Spark for Scientific Computing

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What is Spark?

- A distributed computing framework

Problem 1: Storage

- Big data
- Commodity hardware (Cloud)

Solution: Distributed File System

- redundant
- fault tolerant

Problem 2: Computation

- Slow to move data across network
- Computations fail

Solution: Hadoop Mapreduce / Spark

- Execute computation where data are located
- Rerun failed jobs

Problem 3: Communication

- Most of the times, need to summarize data to get a result
- Reduction phase in MapReduce
- Need data transfer across network

Solution: highly optimized Shuffle (All-to-All)

Spark and Hadoop

- Works within the Hadoop ecosystem
- Extends MapReduce
- Initially developed at UC Berkeley
- Now within the Apache Foundation
- ~400 and more developers

Key features of Spark

- **Resiliency**: tolerant to node failures
- **Speed**: supports in-memory caching
- **Ease of use**:
  - Python/Scala interfaces
  - interactive shells
  - many distributed primitives

	Hadoop MR Record	**Spark Record**	**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 physical	6592 virtualized	6080 virtualized
Cluster disk throughput	3150 GB/s (est.)	618 GB/s	570 GB/s
Sort Benchmark Daytona Rules	Yes	Yes	No
Network	dedicated data center, 10Gbps	virtualized (EC2) 10Gbps network	virtualized (EC2) 10Gbps network
Sort rate	**1.42 TB/min**	**4.27 TB/min**	**4.27 TB/min**
Sort rate/node	**0.67 GB/min**	**20.7 GB/min**	**22.5 GB/min**

Spark 100TB benchmark

HPC: Distributed TBs of data

- Fault-tolerant batch processing
- Data exploration with an interactive console
- SQL operations with Spark-SQL
- Iterative Machine Learning algorithms with Spark-MLlib

Comparison with MPI

- MPI: describe computation and communication explicitly
- Spark: use a graph of high-level operators, the framework decides how and where to run tasks

Clone Github repository

- ssh to Comet
- module load python scipy spark
- git clone https://github.com/sdsc-scicomp/2015-12-03-uci workshop
- cd workshop/

Interactive spark on Comet

$ cd ~/workshop/spark

submit a spark job with:

$ sbatch spark.cmd

check job status with

$ squeue -u $USER

Connect to Spark

```
source slurm-env.sh
ssh $SLURMD_NODENAME

cd workshop/spark
source slurm-env.sh
```

Launch notebook

bash launch_spark_notebook.sh

House prices

see house_price.ipynb

Resilient Distributed Dataset

Dataset

Data storage created from: HDFS, S3, HBase, JSON, text, Local hierarchy of folders

Or created transforming another RDD

Resilient Distributed Dataset

Distributed

Distributed across the cluster of machines

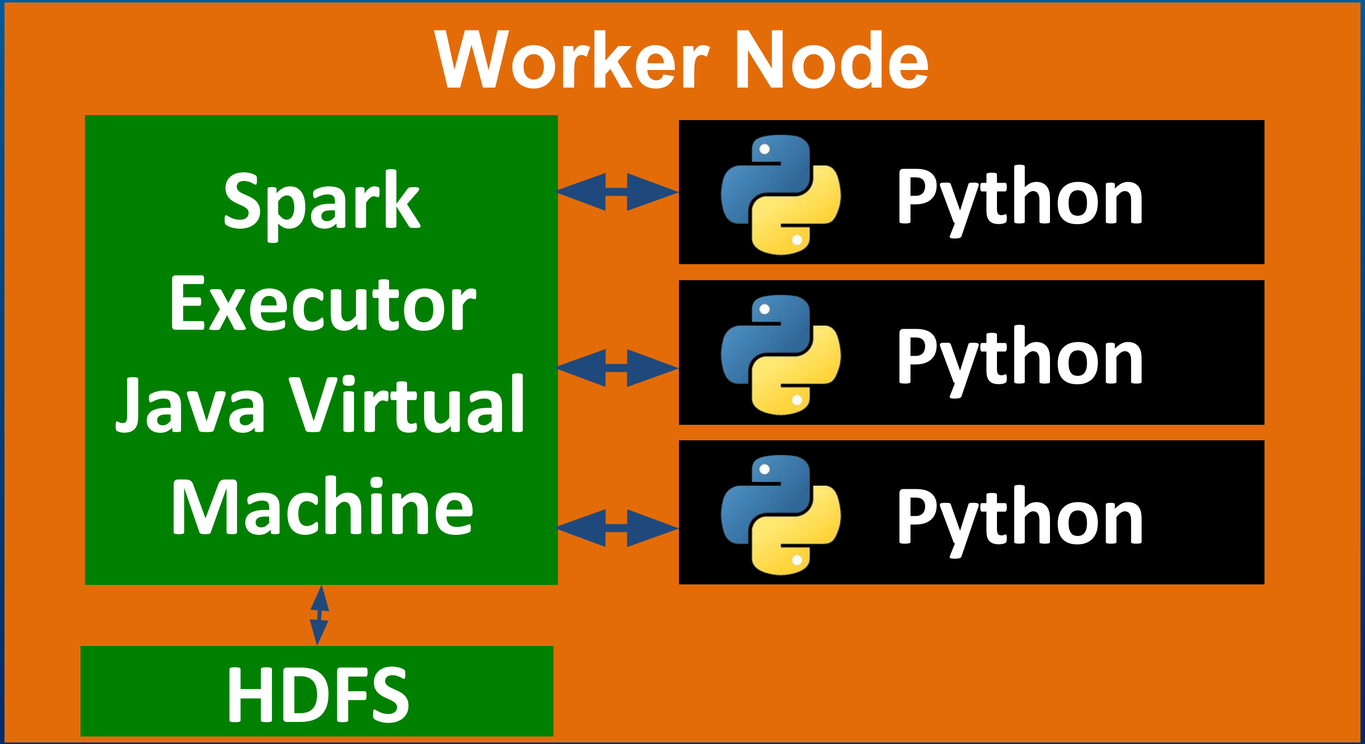
Divided in partitions, atomic chunks of data

