Cutting through the Hype

- Massive and growing amount of data collected
- Moore's law => cost of compute, disk, RAM decreasing rapidly
- But data still growing faster than single-node performance can handle
- Factors:
  - *ease of collection*
  - *cost of storage*
  - *web*
  - *mobile / wearables*
  - *IoT*
  - *science (CERN, SKA)*

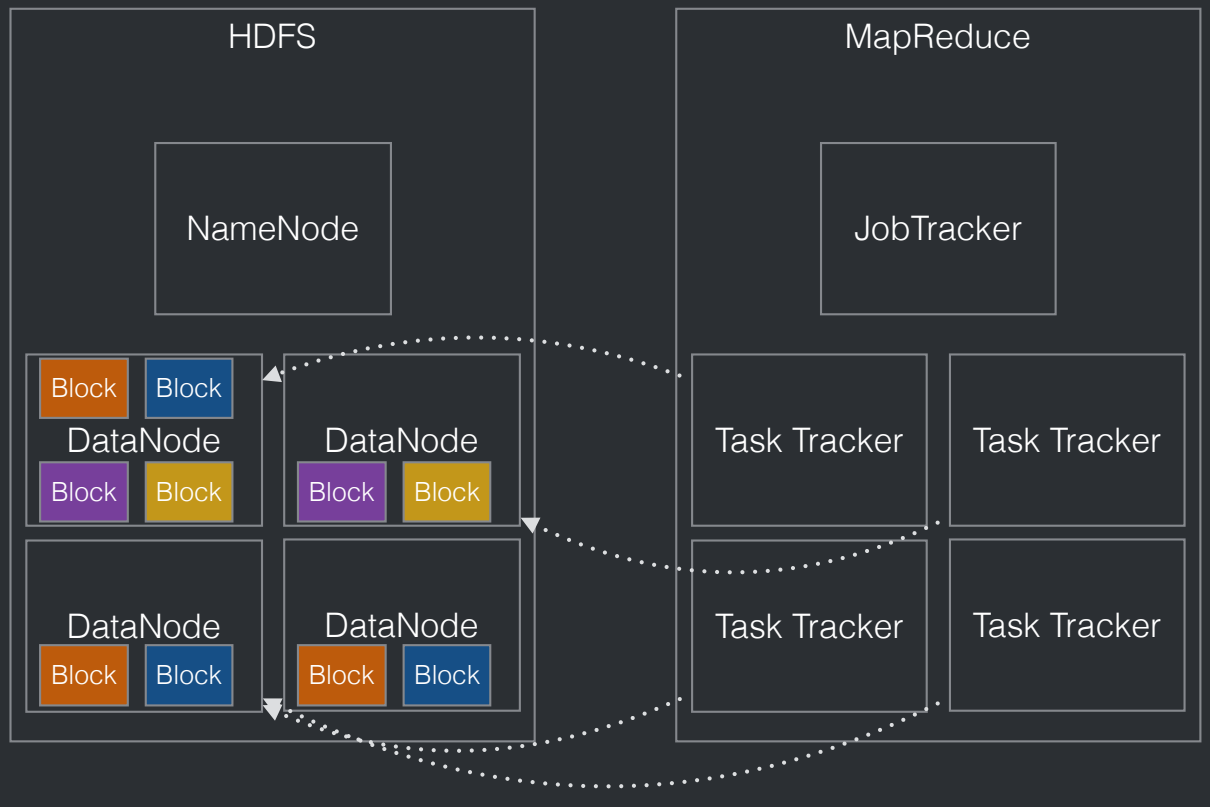
Herding Elephants - Hadoop

- Google was doing big data before it was cool…
- Google File System Paper (2003) -> Apache Hadoop Distributed Filesystem (HDFS)
- Google MapReduce Paper (2004) -> Apache Hadoop MapReduce
- BigTable (2006) -> Apache HBase
- Dremel (2010) -> Apache Drill (and others)

