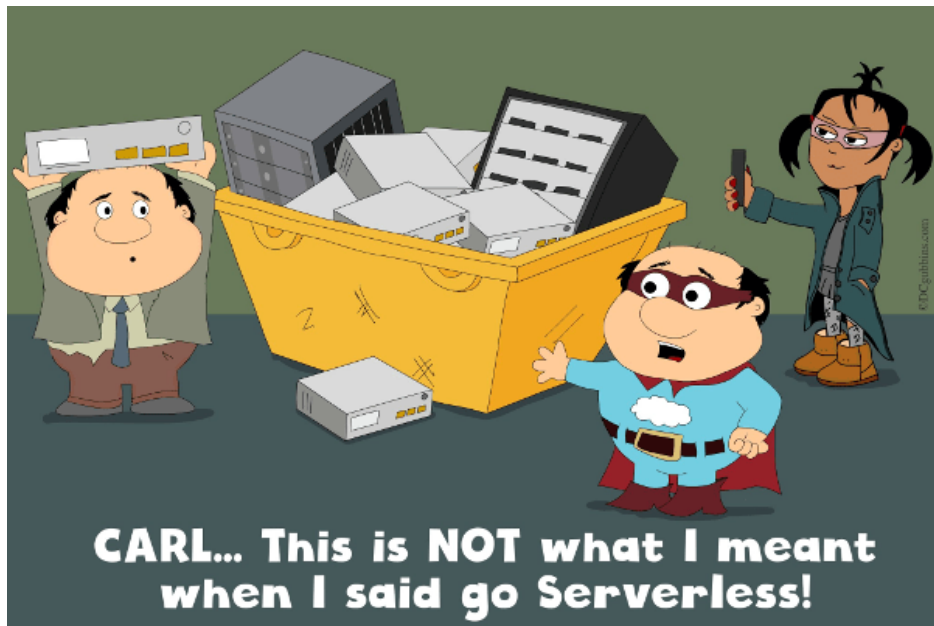


# Serverless Machine Learning on Modern Hardware

Patrick Stuedi  
IBM Research

**#Res6SAIS**

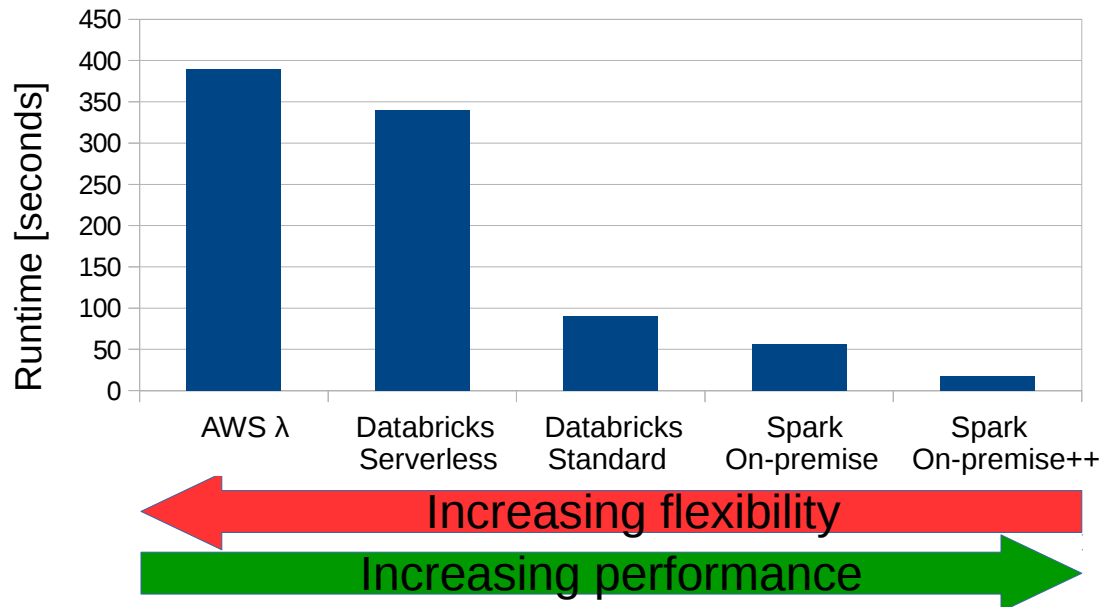
# Serverless Computing



- No need to setup/manage a cluster
- Automatic, dynamic and fine-grained scaling
- Sub-second billing
- Many frameworks: AWS Lambda, Google Cloud Functions, Azure Functions, Databricks Serverless, etc.

