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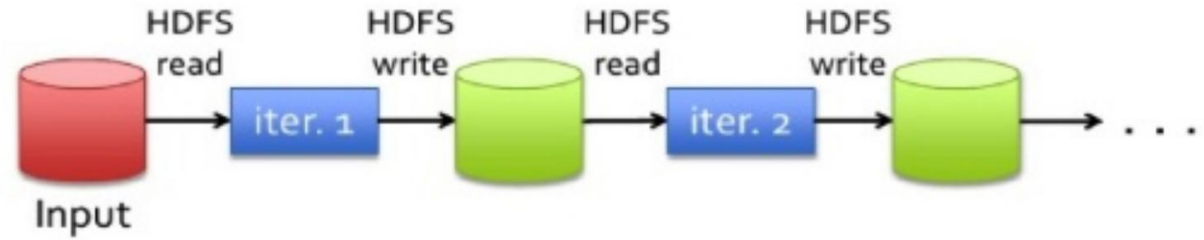
Chapter 6
Batch processing - part 2
Apache Spark

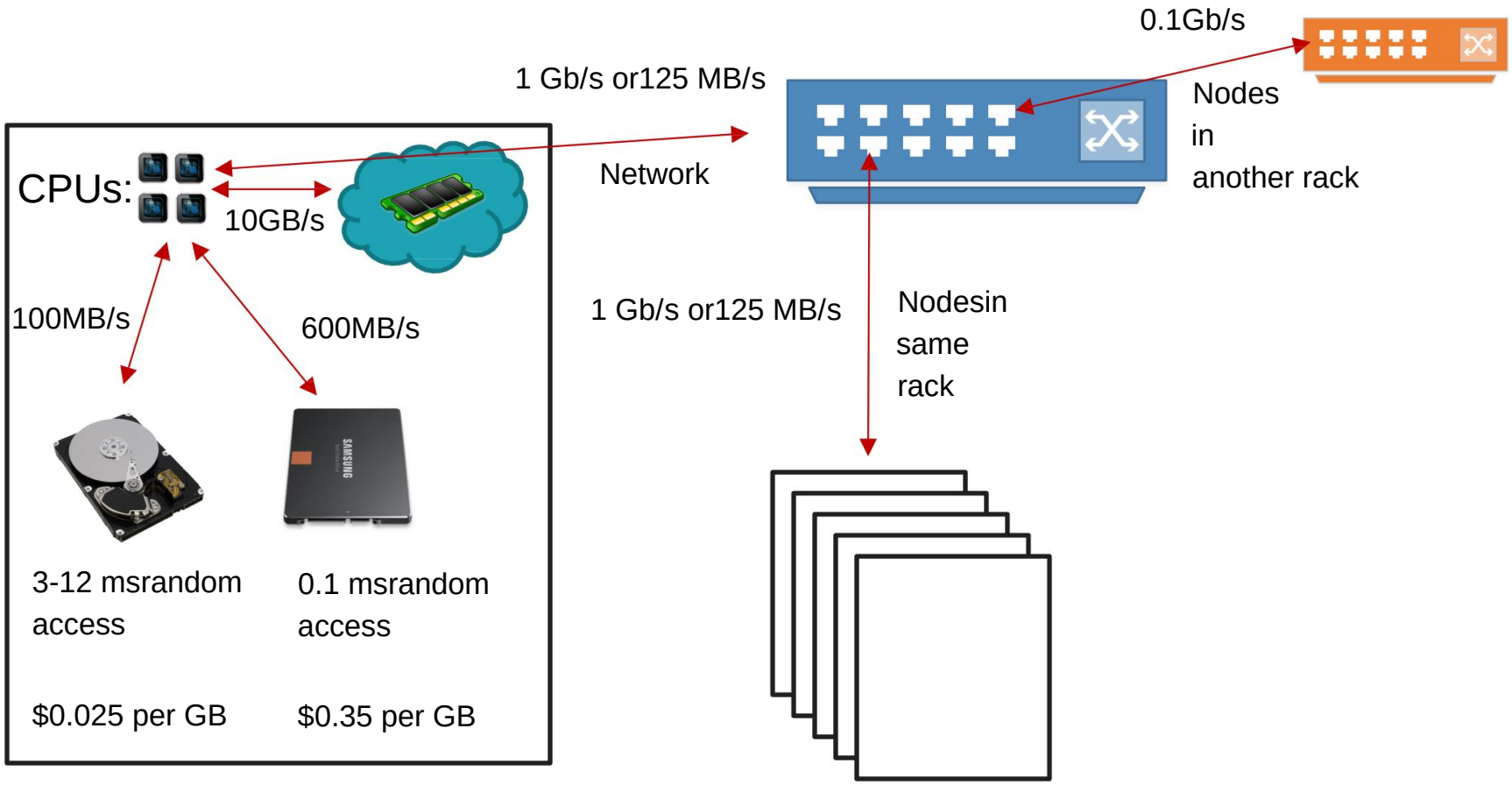
An unified analytics engine for large-scale data processing

Map Reduce: Iterative jobs

- Iterative jobs involve a lot of disk I/O for each repetition

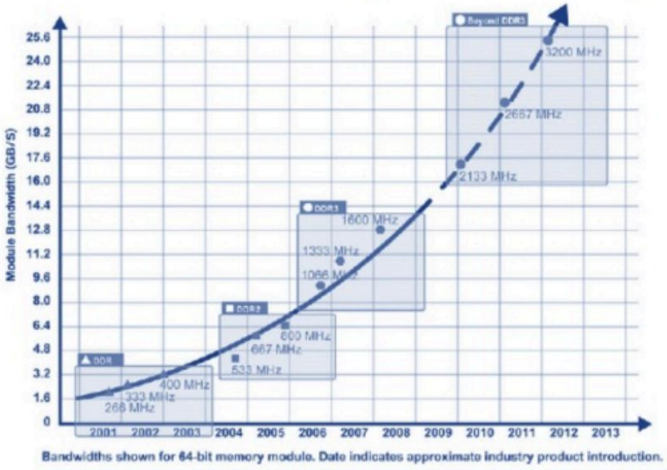


- è Disk I/O is very slow!



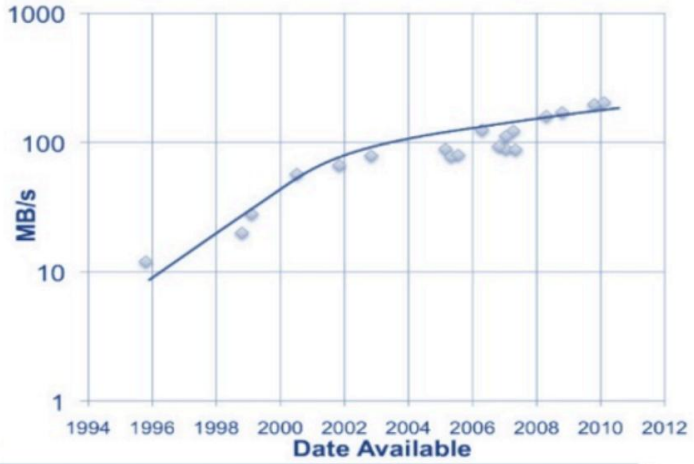
RAM is the new disk

- RAM throughput increasing **exponentially**



Bandwidths shown for 64-bit memory module. Date indicates approximate industry product introduction.

