- při vstupu: např. `sc.textFile(soubor, počet_part)`
- za běhu: `coalesce, repartition, partitionBy`
- shuffle!

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Spuštění a konfigurace

Spuštění Sparku

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

Kde a jak poběží

- na clusteru – plné využití paralelismu
  - mod client
  - mod cluster
- lokálně – paralelní běh na více jádrech
- určeno parametry --master a --deploy-mode

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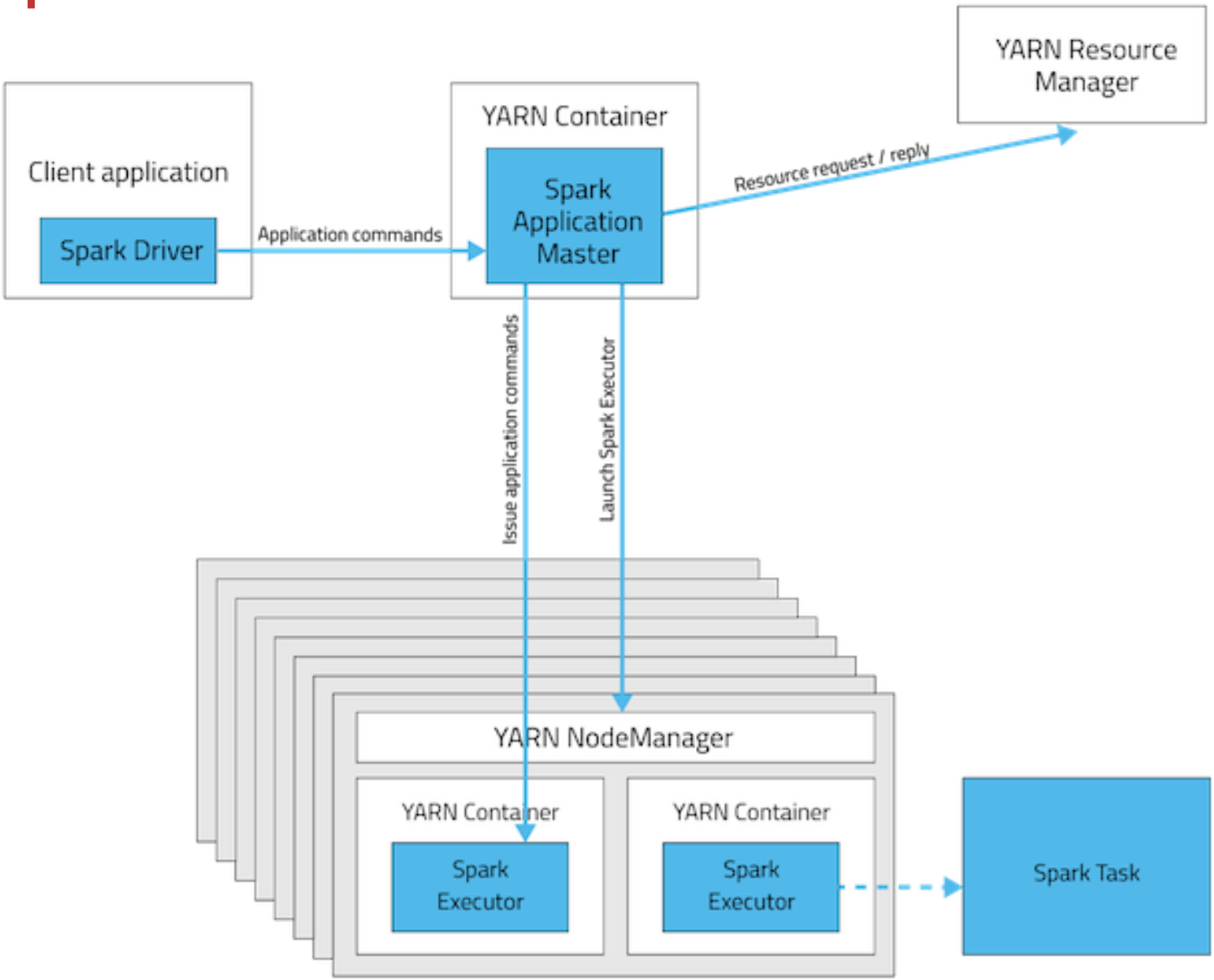
Spark on YARN client mode