# Challenge: Performance

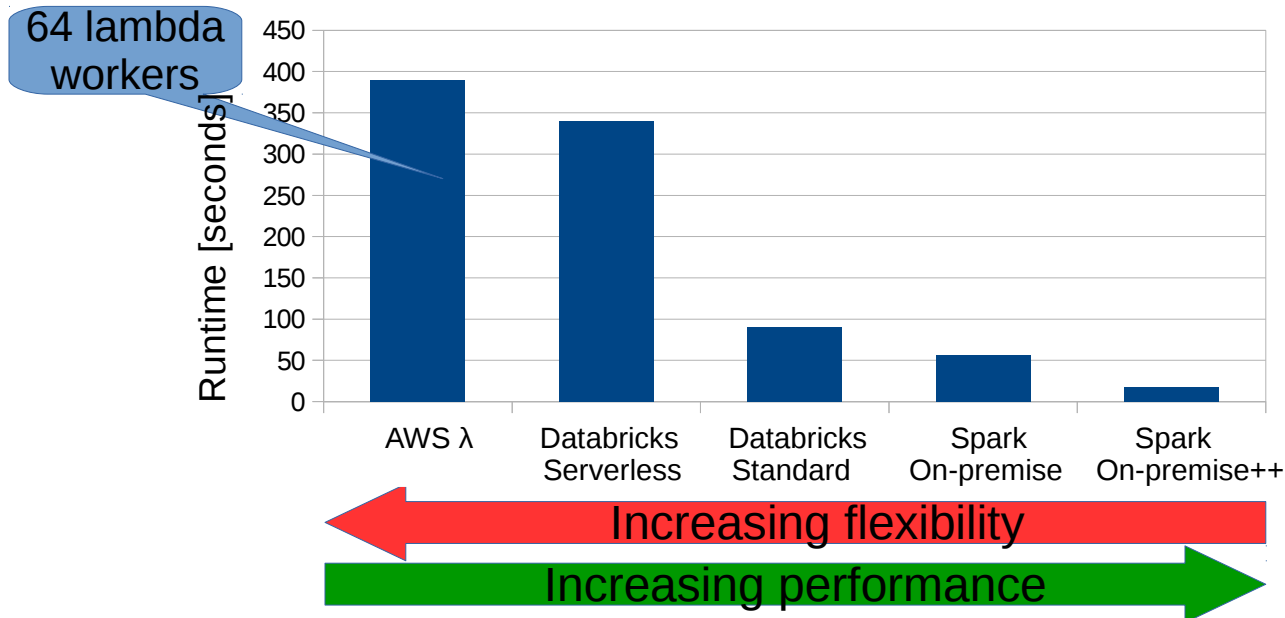
Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17

