Spark I

Big Data Management

Knowledge objectives

1. Name the main Spark contributions and characteristics
2. Compare MapReduce and Spark
3. Define a dataframe
4. Distinguish dataframe from relation and matrix
5. Distinguish Spark and Pandas dataframe
6. Enumerate some abstraction on top of Spark

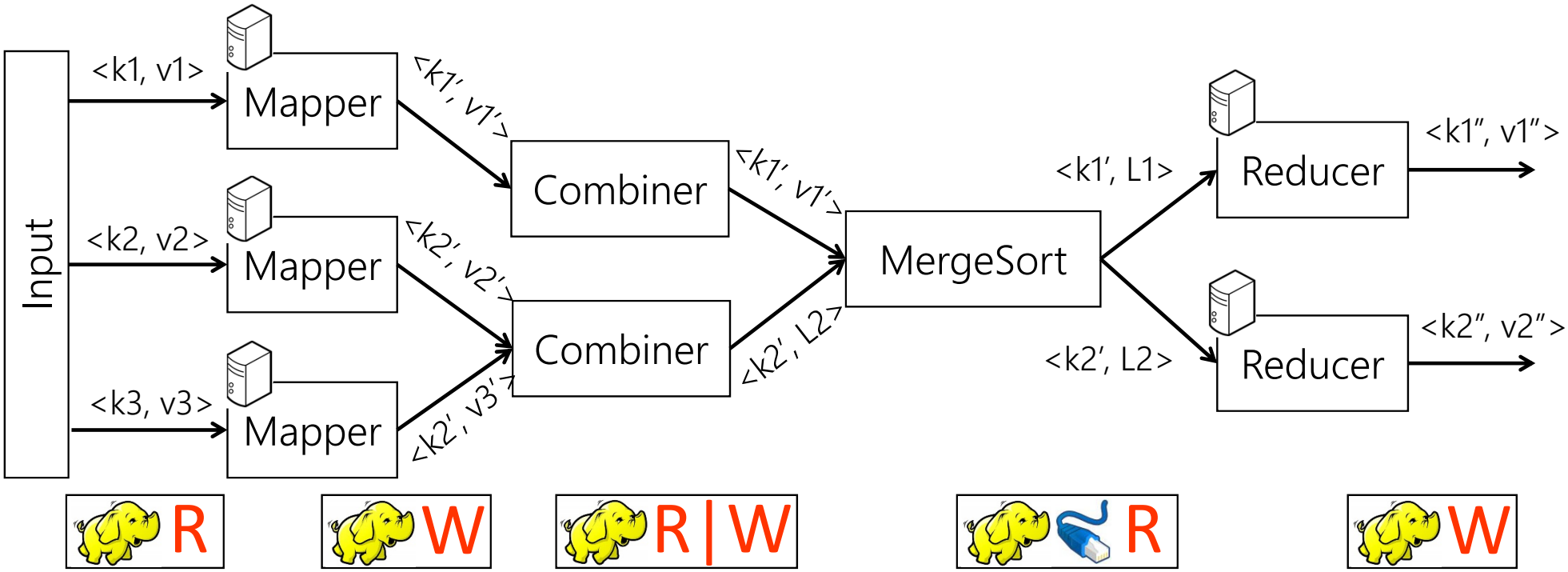
Application Objectives

- Provide the Spark pseudo-code for a simple problem using dataframes

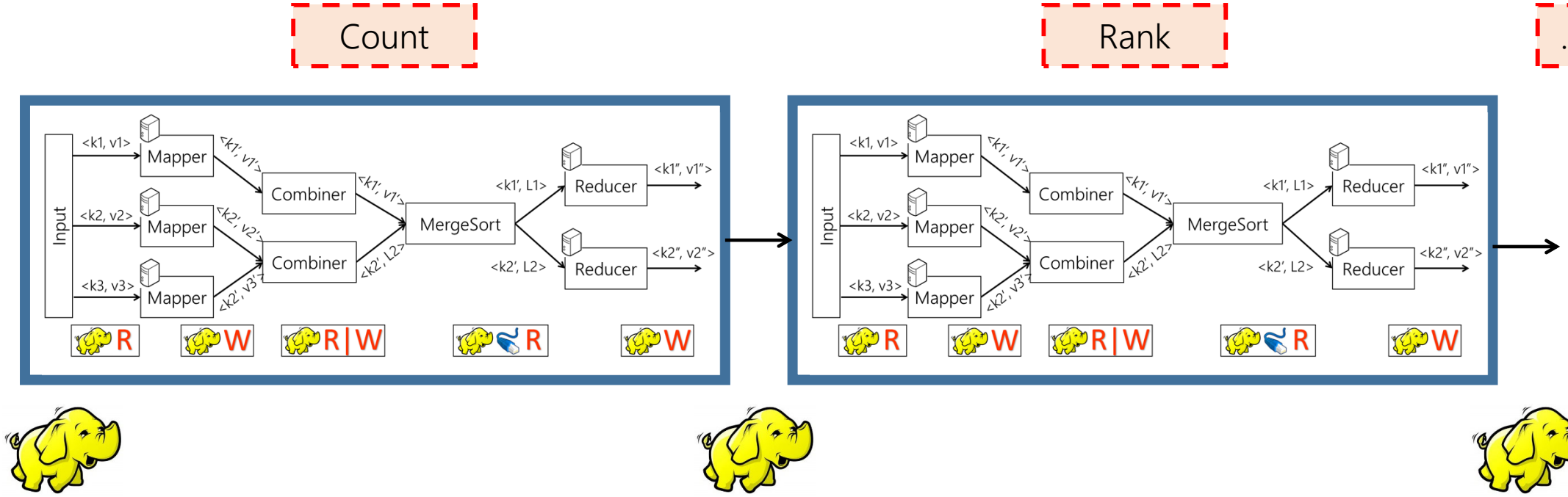
Background

MapReduce limitations

MapReduce intra-job coordination

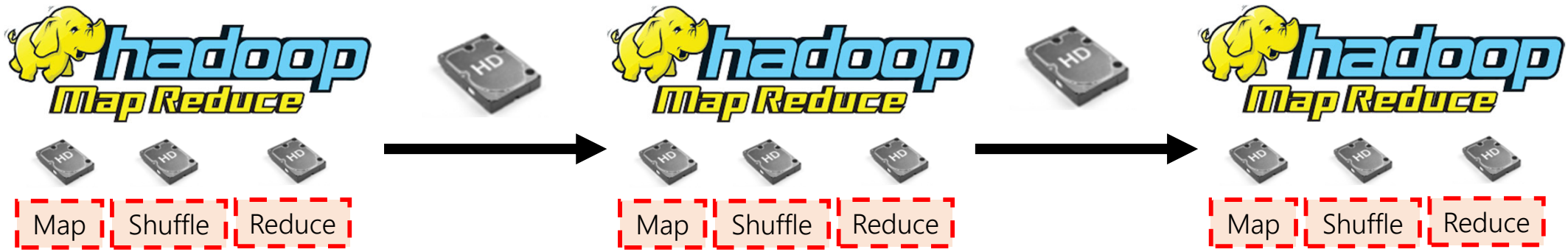


MapReduce inter-job coordination

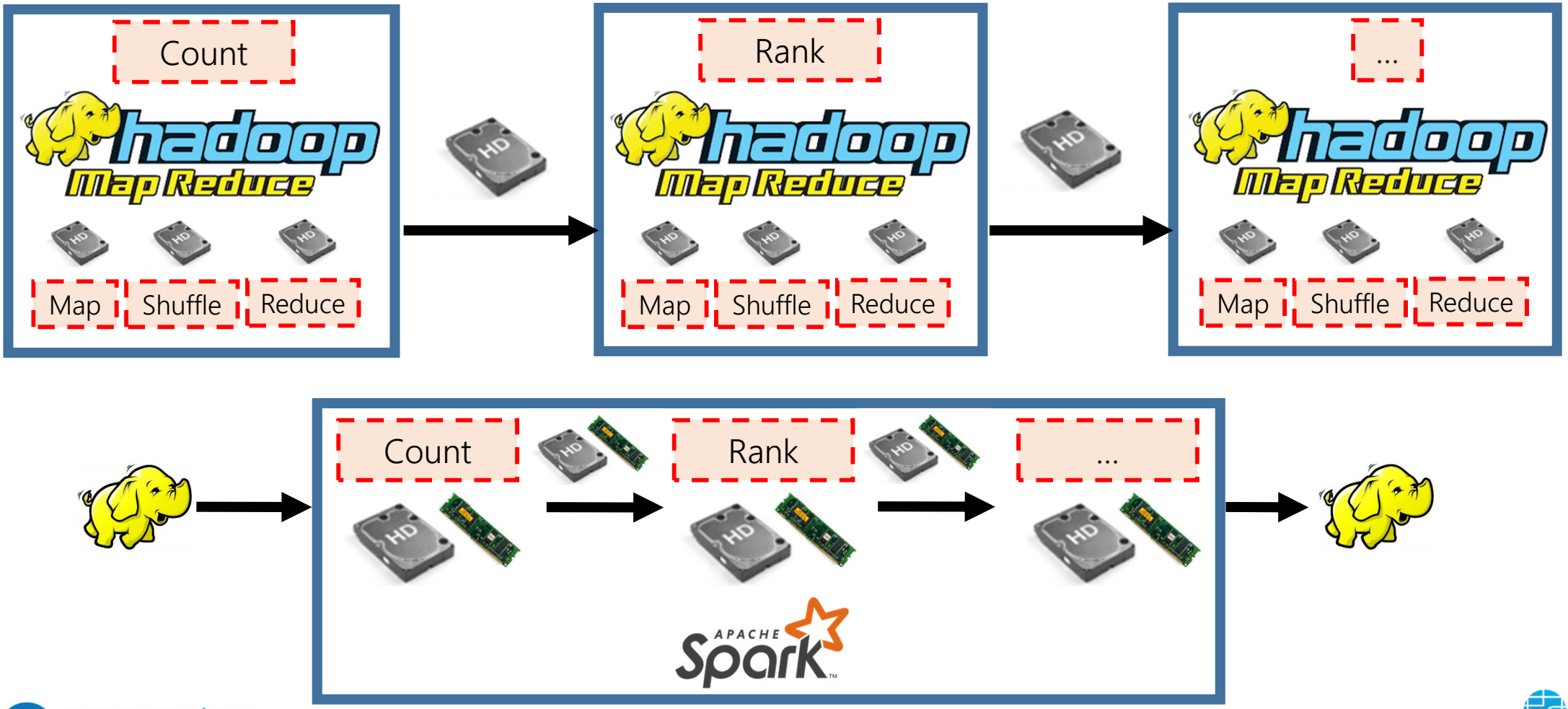


MapReduce limitations

- Coordination between phases using DFS
  - Map, Shuffle, Reduce
- Coordination between jobs using DFS
  - Count, rank, aggregate, …



Main memory coordination in Spark