Resilient Distributed Dataset

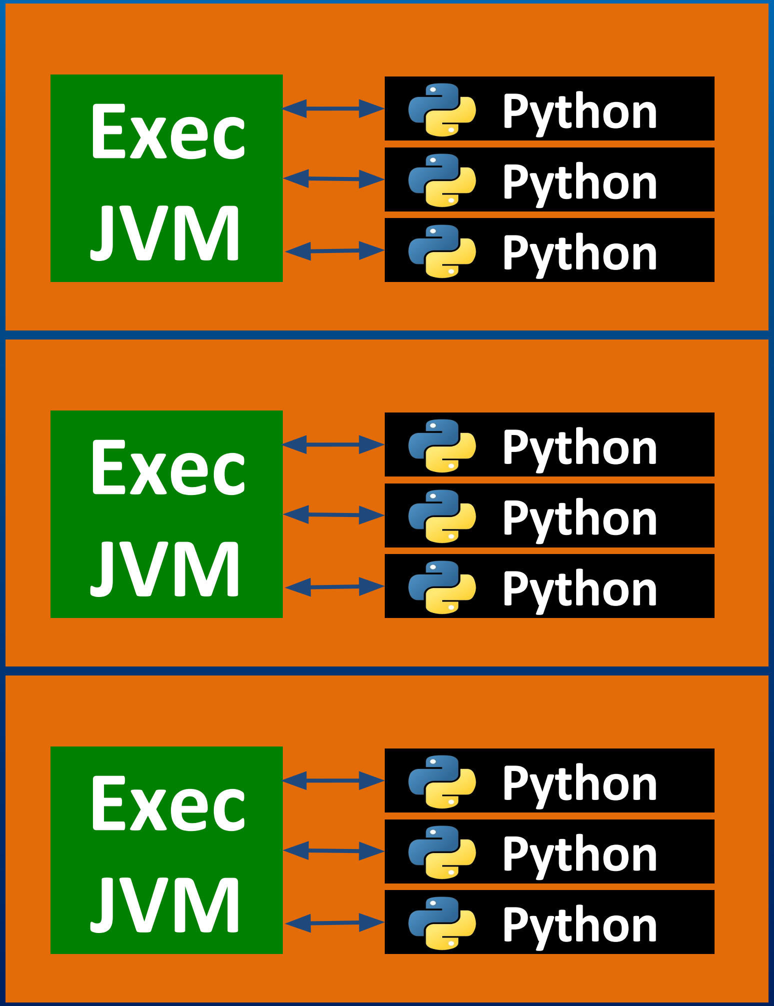
Resilient

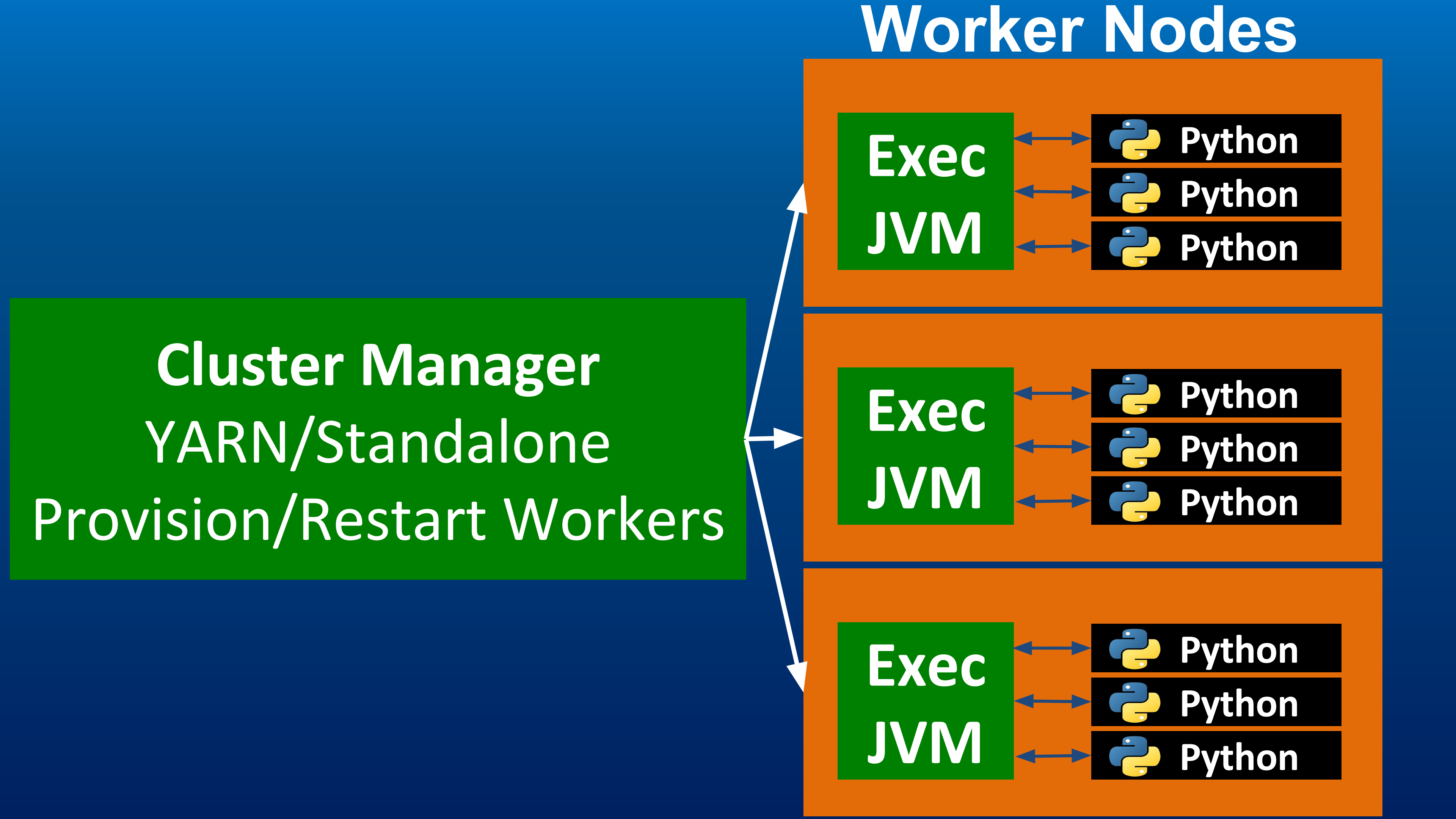
Recover from errors, e.g. node failure, slow processes

