Spark and Shark

High-Speed In-Memory Analytics over Hadoop and Hive Data

Matei Zaharia, in collaboration with
Mosharaf Chowdhury, Tathagata Das, Ankur Dave, Cliff Engle, Michael Franklin, Haoyuan Li, Antonio Lupher, Justin Ma, Murphy McCauley, Scott Shenker, Ion Stoica, Reynold Xin

UC Berkeley

spark-project.org

amplab UC BERKELEY

What is Spark?

Not a modified version of Hadoop

Separate, fast, MapReduce-like engine

- In-memory data storage for very fast iterative queries
- General execution graphs and powerful optimizations
- Up to 40x faster than Hadoop

Compatible with Hadoop's storage APIs

- Can read/write to any Hadoop-supported system, including HDFS, HBase, SequenceFiles, etc

What is Shark?

Port of Apache Hive to run on Spark

Compatible with existing Hive data, metastores, and queries (HiveQL, UDFs, etc)

Similar speedups of up to 40x

Project History

Spark project started in 2009, open sourced 2010

Shark started summer 2011, alpha April 2012

In use at Berkeley, Princeton, Klout, Foursquare, Conviva, Quantifind, Yahoo! Research & others

200+ member meetup, 500+ watchers on GitHub

This Talk

Spark programming model

User applications

Shark overview

Demo

Next major addition: Streaming Spark

Why a New Programming Model?

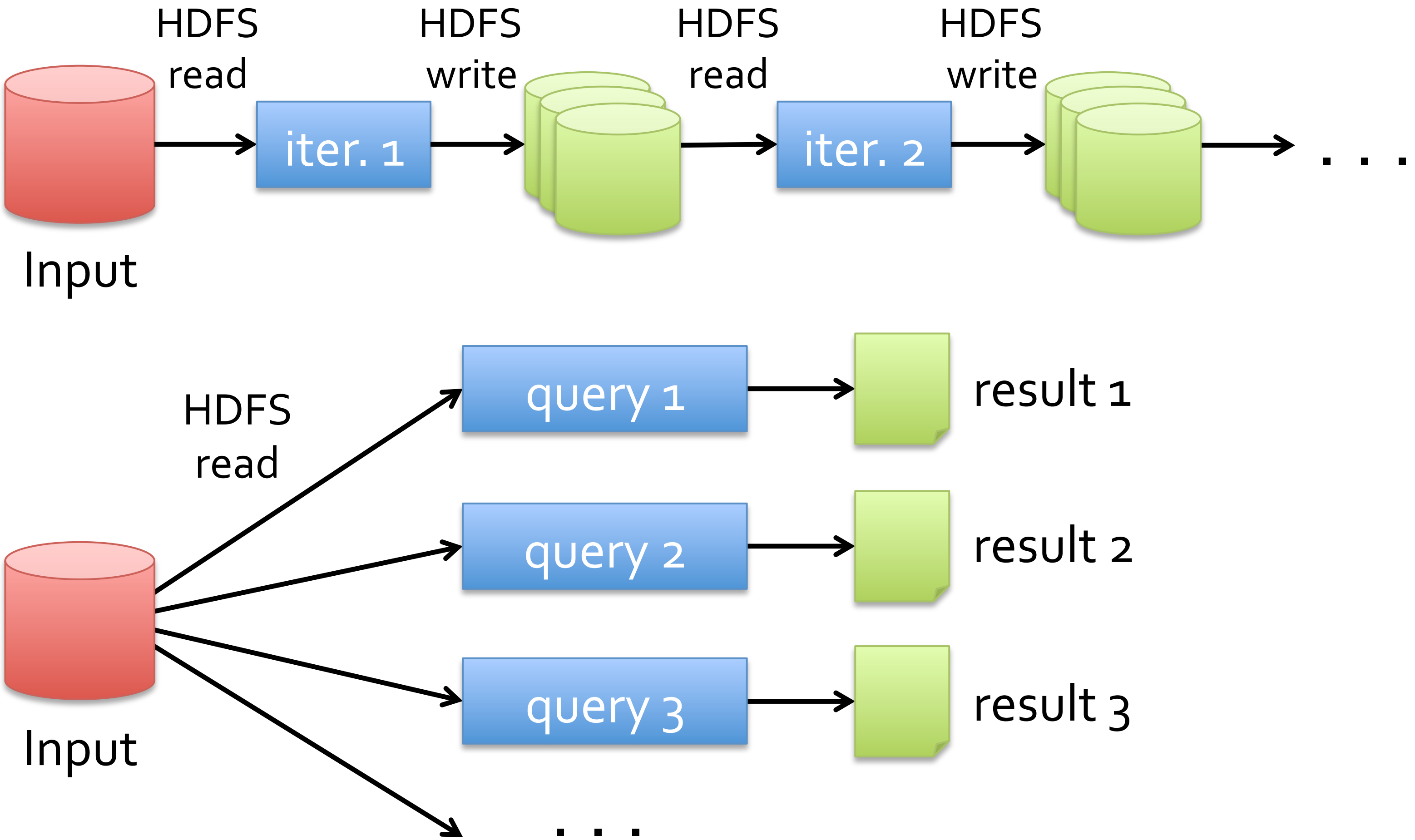
MapReduce greatly simplified big data analysis

But as soon as it got popular, users wanted more:

- More **complex**, multi-stage applications (e.g. iterative graph algorithms and machine learning)
- More **interactive** ad-hoc queries