- Disk throughput increasing **slowly**

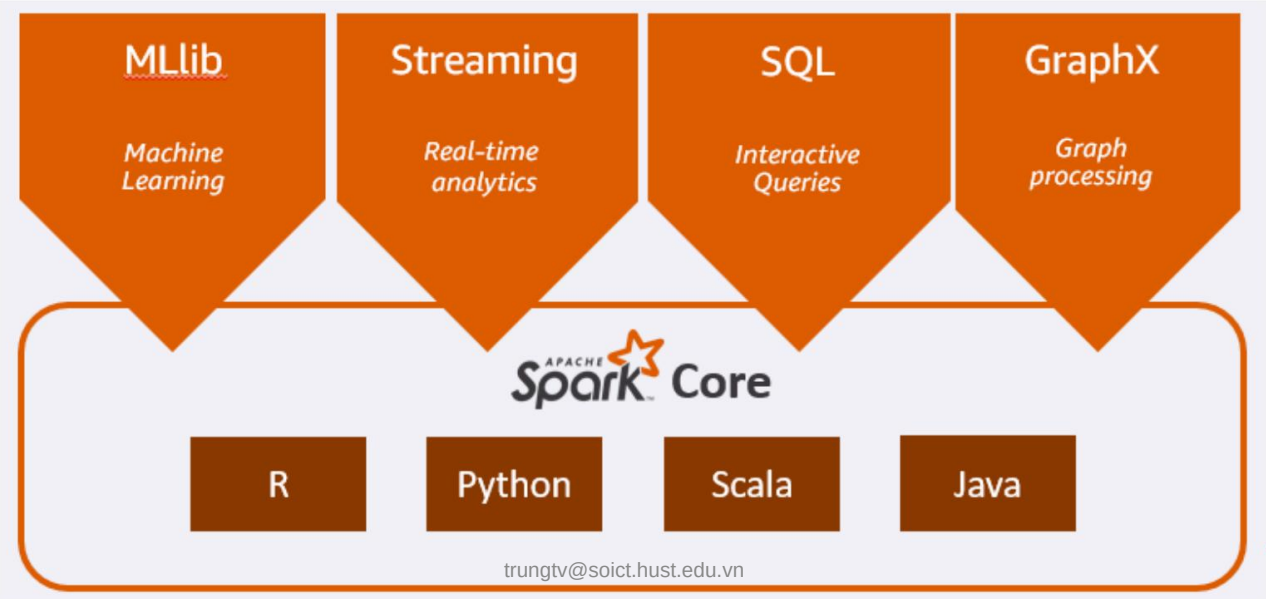


Memory-locality key to interactive response times

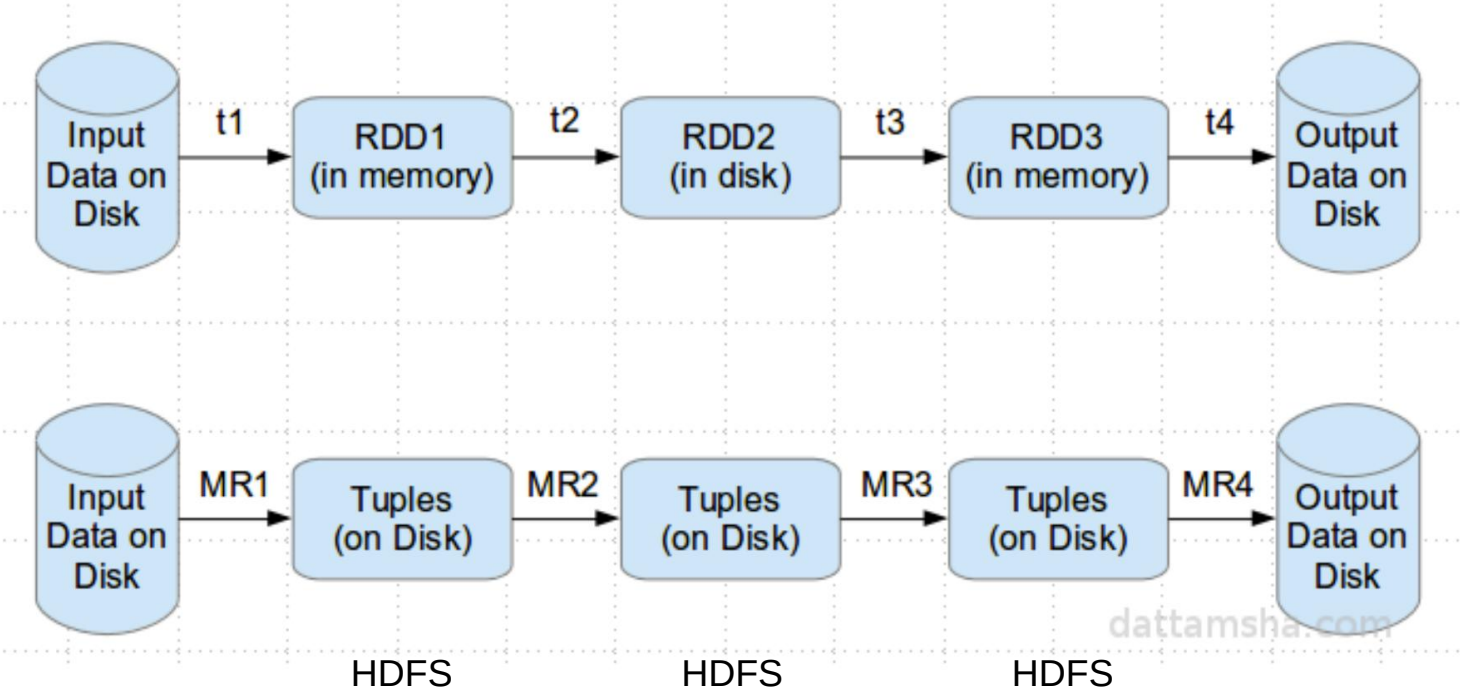
A unified analytics engine for large-scale data processing

- Better support for
  - Iterative algorithms
  - Interactive data mining
- Fault tolerance, data locality, scalability • Hide

complexites: help users avoid the coding for structure the distributed mechanism.



Memory instead of disk



Spark and Map Reduce differences

	Apache Hadoop MR	Apache Spark
Storage	Disk only	In-memory or on disk
Operations	Map and Reduce	Many transformations and actions, including Map and Reduce
Execution model Batch		Batch, iterative, streaming
Languages	Java	Scala, Java, Python and R

Apache Spark vs Apache Hadoop

	Hadoop World Record	Spark 100 TB *	Spark 1 PB
Data Size	102.5 TB	100 TB	1000 TB
Elapsed Time	72 mins	23 mins	234 mins
# Nodes	2100	206	190
# Cores	50400	6592	6080
# Reducers	10,000	29,000	250,000
Rate	1.42 TB/min	4.27 TB/min	4.27 TB/min
Rate/node	0.67 GB/min	20.7 GB/min	22.5 GB/min
Sort Benchmark Daytona Rules	Yes	Yes	No
Environment	dedicated data center	EC2 (i2.8xlarge)	EC2 (i2.8xlarge)

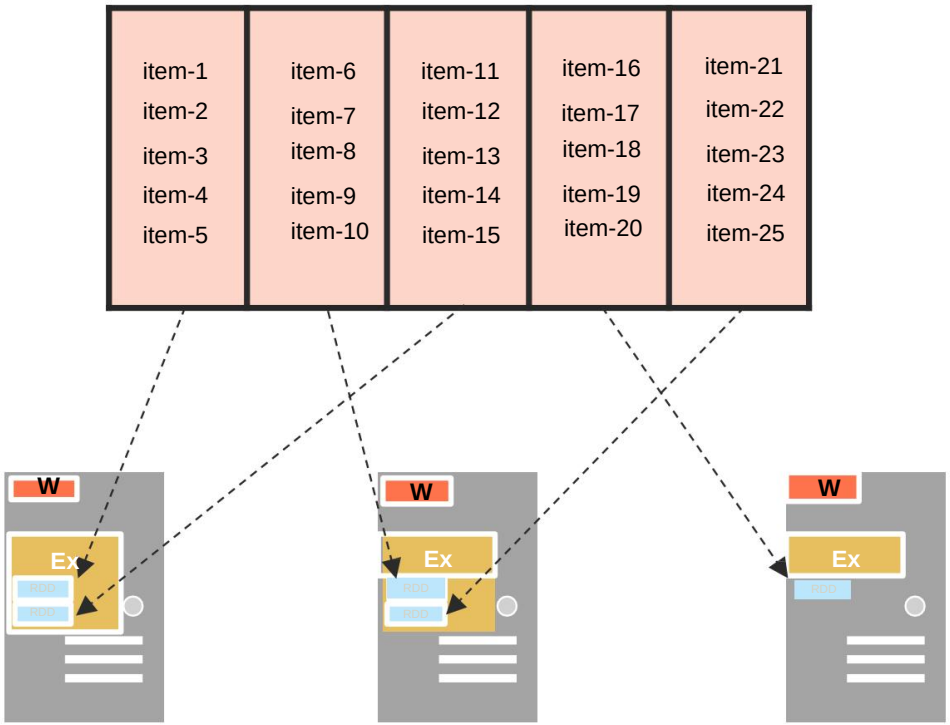
https://databricks.com/blog/2014/10/10/spark-petabyte-sort.html

