BIG DATA

Spark : Architecture

K V Subramaniam
Computer Science and Engineering

Overview of lecture

- Spark High Level Architecture
- Lifetime of a Spark Job
- Lazy Evaluation
- RDDs
- Spark Scheduling
- Dataframes

Spark High Level Architecture

Recall: Log Mining Example

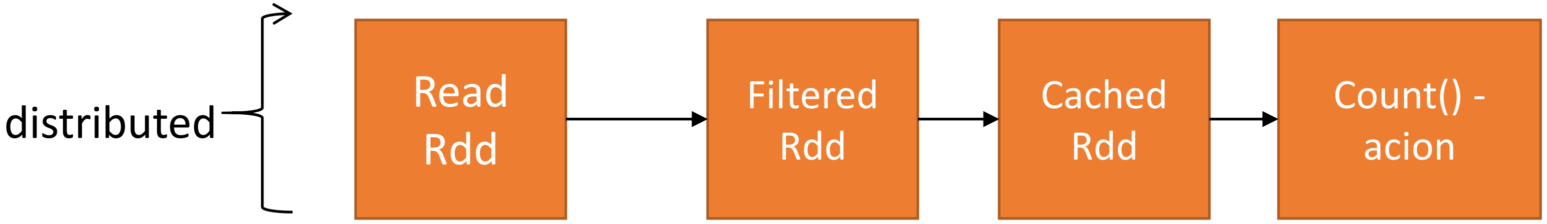
```
val sc = new SparkContext("spark://...", "MyJob", home,
    jars)

val file = sc.textFile("hdfs://...") // This is an RDD

val errors = file.filter(_.contains("ERROR")) // This is
    an RDD

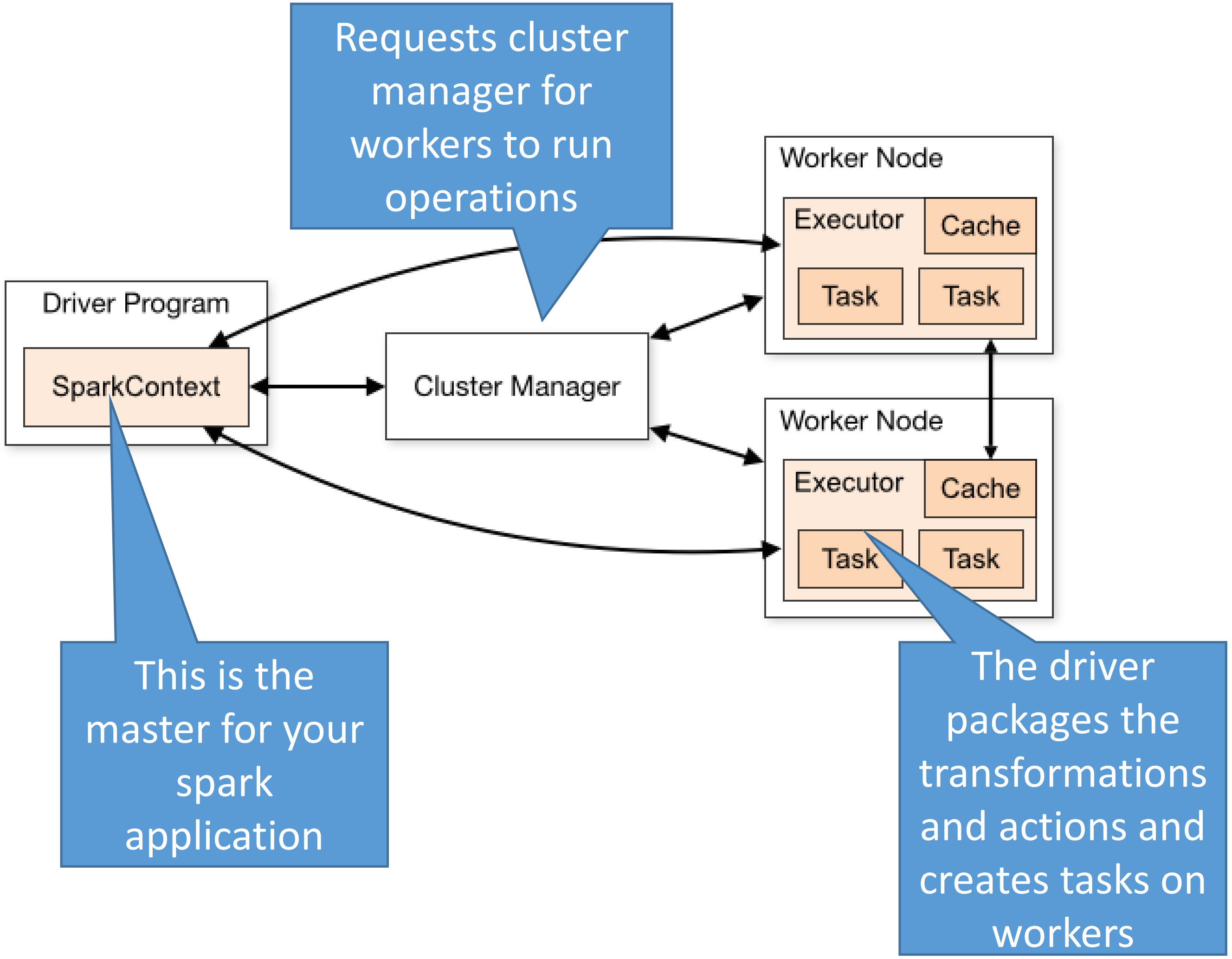
errors.cache()

errors.count() // This is an action
```