Dataframes

Problems of relational tables in data exploration

- Schema needs to be defined before examining the data
- Not well-structured data is difficult to query
- Generating queries requires familiarity with the schema
- Complex declarative queries are hard to debug
  - SQL was not conceived for REPL (Read, Evaluate, Print Loop)

Characteristics of dataframes

- First introduced to S in 1990
- Symmetrical treatment of rows and columns
  - Both can be referenced explicitly
    - By position (data is ordered row- and column-wise)
    - By name
- Data has to adhere to a schema
  - Defined at runtime
    - Useful for data cleaning
- A variety of operations
  - Relational-like (e.g., filter, join)
  - Spreadsheet-like (e.g., pivot)
  - Linear algebra (e.g., multiply)
- Incrementally composable query syntax
- Native embedding in an imperative language

Relation, Dataframe and Matrix

Relation

R

T_1	...	T_n
A_1	...	A_n

Original dataframe

	T_1	T_2	...	T_n
	$1/A_1$	$2/A_2$	...	n/A_n
$1/r_1$	x	"x"	...	T
$2/r_2$	y	"y"	...	F
...	...	...		...
m/r_m	z	None	...	T

Spark dataframe

T_1	T_2	...	T_n
$1/A_1$	$2/A_2$	...	n/A_n
x	"x"	...	T
y	"y"	...	F
...	...		...
z	None	...	T

Matrix

Numeric

	1	2	...	n
1	a_{11}	a_{12}	...	a_{1n}
2	a_{21}	a_{22}	...	a_{2n}
...	...	...		...
m	a_{m1}	a_{m2}	...	a_{mn}

Spark Dataframe definition

"A Dataset is a strongly typed collection of domain-specific objects that can be transformed in parallel using functional or relational operations."

"A Dataframe is an immutable collection of data organized into named columns, potentially distributed in the nodes of a cluster. It is implemented as an indexed Dataset of Rows."