# Challenge: Performance

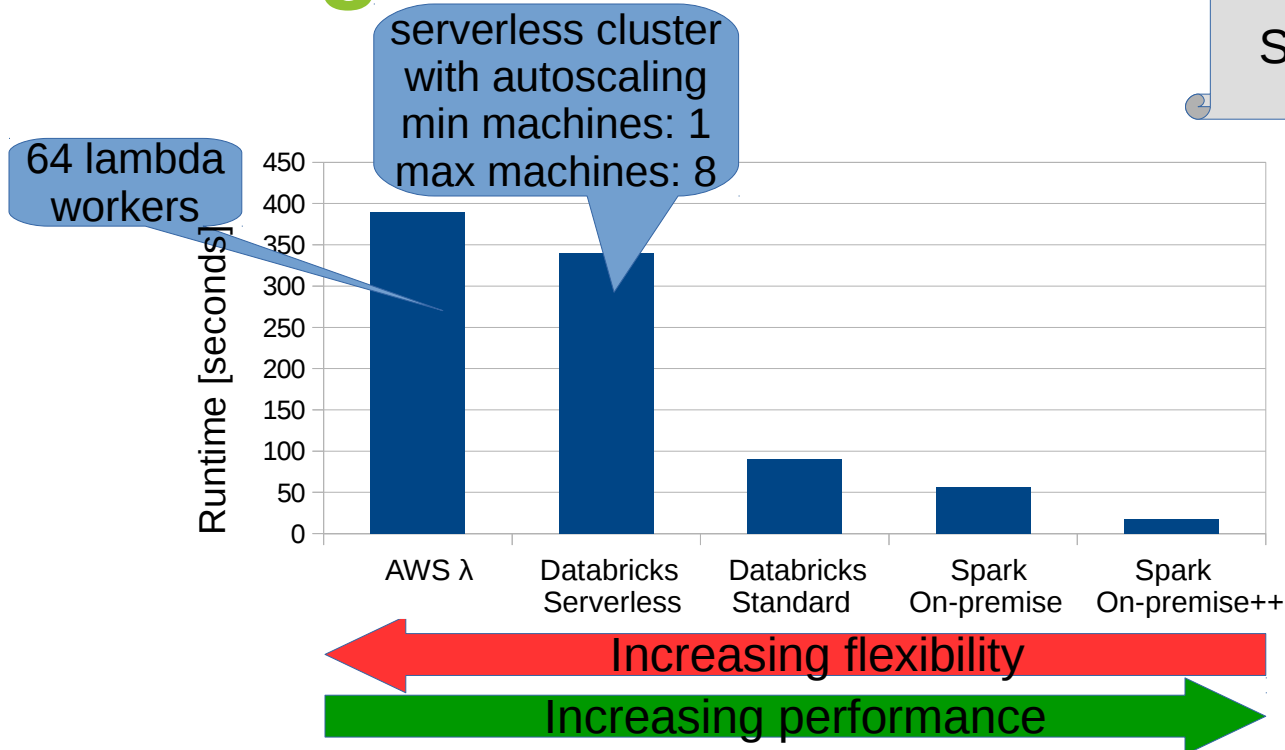
Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17

# Challenge: Performance

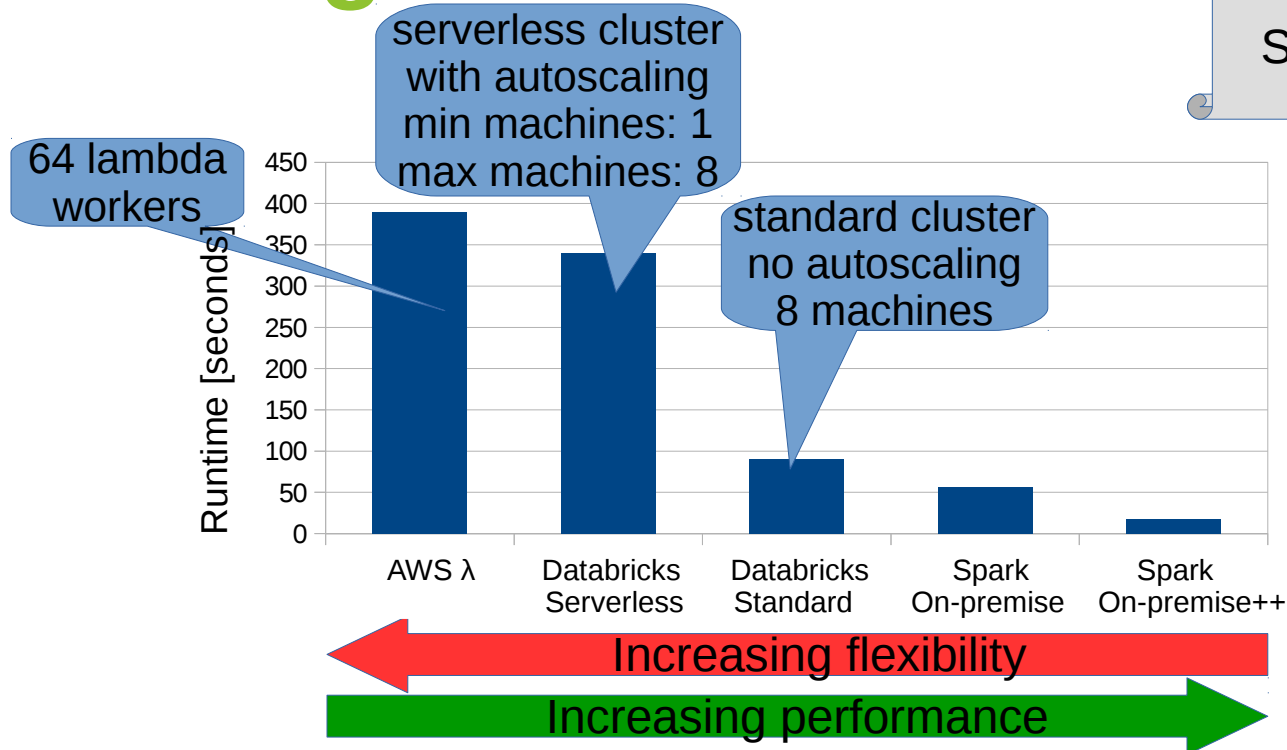
Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17