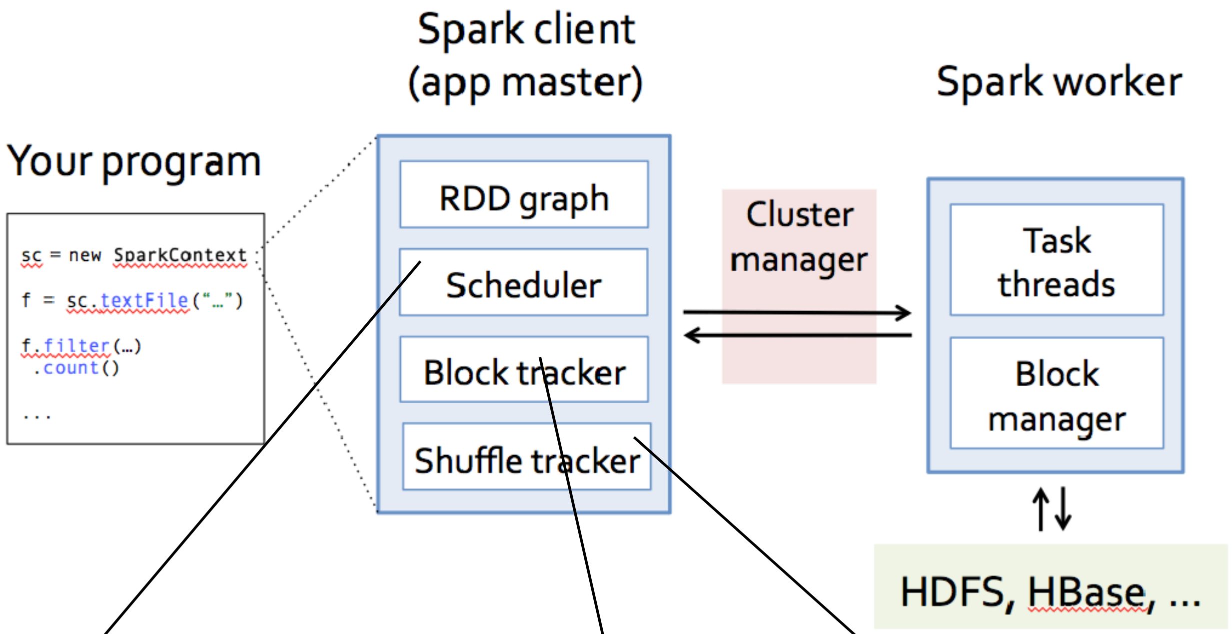
How is this executed by Spark?