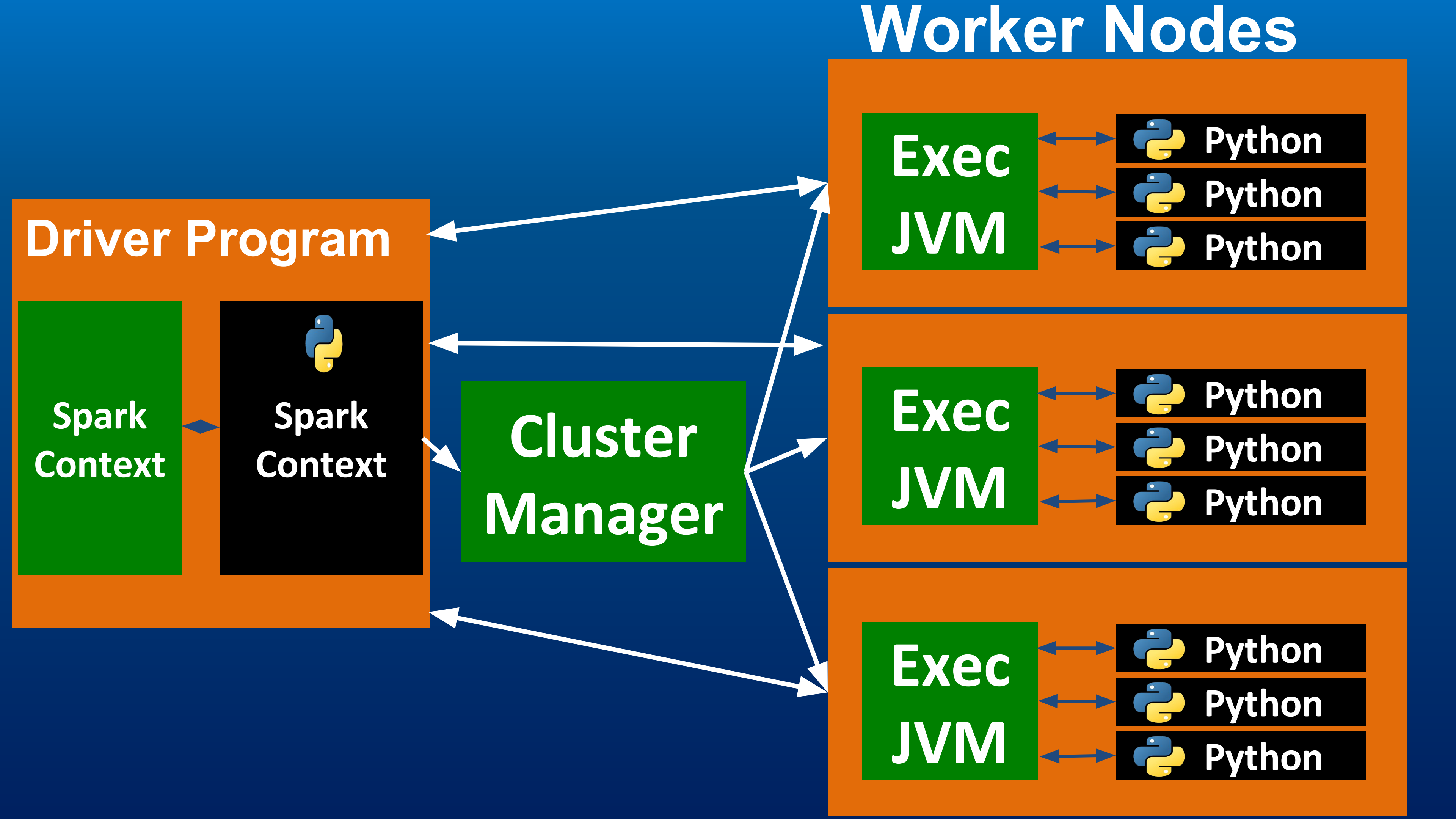
Track history of each partition, re-run


Worker Node
Spark
Executor
Java Virtual
Machine
Python
Python
Python
HDFS

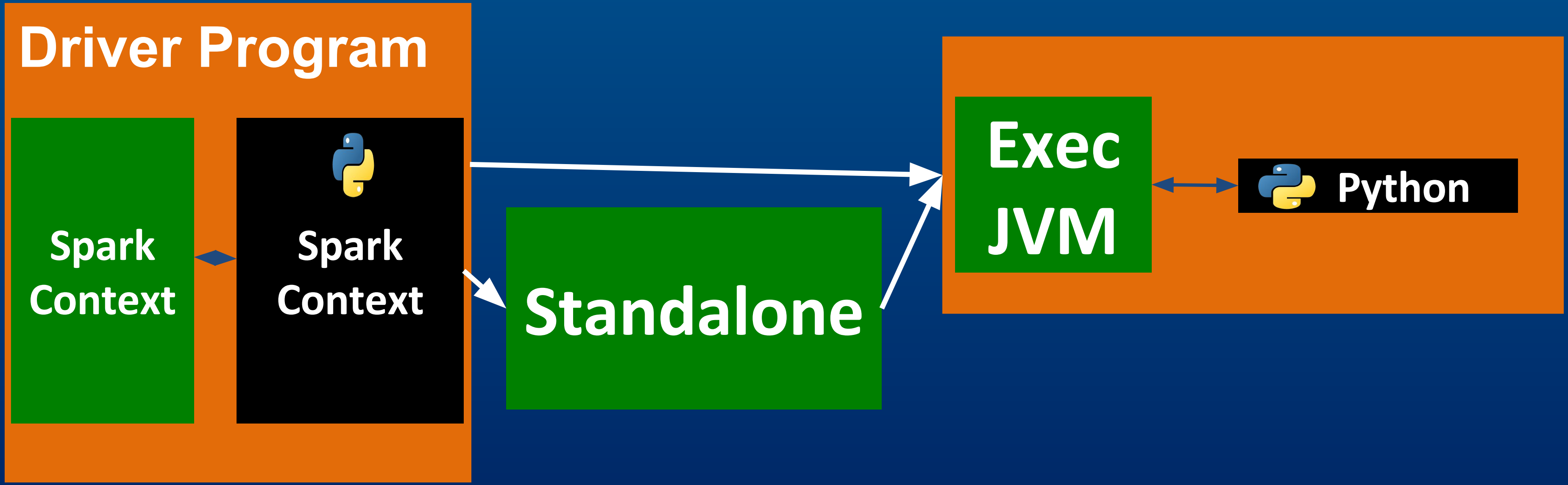
Worker Nodes



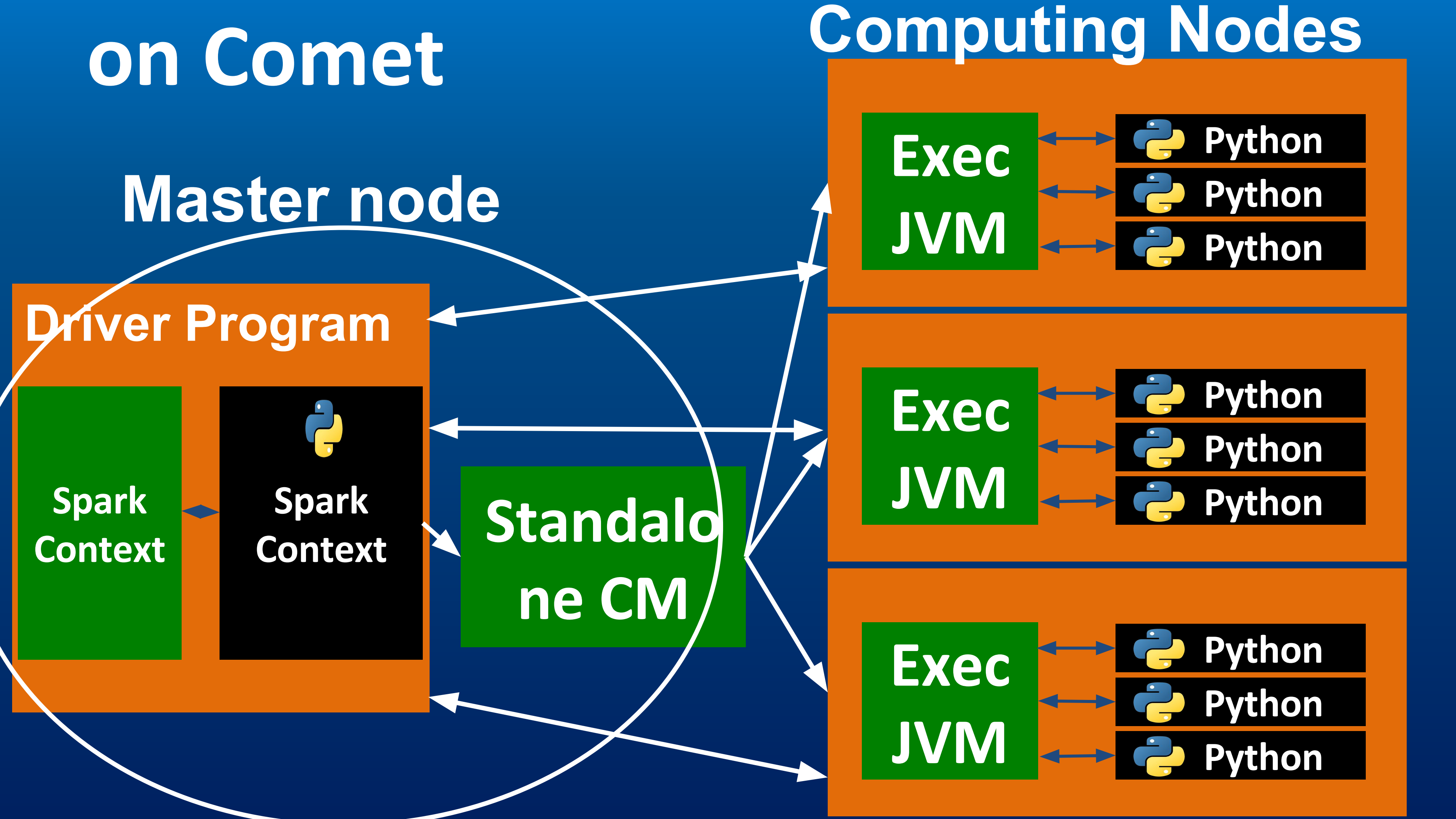

Worker Nodes
Cluster Manager
YARN/Standalone
Provision/Restart Workers
Exec
JVM
Python
Python
Python
Exec
JVM
Python
Python
Python
Exec
JVM
Python
Python
Python


Worker Nodes
Driver Program
Spark Context
Spark Context
Cluster Manager
Exec JVM
Python
Python
Python
Exec JVM
Python
Python
Python
Exec JVM
Python
Python
Python

Spark Local

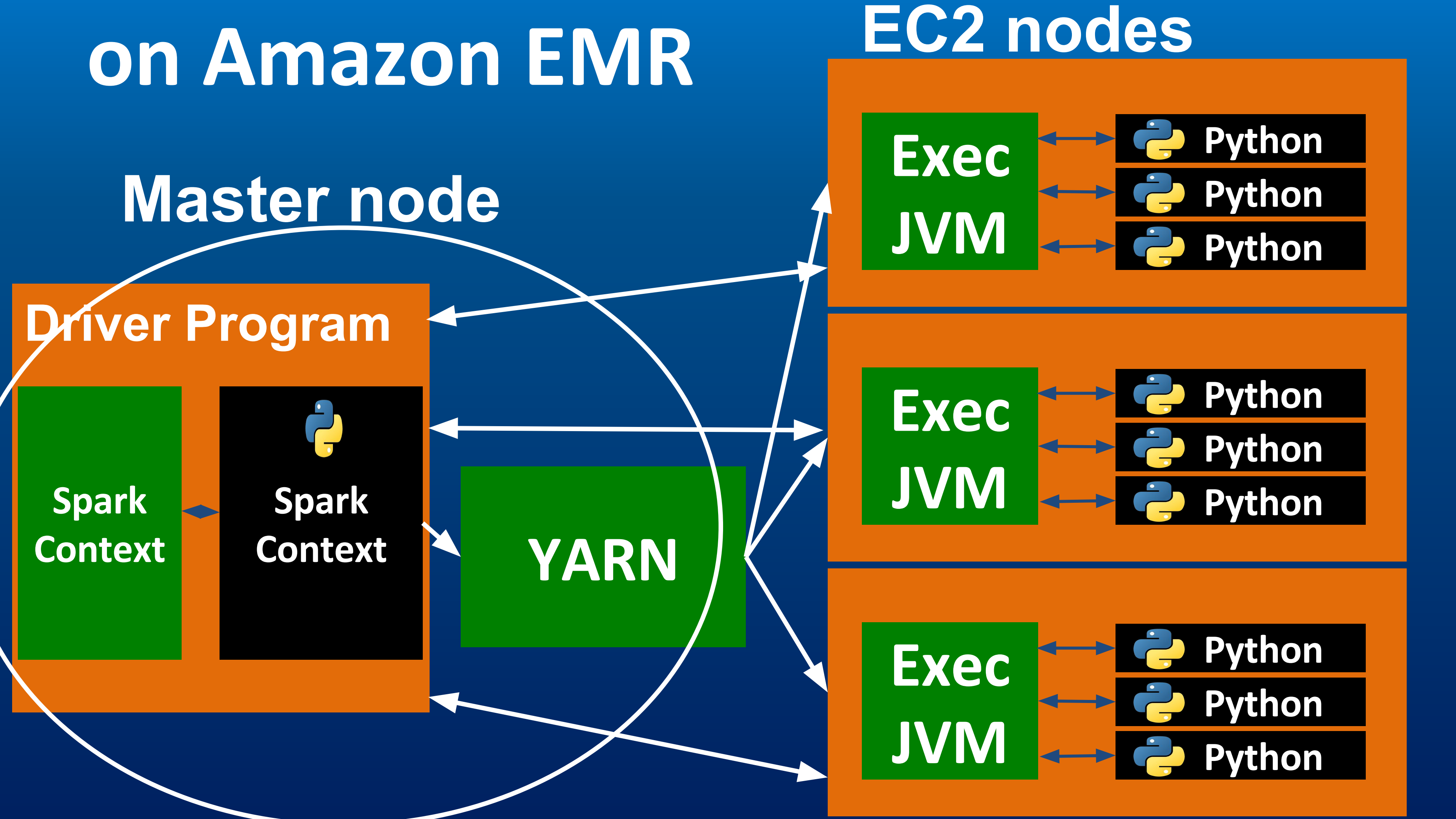

Driver Program
Spark Context
Spark Context
Standalone
Exec JVM
Python

on Comet



Computing Nodes
Master node
Driver Program
Spark Context
Spark Context
Standalone CM
Exec JVM
Python
Python
Python
Exec JVM
Python
Python
Python
Exec JVM
Python
Python
Python