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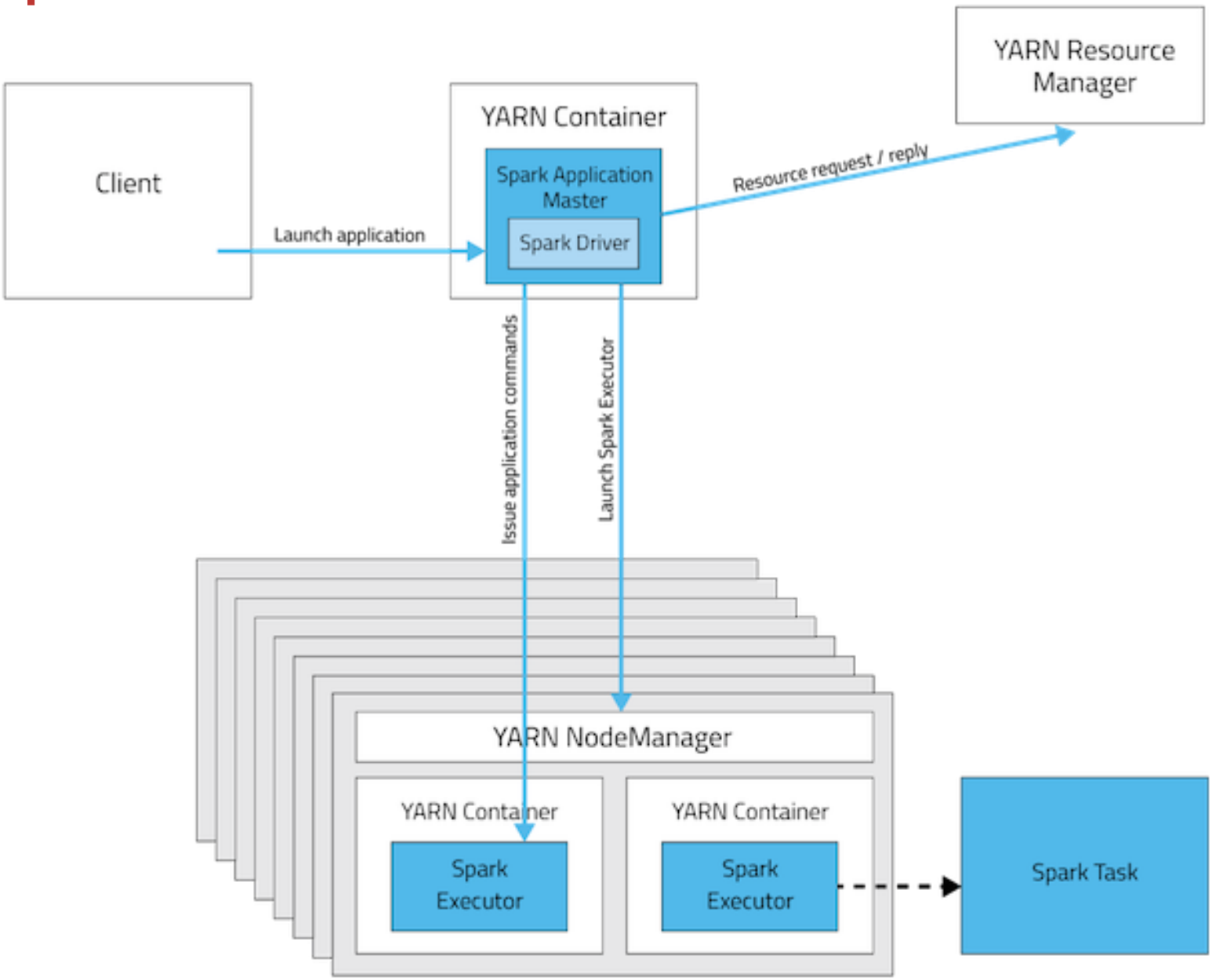
Spark on YARN cluster mode



Mod client versus mod cluster

- default je client
- mod client je vhodný pro interaktivní práci a debugging (výstup jde na lokální konzolu)
- mod cluster je vhodný pro produkční účely

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Konfigurace běhu Sparku – požadavky na zdroje

- --name *jméno aplikace*
- --driver-memory *paměť pro driver*
- --num-executors *počet exekutorů*
- --executor-cores *počet jader pro exekutor*
- --executor-memory *paměť pro exekutor*

Příklad

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

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Příklad plánu alokace zdrojů

Obecná doporučení:

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

Cluster 6 nodů, každý 16 jader a 64 GB RAM

- Rezervovat 1 jádro a 1GB /node pro OS
  zbývá 6 *15 jader a 63 GB
- 1 jádro pro Spark Driver: 6 * 15 – 1 = 89 jader.
- 89 / 5 ~ 17 exekutorů. Každý node (kromě toho s driverem) bude mít 3 exekutory.
- 63 GB / 3 ~ 21 GB paměti na exekutor. Navíc se musí počítat s memory overhead -> nastavit 19 GB na exekutor

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Díky za pozornost

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