Big Data Frameworks: Internals

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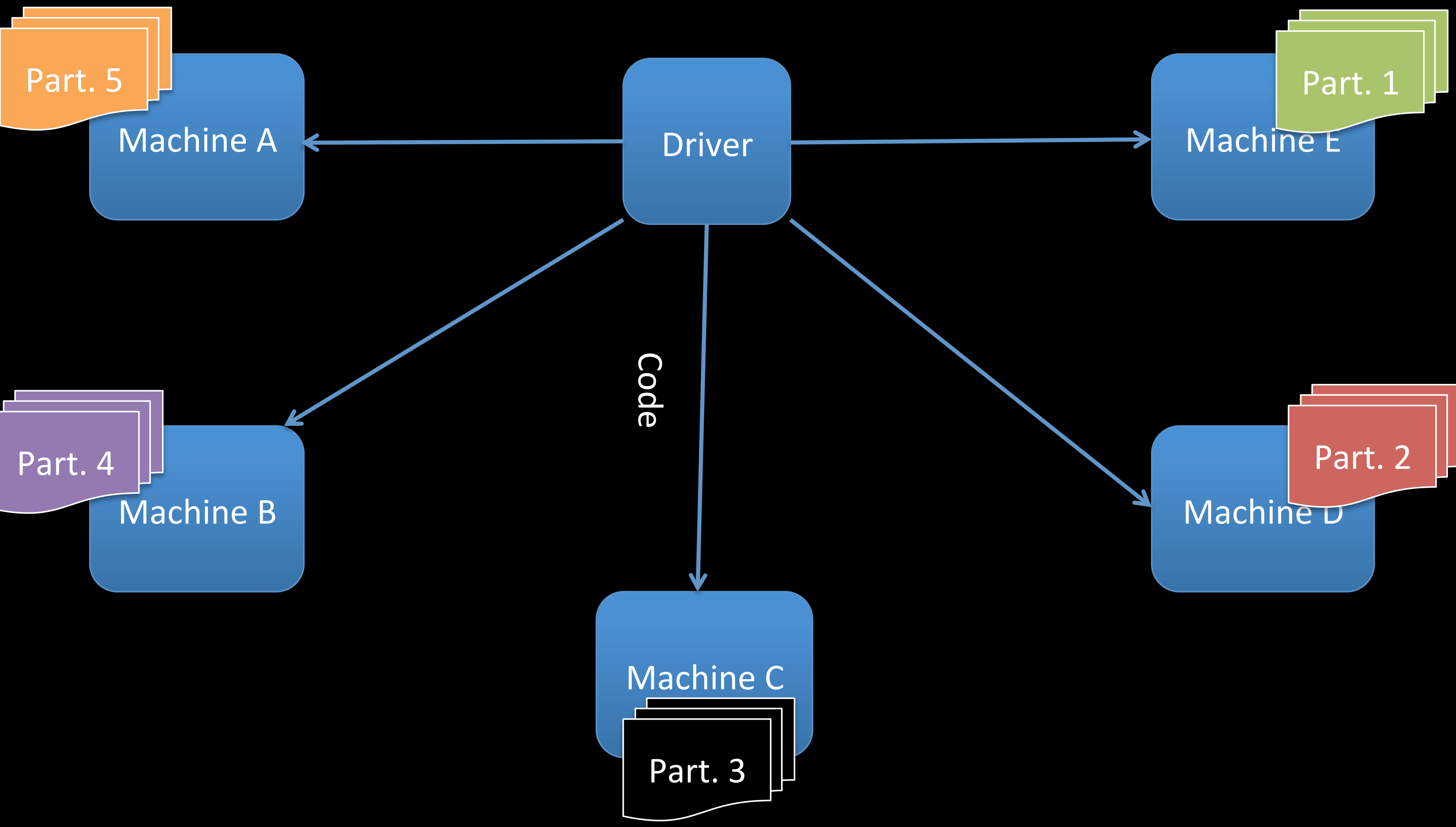
Spark Framework Application

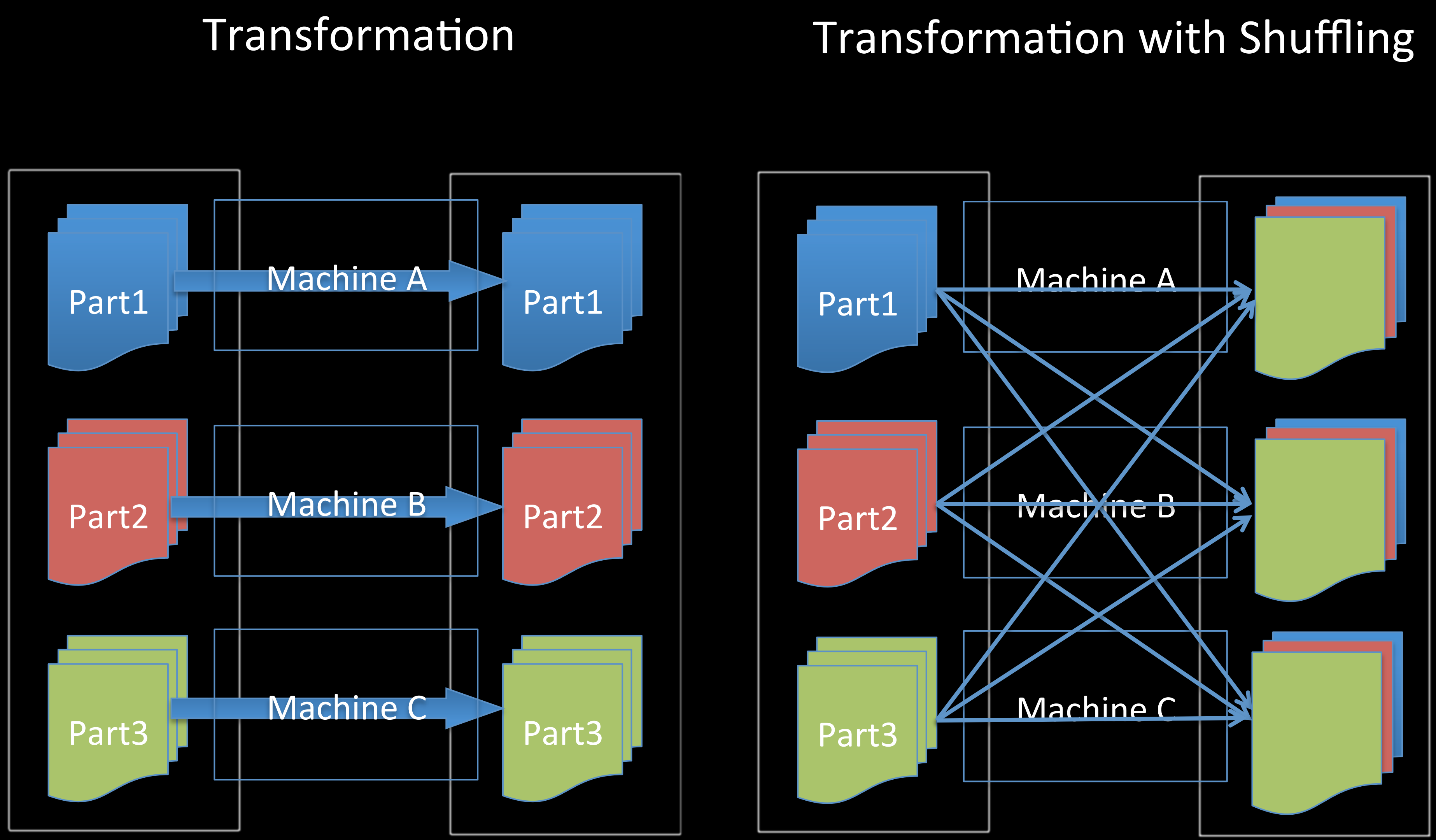
```
object WordCount {
 def main (args: Array[String]){
   val driver = "spark://192.168.0.3:7077"
   val sc = new SparkContext(driver, "SparkWordCount")
   val numPartitions = 10
   val lines = sc.textFile("here"+"sometext.txt", numPartitions)
   val words = lines.flatMap (_.split(" "))
   val groupWords = words.groupBy { x => x}
   val wordCount = groupWords.map( x => (x._1,x._2.size))
   val result = wordCount.saveAsTextFile("there"+"wordcount")
 }
}
```