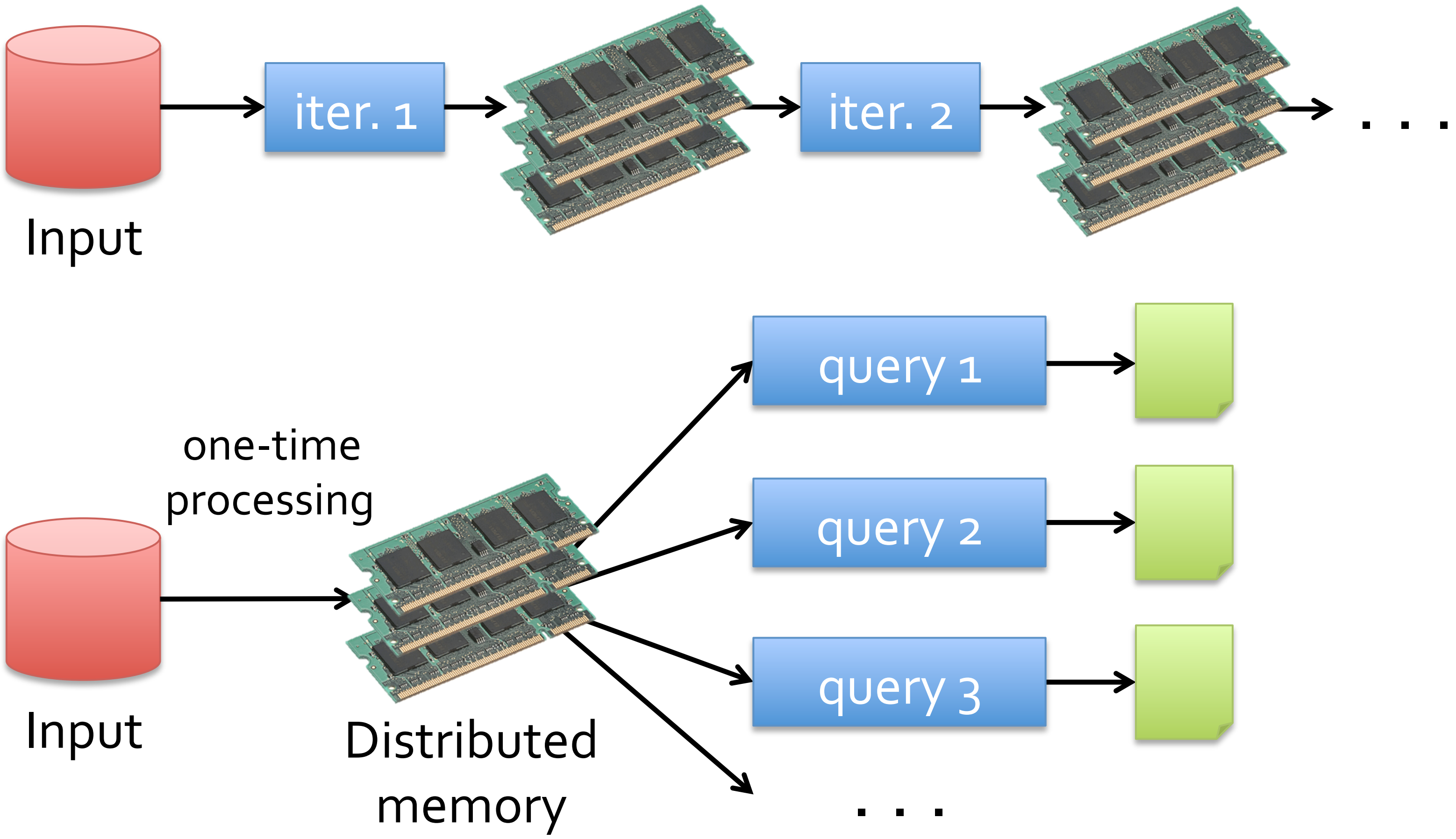
Both multi-stage and interactive apps require faster **data sharing** across parallel jobs

Data Sharing in MapReduce



Slow due to replication, serialization, and disk IO

Data Sharing in Spark



10-100× faster than network and disk

Spark Programming Model

Key idea: *resilient distributed datasets (RDDs)*

- » Distributed collections of objects that can be cached in memory across cluster nodes
- » Manipulated through various parallel operators
- » Automatically rebuilt on failure

Interface

- » Clean language-integrated API in Scala
- » Can be used *interactively* from Scala console

Example: Log Mining

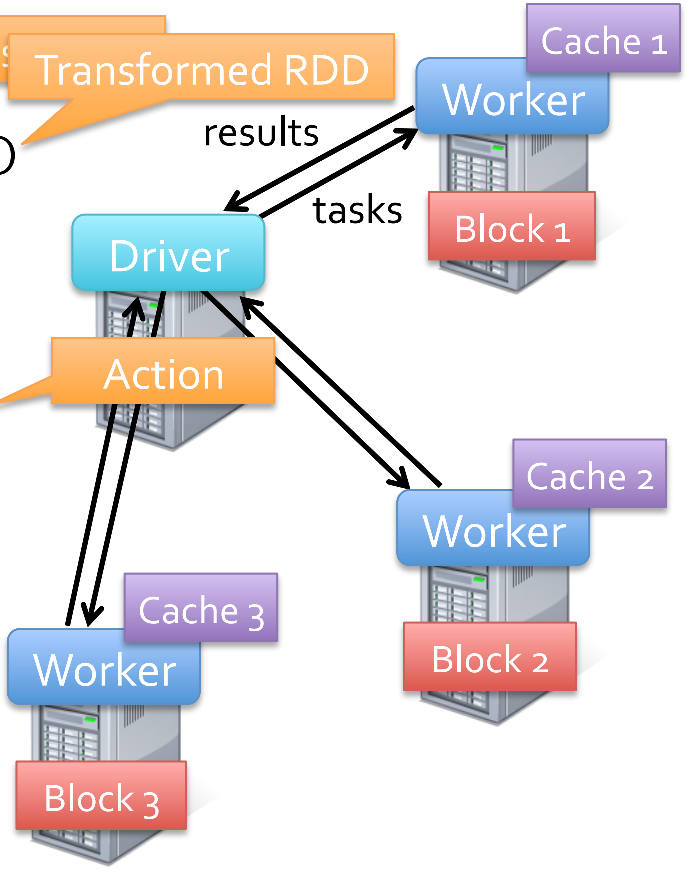
Load error messages from a log into memory, then interactively search for various patterns

```
lines = spark.textFile("hdfs://...")
errors = lines.filter(_.startsWith("ERROR"))
messages = errors.map(_.split('\t')(2))
cachedMsgs = messages.cache()

cachedMsgs.filter(_.contains("foo")).count
cachedMsgs.filter(_.contains("bar")).count
. . .
```

Bas

Transformed RDD

Action



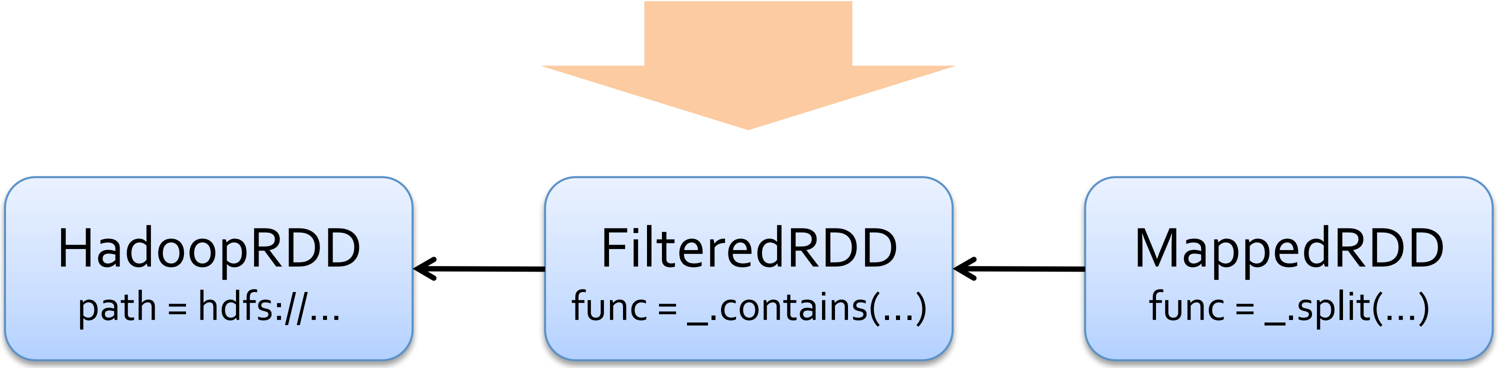
Result: scaled to 1 TB data in 5-7 sec (vs 170 sec for on-disk data)