Spark Architecture



https://spark.apache.org/docs/latest/cluster-overview.html

Spark Architecture

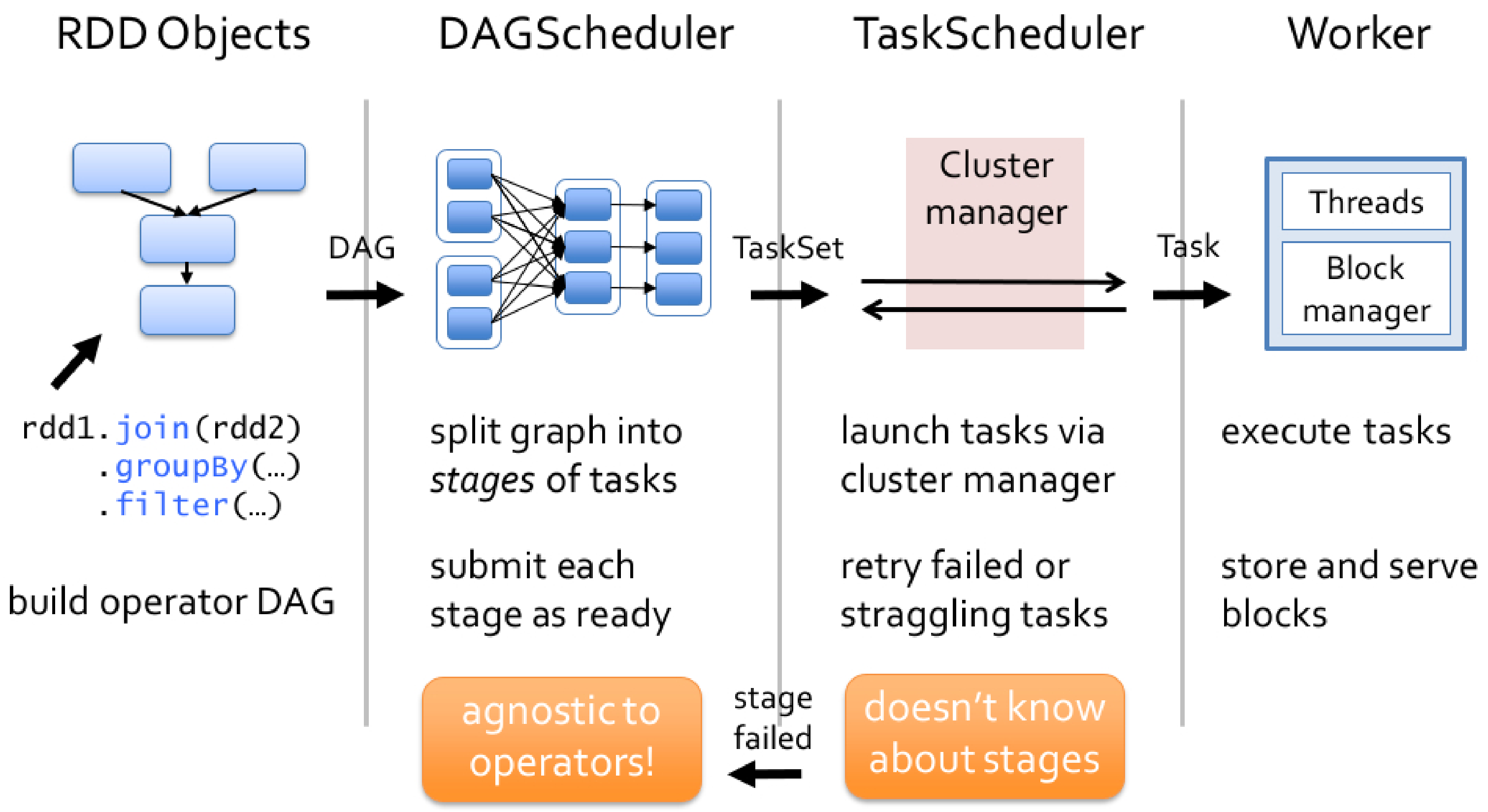


Where to run the tasks

Input Data

Do we have all the data to move forward

Spark Working details



https://hxquangnhat.com/2015/04/03/arch-spark-job-submission-breakdown/

Lazy Execution in Spark

Lazy Execution

- In Hadoop, when we submit a job the master starts executing it
- In Spark, when does the master start executing the job?
  - Spark uses a technique called Lazy execution

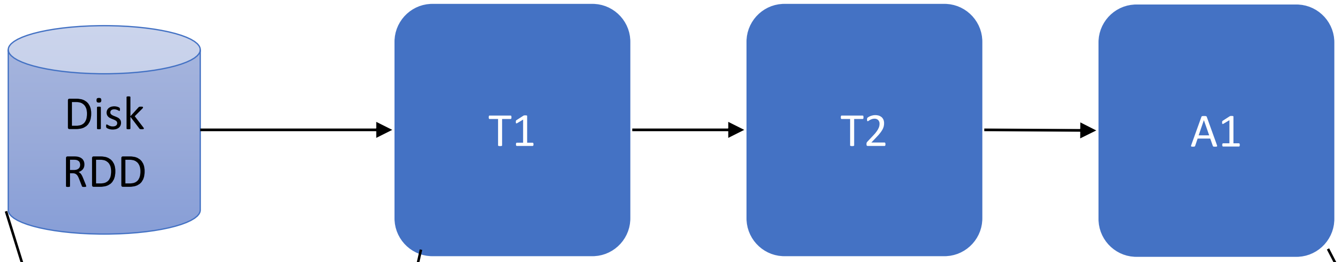
Lazy Execution

- Remember that we defined Spark operations into *transformations* and *actions*

- The spark driver does not execute anything till it encounters an *action*

- *Transformations* are only noted for purpose of lineage.

Lazy Execution



lines = spark.textFile(“hdfs://...”)
// Doesn’t read file. Notes that RDD is to be created