# Challenge: Performance

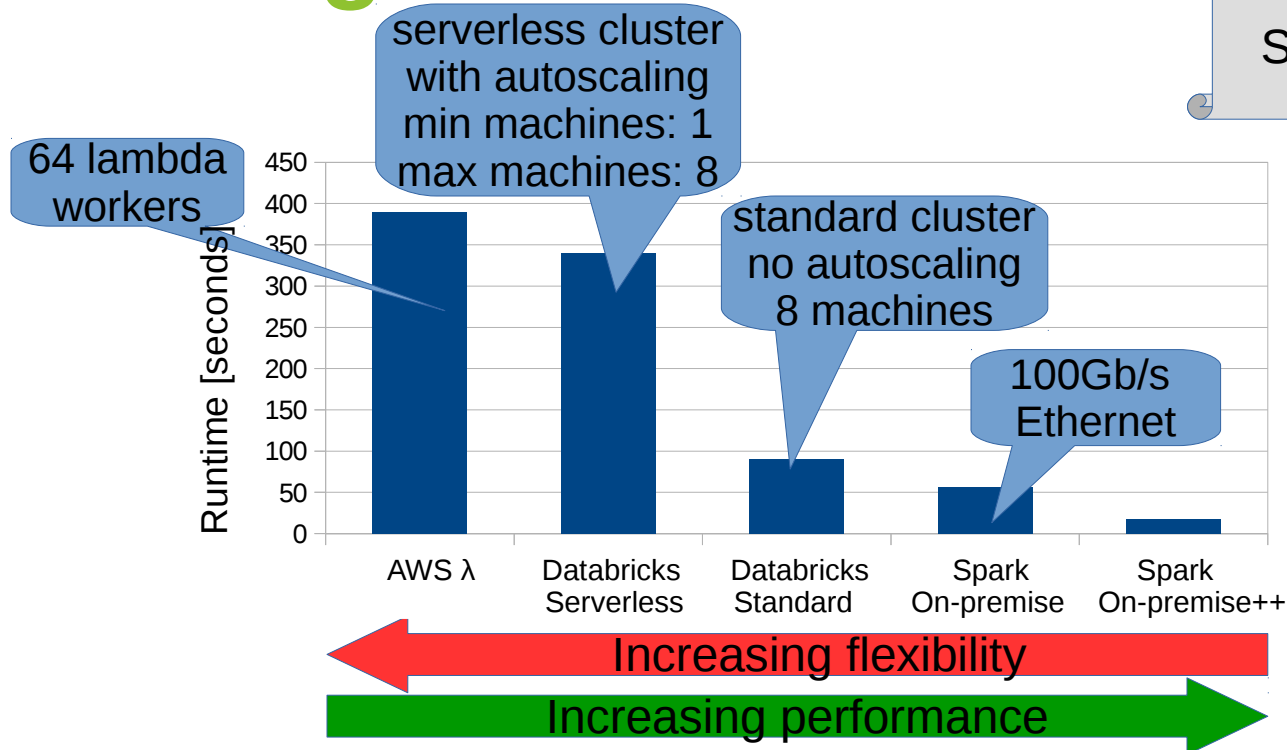
Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17