Spark Application Framework

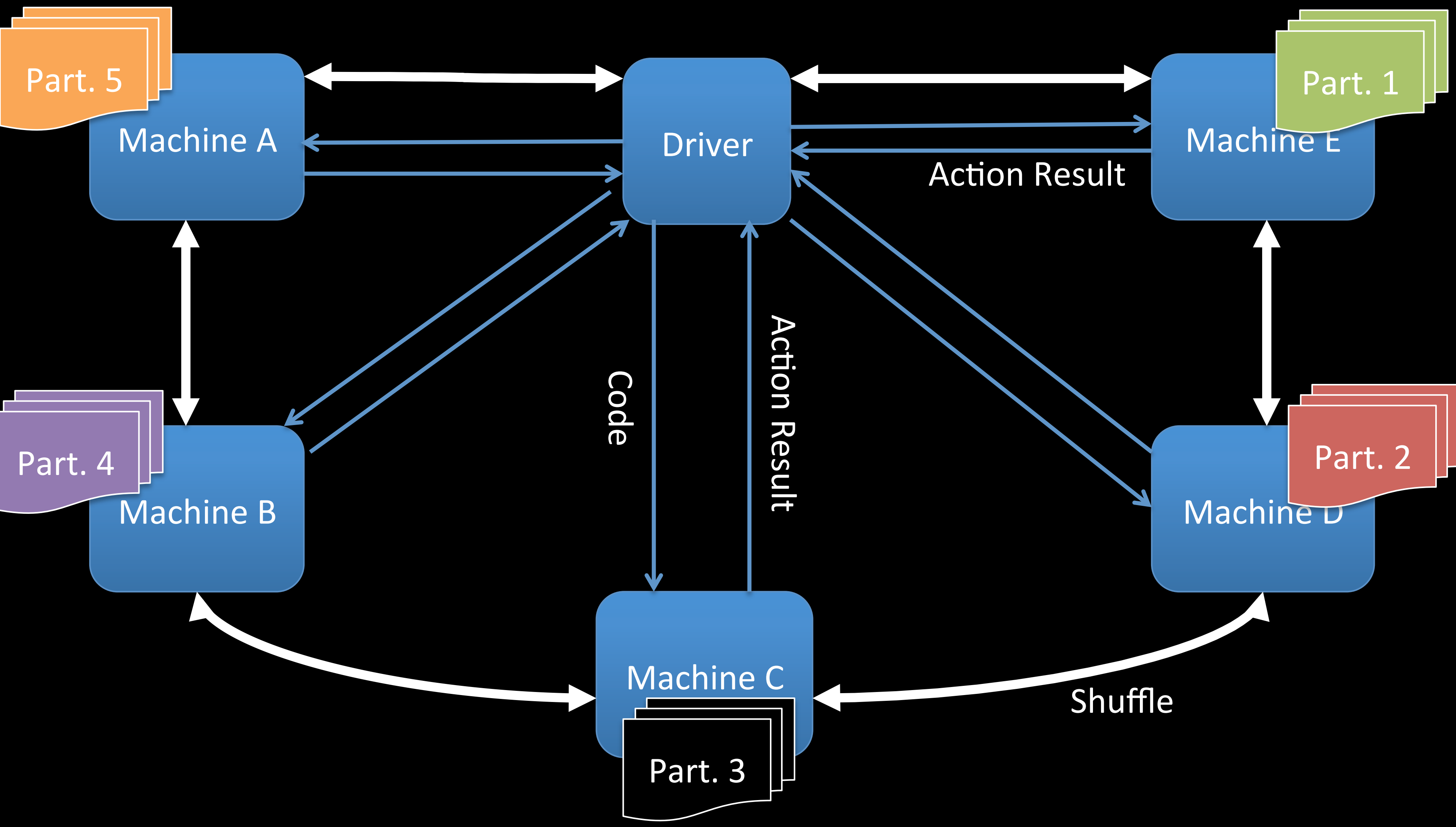
- SparkContext initializes the application driver and gives the application execution to the driver.
- RDD is generated from the external data sources; such as HDFS.
- RDD goes through a number of **Transformations**; such a Map, flatMap, sortByKey, etc.
- Finally, the count/collect/save/take **Action** is performed, which converts the final RDD into an output for storing to an external source.

Spark Application Framework

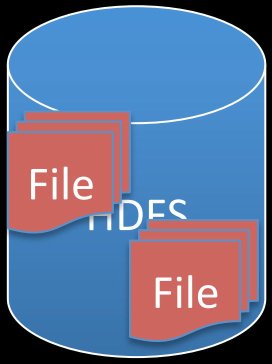



Transformation
Transformation with Shuffling
Machine A
Machine B
Machine C
Part1
Part2
Part3
Part1
Part2
Part3
Part1
Part2
Part3
Machine A
Machine B
Machine C

Spark Application Framework



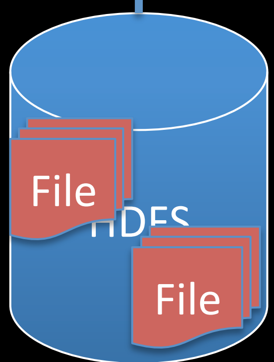
RDD is generated from the input file stored in HDFS



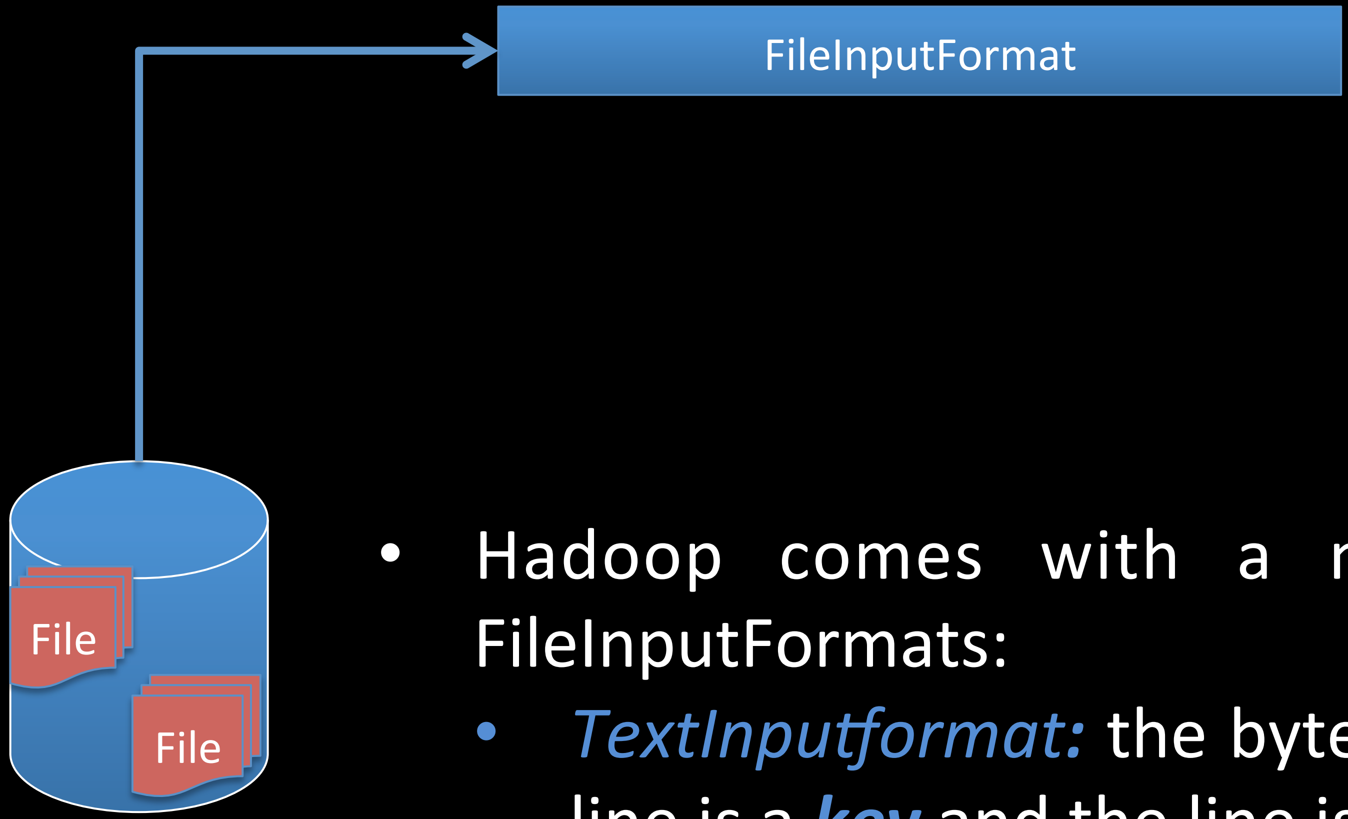
- This is where the data for a MapReduce task is initially stored and the files typically reside in HDFS.