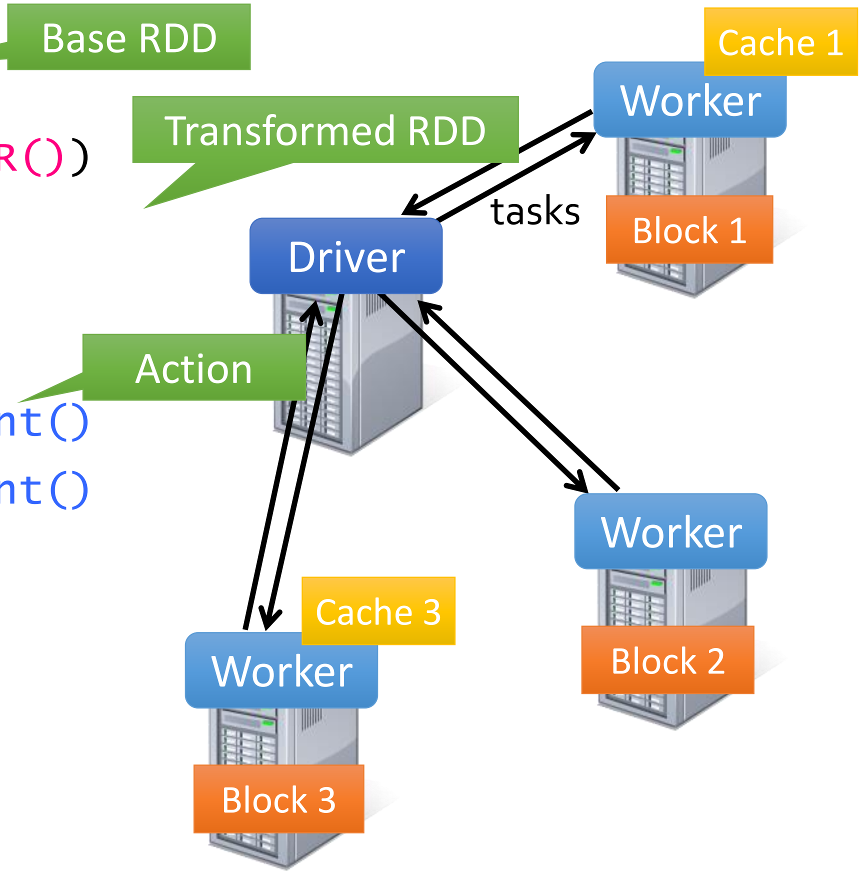
Transformation say *map*
Doesn’t do transformation immediately

Action say *count.* Triggers execution: all transformations done block by block on same server followed by count

Spark Working with Log Mining Example


```
lines = spark.textFile(“hdfs://...”)
errors = lines.filter(startsWithERROR())
messages = errors.map(split(“\t”),2)
cachedMsgs = messages.cache()

cachedMsgs.filter(containsfoo()).count()
cachedMsgs.filter(containsbar()).count()
```



RDDs - details

What is an RDD

- RDD is partitioned, locality aware, distributed collections
  - RDDs are immutable. (Why it's necessary?)

- RDDs are data structures that either
  - Point to the source (HDFS)
  - Apply some transformations to the parent RDDs to generate new data elements

- Computations on RDDs
  - Lazily evaluated lineage DAGs composed of chained RDDs

Why the RDD abstraction?

- Support operations other than map and reduce
- Support in memory computation
- Arbitrary composition of such operators
- Simplify scheduling

How to capture dependencies generically?

Representing RDDs

- Set of partitions (“splits”)
  - Much like Hadoop. Each RDD associated with a input partitions
- List of dependencies on parent RDDs
  - Not there in Hadoop. This is new
- Function to compute a partition given parents
  - User defined code. (similar to map()/reduce() in Hadoop
- Optional preferred locations
  - For data locality
- Optional partitioning information (partitioner)
  - Advanced – for shuffle (see later)

RDDs Interface

Operation	Meanning
partitions()	Return a list of Partition objects
preferredLocations(*p*)	List nodes where partition *p* can be accessed faster due to data locality
dependencies()	Return a list of dependencies
iterator(*p, parentIters*)	Compute the elements of partition *p* given iterators for its parent partitions
partitioner()	Return metadata specifying whether the RDD is hash/range partitioned

Examples of RDDs

- Hadoop RDD
  - Partitions – one per block
  - Dependencies – none
  - Compute (partition) – read corresponding block
  - Preferred locations – HDFS block location
  - Partitioner - none

- Filtered RDD (as in sample application)
  - Partitions – same as parent
  - Dependencies – 1-1 with parent
  - Compute – compute parent and filter it.
  - Preferred locations – ask parent (none)
  - Partitioner - none

Exercise

Based on the sample of the Filter RDD, can you work out what will be the partitions, compute, dependencies, preferred locations and partitioner for a joinRDD

- Filtered RDD (as in sample application)
    - Partitions – same as parent
    - Dependencies – 1-1 with parent
    - Compute – compute parent and filter it.
    - Preferred locations – ask parent (none)
    - Partitioner - none
-

Examples of RDDs

- Joined RDD
  - RDDPartitions – one per reduce task
  - Dependencies – shuffle on each parent
  - Compute (partition) – read and join shuffled data
  - Preferred locations – none
  - Partitioner – HashPartioner (num tasks)

Spark Scheduling

Page Rank example in Spark

- lines = textfile ("urls.txt"))
- links = lines.map (lambda urls: urls.split()).groupByKey().cache()
- ranks = links.map(lambda url_neighbors: (url_neighbors[0], 1.0))
- for iteration in range(MAXITER)):
- contribs = links.join(ranks).flatMap(lambda url_neighbors_rank: computeContribs (url_neighbors_rank)
- ranks = contribs.reduceByKey(add).mapValues (lambda rank: rank * 0.85 + 0.15)

```
def computeContribs (url_neighbors_rank):
"""Calculates URL contributions to the rank of other URLs.
"""
num_neighbors = len (url_neighbors_rank) – 2

rank = url_neighbors_rank [len (url_neighbors_rank) – 1]

for i in range (1, num_neighbors):
        yield (url_neighbors_rank[i], rank / num_neighbors)
```