Fault Tolerance

RDDs track the series of transformations used to build them (their *lineage*) to recompute lost data

E.g:

```
messages = textFile(...).filter(_.contains(“error”))
                        .map(_.split(‘\t’)(2))
```



Example: Logistic Regression

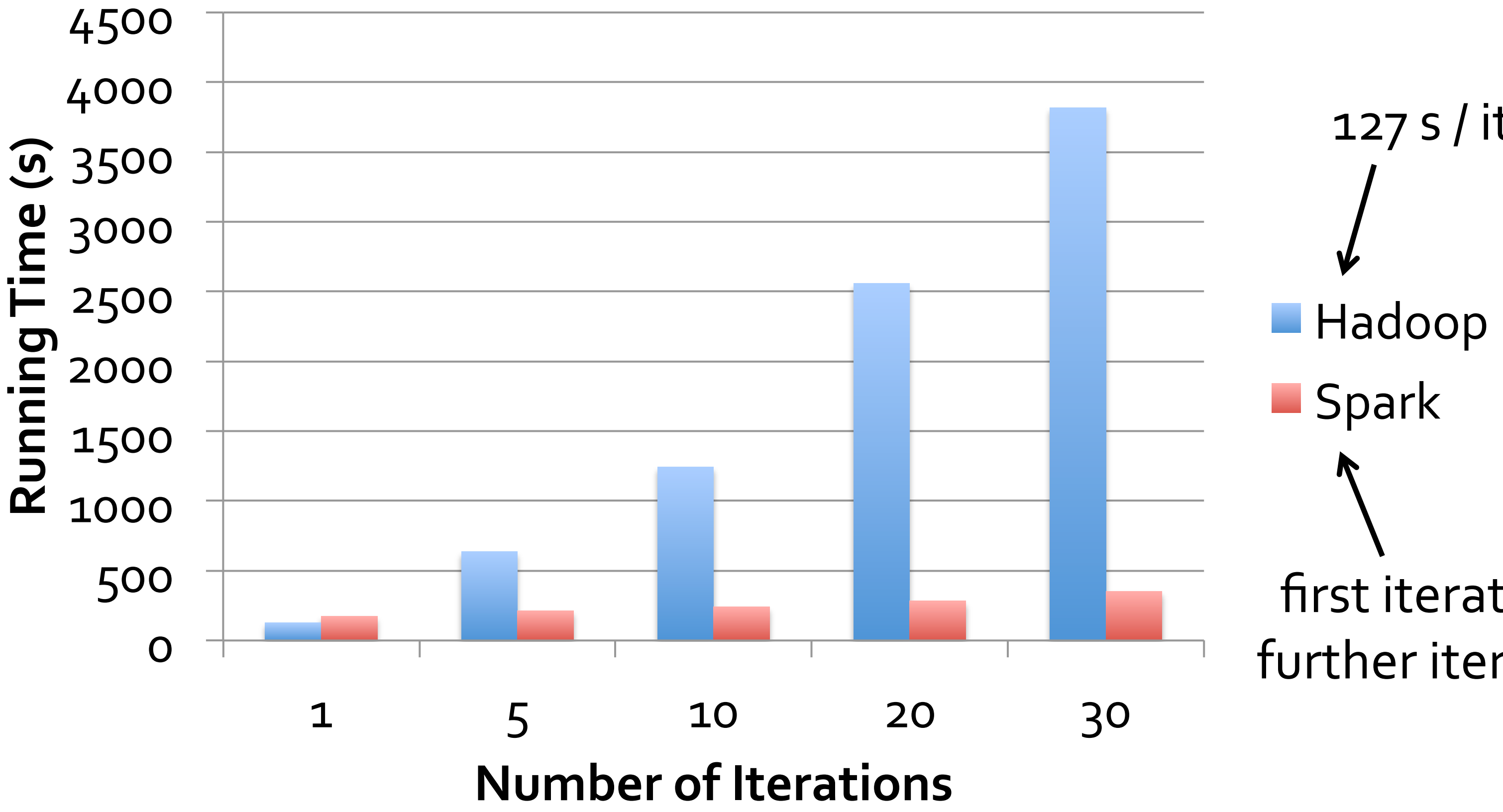
```
val data = spark.textFile(...).map(readPoint).cache()

var w = Vector.random(D)

for (i <- 1 to ITERATIONS) {
  val gradient = data.map(p =>
    (1 / (1 + exp(-p.y*(w dot p.x))) - 1) * p.y * p.x
  ).reduce(_ + _)
  w -= gradient
}

println("Final w: " + w)
```

Load data in memory once

Initial parameter vector

Repeated MapReduce steps to do gradient descent

Logistic Regression Performance



127 s / iteration

first iteration 174 s
further iterations 6 s

Supported Operators

map
filter
groupBy
sort
join
leftOuterJoin
rightOuterJoin

reduce
count
reduceByKey
groupByKey
first
union
cross

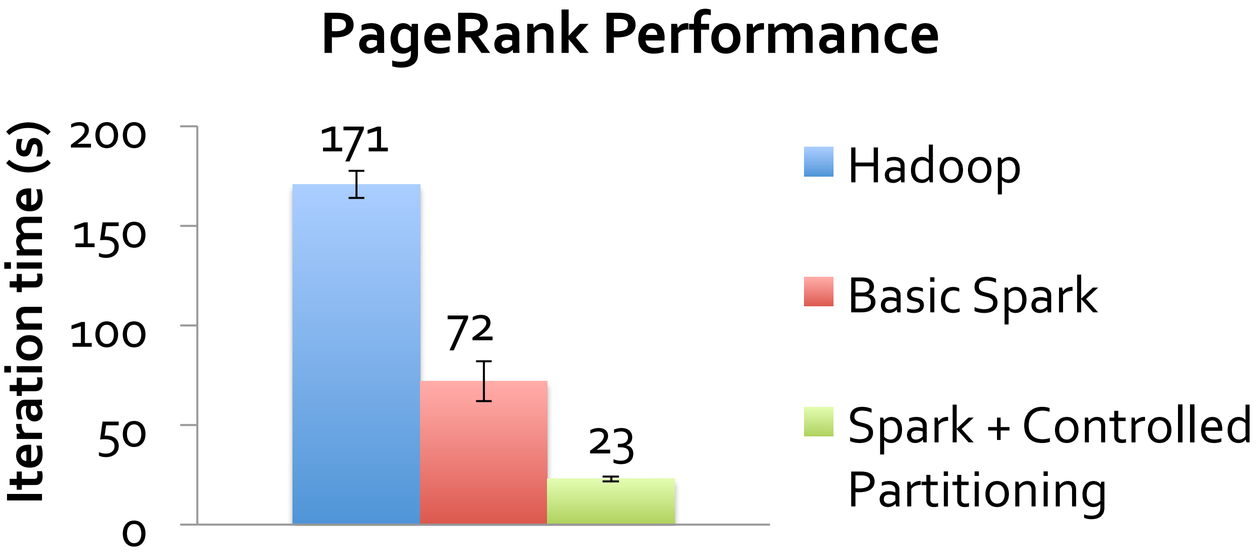
sample
cogroup
take
partitionBy
pipe
save
...