- The format of these files; text and binary
  - Text – Single Line (JSON)
  - Multi-Line (XML)
  - Binary file, with fixed size objects

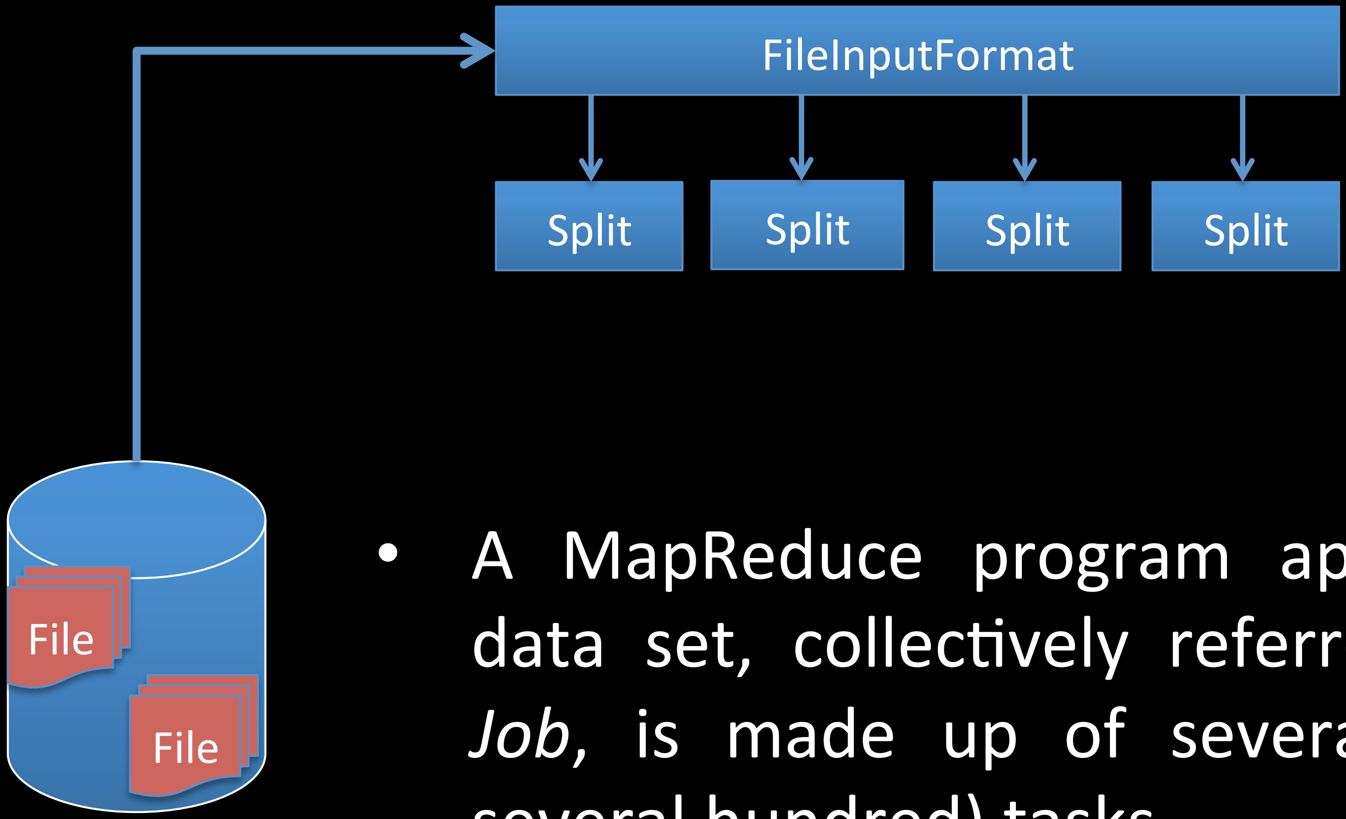
FileInputFormat



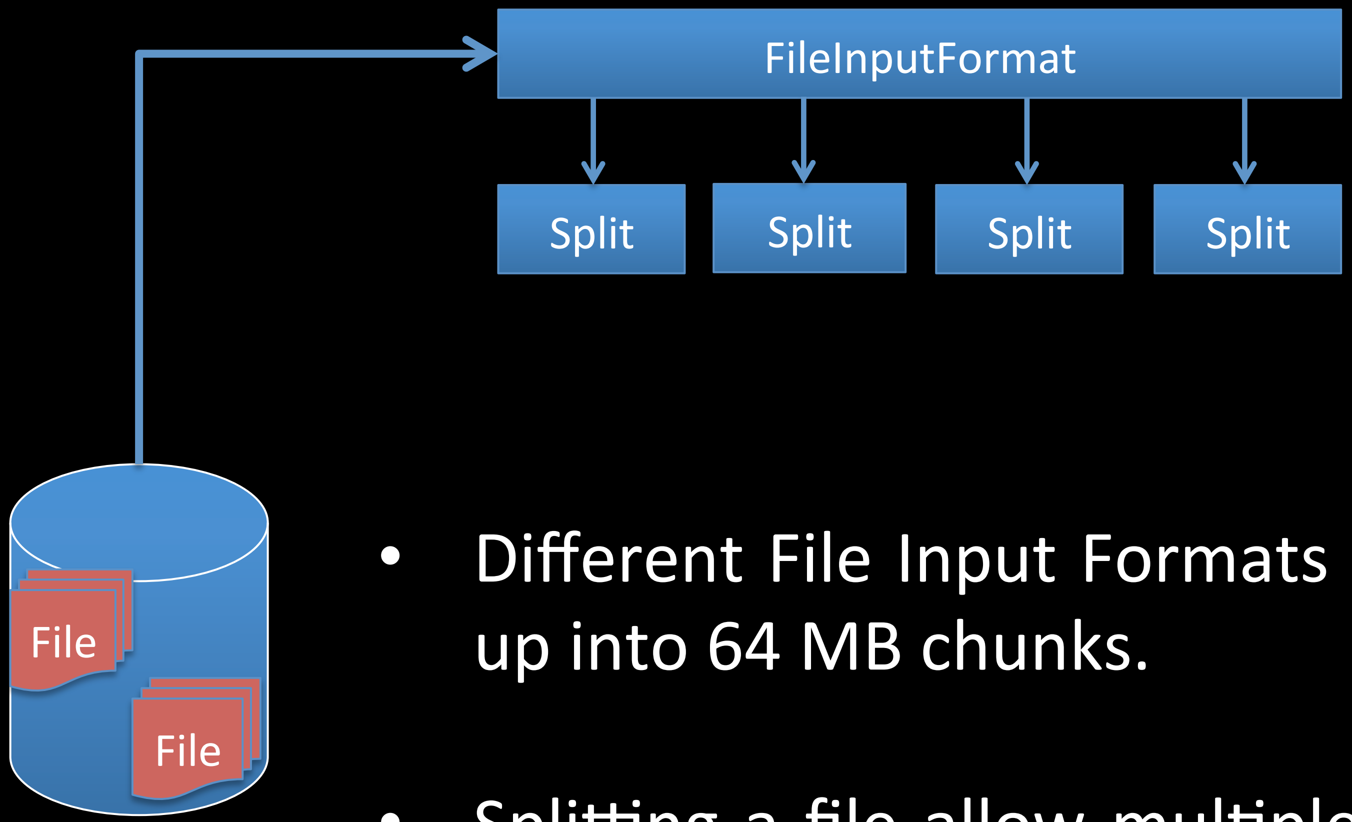
- ***FileInputFormat*** is a class that
  - Selects the files or other objects that should be used for input.
  - Defines the ***InputSplit***s that break a file into tasks.
  - Provides a factory for ***RecordReader*** objects that read the file.



- Hadoop comes with a number of FileInputFormats:
  - *TextInputformat:* the byte offset of a line is a ***key*** and the line is the ***value***.
  - *KeyValueInputFormat:* the text until the first tab is the key and the remaining is the value.
  - *SequenceFileInputFormat:* Object files. Key and values are defined by the user.



- A MapReduce program applied to a data set, collectively referred to as a *Job*, is made up of several (possibly several hundred) tasks.
- An InputSplit describes a unit of work that comprises a single *map task* in a MapReduce program.
- A Map tasks may involve reading a whole file; they often involve reading only part of a file.