1. Start each page with a rank of 1
2. On each iteration, update each page's rank to

$$\Sigma_{i \in neighbors} rank_i / |neighbors_i|$$

DAG representation

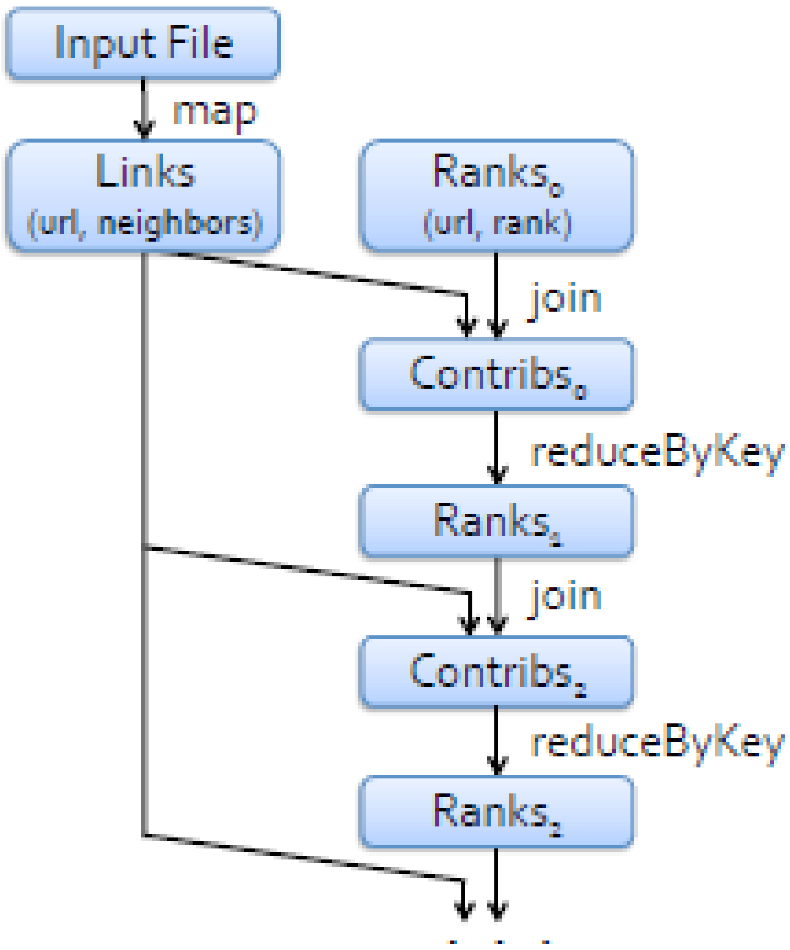
- The Spark Driver will first convert this program into a DAG representation

- What does the DAG representation contain?

  - Each RDD is a node in the graph and

  - all transformations/actions on the RDD as edges

DAG representation of Page Rank



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links = lines.map (lambda urls: urls.split()).groupByKey().cache()

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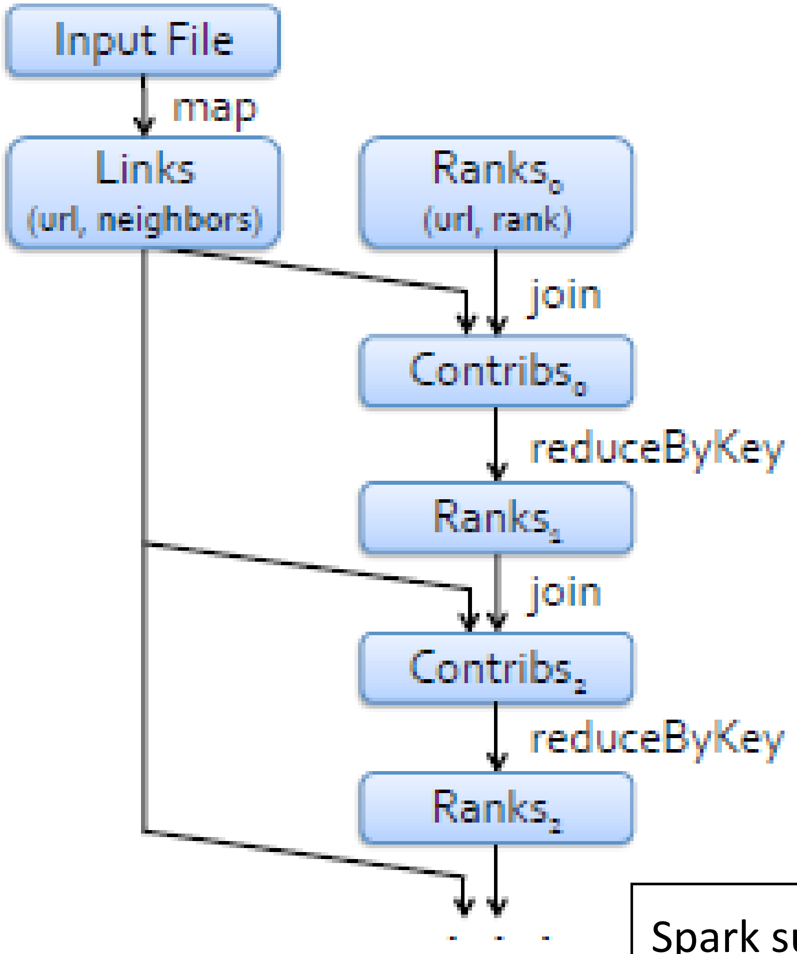
contribs = links.join(ranks).flatMap(lambda url_neighbors_rank: computeContribs (url_neighbors_rank)