Resilient Distributed Dataset (RDD)

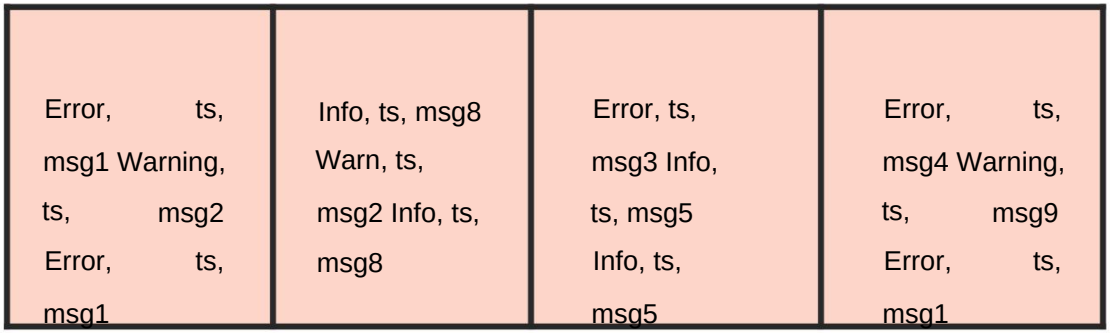
- RDDs are ***fault-tolerant, parallel data structures*** that let users explicitly persist ***intermediate results in memory,*** control their partitioning to optimize data placement, and manipulate them using ***a rich set of operators.***
- coarse-grained transformations vs. fine-grained updates
  - eg, map, filter and join) that applies the same operation to many data items at once.

more partitions= more parallelism

RDD



RDD with 4 partitions



logLinesRDD

A base RDD can be created 2ways:

-Parallelize a collection

- Read data from an external source (S3, C*, HDFS, etc)

Parallelize

```
// Parallelize in Scala
val wordsRDD = sc.parallelize(List("fish", "cats", "dogs"))
```

```
# Parallelize in Python
wordsRDD = sc.parallelize(["fish", "cats", "dogs"])
```

```
// Parallelize in Java
JavaRDD<String> wordsRDD = sc.parallelize(Arrays.asList("fish", "cats", "dogs"));
```

- Take an existing in-memory collection and pass it toSparkContext's parallelizemethod
- Not generally used outside of prototyping and testing since it requiresentiredataset in memory ononemachine

Read from Text File

```
// Read a local txt file in Scala
val linesRDD = sc.textFile("/path/to/README.md")
```

```
# Read a local txt file in Python
linesRDD = sc.textFile("/path/to/README.md")
```

```
// Read a local txt file in Java
JavaRDD<String> lines = sc.textFile("/path/to/README.md");
```

There are other methods to read data from HDFS, C*, S3, HBase, etc.