Herding Elephants - Hadoop

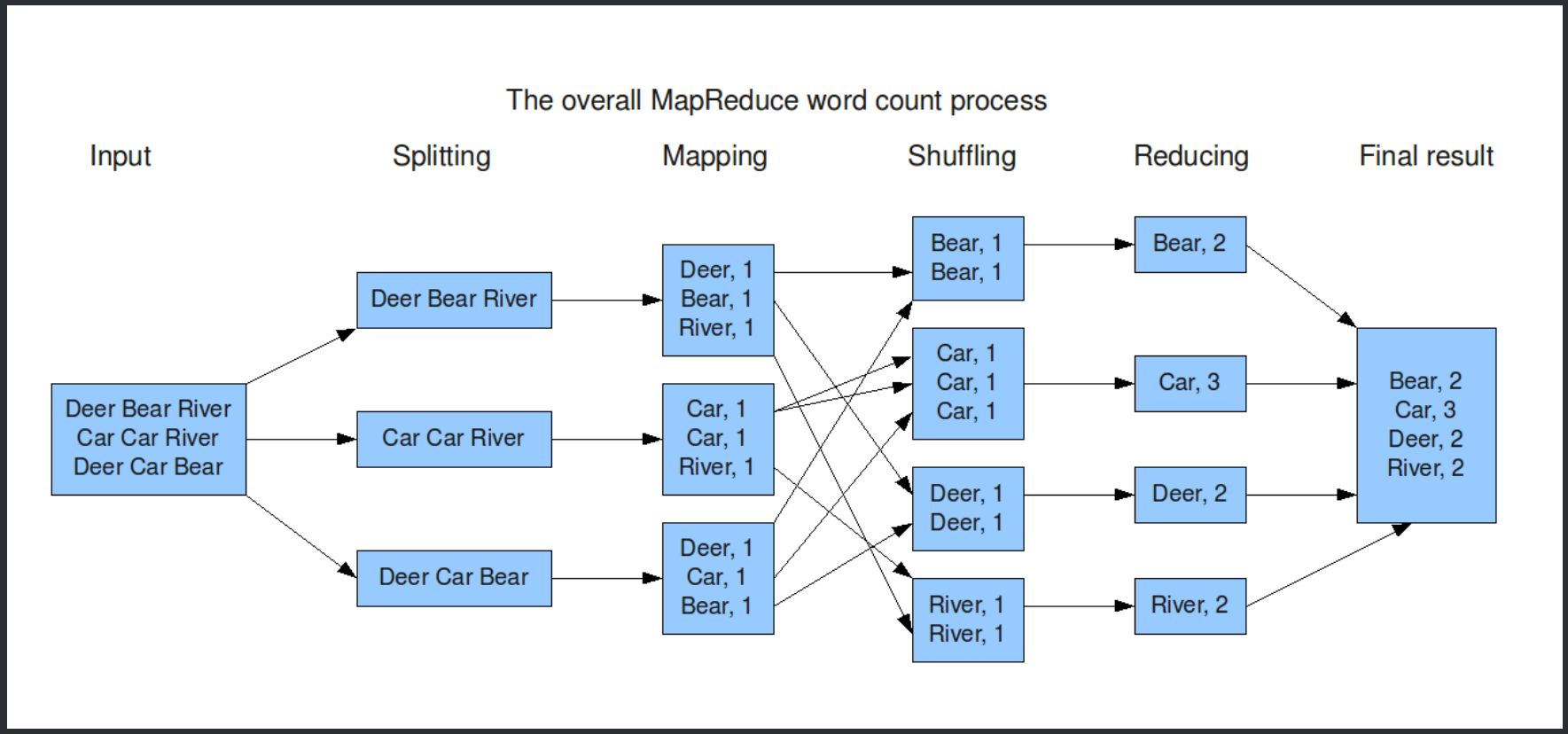
- Hadoop started at Yahoo
- Open sourced -> Apache Hadoop
- Spawned Cloudera, MapR, Hortonworks… and an entire big data industry
- Old scaling == vertical, big tin
- New scaling == horizontal, shared nothing, data parallel, commodity hardware, embrace failure!

Herding Elephants - Hadoop



- HDFS
  - *Replication*
  - *Fault tolerance*
- Map Reduce
  - *Data locality*
  - *Fault tolerance*

MapReduce


The overall MapReduce word count process
Input
Splitting
Mapping
Shuffling
Reducing
Final result
Deer Bear River
Car Car River
Deer Car Bear
Deer Bear River
Car Car River
Deer Car Bear
Deer, 1
Bear, 1
River, 1
Car, 1
Car, 1
River, 1
Deer, 1
Car, 1
Bear, 1
Bear, 1
Bear, 1
Car, 1
Car, 1
Car, 1
Deer, 1
Deer, 1
River, 1
River, 1
Bear, 2
Car, 3
Deer, 2
River, 2
Bear, 2
Car, 3
Deer, 2
River, 2