ranks = contribs.reduceByKey(add).mapValues(lambda rank: rank * 0.85 + 0.15)

Ranks and Links are spread across multiple nodes. How does Spark ensure join works properly? Hint: Think about how join works.

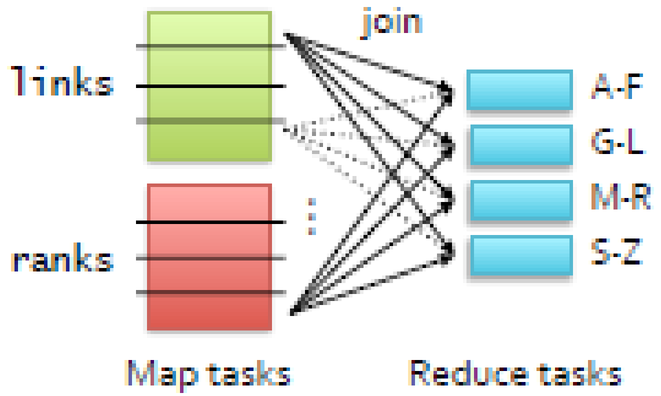
DAG representation of Page Rank



`links` and `ranks` are repeatedly joined

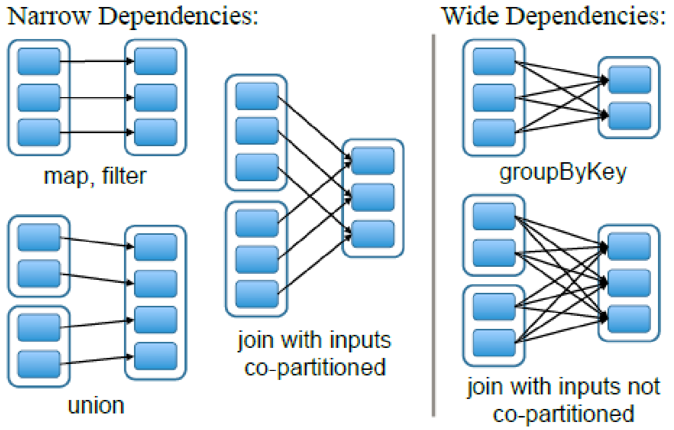
Each join requires a full shuffle over the network

» Hash both onto same nodes



Spark supports two types of partitioning – hash and range

- narrow dependencies
  - where each partition of the parent RDD is used by at most one partition of the child RDD
  - Does not need a shuffle; pipeline operations
  - Shuffle: movement of data from one node to another

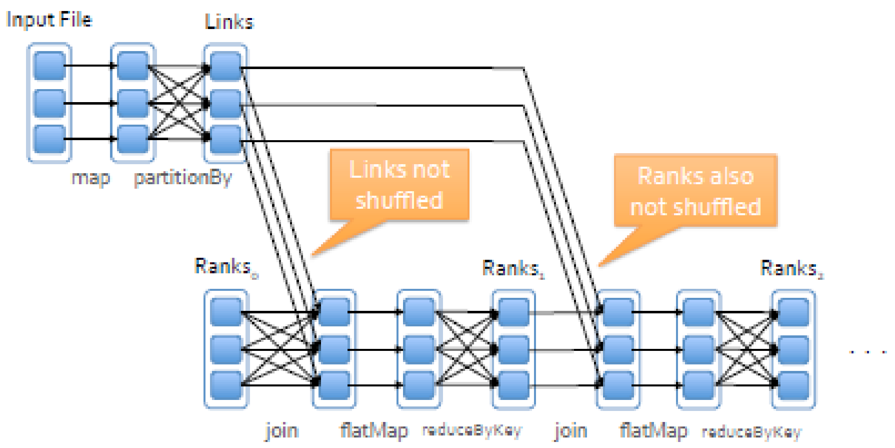


- wide dependencies
  - where multiple child partitions may depend on it.
  - May need a shuffle

- Copartition → technique to make sure that both inputs to a join are partitioned using same function

Lineage and Optimizing Placement

- links & ranks repeatedly joined
- Can copartition them (e.g.hash both on URL) to avoid shuffles
- Spark supports two types of partitioning: hash and range