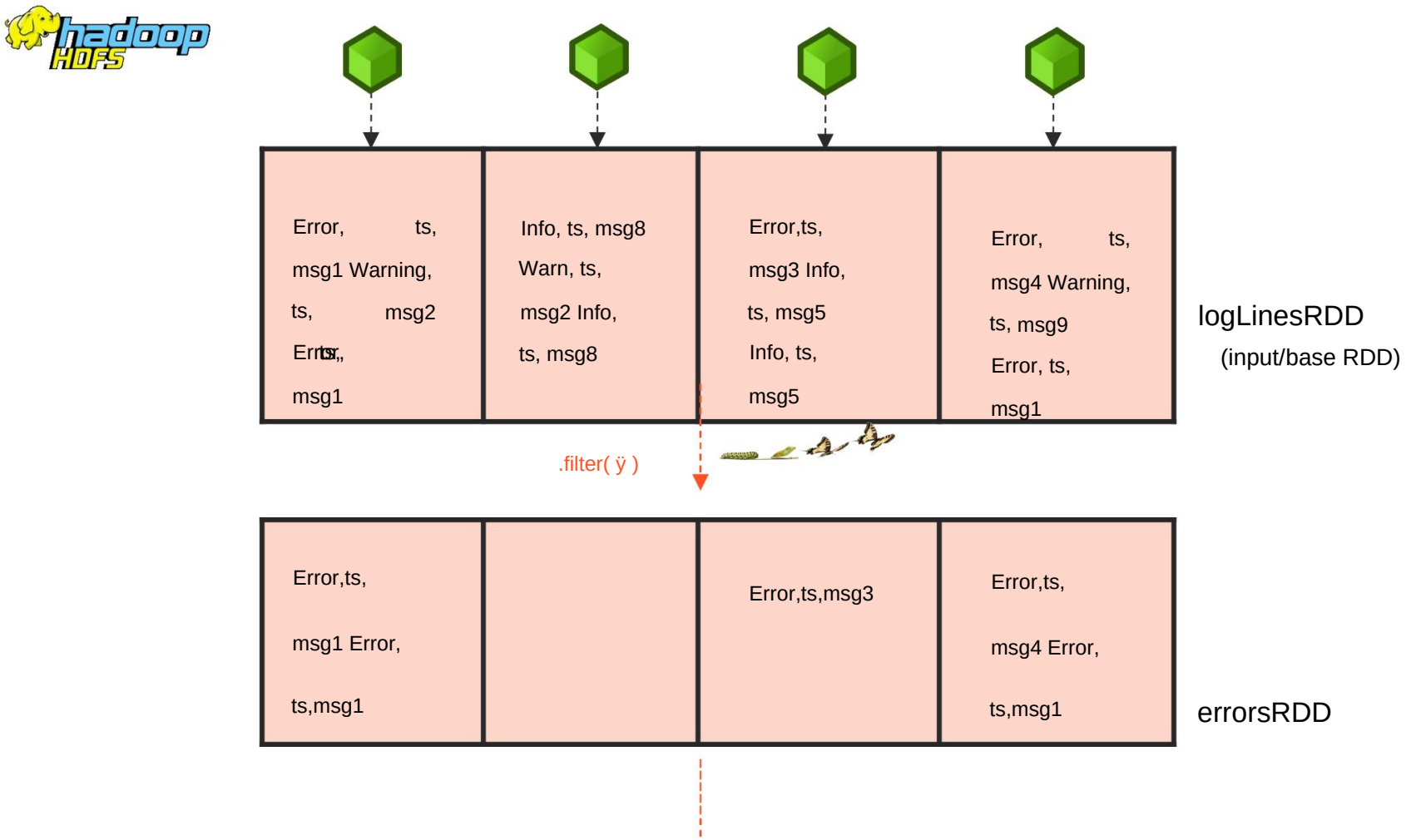
Operations on Distributed Data

- Two types of operations: transformations and actions •

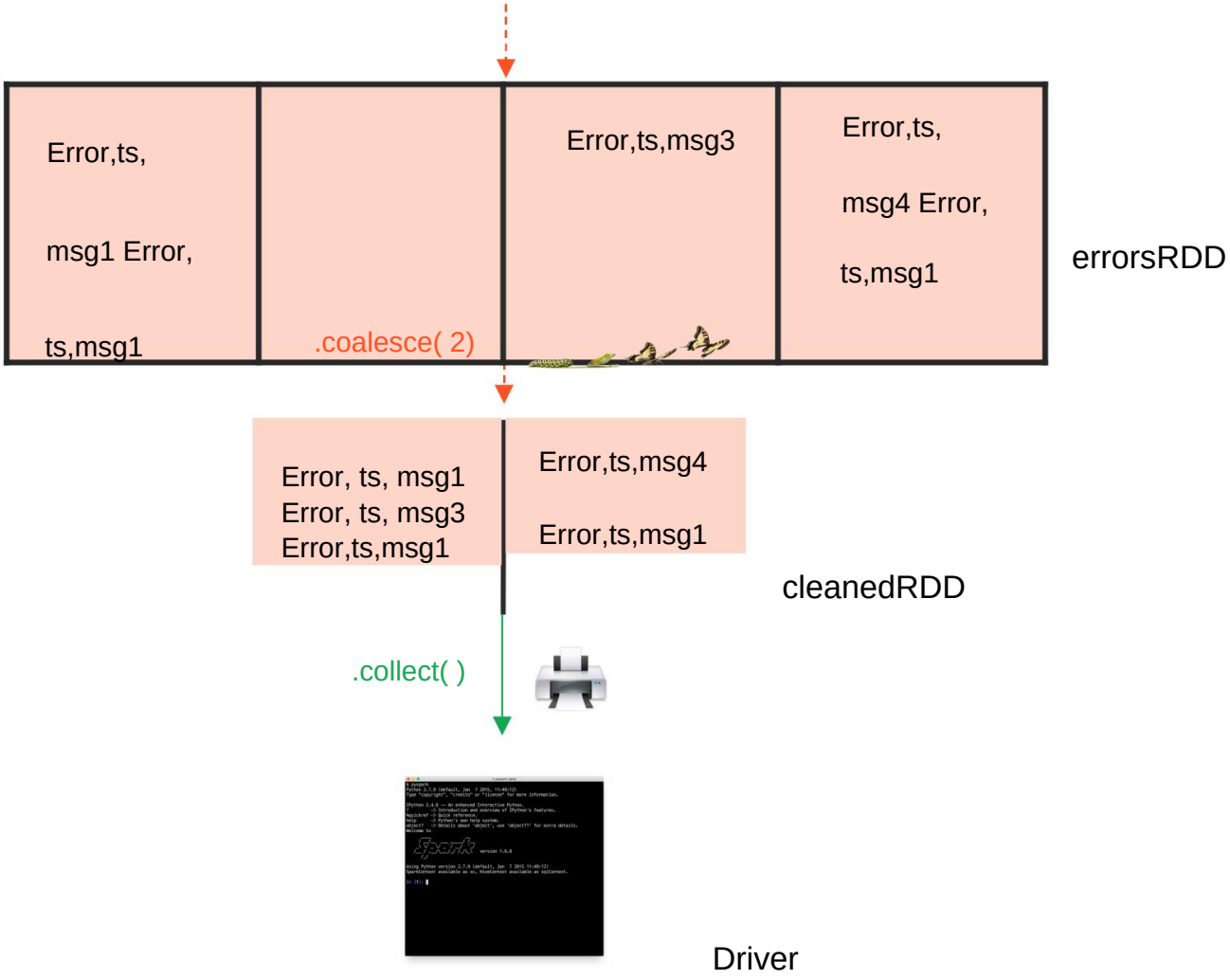
Transformations are lazy (not computed immediately) • Transformations are executed when an action is run