on Amazon EMR

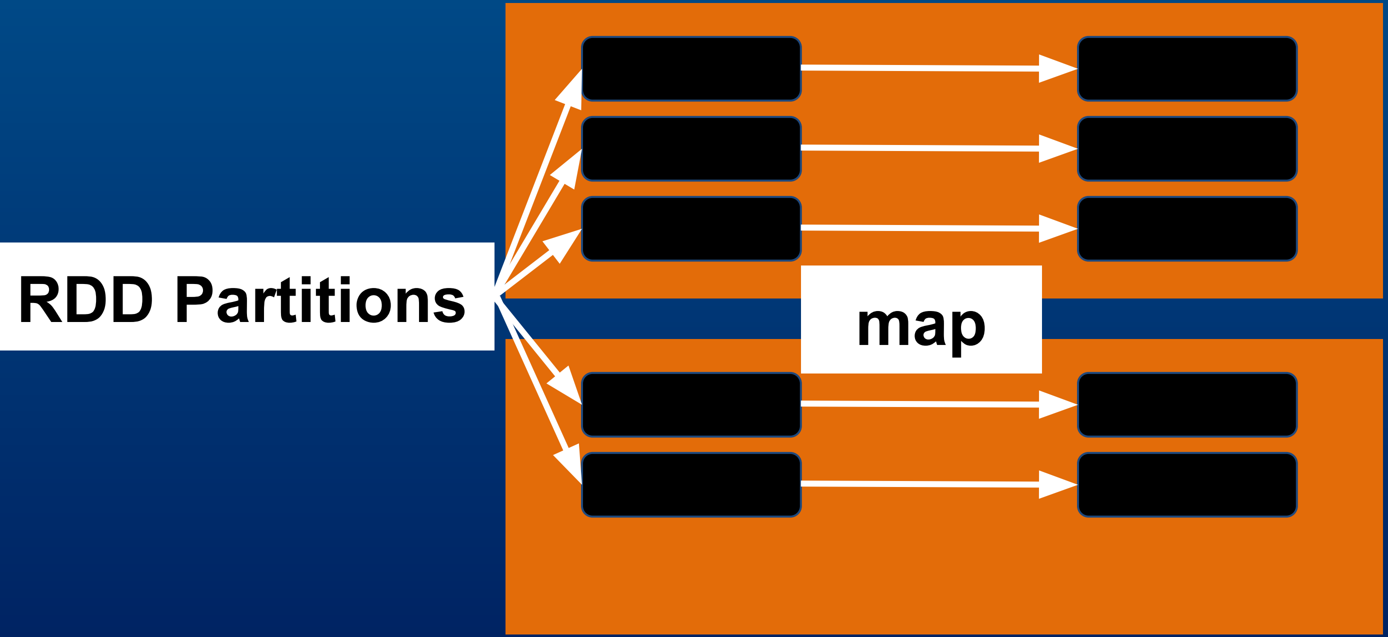


House price with HDFS

see house_price_hdfs.ipynb

map

map : apply function to each element of RDD

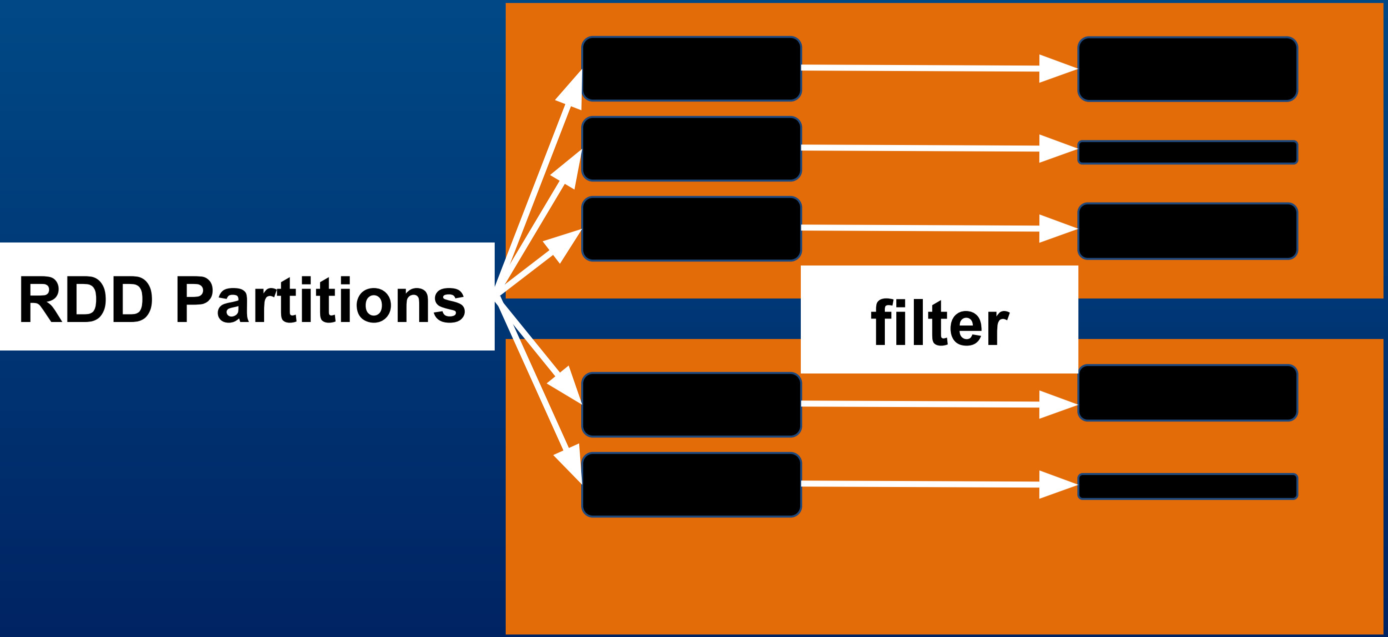


Other transformations

- filter(func) - keep only elements where func is true
- sample(withReplacement, fraction, seed) - get a random data fraction
- coalesce(numPartitions) - merge partitions to reduce them to numPartitions

filter

filter : keep only elements where func is true



coalesce

```
sc.parallelize(range(10), 4).glom().collect()
```

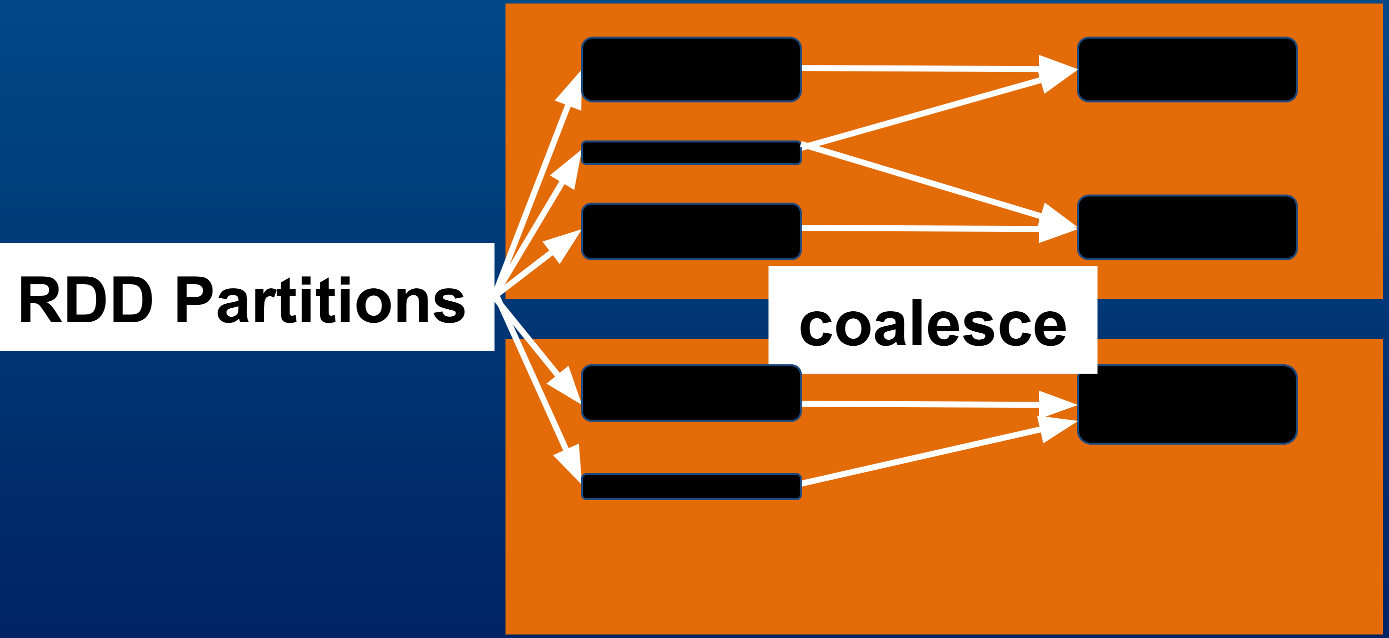
```
Out[]: [[0, 1], [2, 3], [4, 5], [6, 7, 8, 9]]
```

```
sc.parallelize(range(10), 4).coalesce(2).glom().collect()
```

```
Out[]: [[0, 1, 2, 3], [4, 5, 6, 7, 8, 9]]
```