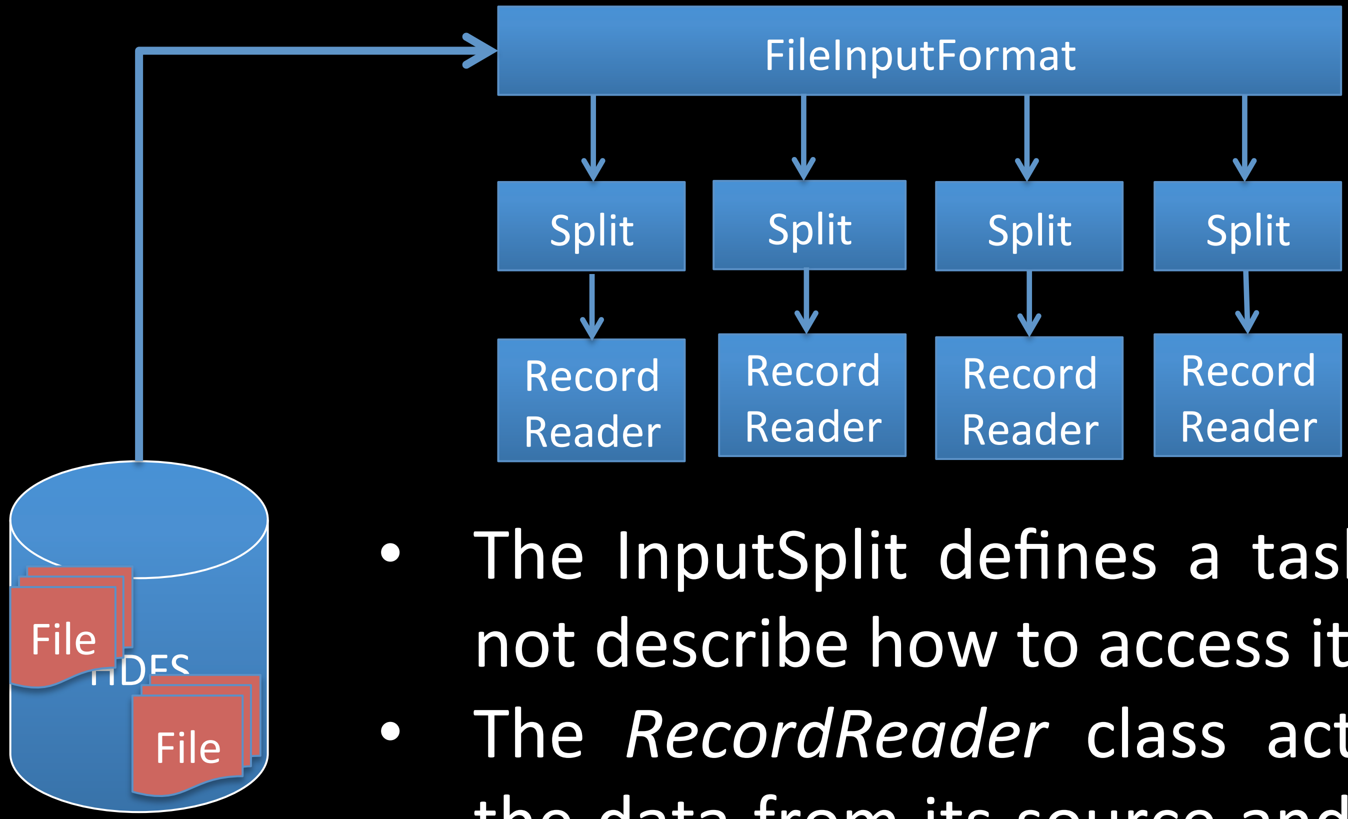


- Different File Input Formats break a file up into 64 MB chunks.

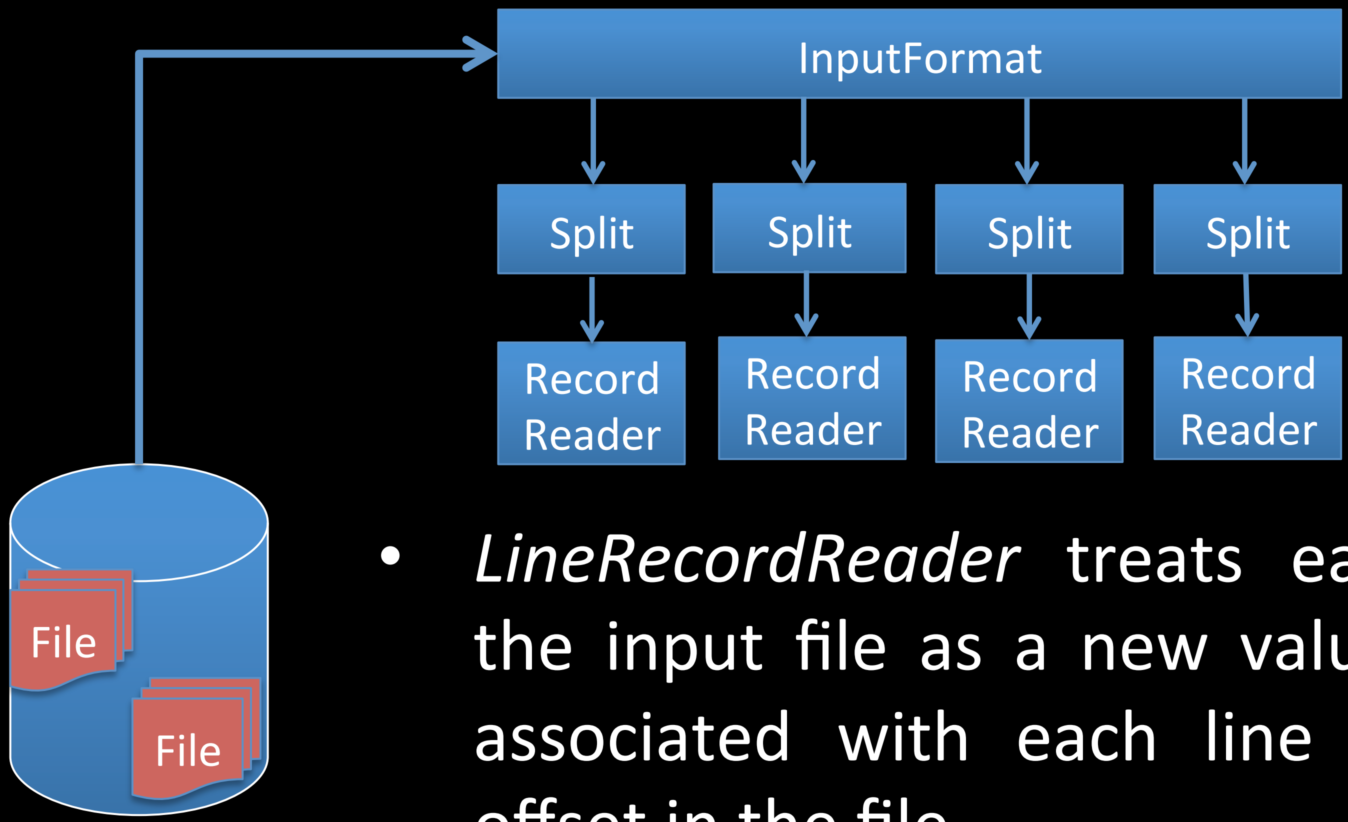
- Splitting a file allow multiple map tasks over a single file in parallel.

- If the file is very large, the performance can be improved significantly through such parallelism.

```
for (FileStatus file: files) {
    Path path = file.getPath();
    FileSystem fs = path.getFileSystem(job.getConfiguration());
    long length = file.getLen();
    BlockLocation[] blkLocations = fs.getFileBlockLocations(file, 0, length);
    if ((length != 0) && isSplitable(job, path)) {
      long blockSize = file.getBlockSize();
      long splitSize = computeSplitSize(blockSize, minSize, maxSize);
      long bytesRemaining = length;
      while (((double) bytesRemaining)/splitSize > SPLIT_SLOP) {
        int blkIndex = getBlockIndex(blkLocations, length-bytesRemaining);
        splits.add(new FileSplit(path, length-bytesRemaining, splitSize,
                      blkLocations[blkIndex].getHosts()));
        bytesRemaining -= splitSize;
      }
      if (bytesRemaining != 0) {
        splits.add(new FileSplit(path, length-bytesRemaining, bytesRemaining,
                  blkLocations[blkLocations.length-1].getHosts()));
      }
    } else if (length != 0) {
      splits.add(new FileSplit(path, 0, length, blkLocations[0].getHosts()));
    } else {
       splits.add(new FileSplit(path, 0, length, new String[0]));
    }
  }
```



- The InputSplit defines a task, but does not describe how to access it.
- The *RecordReader* class actually loads the data from its source and converts it into (key, value) pairs suitable for reading by the Mapper.



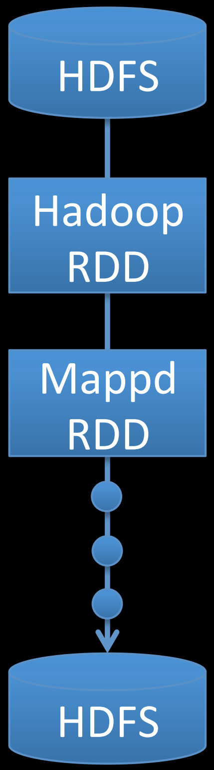
- *LineRecordReader* treats each line of the input file as a new value. The key associated with each line is its byte offset in the file.
- The RecordReader is invoke repeatedly until the entire InputSplit has been consumed.
- Each invocation of the RecordReader leads to another call to the map() method of the Mapper.