- Persist (cache) distributes data in memory or disk

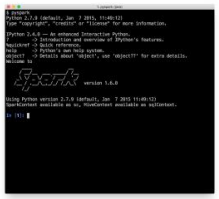
Transformation: Filter



Action: Collect

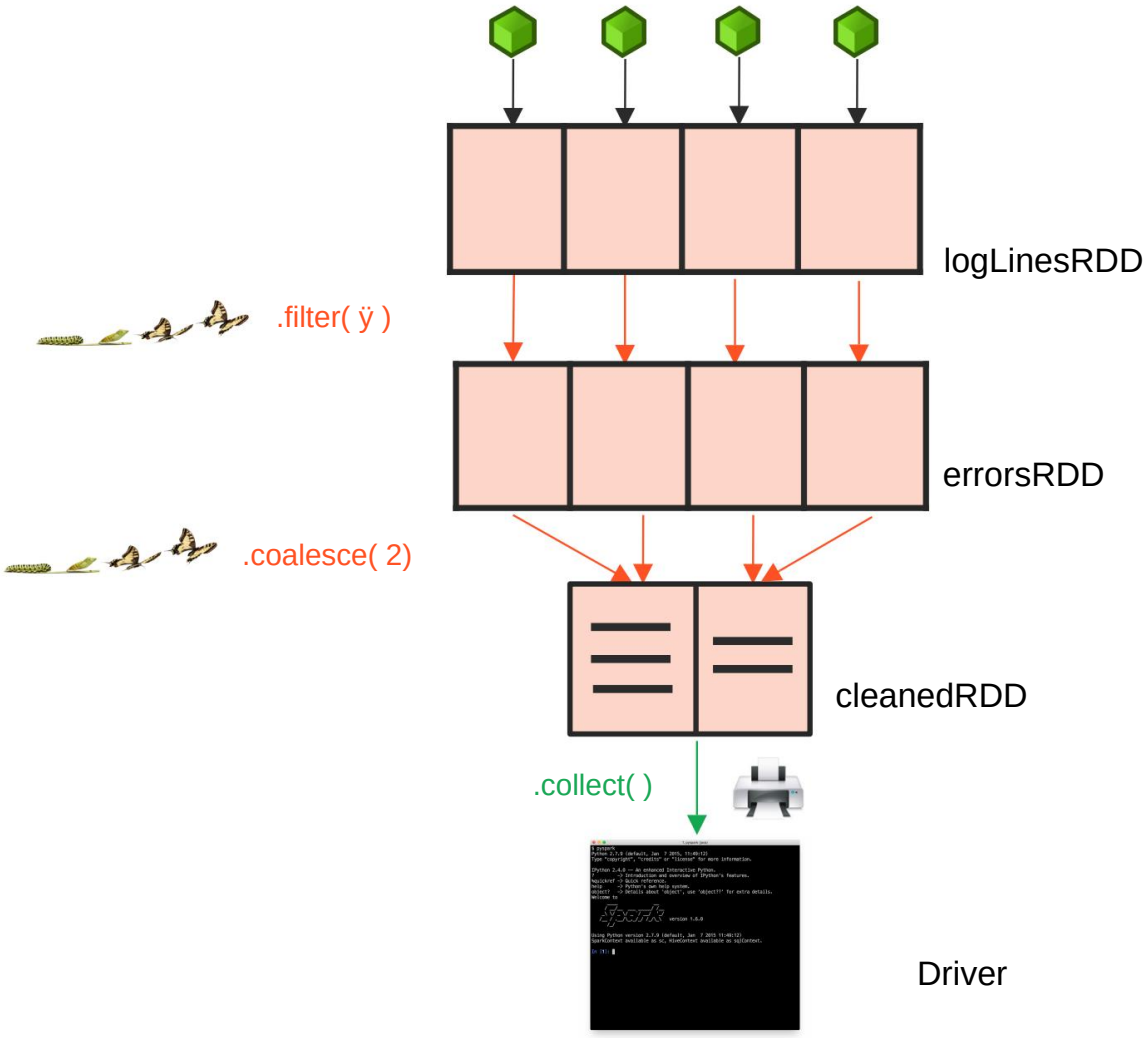


DAG execution

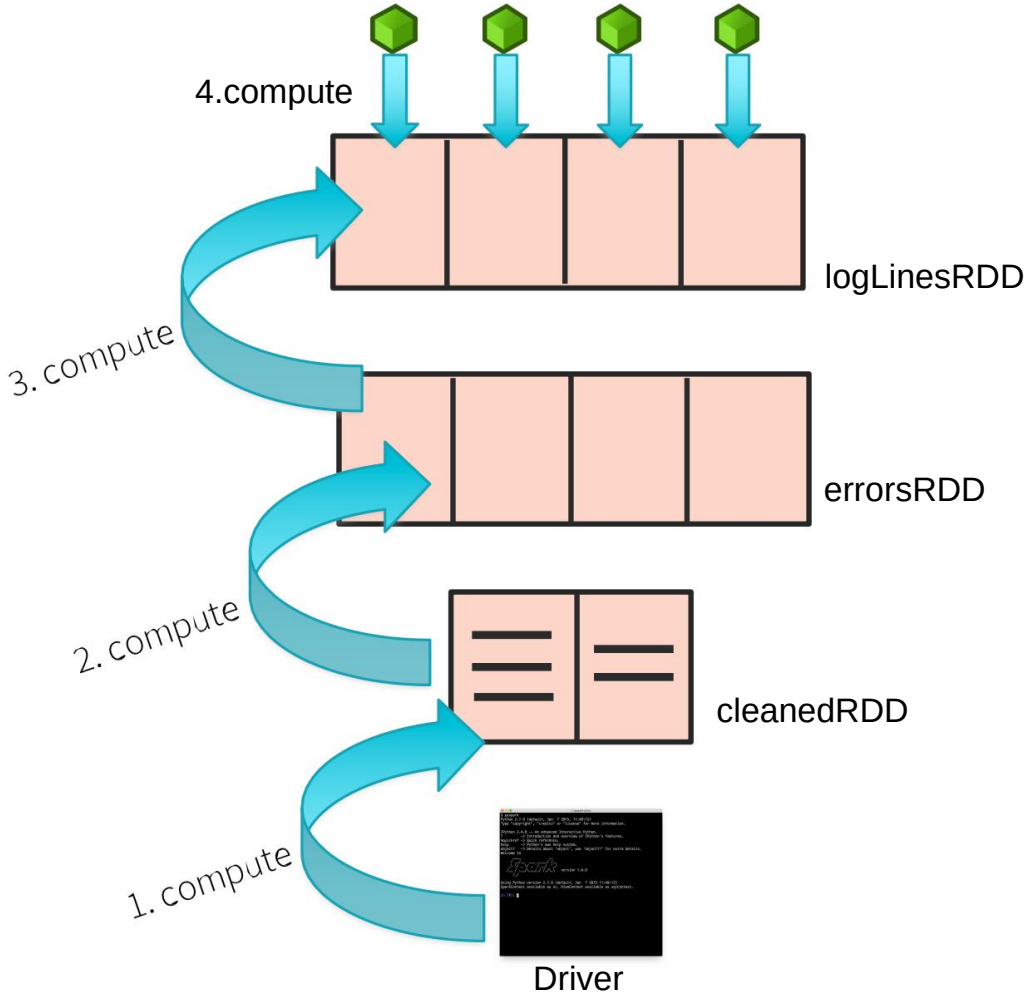


Driver

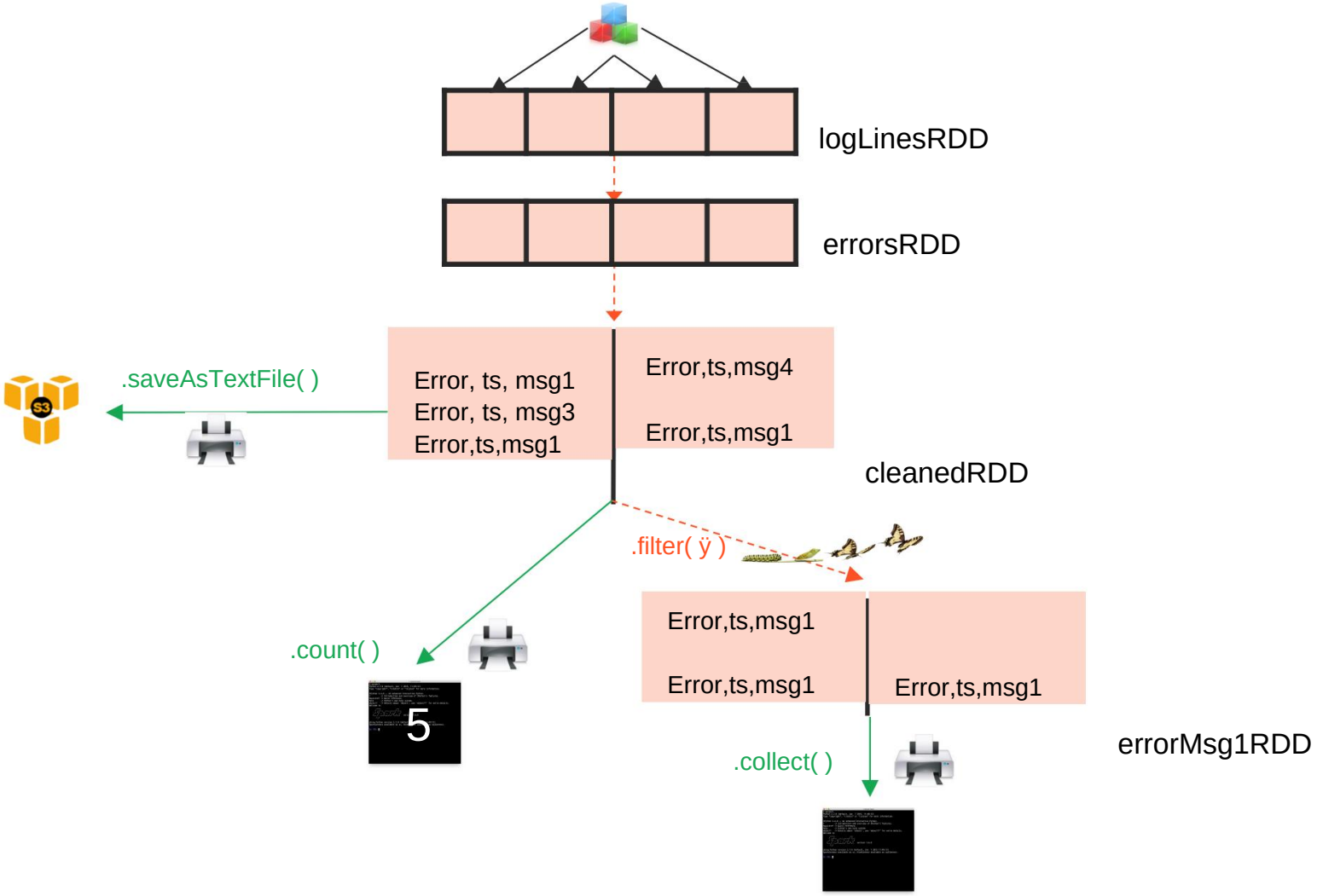
Logical



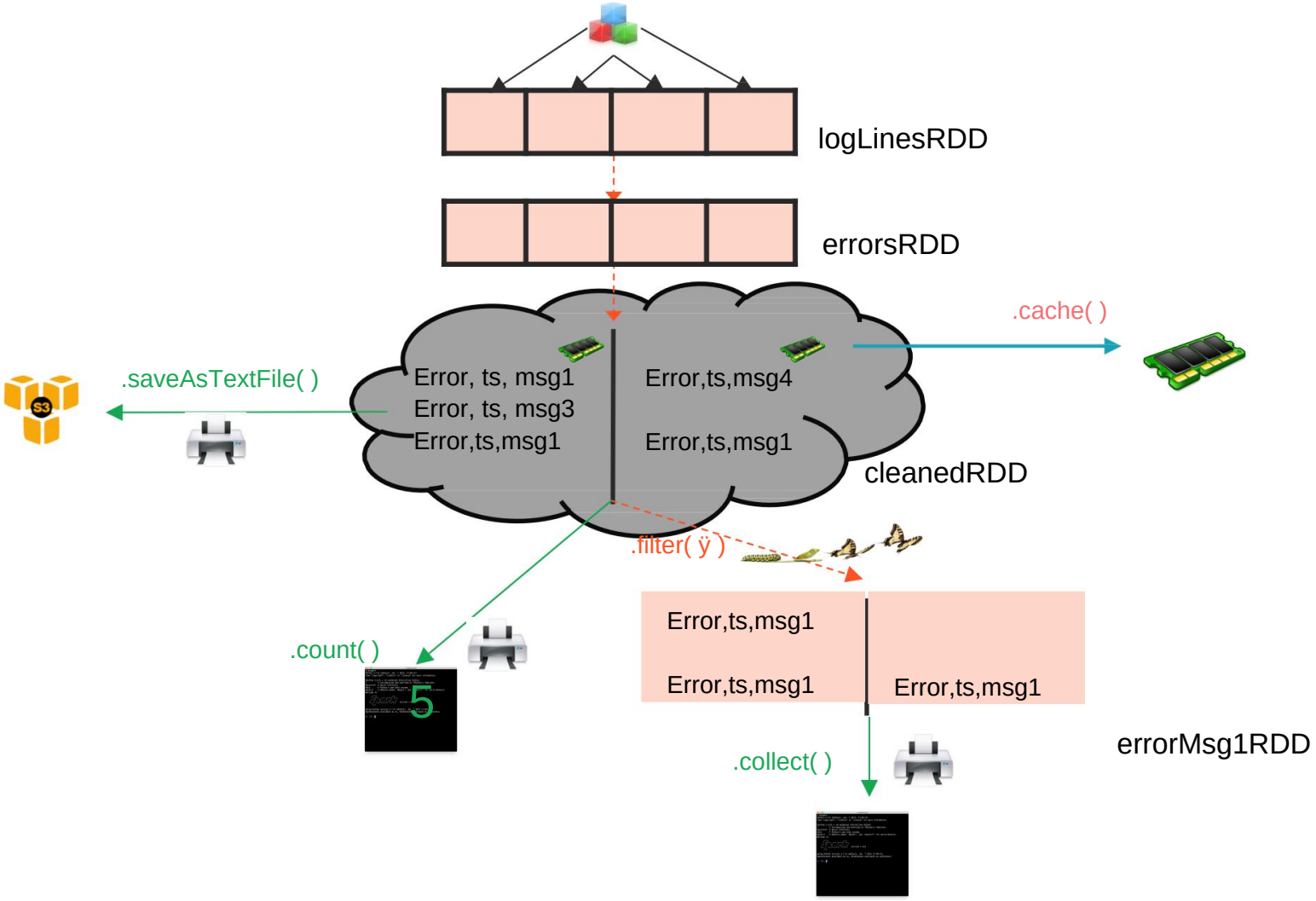
Physical



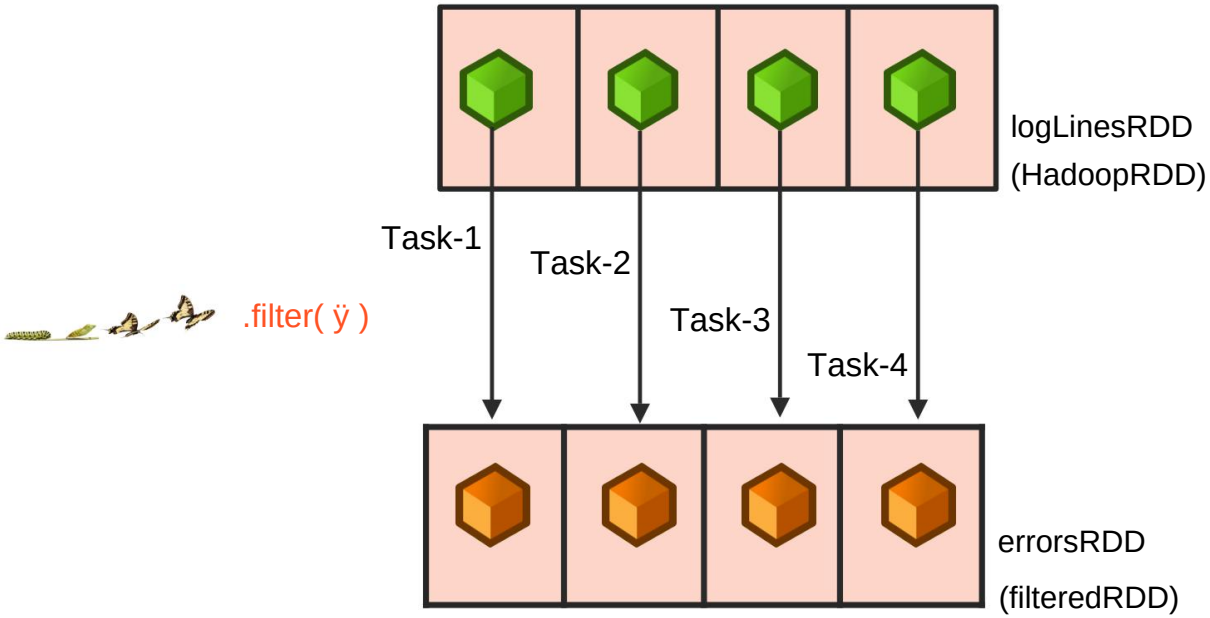
DAG



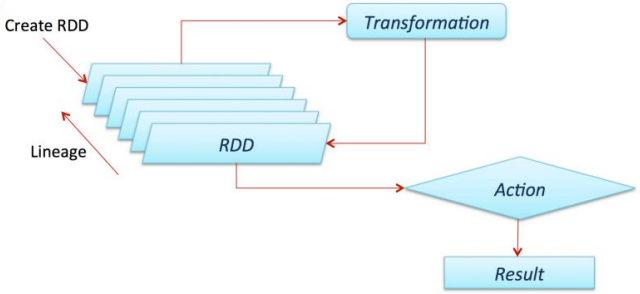
Cache

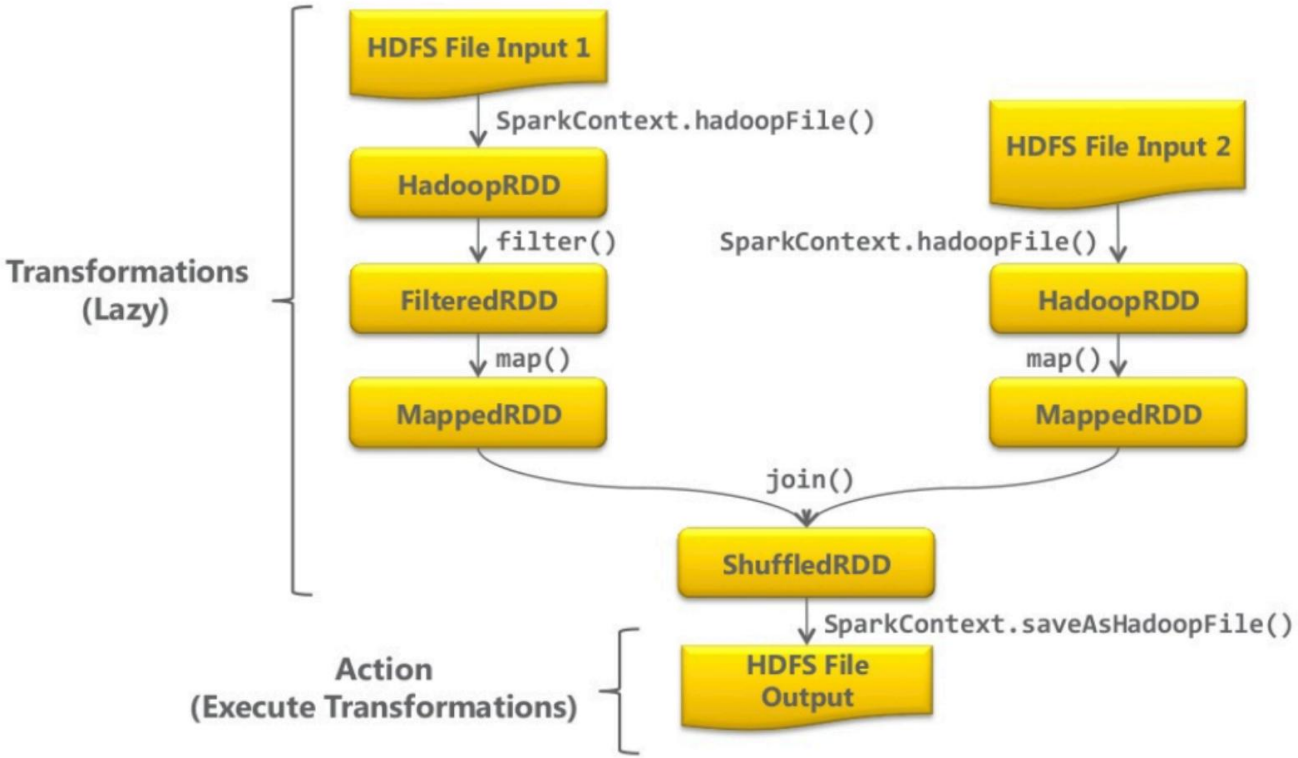


Partition >>> Task >>> Partition



RDD Lineage





Resilient Distributed Dataset (RDD)

• Initial RDD on **disks** (HDFS, etc) • Intermediate RDD on **RAM**

• Fault recovery is based on **lineage** • RDD operations are distributed

DataFrame

- A primary abstraction in Spark 2.0
  - Immutable once constructed • Track lineage information to efficiently re-compute lost data • Enable operations on collection of elements in parallel
- To construct DataFrame
  - By parallelizing existing Python collections (lists) • By transforming an existing Spark or pandas DataFrame • From files in HDFS or other storage system

Using DataFrame

```
>>> data = [('Alice', 1), ('Bob', 2), ('Bob', 2)]
>>> df1 = sqlContext.createDataFrame(data, ['name', 'age'])
[Row(name=u'Alice', age=1),
Row=(name=u'Bob', age=2),
Row=(name=u'Bob', age=2)]
```