Other Engine Features

General graphs of operators (e.g. map-reduce-reduce)

Hash-based reduces (faster than Hadoop's sort)

Controlled data partitioning to lower communication



Spark Users

CONVIVA®

foursquare

quantiFind

KLOUT

YAHOO!® RESEARCH

University of California Berkeley

PRINCETON UNIVERSITY

UCSF

User Applications

In-memory analytics & anomaly detection (Conviva)

Interactive queries on data streams (Quantifind)

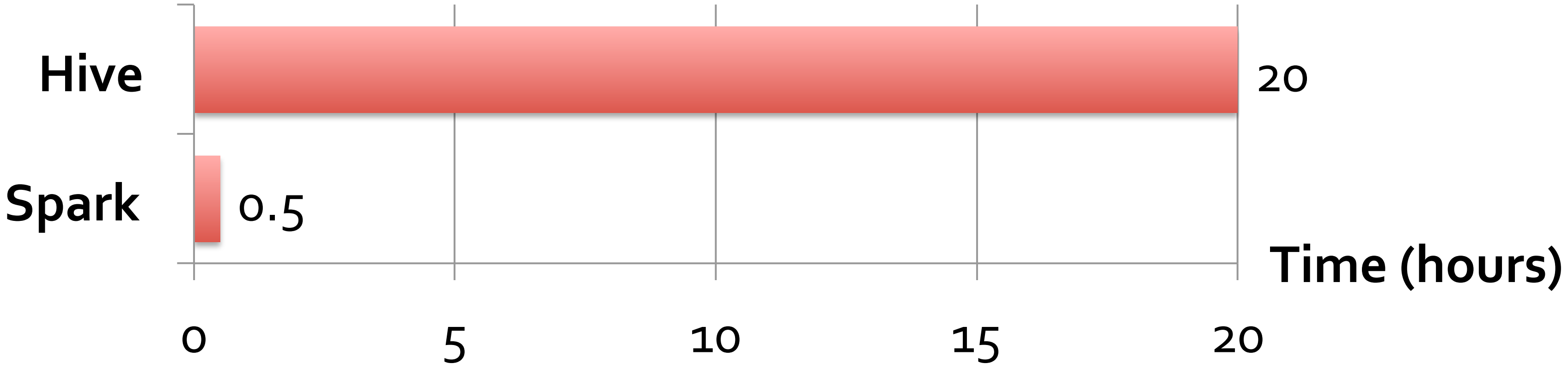
Exploratory log analysis (Foursquare)

Traffic estimation w/ GPS data (Mobile Millennium)

Twitter spam classification (Monarch)

. . .

Conviva GeoReport



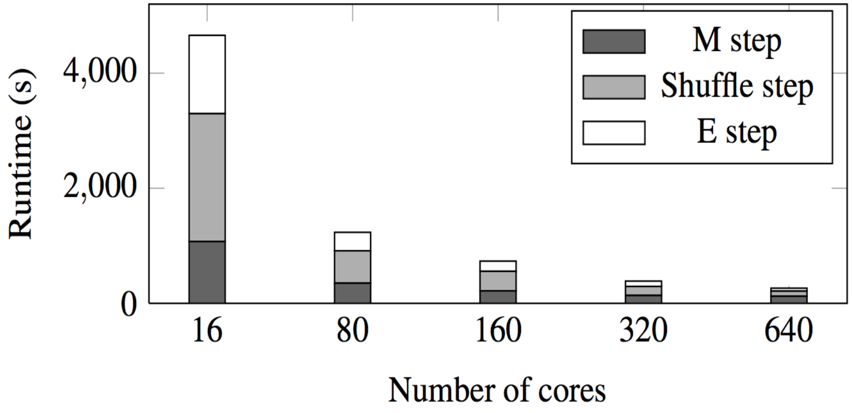
Group aggregations on many keys w/ same filter

40× gain over Hive from avoiding repeated reading, deserialization and filtering

Mobile Millennium Project

Estimate city traffic from crowdsourced GPS data

Iterative EM algorithm scaling to 160 nodes



Credit: Tim Hunter, with support of the Mobile Millennium team; P.I. Alex Bayen; traffic.berkeley.edu

Shark: Hive on Spark

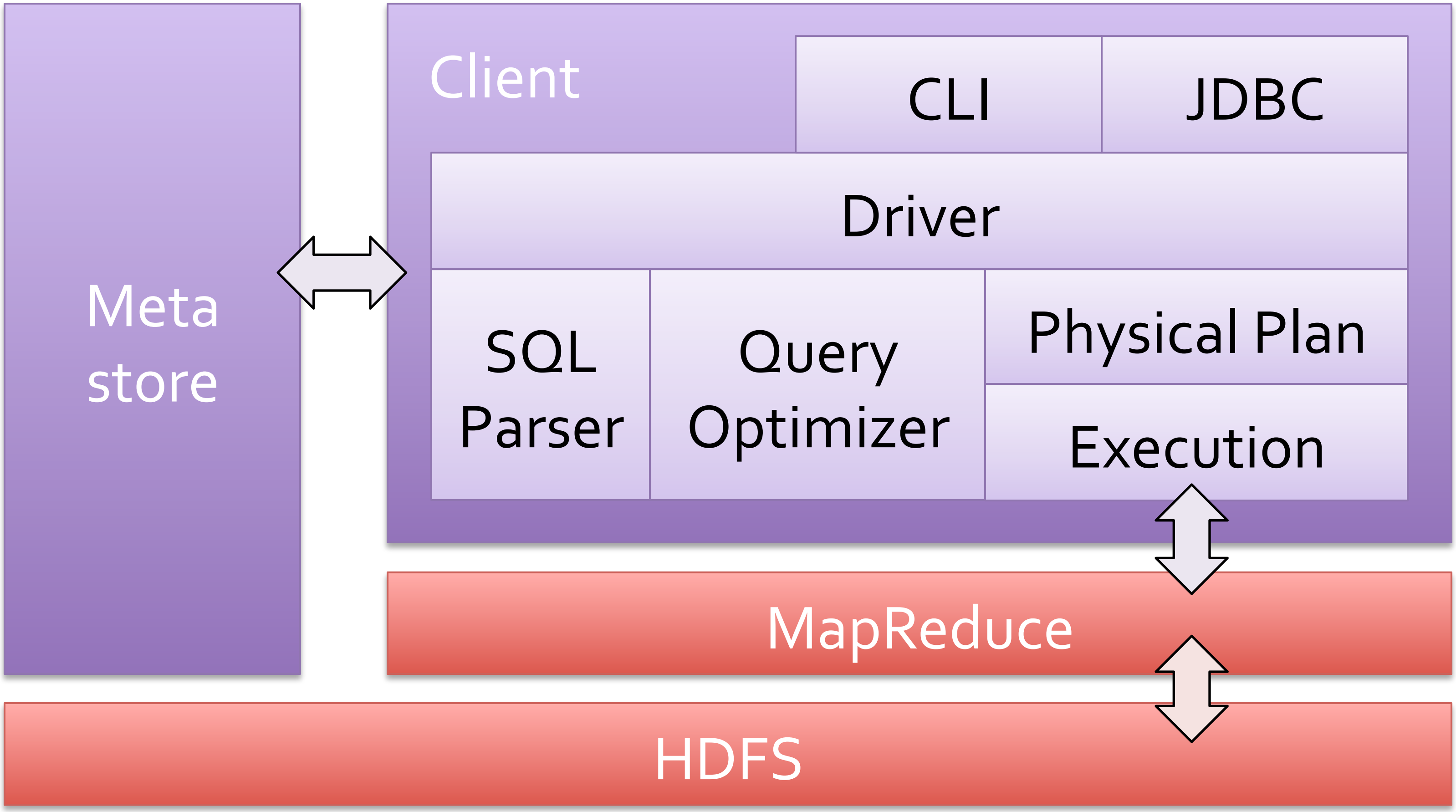
Motivation

Hive is great, but Hadoop’s execution engine makes even the smallest queries take minutes

Scala is good for programmers, but many data users only know SQL

Can we extend Hive to run on Spark?