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```

Narrow and Wide Dependencies

Narrow Dependencies

- Map
- FlatMap
- MapPartitions
- Filter
- Sample
- Union

W I d e Dependencies

- Intersection
- Distinct
- ReduceByKey
- GroupByKey
- Join
- Cartesian
- Repartition
- Coalesce

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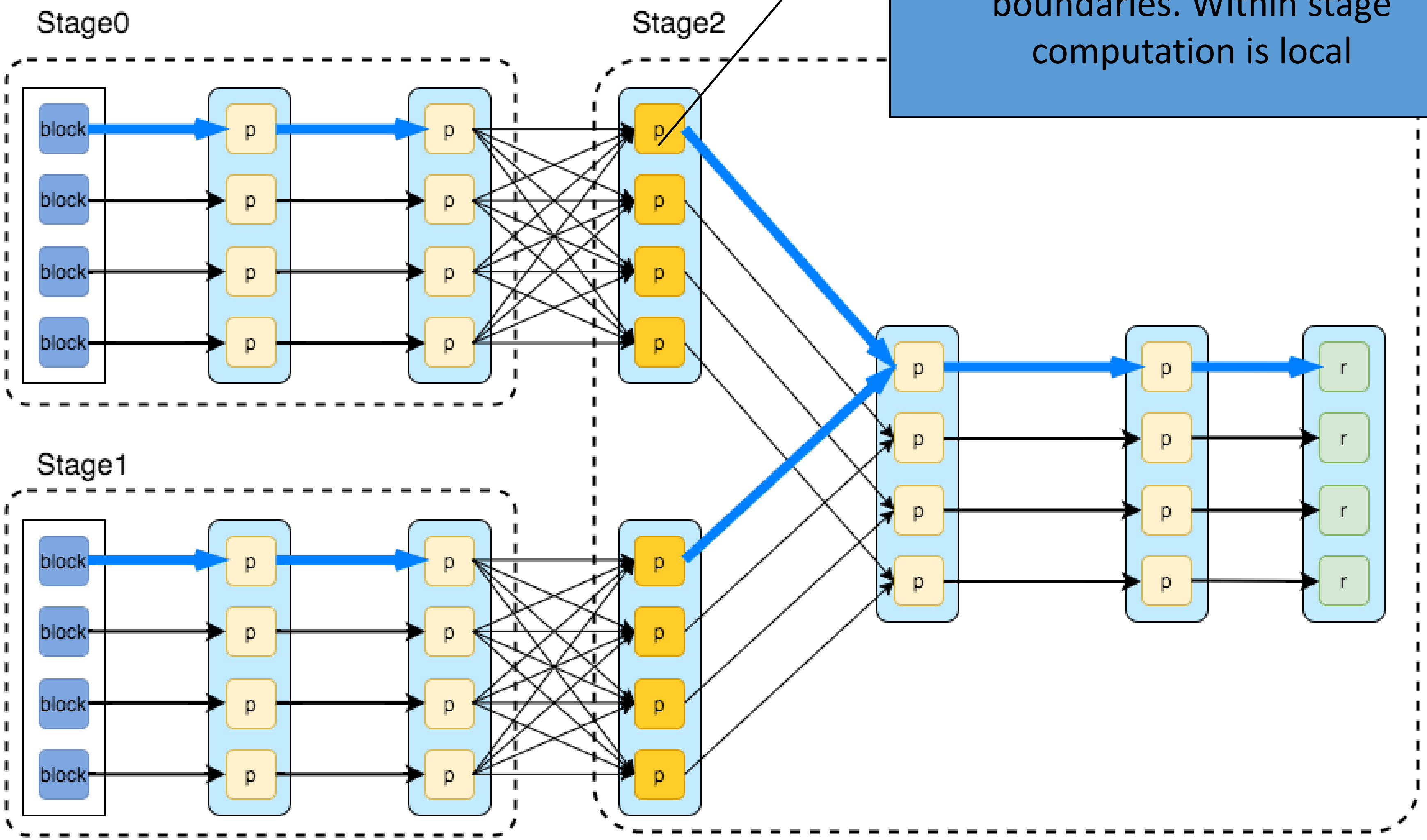
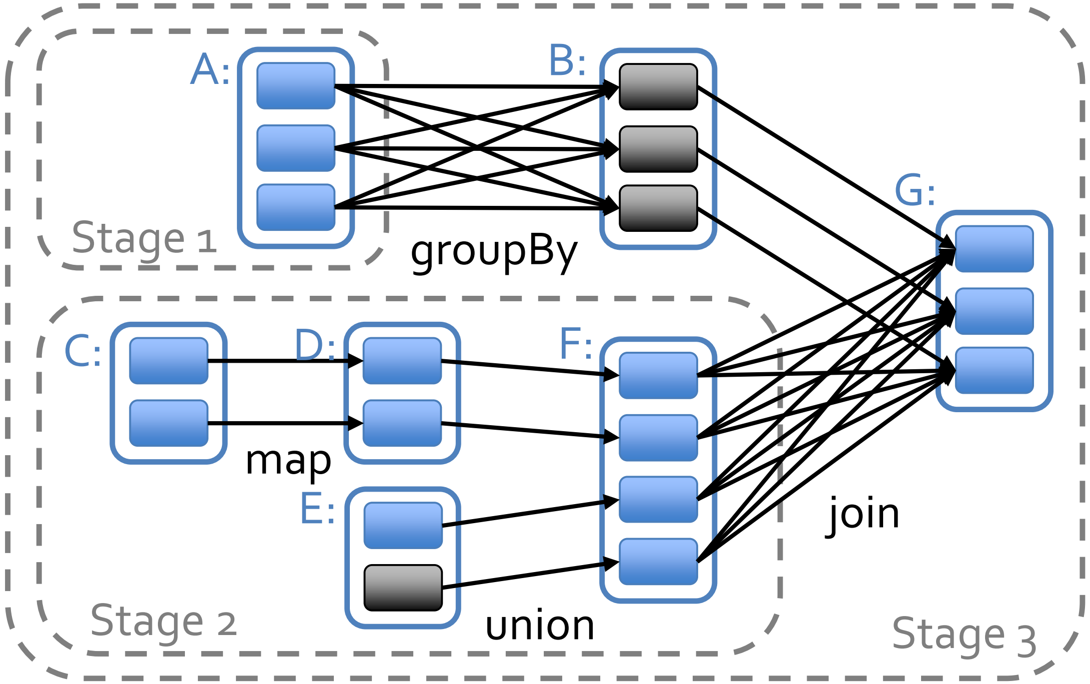
Scheduling