MapReduce: Counting Words

- “Hadoop is a distributed system for counting words” (Scalding GitHub)
- Map

```
public class WordCount {

 public static class Map extends Mapper<LongWritable, Text, Text, IntWritable> {
    private final static IntWritable one = new IntWritable(1);
    private Text word = new Text();

    public void map(LongWritable key, Text value, Context context) throws
IOException, InterruptedException {
        String line = value.toString();
        StringTokenizer tokenizer = new StringTokenizer(line);
        while (tokenizer.hasMoreTokens()) {
            word.set(tokenizer.nextToken());
            context.write(word, one);
        }
    }
```

MapReduce: Counting Words

- Reduce

```
public static class Reduce extends Reducer<Text, IntWritable, Text, IntWritable> {

   public void reduce(Text key, Iterable<IntWritable> values, Context context)
     throws IOException, InterruptedException {
       int sum = 0;
       for (IntWritable val : values) {
           sum += val.get();
       }
       context.write(key, new IntWritable(sum));
   }
}
```

MapReduce: Counting Words

- Job Setup

```
public static void main(String[] args) throws Exception {
   Configuration conf = new Configuration();

       Job job = new Job(conf, "wordcount");

   job.setOutputKeyClass(Text.class);
   job.setOutputValueClass(IntWritable.class);

   job.setMapperClass(Map.class);
   job.setReducerClass(Reduce.class);

   job.setInputFormatClass(TextInputFormat.class);
   job.setOutputFormatClass(TextOutputFormat.class);

   FileInputFormat.addInputPath(job, new Path(args[0]));
   FileOutputFormat.setOutputPath(job, new Path(args[1]));

   job.waitForCompletion(true);
```

MapReduce Streaming: Counting Words with Python

- Map

```
# input comes from STDIN (standard input)
for line in sys.stdin:
   # remove leading and trailing whitespace
   line = line.strip()
   # split the line into words
   words = line.split()
   # increase counters
   for word in words:
      # write the results to STDOUT (standard output);
      # what we output here will be the input for the
      # Reduce step, i.e. the input for reducer.py
      #
      # tab-delimited; the trivial word count is 1
      print '%s\t%s' % (word, 1)
```

https://gist.github.com/josephmisiti/3336891

MapReduce Streaming: Counting Words with Python

- Reduce

```
# input comes from STDIN
for line in sys.stdin:
   …
   # parse the input we got from mapper.py
   word, count = line.split('\t', 1)
   …
   # this IF-switch only works because Hadoop sorts map output
   # by key (here: word) before it is passed to the reducer
   if current_word == word:
      current_count += count
   else:
      if current_word:
         # write result to STDOUT
         print '%s\t%s' % (current_word, current_count)
   …
```

https://gist.github.com/josephmisiti/3336897

MapReduce Streaming: Counting Words with Python

- Job Setup

```
hadoop jar /…/streaming/hadoop-*streaming*.jar \
        -file /path/to/mapper.py \
        -mapper /path/to/mapper.py \
        -file /path/to/reducer.py \
        -reducer /path/to/reducer.py \
        -input /path/to/input/* \
        -output /path/to/output
```

With thanks to Joseph Misiti:
https://medium.com/cs-math/a-simple-map-reduce-word-counting-example-using-hadoop-1-0-3-and-python-streaming-1a9e00c7f4b4

https://gist.github.com/josephmisiti/3336977

Hadoop Issues

- Pros
  - Reliable in face of failure (*will* happen at scale) - disk, network, node, rack …
  - Very scalable: ~40,000 nodes at Yahoo!
- Cons
  - Disk I/O for every job
  - Unwieldy API (hence Cascading, Scalding, Crunch, Hadoopy …)
  - Very hard to debug - especially Streaming jobs 😱

So Why Spark?

- **In-memory** caching == fast!
- Broadcast variables and accumulator primitives built-in
- Resilient Distributed Datasets (RDD) - recomputed on the fly in case of failure
- **Hadoop compatible**
- Rich, functional API in **Scala**, **Python**, **Java** and **R**
- One platform for multiple use cases:
  - Shark / SparkSQL - **SQL** on Spark
  - Spark **Streaming** - Real time processing
  - **Machine Learning** - MLlib
  - **Graph Processing** - GraphX

Spark Word Count

- Power of functional constructs and the Python language

```
file = spark.textFile("hdfs://...")
counts = file.flatMap(lambda line: line.split(" ")) \
             .map(lambda word: (word, 1)) \
             .reduceByKey(lambda a, b: a + b)
counts.saveAsTextFile("hdfs://...")
```

- Same code locally or on a cluster

```
sparkLocal = SparkContext(“local[4]”, “Local 4 Threads”)
sparkOnCluster = SparkContext(“spark://...:7077”,
                              “Cluster of 1000 Nodes”)
```