Mahout XMLRecordReader

```
public XmlRecordReader(FileSplit split,
JobConf jobConf) throws IOException
{
	startTag = jobConf.get(”<article>").
		getBytes("utf-8");
	endTag = jobConf.get(”<article>”).
		getBytes("utf-8");
	start = split.getStart();
	end = start + split.getLength();
	Path file = split.getPath();
	FileSystem fs =
	file.getFileSystem(jobConf);
	fsin = fs.open(split.getPath());
	fsin.seek(start);
}
```

```
public boolean next(LongWritable key, Text
value) throws IOException {
if (fsin.getPos() < end) {
	if (readUntilMatch(startTag, false)) {
	  try {
		buffer.write(startTag);
		if (readUntilMatch(endTag, true)) {
		  key.set(fsin.getPos());
		  value.set(buffer.getData(), 0,
buffer.getLength());
			return true;
			}

		} finally {buffer.reset();}
	  }
	}
	return false;
}
```


HDFS
Hadoop RDD
Mappd RDD
HDFS

RDD goes through a number of Transformations

Spark Application

```
object WordCount {
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    val sc = new SparkContext(driver, "SparkWordCount")
    val numPartitions = 10
    val lines = sc.textFile("here"+"sometext.txt", numPartitions)
    val words = lines.flatMap (_.split(" "))
    val groupWords = words.groupBy { x => x}
    val wordCount = groupWords.map( x => (x._1,x._2.size))
    val result = wordCount.saveAsTextFile("there"+"wordcount")
  }
}
```

Spark Application Execution

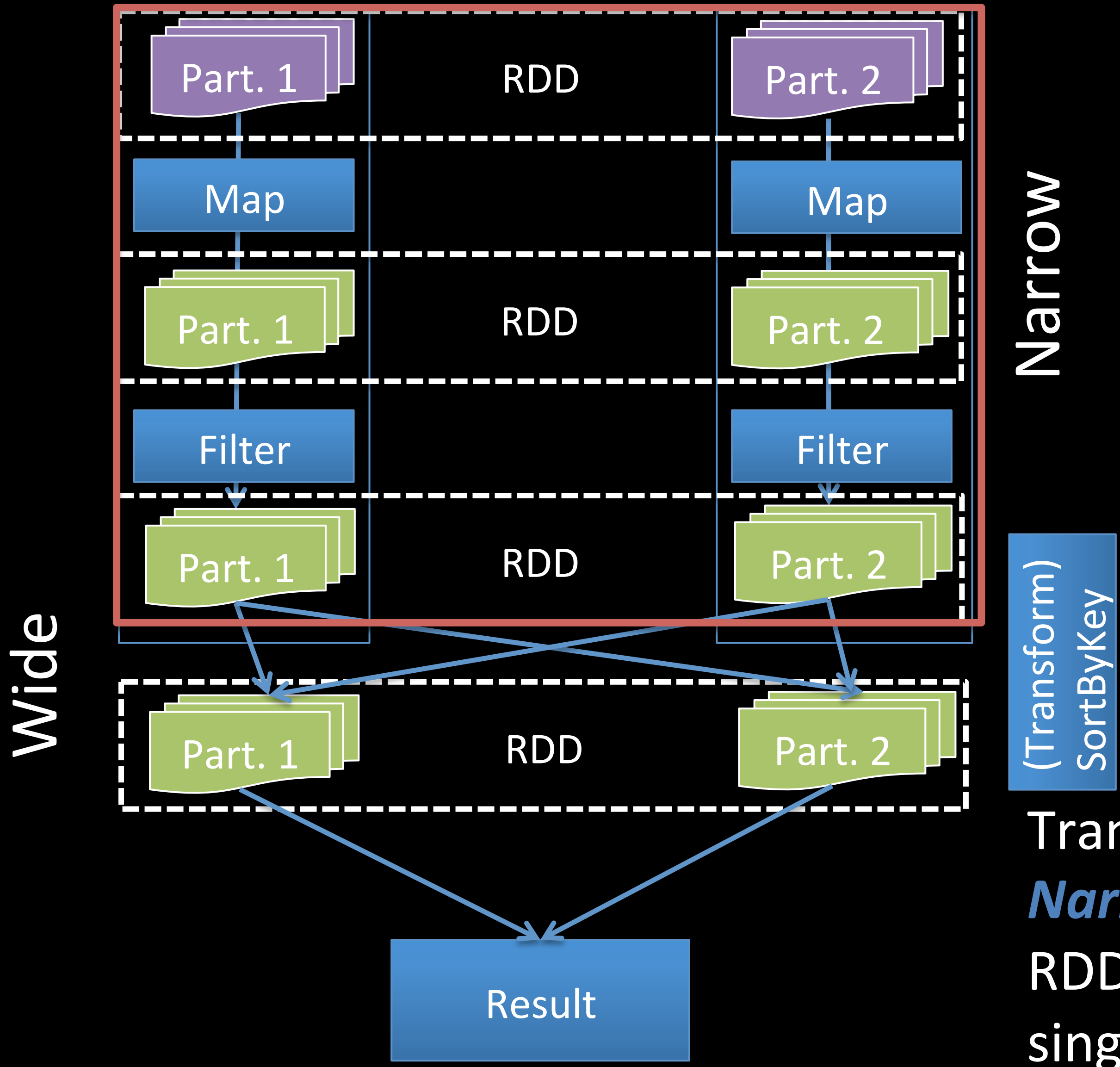
- How does the spark submit the job to the worker?
  - (1) Map, (2) flatMap, (2) groupBy, (3) Map, Or
  - (1) Map ->flatMap, (2) groupBy, (3) Map

- How Many tasks per submission?
- Before submitting tasks of a job, how does the driver know about the resource information of the workers?

How does the spark submit the job to the workers?

DAG Scheduler

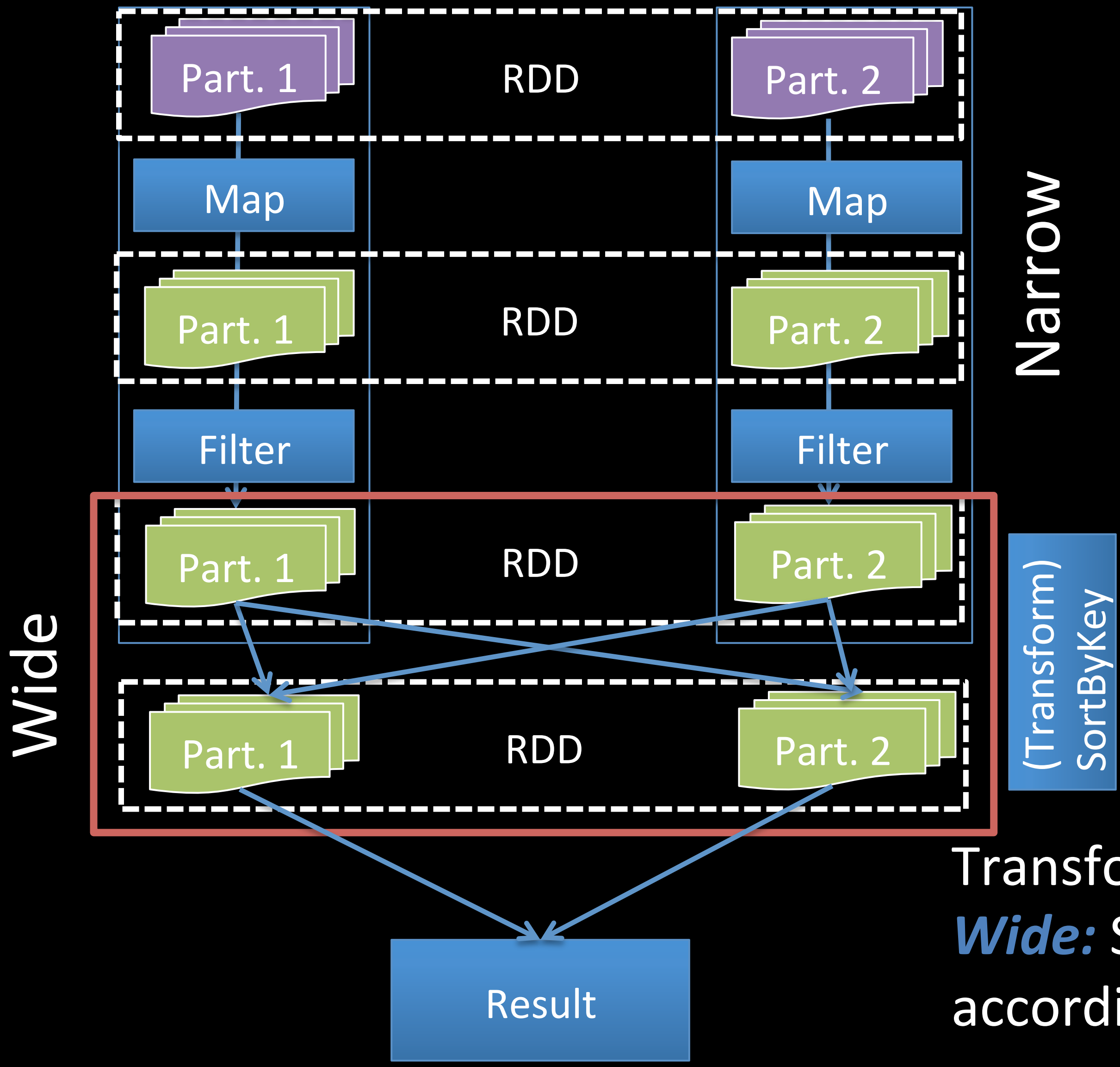
DAG Scheduler



Transformation

Narrow : All partitions of an RDD will be consumed by a single child RDD , no shuffling.