coalesce

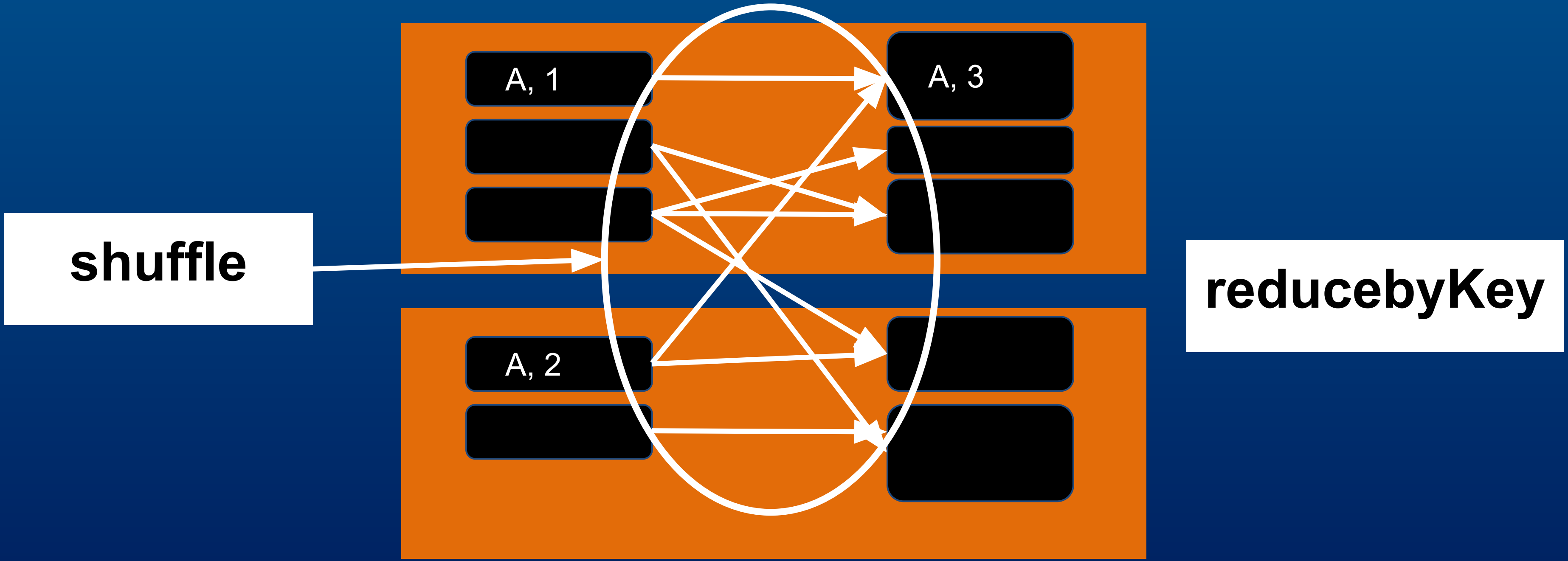
coalesce : reduce the number of partitions



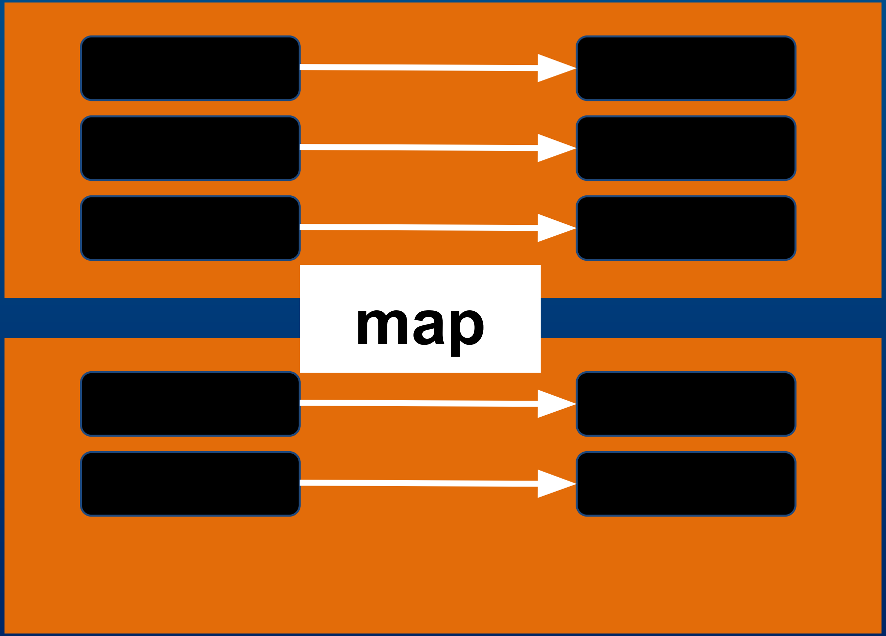
Wide transformations

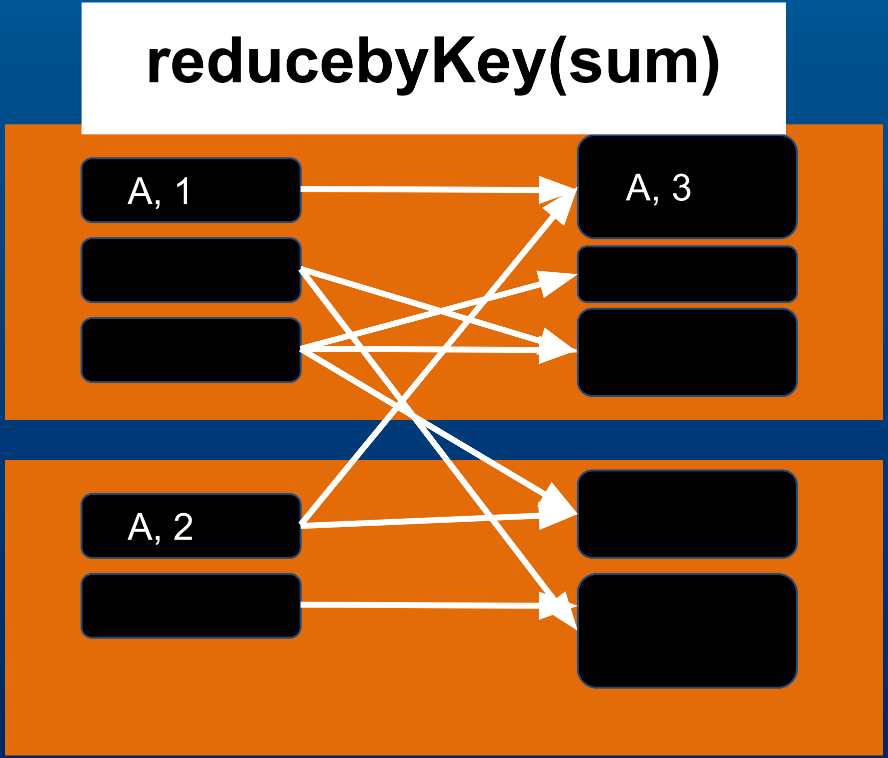
reduceByKey(func)

(K, V) pairs => (K, reduce V with func)