Functional API

- Functional Python

```
lines = open(“somefile").readlines()
words = [(word, 1) for line in lines for word in line.split(" ")]
counts = [(key, len(list(group))) for key, group in
      groupby(sorted(counts, key=lambda x: x[0]), lambda x: x[0])]
```

- Functional PySpark

```
counts = file.flatMap(lambda line: line.split(" ")) \
              .map(lambda word: (word, 1)) \
              .reduceByKey(lambda a, b: a + b)
```

Spark Machine Learning

- Caching data in memory allows subsequent iterations to be faster

```
points = spark.textFile(...).map(parsePoint).cache()
w = numpy.random.rand(D) # initial weight vector
for i in range(100):
  gradient = points.map(lambda p:
    (1 / (1 + exp(-p.y*(w.dot(p.x)))) - 1) * p.y * p.x
  ).reduce(lambda a, b: a + b)
  w -= gradient
```

- Python and NumPy allow concise code, closer to the actual maths!

Plugging in Python Libraries

- Such as scikit-learn

```
from sklearn import linear_model as lm

# init stochastic gradient descent
sgd = lm.SGDClassifier(loss='log')
# training
for i in range(100):
  sgd = sc.parallelize(data, numSlices=slices) \
          .mapPartitions(lambda x: train(x, sgd)) \
          .reduce(lambda x, y: merge(x, y))
  sgd = avg_model(sgd, slices) # averaging weight vector
```

SparkSQL

- SparkSQL

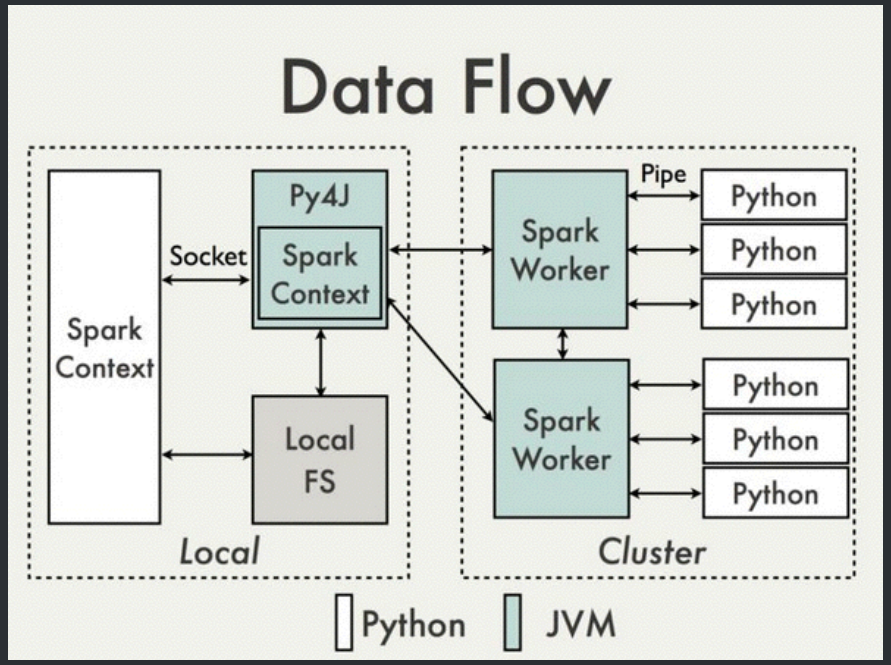
```
events = rdd.map(lambda row: Row(time = row[0], event=row[1], …))

# complex join and filter in Spark
...

schema = sqlContext.inferSchema(events)
events.registerTempTable('events')
val aggs = sql(“select
               from_unixtime(cast(time/1000.0 as bigint), 'yyyy-MM-dd HH:00:00') hour,
               event,
               count(1)
             from events …”)

# aggs is a normal PySpark RDD, with all the normal operations available
aggs.map( … )
...
```

PySpark Internals



- Python driver
  - *Py4J: Python <-> Java*
  - *Large data transfer through filesystem rather than socket*
- Workers
  - *Launch Python subprocesses*
  - *Functions pickled and shipped to workers*
  - *Bulk pickling optimizations*
  - *Works in console - IPython FTW!*

https://cwiki.apache.org/confluence/display/SPARK/PySpark+Internals

PySpark Internals

- Still quite a lot slower than Scala / Java :-(
  - … but improving all the time
- Not quite feature-parity with Scala / Java …
  - … but almost
  - e.g. PySpark Streaming PR: https://github.com/apache/spark/pull/2538
- Python 1st class citizen!