- Resembles a Relational table
- Row class does not fix a schema at compile time, but at execution time
  - Uses StructType
  - Allows to infer schemas from the file (e.g., CSV or JSON)
- Can be partitioned and distributed
  - Implemented on top of Resilient Distributed Datasets (RDD)

https://spark.apache.org/docs/latest/api/java/org/apache/spark/sql/Dataset.html
https://spark.apache.org/docs/latest/api/java/org/apache/spark/sql/Row.html
https://spark.apache.org/docs/latest/api/java/org/apache/spark/sql/types/StructType.html

Dataframe vs Matrix/Array/Tensor

Dataframe	Matrix
Heterogeneously typed	Homogeneously typed
Both numeric and non-numeric types	Only numeric types
Explicit column names (also row in Pandas)	No names at all
Supports relational algebra	Does not support relational algebra

D. Petersohn, et al. *Towards Scalable Dataframe Systems. Proc. VLDB Endow. 13(11), 2020*

Dataframe vs Relation/Table

Pandas Dataframe	Spark Dataframe	Relation
Ordered	Unordered	
Named rows	Unnamed rows	
Lazily-induced schema		Rigid schema
Column-row symmetry	Columns and rows are different	
Supports linear algebra	Does not support linear algebra	

D. Petersohn, et al. *Towards Scalable Dataframe Systems. Proc. VLDB Endow. 13(11), 2020*

Dataframe implementations

Pandas	Spark
Eager evaluation of transformations	Lazy evaluation of transformations
Resides in memory	Requires a SparkSession
Not scalable (multithread operators exist, but manual split is required)	Transparently scalable in the Cloud
Transposable	Non-transposable (problems with too many rows)

D. Petersohn, et al. *Towards Scalable Dataframe Systems. Proc. VLDB Endow. 13(11), 2020*

Spark dataframe operations

a) Input/Output
b) Transformations
   - Lower abstraction: O-O interface (similar to RDDs)
     - Functions over columns
   - Higher abstraction: SQL
c) Actions
d) Schema management

Input/Output

- Matrix
- Pandas dataframe
- CSV
- JSON
- RDBMS
- HDFS file formats:
  - ORC
  - Parquet

Transformations available

- select
- filter/where
- sample
- distinct/dropDuplicates
- sort
- replace
- groupBy+agg
- union/unionAll/unionByName
- subtract
- join
- …

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/dataframe.html

Functions over columns

- Normal (*lit*, *isNull*, ...)
- Math (*sqrt*, *sin*, *ceil*, *log*, ...)
- Daytime (*current_date*, *dayofweek*, ...)
- Collection (*array_sort*, *forall*, *zip_with*, ...)
- Aggregate (*avg*, *count*, *first*, *corr*, *max*, *min*, ...)
- Sort (*asc*, *desc*, *asc_nulls_first*, ...)
- String (*length*, *lower*, *trim*, ...)

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/functions.html

Actions available

- count
- first
- collect ☠
- take/head/tail
- show
- write
- toPandas ☠
- …

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/dataframe.html

Schema operations

- summary/describe
- printSchema
- columns

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/dataframe.html

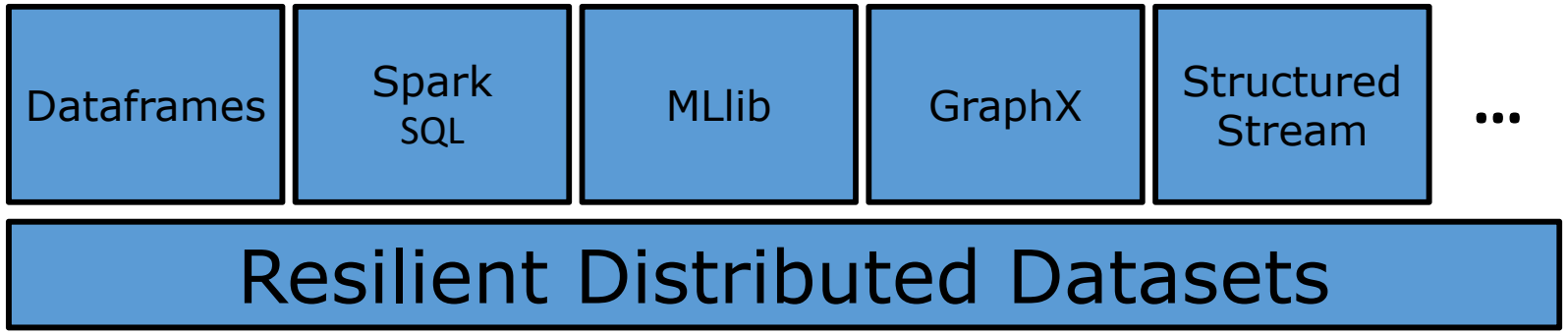
Optimizations

- Lazy evaluation
  - cache/persist
    - unpersist
  - checkpoint
- Parallelism
  - repartition/coalesce