Transformations

- Create new DataFrame from an existing one
- Use lazy evaluation
  - Nothing executes
  - Spark saves recipe for transformation source

Transformation	Description
select(*cols)	Selects columns from this DataFrame
drop(col)	Returns a new Dataframe that drops the specific column
filter(func)	Returns a new DataFrame formed by selecting those rows of the source on which *func* returns true
where(func)	Where is an alias for filter
distinct()	Returns a new DataFrame that contains the distinct rows of the source DataFrame
*sort(*cols, **kw)*	Returns a new DataFrame sorted by the specified columns and in the sort order specified by *kw*

Using Transformations

```
>>> data = [('Alice', 1), ('Bob', 2), ('Bob', 2)]
>>> df1 = sqlContext.createDataFrame(data, ['name', 'age'])
>>> df2 = df1.distinct()
[Row(name=u'Alice', age=1), Row=(name=u'Bob', age=2)]
>>> df3 = df2.sort("age", asceding=False)
[Row=(name=u'Bob', age=2), Row(name=u'Alice', age=1)]
```

Actions

- Cause Spark to execute recipe to transform source
- Mechanisms for getting results out of Spark

Action	Description
show(n, *truncate)*	Prints the first n rows of this DataFrame
take(n)	Returns the first n rows as a list of Row
collect()	Returns all the records as a list of Row (*)
count()	Returns the number of rows in this DataFrame
describe(*cols)	Exploratory Data Analysis function that computes statistics (count, mean, stddev, min, max) for numeric columns

Using Actions

```
>>> data = [('Alice', 1), ('Bob', 2)]
>>> df = sqlContext.createDataFrame(data, ['name', 'age'])
>>> df.collect()
[Row(name=u'Alice', age=1), Row=(name=u'Bob', age=2)]
>>> df.count()
2
>>> df.show()
+------+--------+

|name| age |
+-------+-------+

|Alice|          1|
|Bob |          2|
+-----+-------+
```

Caching

```
>>> linesDF = sqlContext.read.text('…')
>>> linesDF.cache()
>>> commentsDF = linesDF.filter(isComment)
>>> print linesDF.count(), commentsDF.count()
> >> commentsDF.cache()
```

Spark Programming Routine

- Create DataFrames from external data or createDataFrame from a collection in driver program
- Lazily transform them into new DataFrames
- cache() some DataFrames for reuse
- Perform actions to execute parallel computation and produce results

DataFrames versus RDDs

- For new users familiar with data frames in other programming languages, this API should make them feel at home
- For existing Spark users, the API will make Spark easier to program than using RDDs
- For both sets of users, DataFrames will improve performance through intelligent optimizations and code-generation

Write Less Code: Input & Output

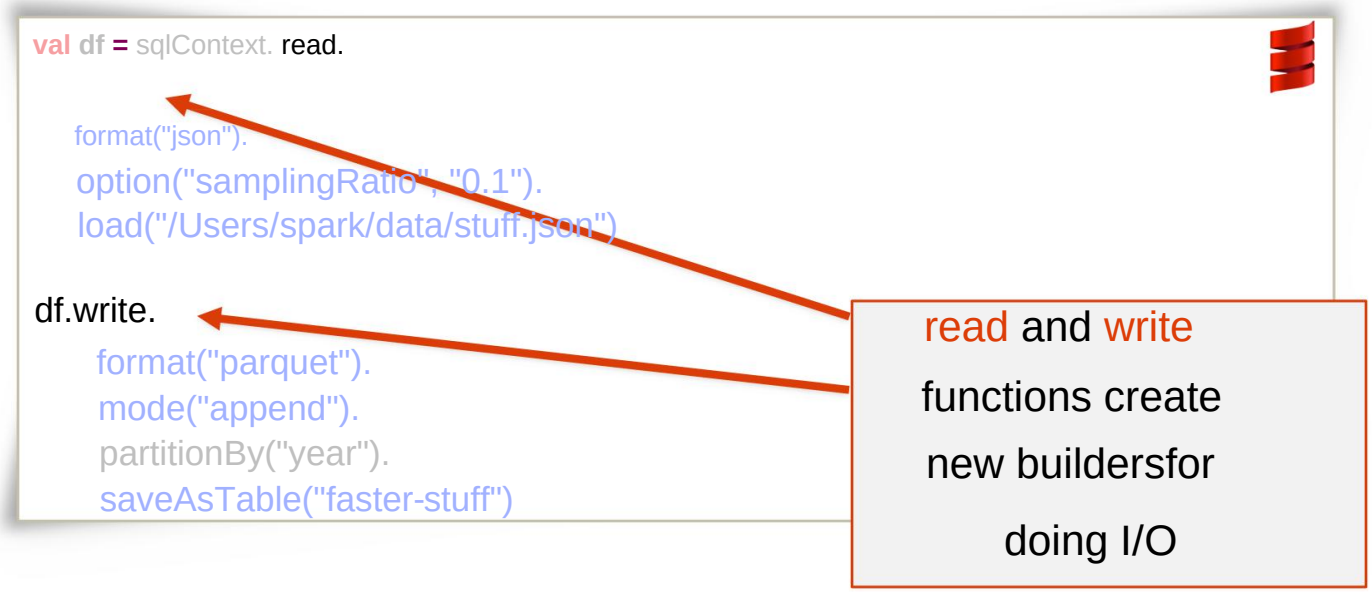
Unified interface to reading/writing data ina variety of formats.

```
val df = sqlContext.
    read.
    format("json").
    option("samplingRatio", "0.1").
    load("/Users/spark/data/stuff.json")

df.write.
     format("parquet").
     mode("append").
     partitionBy("year").
     saveAsTable("faster-stuff")
```

Write Less Code: Input & Output

Unified interface to reading/writing data ina variety of formats.



Write Less Code: Input & Output

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```
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    load("/Users/spark/data/stuff.json")

df.write.
    mode("append").
    format("parquet").
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    saveAsTable("faster-stuff")
```
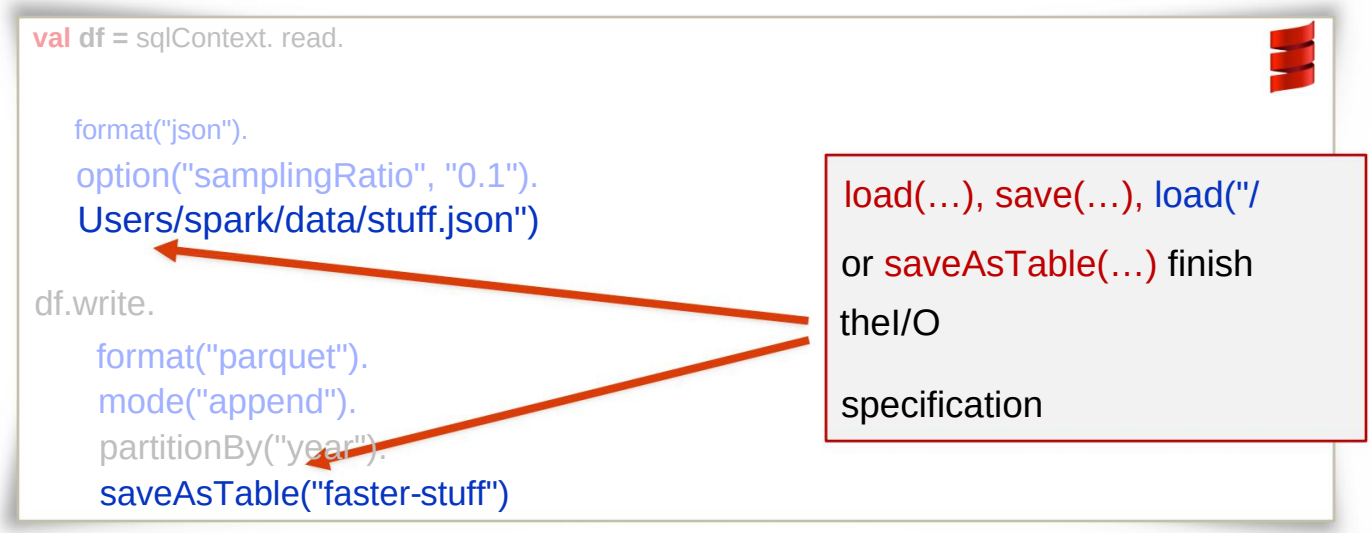

Builder methods specify:

- partitioning
- handling of existing data

Write Less Code: Input & Output

Unified interface to reading/writing data ina variety of formats.



Data Sources supported by DataFrames

built-in

external

and more…

Write Less Code: High-Level Operations

- Solve common problems concisely with DataFrame functions:
  - selecting columns and filtering
  - joining different data sources
  - aggregation (count, sum, average, etc.)
  - plotting results (eg, with Pandas)

Write Less Code: Compute an Average