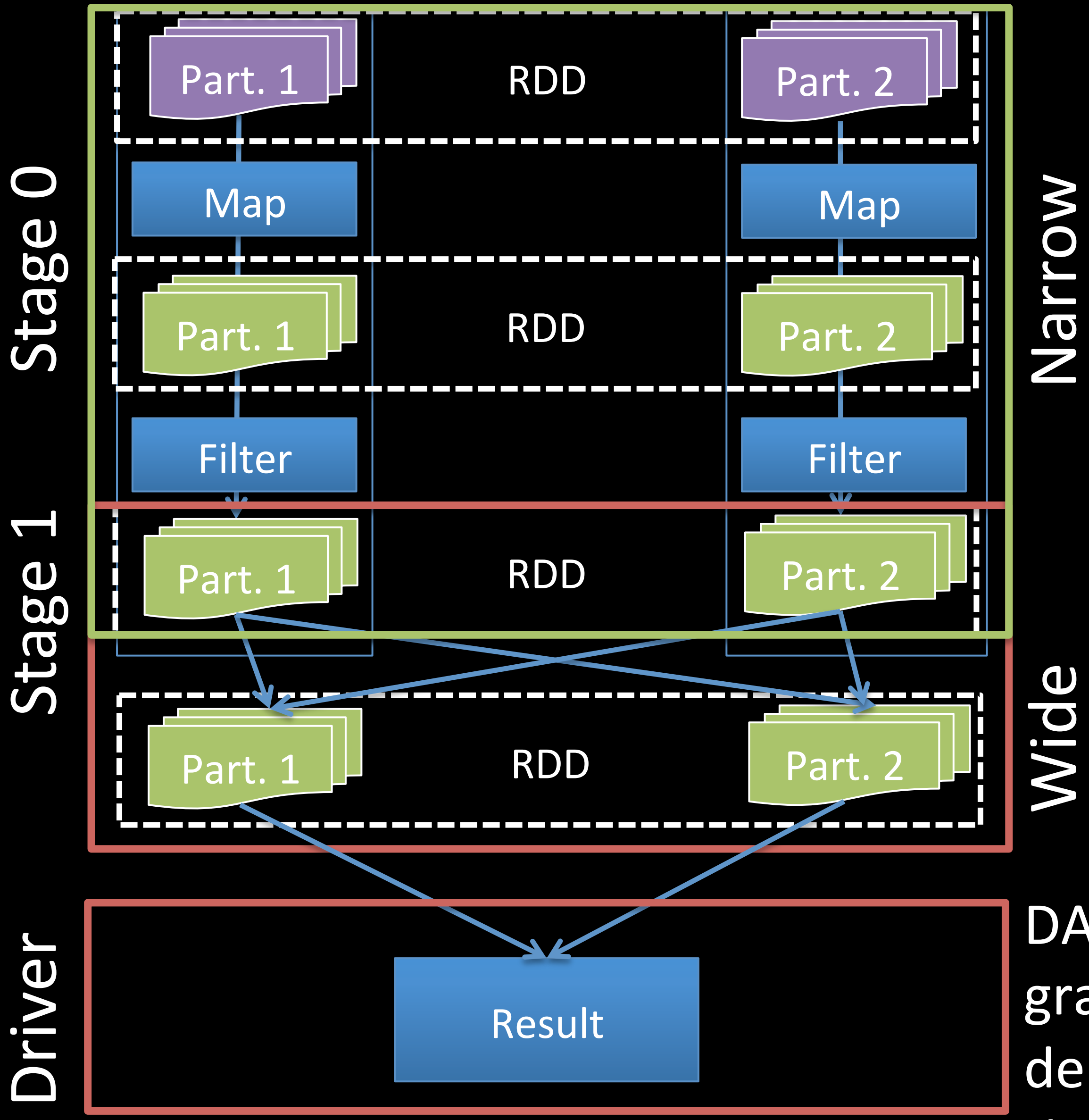
DAG Scheduler



Transformation

Wide: Shuffling takes place according to their key value.

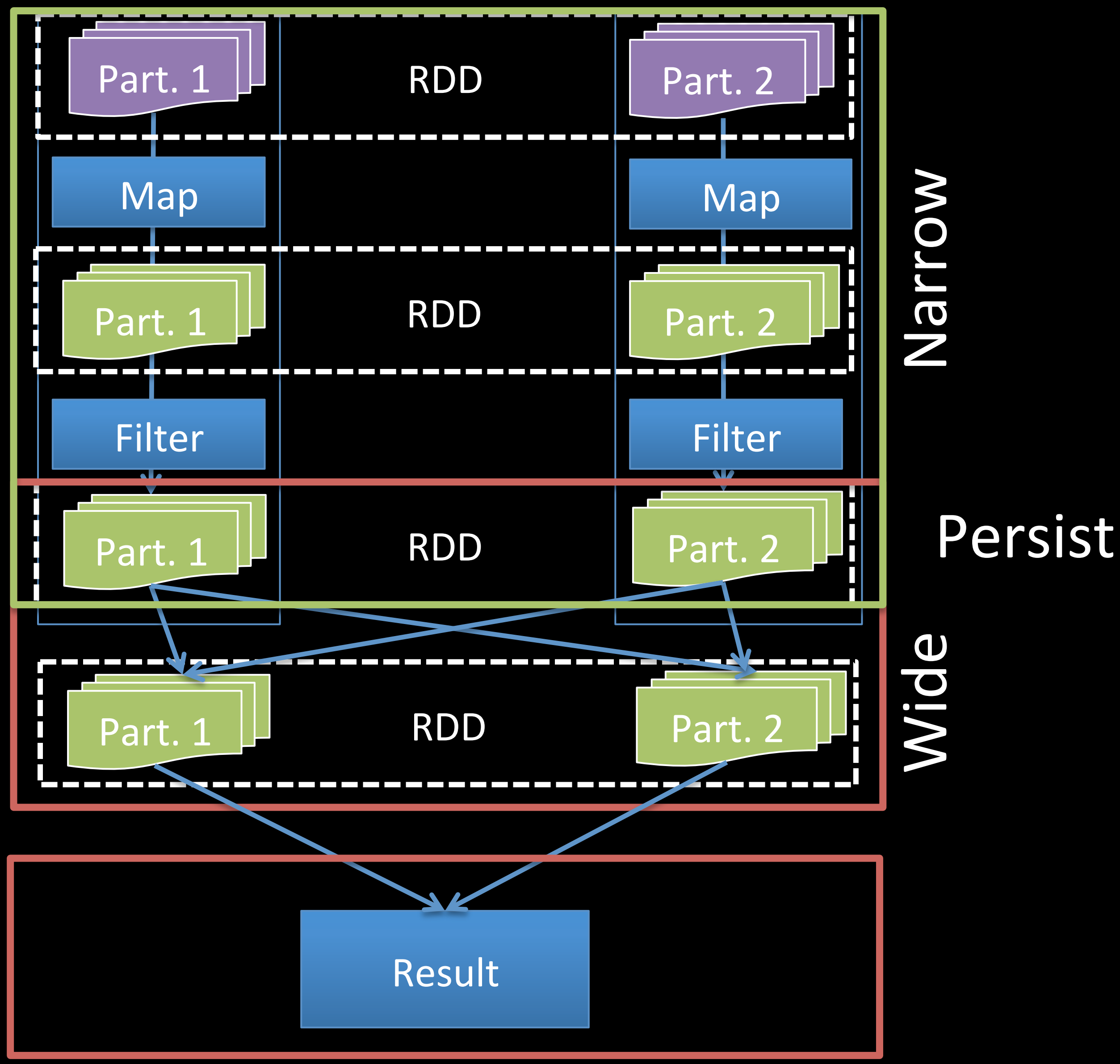
DAG Scheduler



DAG Scheduler Splits the graph according to the dependency and submits to the lower layer Scheduler.