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/dataframe.html

Abstractions

Spark Abstractions



Spark SQL

- Besides the O-O interface of dataframes, there is a declarative one
- It can be used independently of the kind of source
  - Not only Relational tables
- It is translated into functional programming by an optimizer
  - Based on
    a) Rules
       - Predicate push down
       - Column pruning
    b) Cost model
  - Extensible

https://spark.apache.org/sql

Spark SQL interface

- There is a catalog with all tables available

  SparkSession.catalog

- Dataframes are registered as views in the catalog

  DataFrame.createOrReplaceTempView(<tablename>)

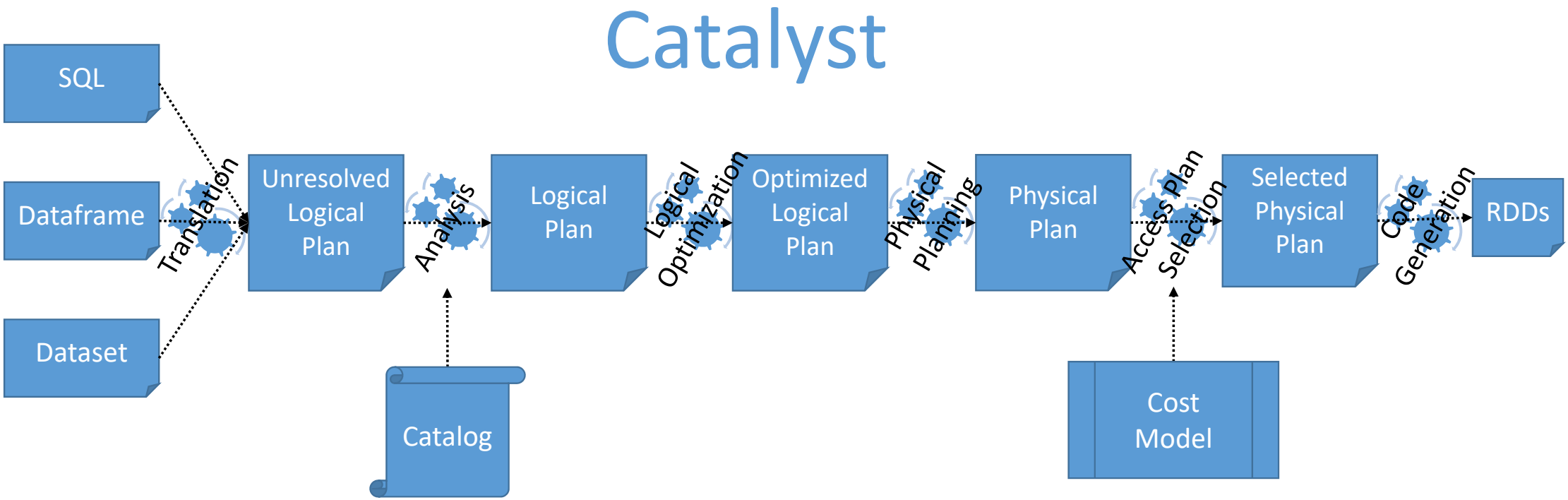
- Queries:

  SparkSession.sql(<query>)

  - Input is simply a string
  - Output is a dataframe

https://spark.apache.org/docs/latest/api/python/reference/pyspark.sql/catalog.html

Shared Optimization and Execution



Closing

Summary

- Overcoming MapReduce limitations
- Dataframes
  - Comparison
    - Differences with Relations
    - Differences with Matrixes
    - Differences in Pandas and Spark
  - Operations
    - Transformations
    - Actions
  - Optimizations
    - Lazy evaluation
    - Parallelism
- Abstraction

References

- H. Karau et al. *Learning Spark*. O'Really, 2015
- D. Petersohn, W. W. Ma, D. Jung Lin Lee, S. Macke, D. Xin, X. Mo, J. Gonzalez, J. M. Hellerstein, A. D. Joseph, A. G. Parameswaran. *Towards Scalable Dataframe Systems. Proc. VLDB Endow. 13(11), 2020*
- A. Hogan. *Procesado de Datos Masivos* (Universidad de Chile). http://aidanhogan.com/teaching/cc5212-1-2020