Hive Architecture



Meta store

Client

CLI

JDBC

Driver

SQL Parser

Query Optimizer

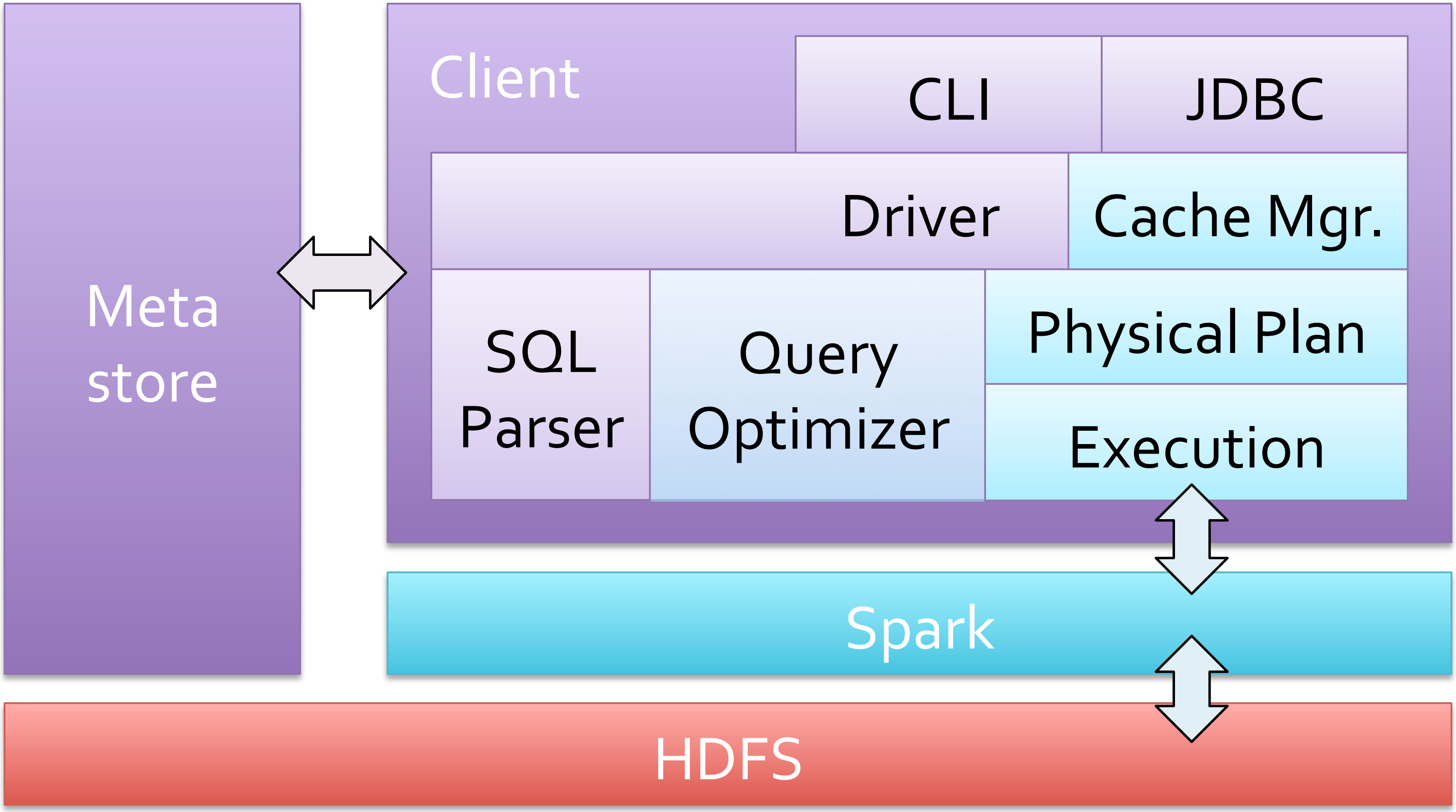
Physical Plan

Execution

MapReduce

HDFS

Shark Architecture

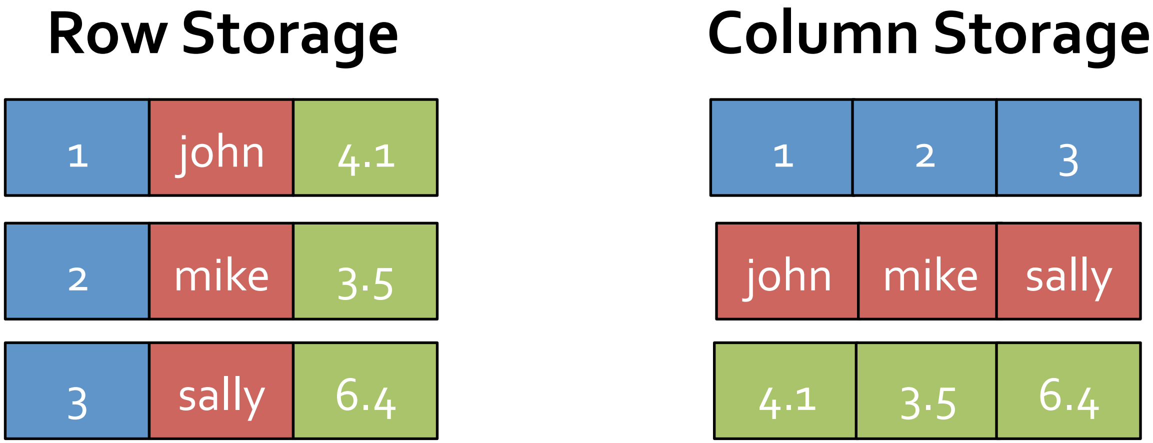


[Engle et al, SIGMOD 2012]

Efficient In-Memory Storage

Simply caching Hive records as Java objects is inefficient due to high per-object overhead

Instead, Shark employs column-oriented storage using **arrays of primitive types**