# Challenge: Performance

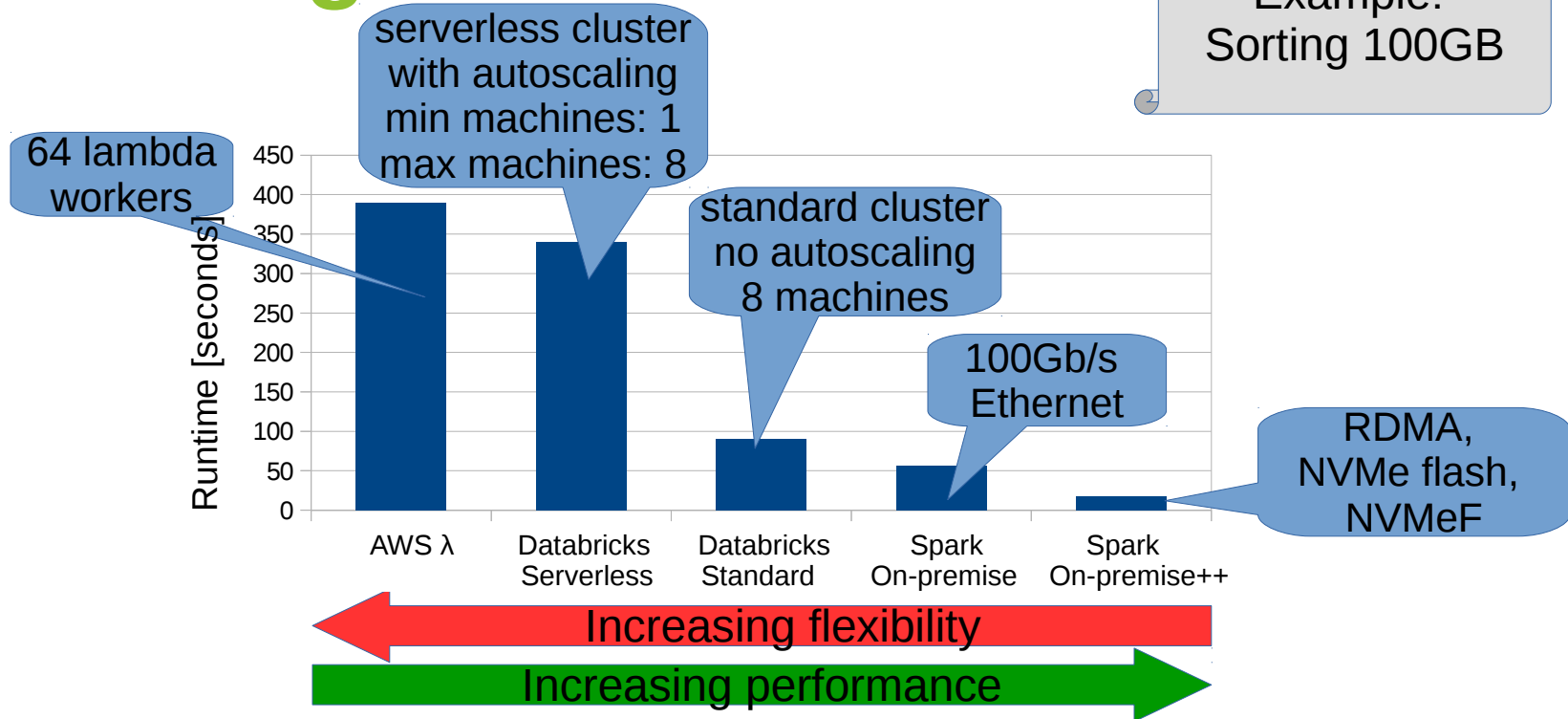
Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17