```
private IntWritable one = new IntWritable(1); private IntWritable
output =new IntWritable(); protected void map(LongWritable
key,
                                Text value,
                                Context context) {
        String[] fields = value.split("\t");
        output.set(Integer.parseInt(fields[1])); context.write(one,
        output);
}

-------------------------


IntWritable one = new IntWritable(1)
DoubleWritable average = new DoubleWritable();

protected void reduce(IntWritable key,
                                Iterable<IntWritable> values,
                                Context context) {
        int sum = 0; int
        count = 0; for
        (IntWritable value: values) { sum +=
                value.get(); count++;


        } average.set(sum / (double) count);
        context.write(key, average);
}
```

```
rdd = sc.textFile(...).map(_.split(" ")) rdd.map { x => (x(0),
(x(1).toFloat, 1)) }. reduceByKey { case ((num1, count1),
        (num2, count2)) =>
            (num1 + num2, count1 + count2)
        }.
        map { case (key, (num, count)) => (key, num / count) }. collect()
```

```
rdd = sc.textFile(...).map(lambda s: s.split()) rdd.map(lambda x:
(x[0], (float(x[1]), 1))).\ reduceByKey(lambda t1, t2: (t1[0] + t2[0],
        t1[1] + t2[1])).\ map(lambda t: (t[0], t[1][0] / t[1][1])).\ collect()
```

Write Less Code: Compute safely Average

UsingRDDs

```
rdd = sc.textFile(...).map(_.split(" ")) rdd.map { x =>
(x(0), (x(1).toFloat, 1)) }. reduceByKey { case ((num1,
      count1), (num2, count2)) =>
          (num1 + num2, count1 + count2) }.

      map { case (key, (num, count)) => (key, num / count) }. collect()
```

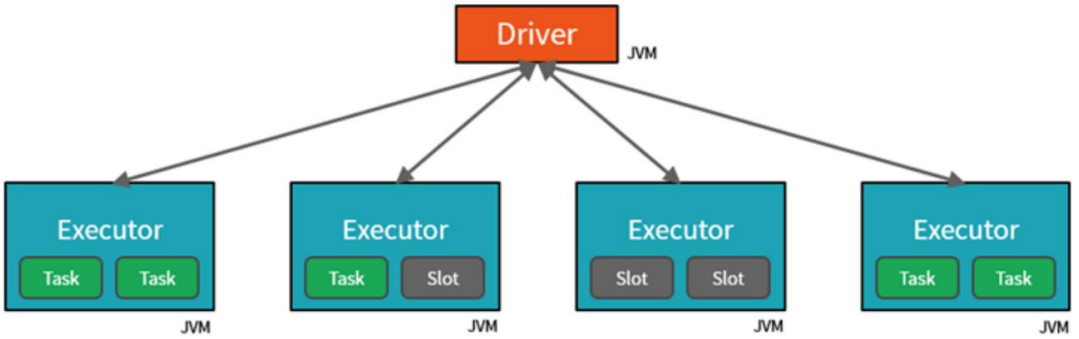
Full APIDocs • Scala • Java • Python • R

Using DataFrames

```
import org.apache.spark.sql.functions._

val df = rdd.map(a => (a(0), a(1))).toDF("key", "value") df.groupBy("key")

    .agg(avg("value")) .collect()
```

Architecture

- A master-worker type architecture
  - A driver or master node
  - Worker nodes



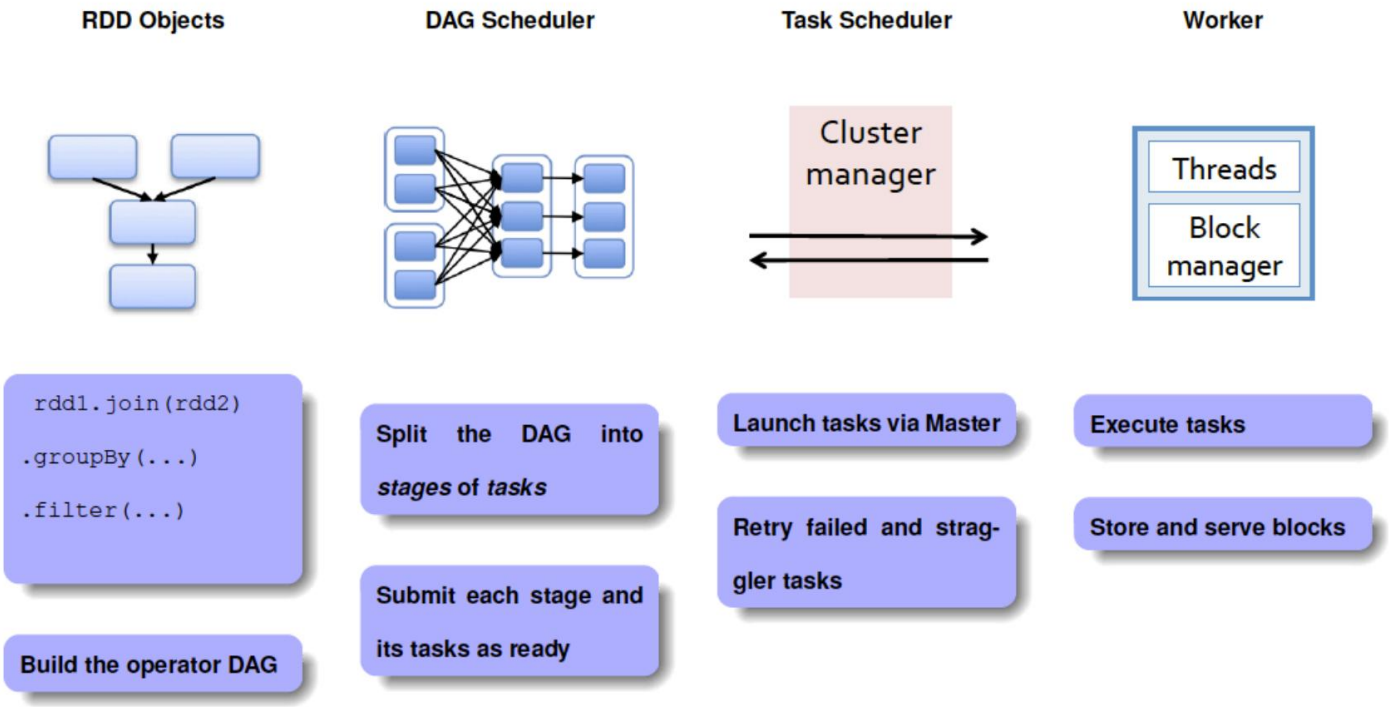
- The master sends works to the workers and either instructs them to pull data from memory or from hard disk (or from another source like S3 or HDSF)

Architecture(2)

- A Spark program first creates a SparkContext object
  - SparkContext tells Spark how and where to access a cluster
  - The master parameter for a SparkContext determines which type and size of cluster to use

Master parameter	Description
local	Run Spark locally with one worker thread (no parallelism)
local[K]	Run Spark locally with K worker threads (ideal set to number of cores)
spark://HOST:PORT	Connect to a Spark standalone cluster
mesos://HOST:PORT	Connect to a Mesos cluster
yarn	Connect to a YARN cluster

Lifetime of a Job in Spark



Demo

References

- Zaharia, Matei, et al. "Resilient distributed datasets: A fault-tolerant abstraction for in-memory cluster computing." *Presented as part of the 9th {USENIX} Symposium on Networked Systems Design and Implementation ({NSDI} 12).* 2012.
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- Zaharia, Matei, et al. "Discretized streams: Fault-tolerant streaming computation at scale." *Proceedings of the twenty-fourth ACM symposium on operating systems principles.* 2013.
- Chambers, Bill, and Matei Zaharia. *Spark: The definitive guide: Big data processing made simple.* "O'Reilly Media, Inc.", 2018.

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