Row Storage

1	john	4.1
2	mike	3.5
3	sally	6.4

Column Storage

1	2	3
john	mike	sally
4.1	3.5	6.4

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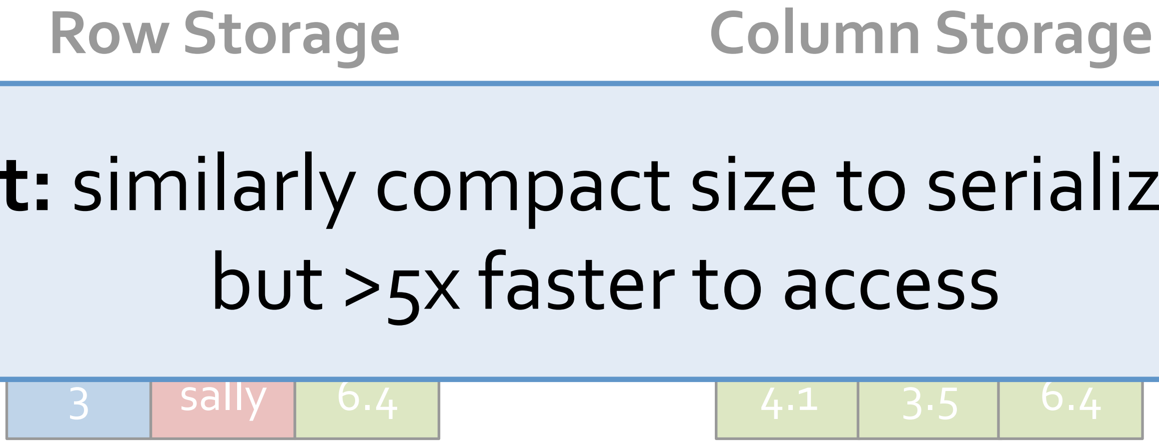


Row Storage

Column Storage

3 | sally | 6.4

4.1 | 3.5 | 6.4

Benefit: similarly compact size to serialized data, but >5x faster to access

Using Shark

```
CREATE TABLE mydata_cached AS SELECT …
```

Run standard HiveQL on it, including UDFs

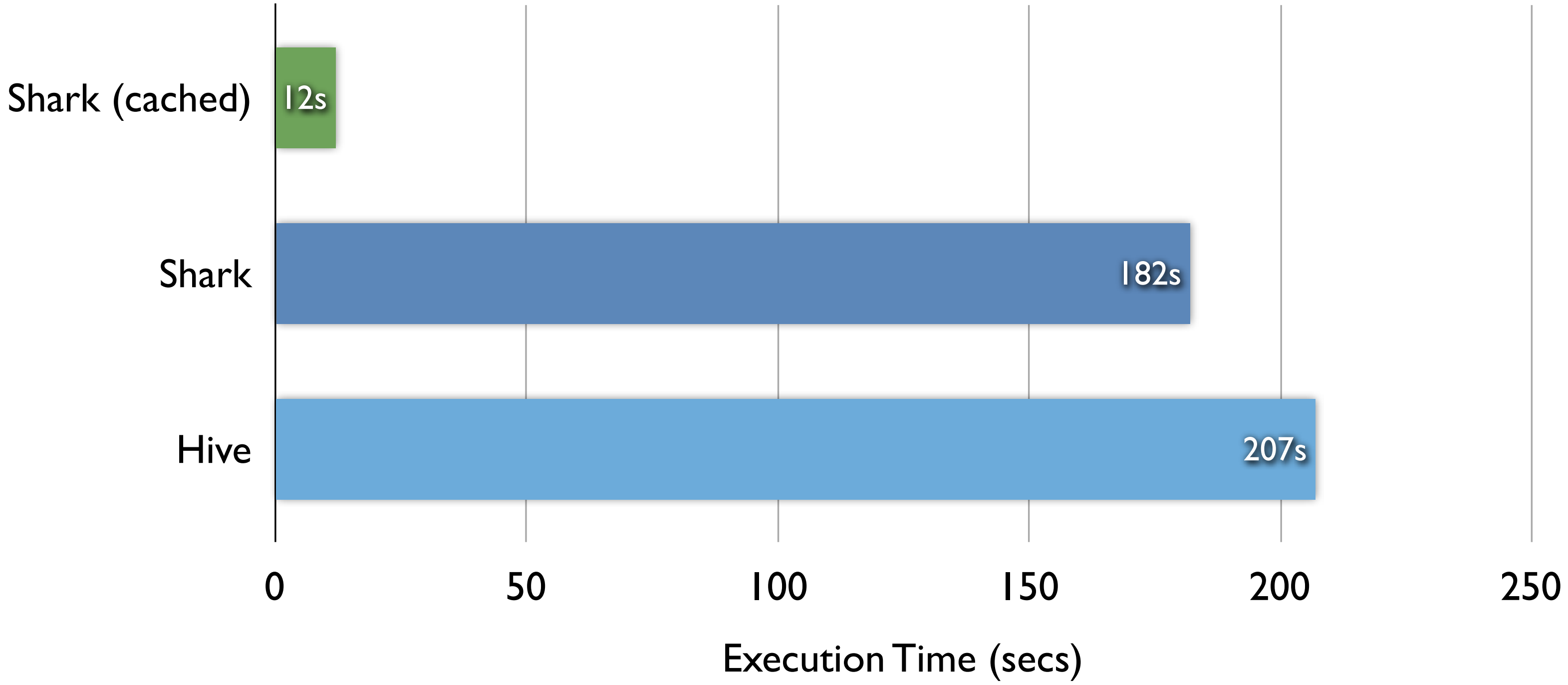
» A few esoteric features are not yet supported

Can also call from Scala to mix with Spark

Early alpha release at shark.cs.berkeley.edu

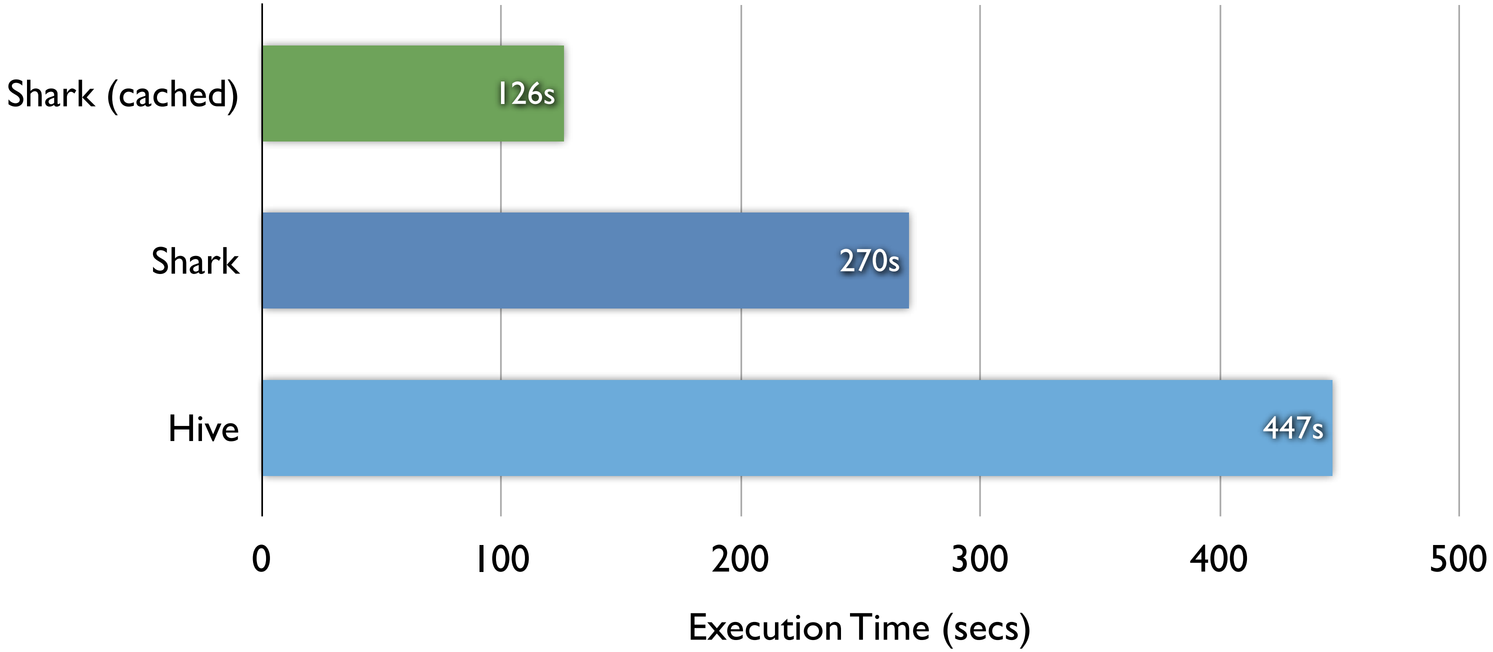
Benchmark Query 1

```
SELECT * FROM grep WHERE field LIKE ‘%XYZ%’;
```