Narrow vs Wide





Wide transformations

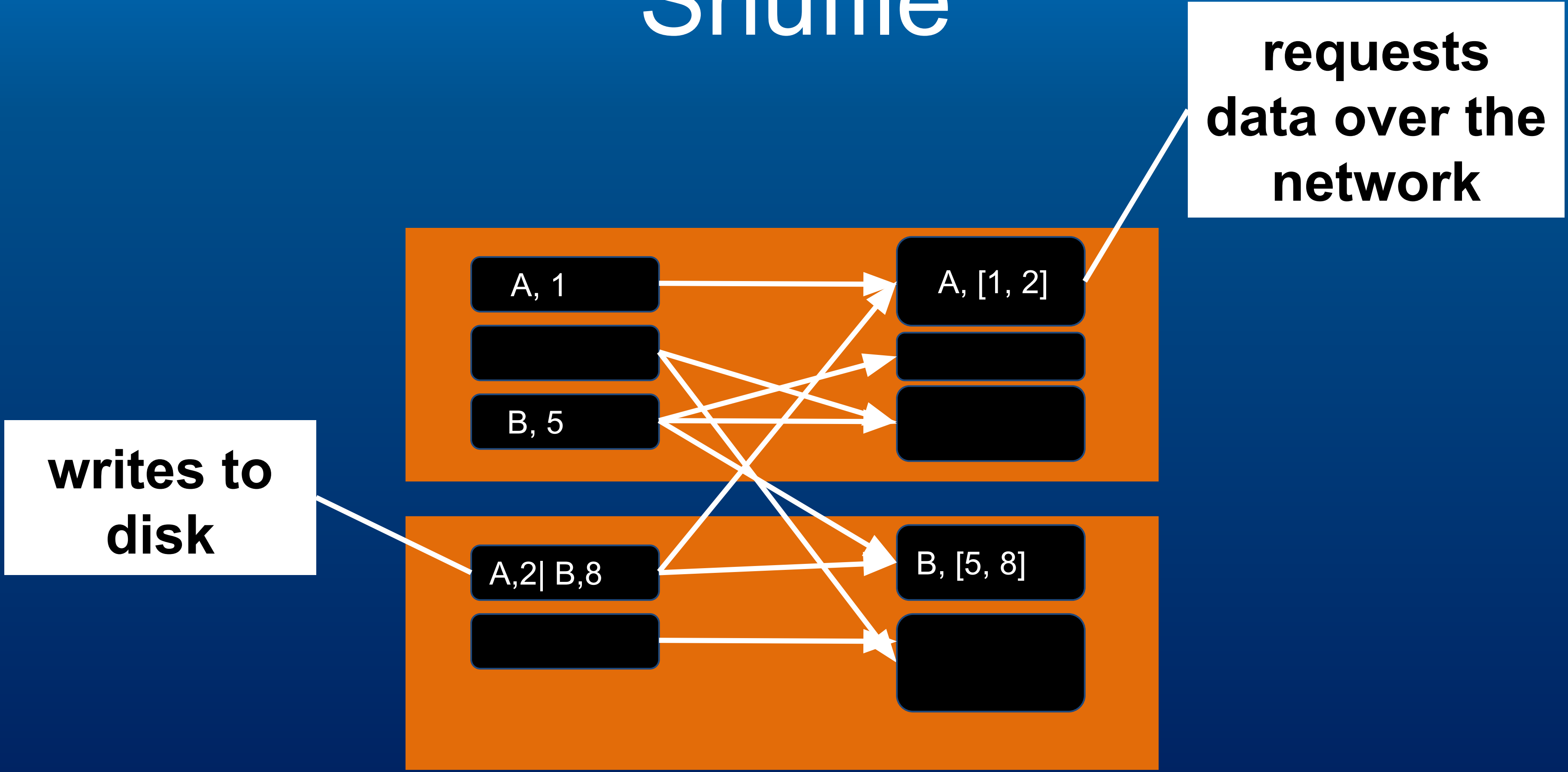
- `groupByKey` : (K, V) pairs => (K, iterable of all V)
- `reduceByKey(func)` : (K, V) pairs => (K, result of reduction by func on all V)
- `repartition(numPartitions)` : similar to coalesce, shuffles all data to increase or decrease number of partitions to numPartitions

Shuffle

Shuffle

- Global redistribution of data
- High impact on performance

Shuffle


requests data over the network
writes to disk
A, 1
B, 5
A,2| B,8
A, [1, 2]
B, [5, 8]

Know shuffle, avoid it

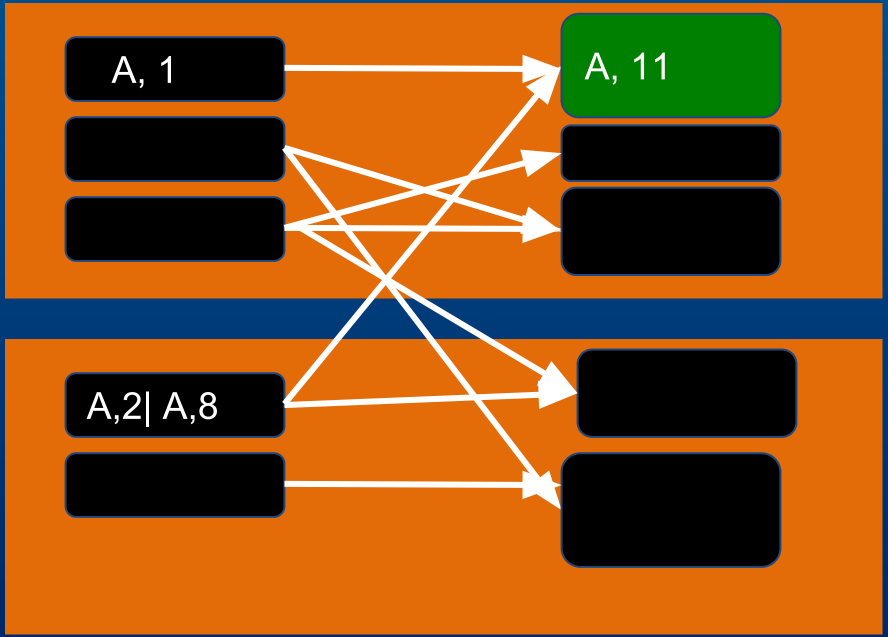
- Which operations cause it?
- Is it necessary?

Really need groupByKey?

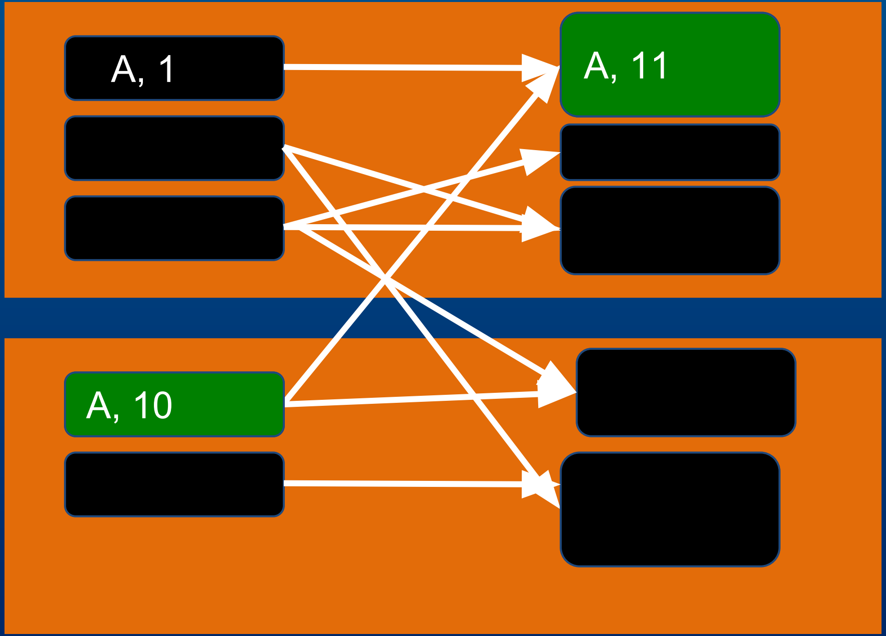
groupByKey: (K, V) pairs => (K, iterable of all V)

if you plan to call reduce later in the pipeline,
use reduceByKey instead.