# Challenge: Performance

Example:  
Sorting 100GB



**Spark/On-Premise++:** Running Apache Spark on a High-Performance Cluster using RDMA and NVMe Flash, Spark Summit'17



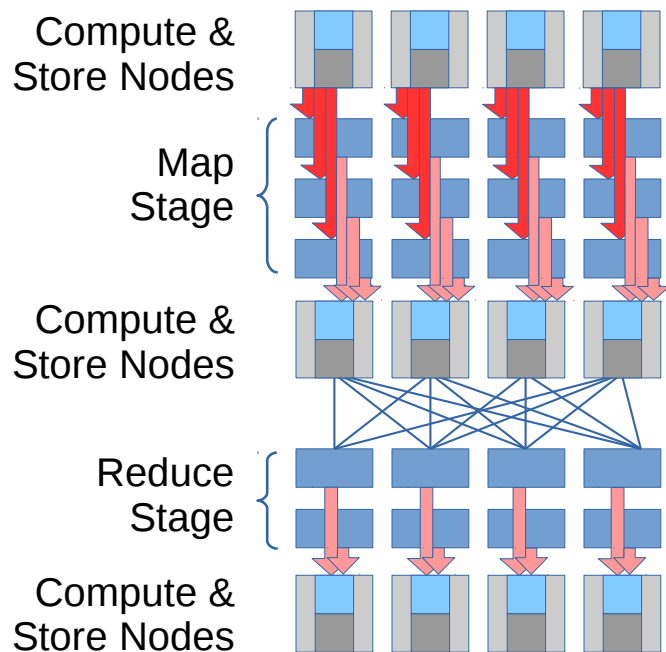
# Why is it so hard?

- **Scheduler:** when to best add/remove resources?
- **Container startup:** may have to dynamically spin up containers
- **Storage:** input data needs to be fetched from remote storage (e.g., S3)
  - As opposed to compute-local storage such as HDFS
- **Data sharing:** intermediate needs to be temporarily stored on remote storage (S3, Redis)
  - Affects operations like shuffle, broadcast, etc.,

# Why is it so hard?

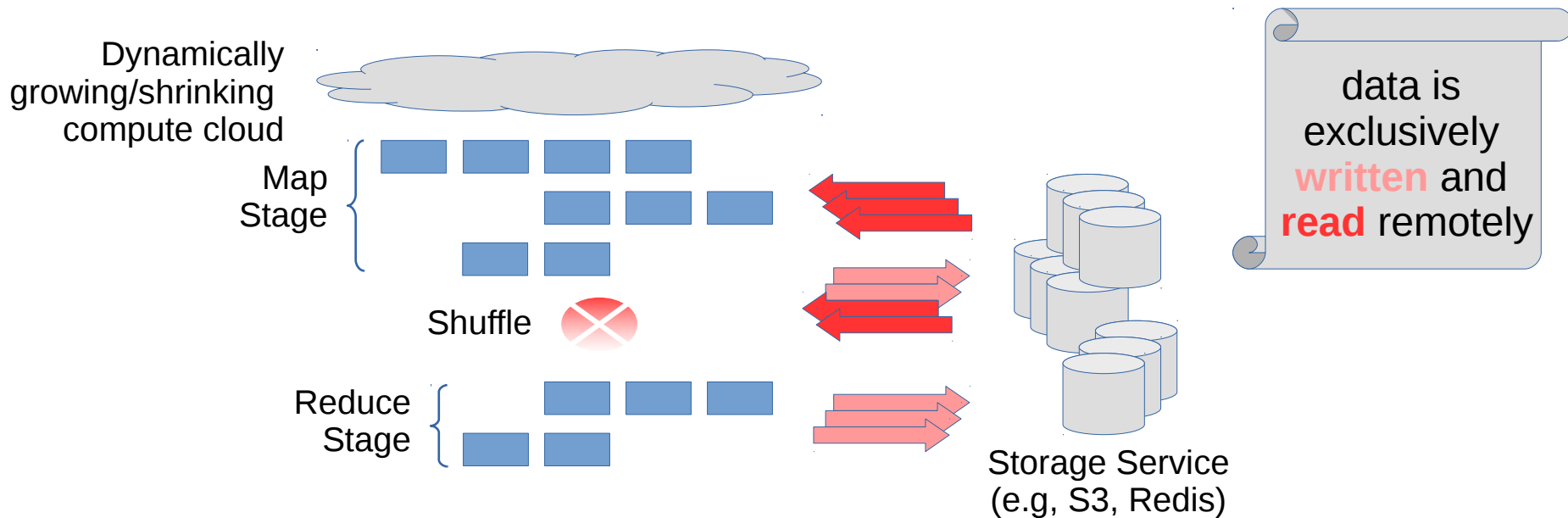
- **Scheduler:** when to best add/remove resources?
- **Container startup:** may have to dynamically spin up containers
- **Storage:** input data needs to be fetched from remote storage (e.g., S3)
  - As opposed to compute-local storage such as HDFS
- **Data sharing:** intermediate needs to be temporarily stored on remote storage (S3, Redis)
  - Affects operations like shuffle, broadcast, etc.,