Benchmark Query 2

```
SELECT sourceIP, AVG(pageRank), SUM(adRevenue) AS earnings
FROM rankings AS R, userVisits AS V ON R.pageURL = V.destURL
WHERE V.visitDate BETWEEN ‘1999-01-01’ AND ‘2000-01-01’
GROUP BY V.sourceIP
ORDER BY earnings DESC
LIMIT 1;
```



Demo

What's Next?

Recall that Spark's model was motivated by two emerging uses (interactive and multi-stage apps)

Another emerging use case that needs fast data sharing is **stream processing**

- » Track and update state in memory as events arrive
- » Large-scale reporting, click analysis, spam filtering, etc

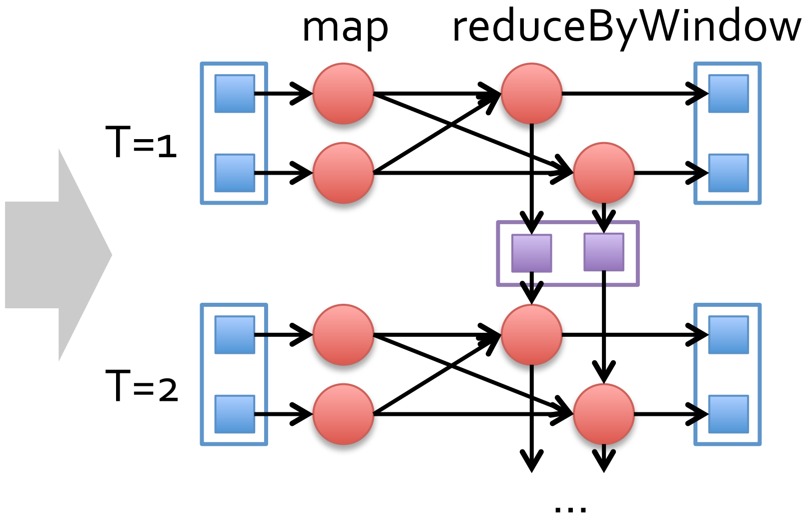
Streaming Spark

Extends Spark to perform streaming computations

Runs as a series of small (~1 s) batch jobs, keeping state in memory as fault-tolerant RDDs

Intermix seamlessly with batch and ad-hoc queries

```
tweetStream
 .flatMap(_.toLower.split)
 .map(word => (word, 1))
 .reduceByWindow("5s", _ + _)
```



[Zaharia et al, HotCloud 2012]

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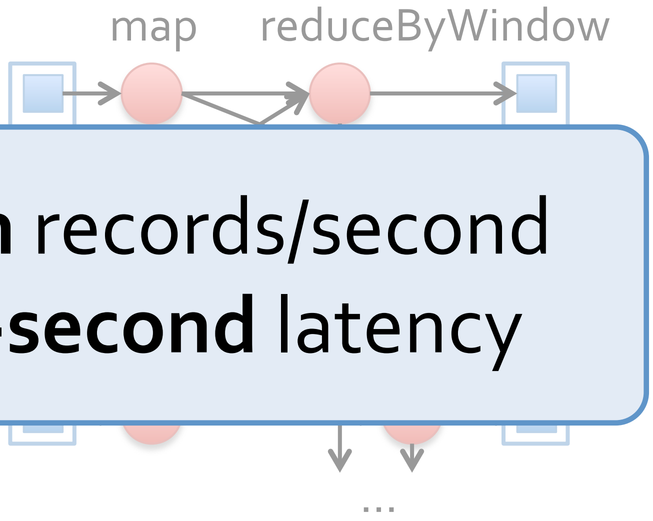

Result: can process **42 million** records/second (4 GB/s) on 100 nodes at **sub-second** latency

[Zaharia et al, HotCloud 2012]

Streaming Spark

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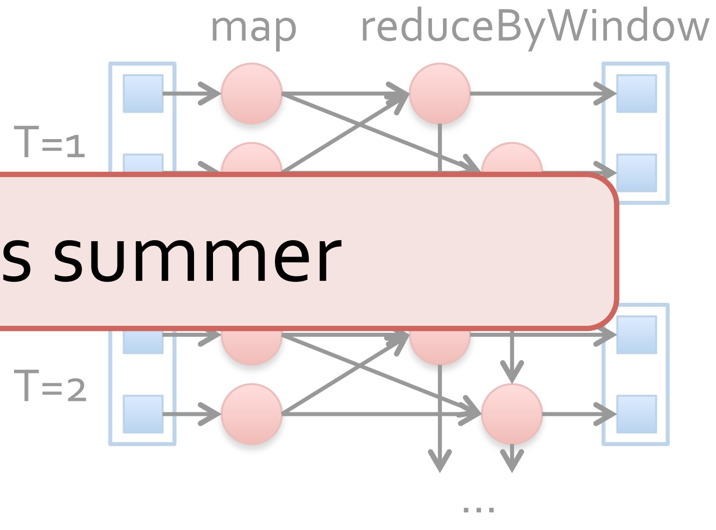
```
tweetStream
  .fl
  .ma
  .re
```



Alpha coming this summer

[Zaharia et al, HotCloud 2012]