DAG serves Fault tolerance

- If a partition is lost while executing a stage consisting of transformations with Narrow dependencies
  - It traces back and re-computes only the lost partition of the parent RDD, and
  - The responsible machine will take care.
- In the case of Wide dependencies, the lost partition can affect a lot of others
  - Spark mitigates this my persisting the last computed partitions before the shuffling takes place.
- There is also checkpoint API which enables to persist RDD on desired transformation.



Part. 1
RDD
Part. 2
Map
Map
Part. 1
RDD
Part. 2
Filter
Filter
Part. 1
RDD
Part. 2
Part. 1
RDD
Part. 2
Result
Narrow
Persist
Wide

DAG Scheduler

INFO [Executor task launch worker-1] (Logging.scala:59) - Input split: file:/data/mmbrain/2015/inputJson/group5/part-dp:939524096+33554432
INFO [task-result-getter-3] (Logging.scala:59) - Finished task 27.0 in **stage 0.0** (TID 27) in 2455 ms on localhost (28/43)
INFO [Executor task launch worker-1] (Logging.scala:59) - Finished task 28.0 in stage 0.0 (TID 28). 4565 bytes result sent to driver
INFO [sparkDriver-akka.actor.default-dispatcher-2] (Logging.scala:59) - Starting task 29.0 in stage 0.0 (TID 29, localhost, PROCESS_LOCAL, 1650 byte
INFO [Executor task launch worker-1] (Logging.scala:59) - Running task 29.0 in stage 0.0 (TID 29)

INFO [Executor task launch worker-1] (Logging.scala:59) - Input split: file:/data/mmbrain/2015/inputJson/group5/part-dp:973078528+33554432
INFO [task-result-getter-0] (Logging.scala:59) - Finished task 28.0 in stage 0.0 (TID 28) in 2084 ms on localhost (29/43)
INFO [Executor task launch worker-1] (Logging.scala:59) - Finished task 29.0 in stage 0.0 (TID 29). 4728 bytes result sent to driver
INFO [sparkDriver-akka.actor.default-dispatcher-2] (Logging.scala:59) - Starting task 30.0 in stage 0.0 (TID 30, localhost, PROCESS_LOCAL, 1650 byte

INFO [Executor task launch worker-1] (Logging.scala:59) - Running task 9.0 in **stage 1.0** (TID 52)
INFO [Executor task launch worker-1] (Logging.scala:59) - Partition rdd_9_9 not found, computing it
INFO [Executor task launch worker-1] (Logging.scala:59) - Input split: file:/data/mmbrain/2015/inputJson/group5/part-dp:301989888+33554432
INFO [Executor task launch worker-1] (Logging.scala:59) - ensureFreeSpace(16880) called with curMem=471734, maxMem=4123294433
INFO [Executor task launch worker-1] (Logging.scala:59) - Block rdd_9_9 stored as values in memory (estimated size 16.5 KB, free 3.8 GB)
INFO [sparkDriver-akka.actor.default-dispatcher-14] (Logging.scala:59) - Added rdd_9_9 in memory on localhost:43449 (size: 16.5 KB, free: 3.8 GB)
INFO [Executor task launch worker-1] (Logging.scala:59) - Updated info of block rdd_9_9

How Many tasks per Stage?

Number of Tasks

- Number of InputSplit defines the number of tasks.
  - Hadoop FileInputFormat defines
  - Immediate Narrow transformations will follow the parent
- If GroupBy is used
  - The number of keys define the number of tasks