# Example: MapReduce (Cluster)

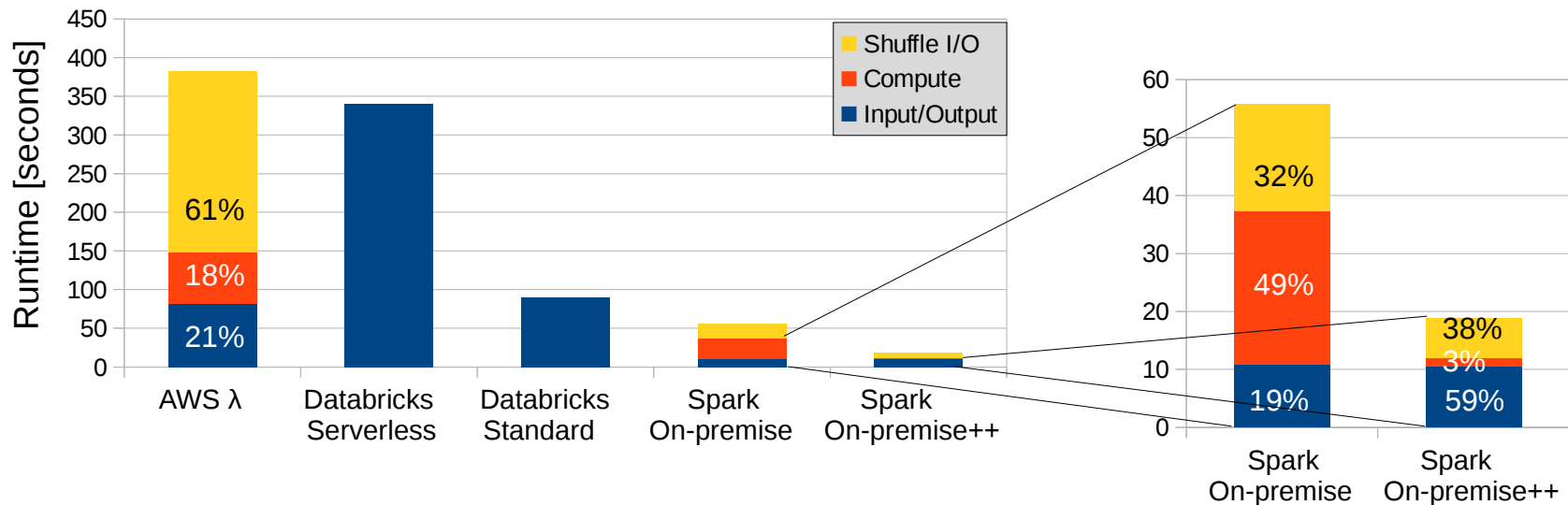


data is mostly  
**written** and  
**read** locally

# Example: MapReduce (Serverless)



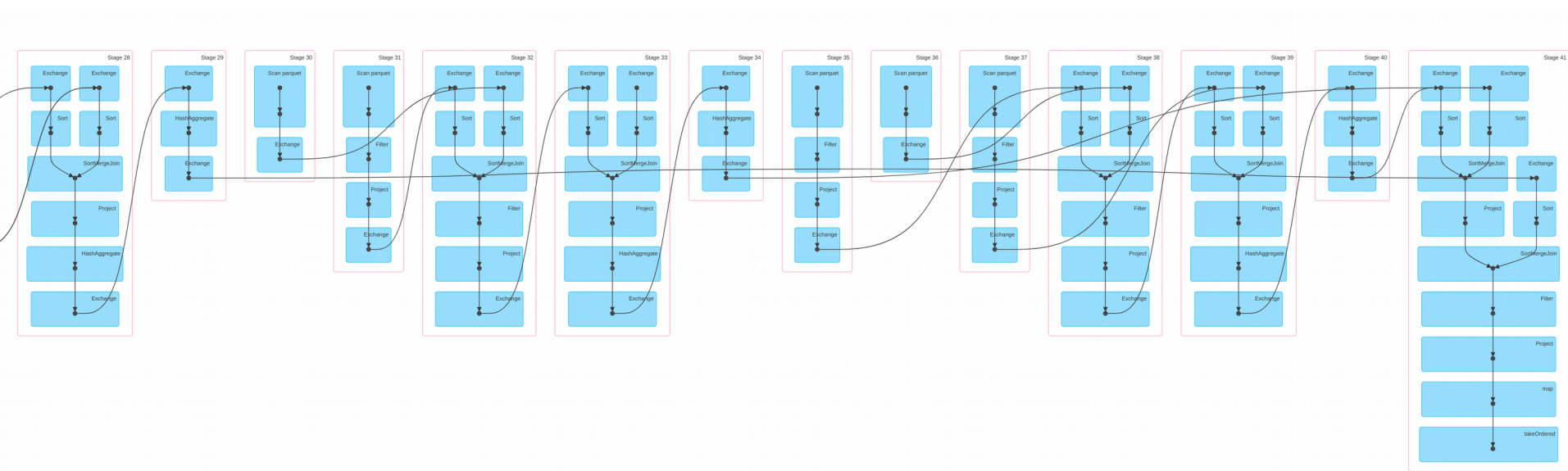