groupByKey + reduce



reduceByKey



Extract data from RDD

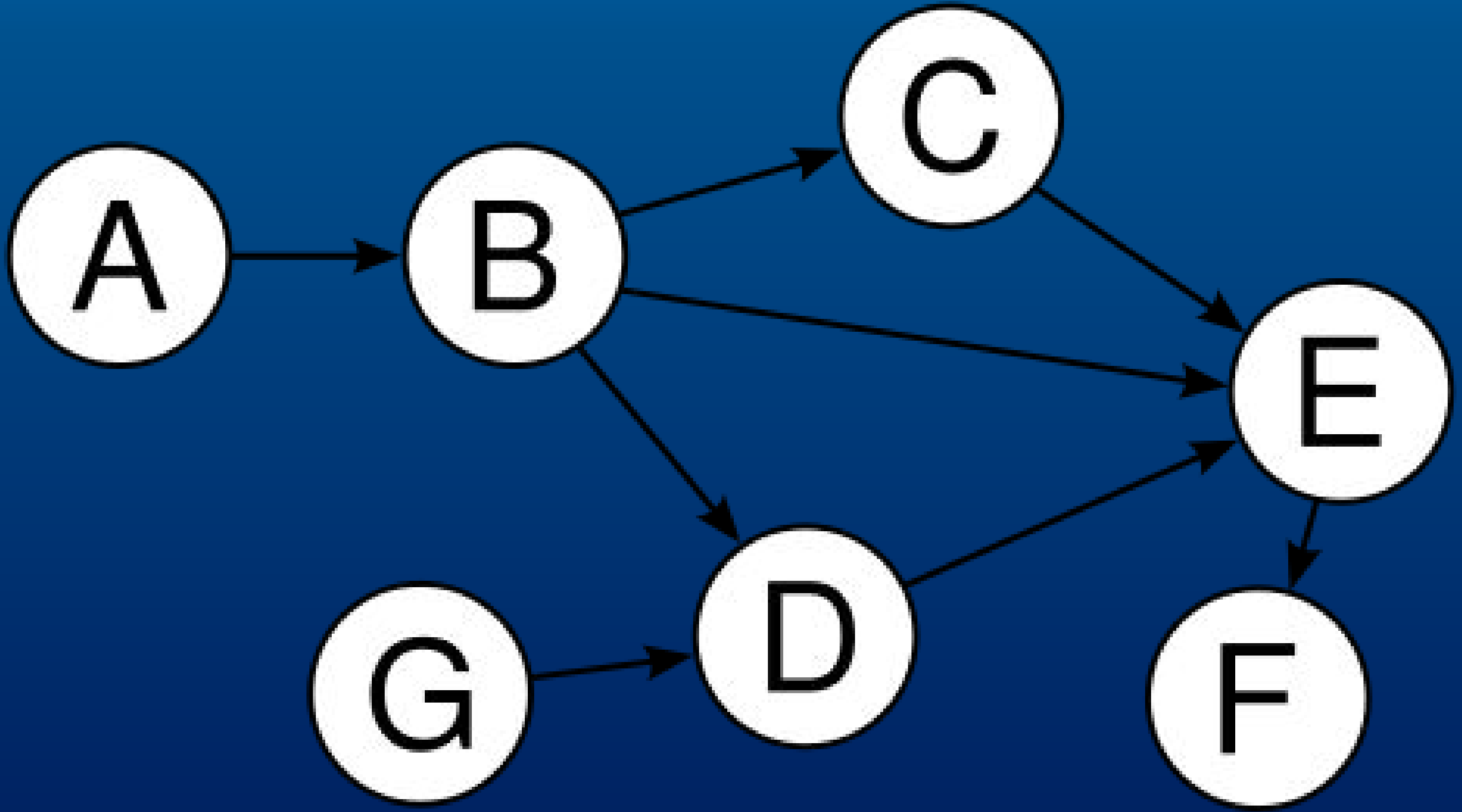
- collect() - copy all elements to the driver
- take(n) - copy first n elements
- saveAsTextFile(filename) - save to file
- reduce(func) - aggregate elements with func (takes 2 elements, returns 1)

Cached RDD

- Generally recommended after data cleaning
- Reusing cached data: 10x speedup
- Great for iterative algorithms
- If RDD too large, will only be partially cached in memory

Directed Acyclic Graph Scheduler

Directed Acyclic Graphs



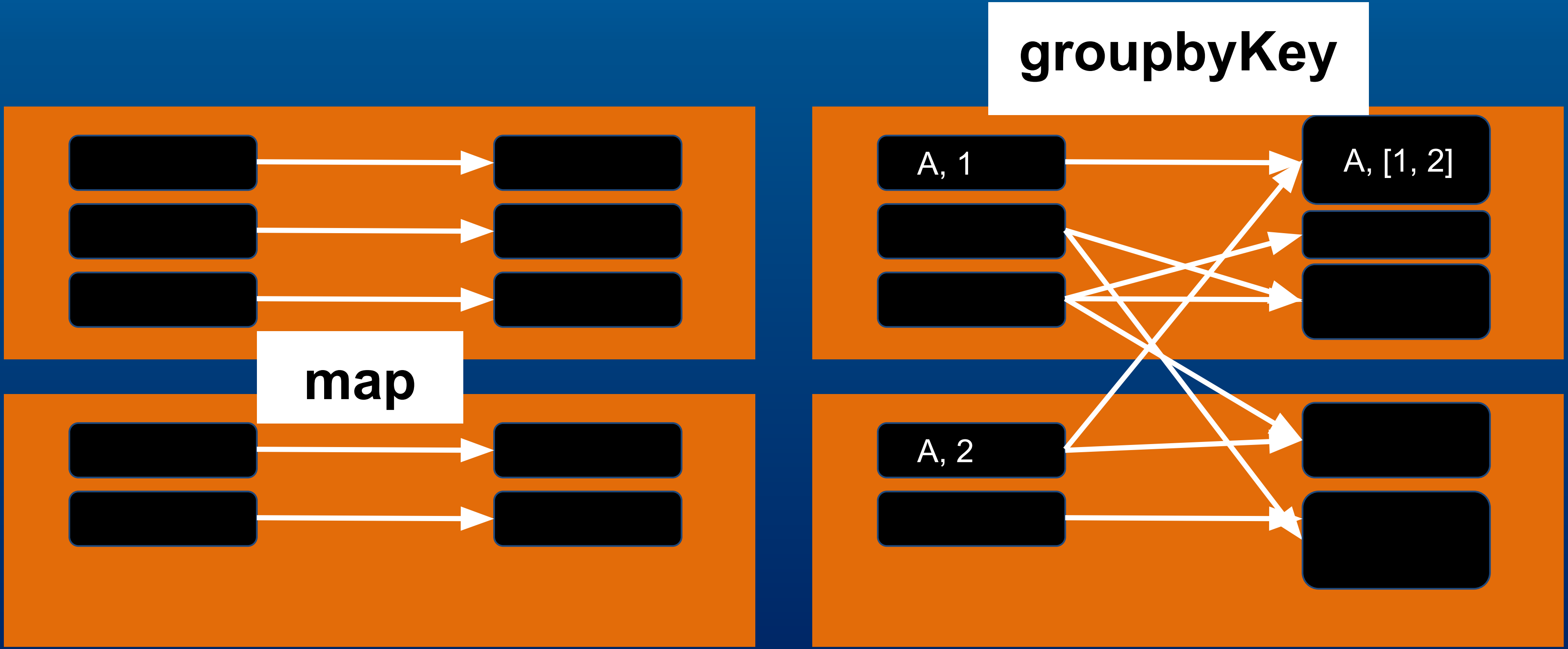
Directed Acyclic Graphs

Track **dependencies**!
(also known as lineage or provenance)