Control Number of Tasks

```
object WordCount {
  def main (args: Array[String]){
    val driver = "spark://192.168.0.3:7077"
    val sc = new SparkContext(driver, "SparkWordCount")
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    val words = lines.flatMap (_.split(" "))
    val groupWords = words.groupBy { x => x}
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    val result = wordCount.saveAsTextFile("there"+"wordcount")
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```
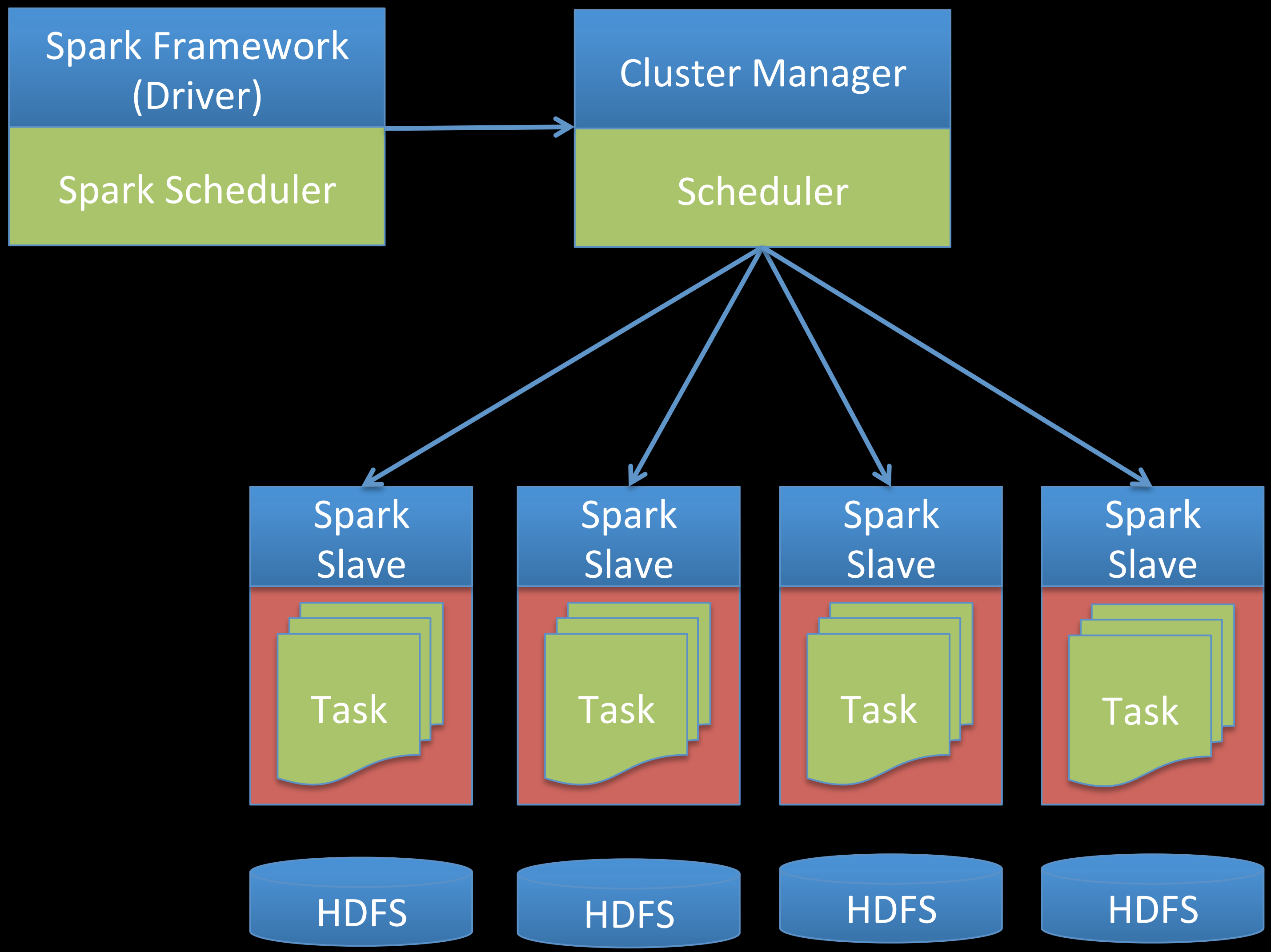

Control Number of Tasks

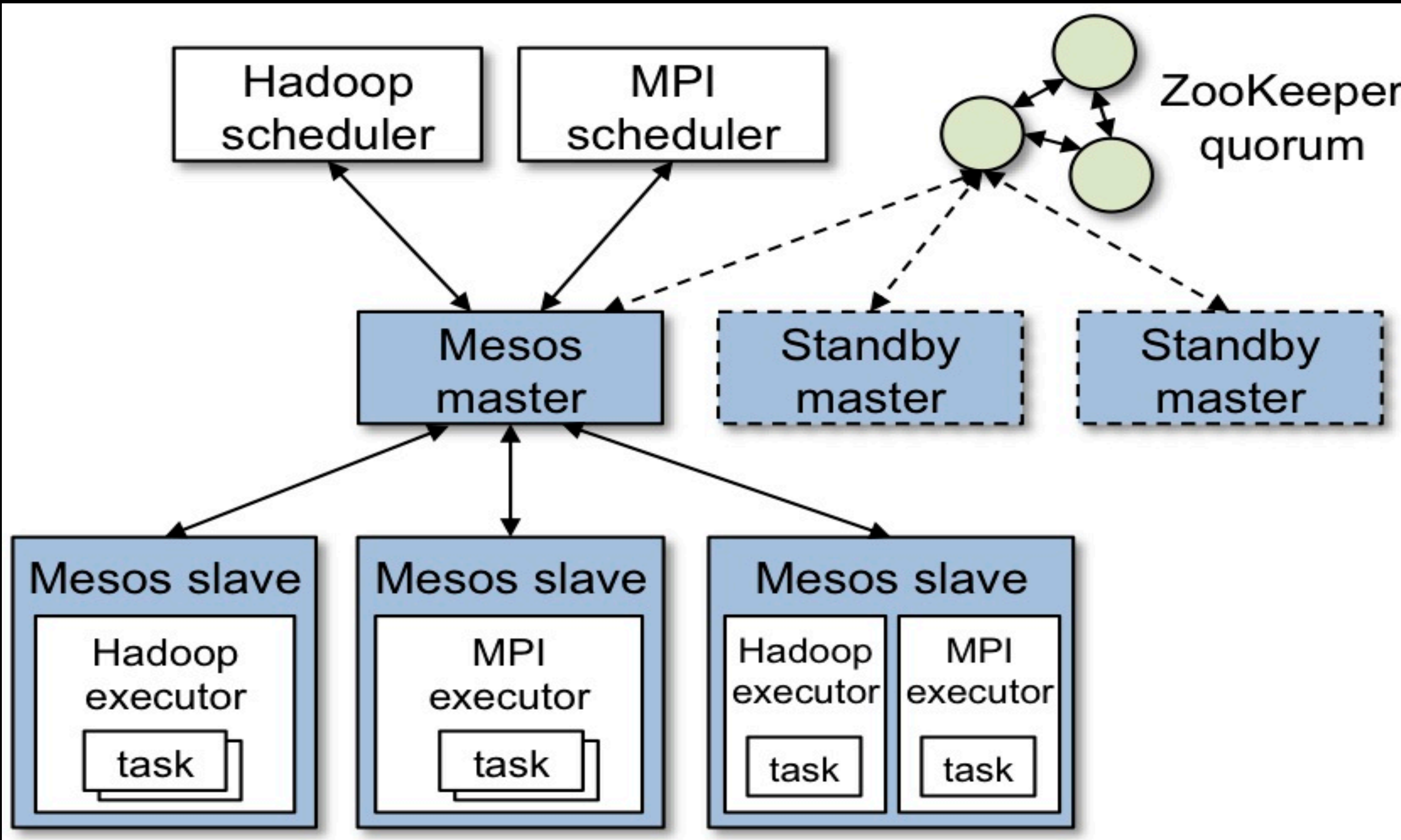
```
object WordCount {
  def main (args: Array[String]){
    val driver = "spark://192.168.0.3:7077"
    val sc = new SparkContext(driver, "SparkWordCount")
    val numPartitions = 10
    val lines = sc.textFile("here"+"sometext.txt", numPartitions).coalesce(numPartitions)
    val words = lines.flatMap (_.split(" "))
    val groupWords = words.groupBy { x => x}
    val wordCount = groupWords.map( x => (x._1,x._2.size))
    val result = wordCount.saveAsTextFile("there"+"wordcount")
  }
}
```

How does the driver know about the resource information of the workers?

Spark Application Framework



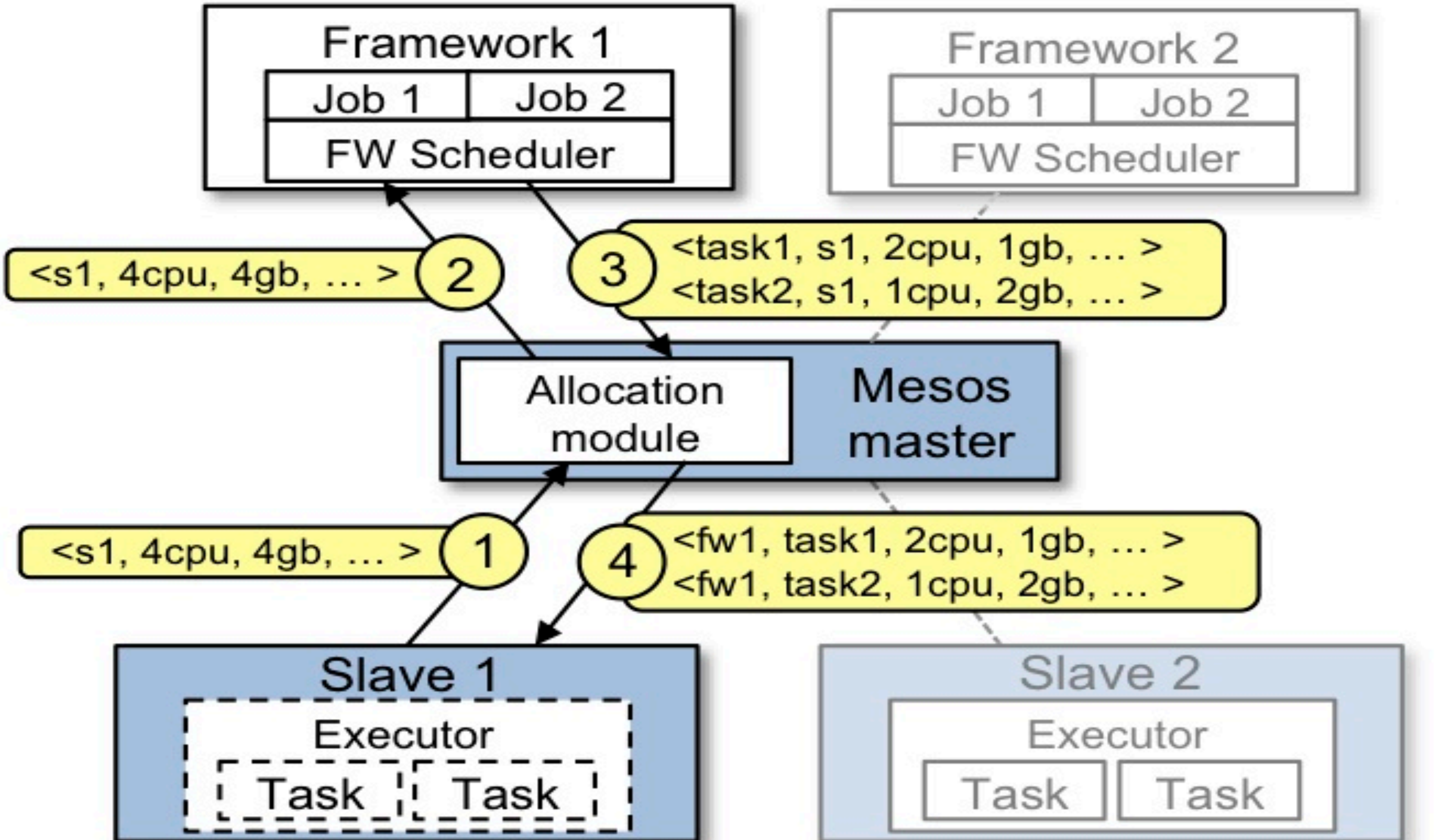
MESOS Architecture



Resource Allocation Example

- Slave 1 reports to the master that it has 4 CPUs and 4 GB of memory free.
- The master then invokes the allocation policy module, which tells it that framework 1 should be offered all available resources.
- The master sends a resource offer describing what is available on slave 1 to framework 1.
- The framework's scheduler replies to the master with information about two tasks to run on the slave, using <2 CPUs, 1 GB RAM> for the first task, and <1 CPUs, 2 GB RAM> for the second task.

Resource Allocation Example



Resource Allocation Example

- Finally, the master sends the tasks to the slave, which allocates appropriate resources to the framework's executor, which in turn launches the two tasks (depicted with dotted-line borders in the figure). Because 1 CPU and 1 GB of RAM are still unallocated, the allocation module may now offer them to framework 2.
- Again the steps are repeated when some tasks are finished or resources become available.

Resource Allocation Example

- For example, how can a framework achieve data locality without MESOS knowing which nodes store the data required by the framework?
  - MESOS answers these questions by simply giving frameworks the ability to **reject** offers. A framework will reject the offers that do not satisfy its constraints and accept the ones that do.