Conclusion

Spark and Shark speed up your interactive and complex analytics on Hadoop data

Download and docs: www.spark-project.org

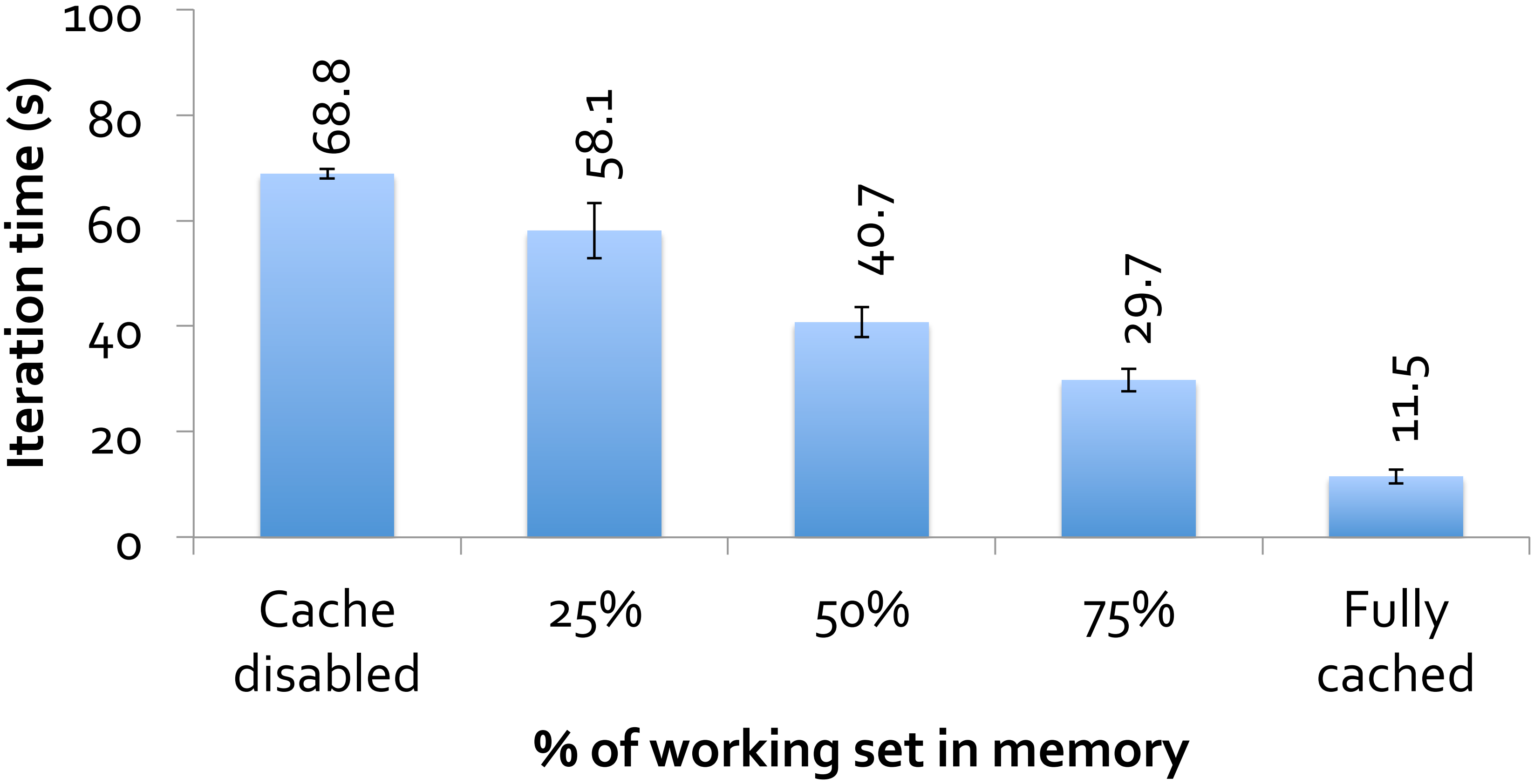
» Easy to run locally, on EC2, or on Mesos and soon YARN

User meetup: meetup.com/spark-users

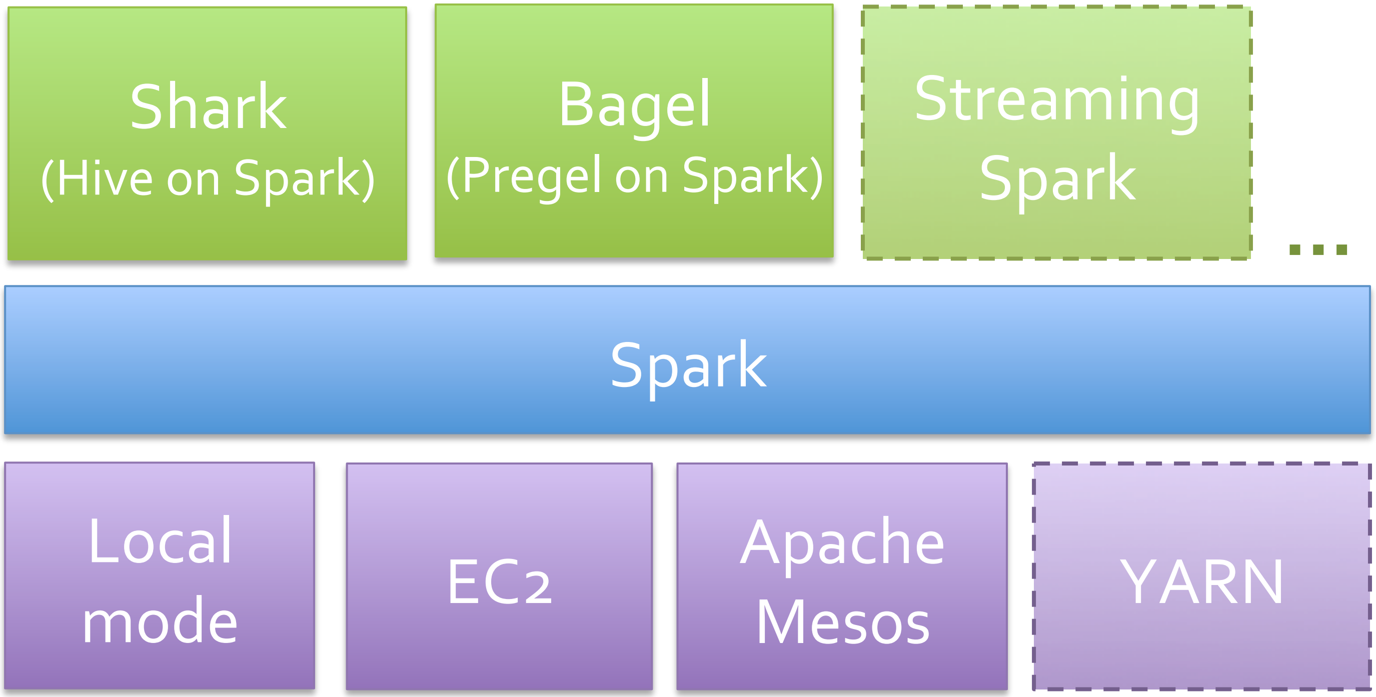
Training camp at Berkeley in August!

matei@berkeley.edu / @matei_zaharia

Behavior with Not Enough RAM



Software Stack



Shark (Hive on Spark)

Bagel (Pregel on Spark)

Streaming Spark

…

Spark

Local mode

EC2

Apache Mesos

YARN