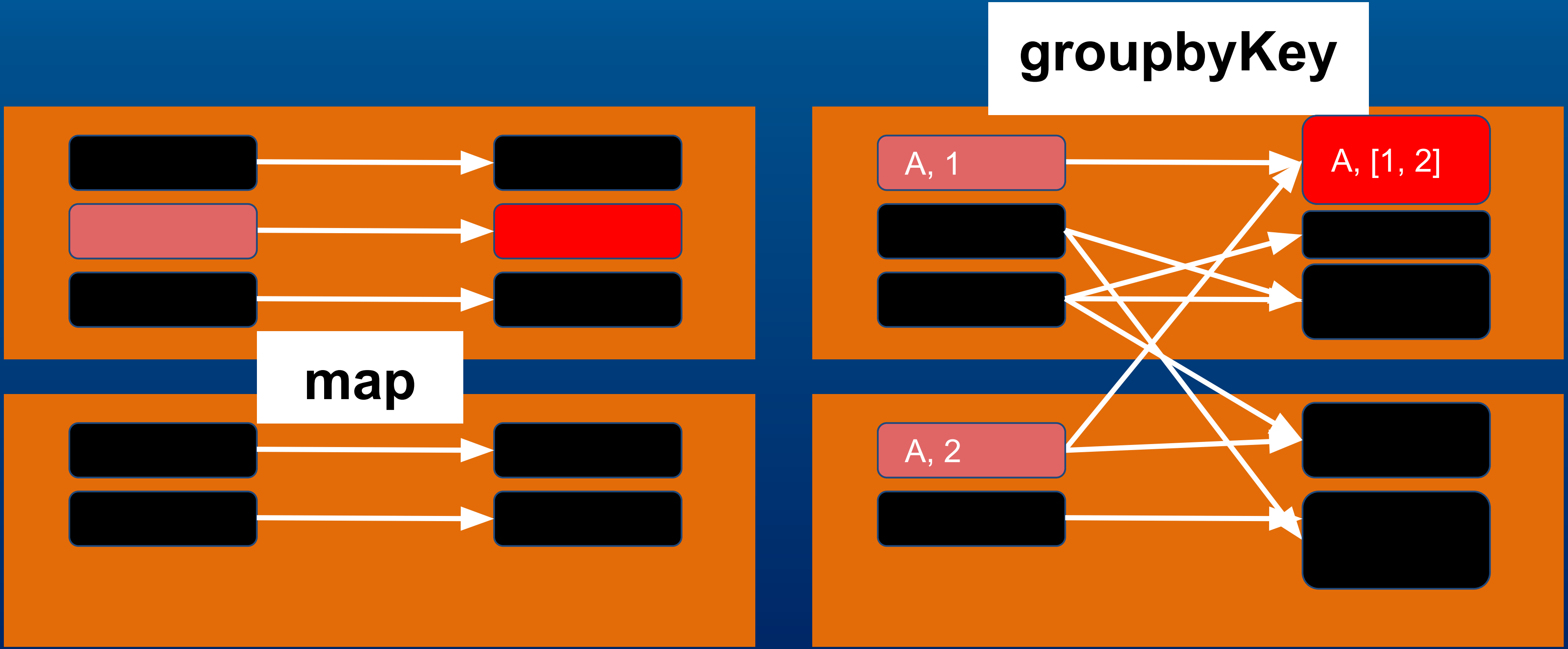
DAG in Spark

- nodes are RDDs
- arrows are Transformations

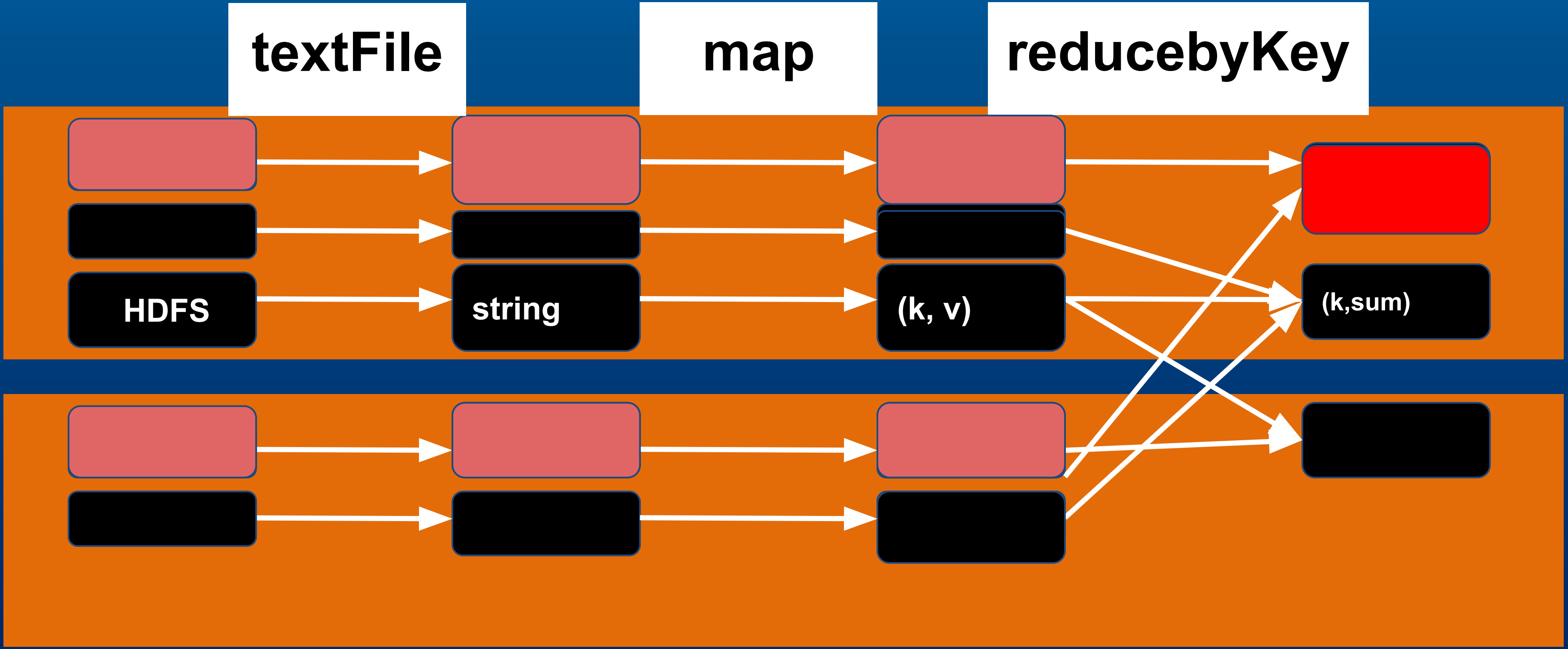
Narrow vs Wide



Narrow vs Wide

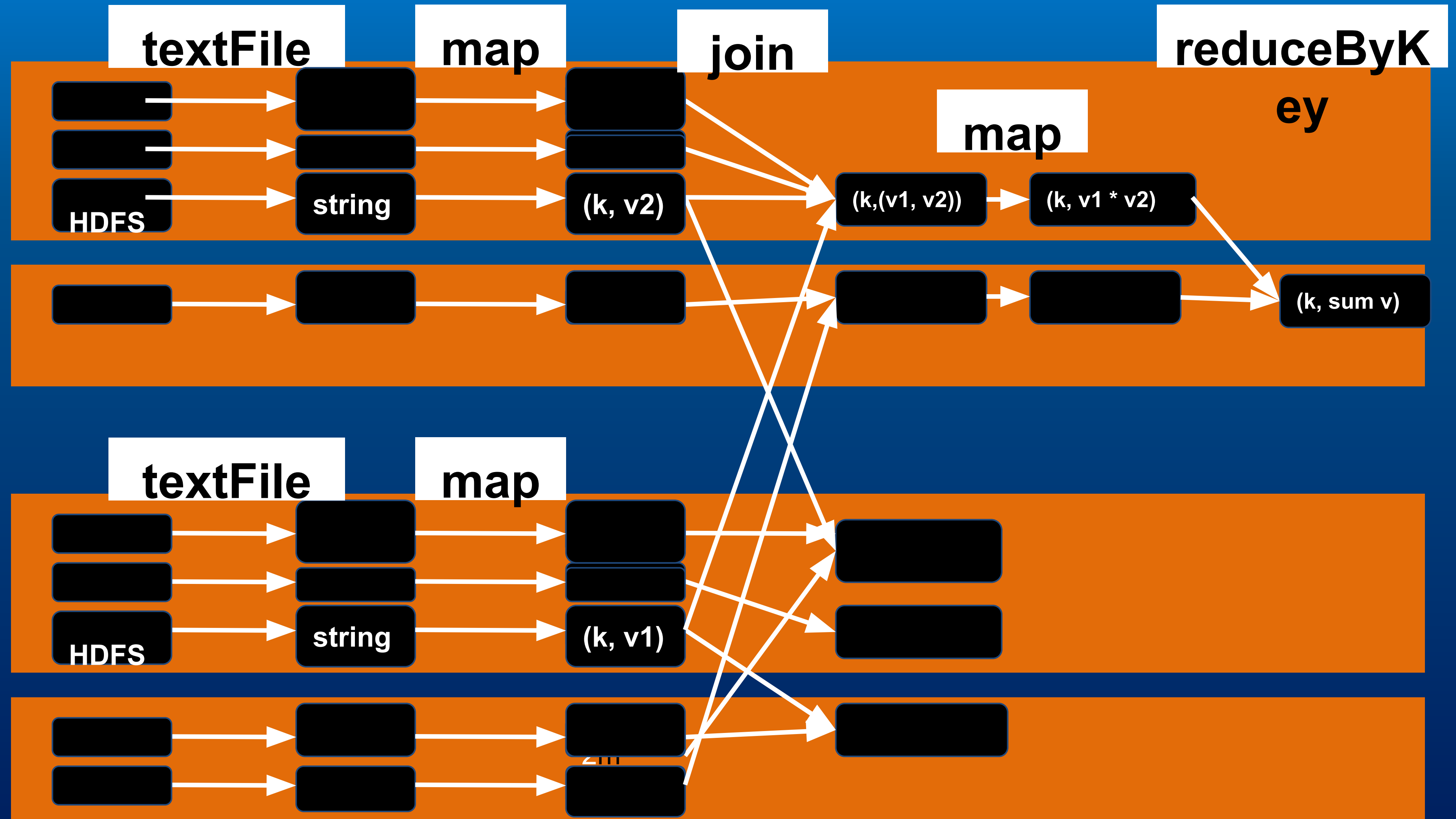


Spark DAG of transformations



House price JOIN

see house_price_join.ipynb


textFile
map
join
reduceByK
ey
map
HDFS
string
(k, v2)
(k,(v1, v2))
(k, v1 * v2)
(k, sum v)
textFile
map
HDFS
string
(k, v1)

Thanks

Questions?

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