Breakup DAG into stages at shuffle boundaries. Within stage computation is local

Task Assignment

- scheduler assigns tasks to machines based on data locality using delay scheduling
    - if a task needs to process a partition that is available in
    - memory on a node, then send it to that node
    - otherwise, a task processes a partition for which the containing RDD provides preferred locations (e.g., an HDFS file), then send it to those



Simplifying tasks for programmers - DataFrames

Need for dataframes

- Data RDDs are completely opaque to Spark
  - Meaning Spark cannot parse these values
- Is there some way to make Spark understand the format, so that we can do processing more easily
  - Like sql type queries
- Consider data like on the right that we need to run a query on?

USN	Name	Marks
45	Vkoli	11
10	Stendul	43
195	Abachpan	28

What is a dataframe

- Introduced in 2015
- Inspired by Dataframes in R and Pandas in python
- Distributed collection of data into named columns
- An abstraction built over RDD that allows
  - Schema to be defined on a RDD
- Also has an optimizer built in for queries

USN	Name	Marks
45	Vkoli	11
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Creating dataframes

Dataframes can be created from existing RDDs, HIVE tables other Data sources.

This example is creating from a JSON file

```
from pyspark.sql import SQLContext
sqlContext = SQLContext(sc)

df = sqlContext.jsonFile("pes/students.json")

# let us display the contents
df.show()
## USN  name    marks
## 045  Vkoli    11
## 010  Stendul   43
## 195  Abachpan   28

Df = rdd.toDF("age", "name")
```

Alternatively, from an existing RDD by naming the columns

Using a dataframe

```
# Print the schema in a tree format
df.printSchema()
## root
## |-- usn: long (nullable = true)
## |-- name: string (nullable = true)
## |-- marks: long (nullable = true)

# Select only the "name" column
df.select("name").show()
## name
## VKoli
## STendul
## ABachpan

# Select everybody, but increment the age by 1
df.select("name", df.marks + 1).show()
## name    (marks + 1)
## Vkoli       12
## STendul     44
## ABachpan    29
```

Exercise

- Consider a case where you have data in a CSV file that consists of <pan number, date, tax_paid> and you wanted to find out the total tax paid by each individual pan holder
  - How will you do it in Spark?
  - How will you do it with Spark Data frames

- Consider a case where you have data in a CSV file that consists of <pan number, date, tax_paid> and you wanted to find out the total tax paid by each individual pan holder
  - How will you do it in Spark?
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Using Dataframes

```
Df = rdd.toDF("pan number", "date", "taxpaid")
Df.select("pan number", "tax paid").groupBy("pan number").sum()
```

Note that this is done using the name of the column rather than by splitting the data which we would do if used Spark.

DryadLINQ, FlumeJava

- Similar “distributed collection” API, but cannot reuse datasets efficiently *across* queries

- Relational databases
  - Lineage/provenance, logical logging, materialized views

GraphLab, Piccolo, BigTable, RAMCloud

- Fine-grained writes similar to distributed shared memory

- Iterative MapReduce (e.g. Twister, HaLoop)
  - Implicit data sharing for a fixed computation pattern
- Caching systems (e.g. Nectar)
  - Store data in files, no explicit control over what is cached

THANK YOU

K V Subramaniam, Usha Devi
Dept. of Computer Science and Engineering

subramaniamkv@pes.edu
ushadevibg@pes.edu