# I/O Overhead: Sorting 100GB



Shuffle overheads are significantly higher when intermediate data is stored remotely

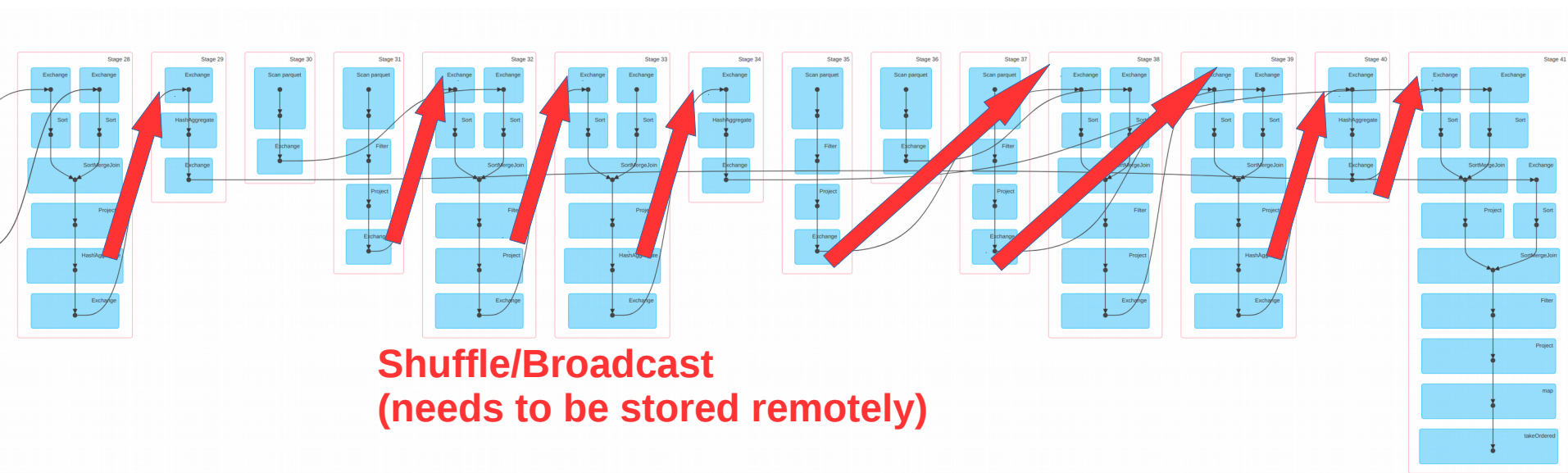
# What about other workloads?

Example: SQL, Query 77 / TPC-DS benchmark



# What about other workloads?

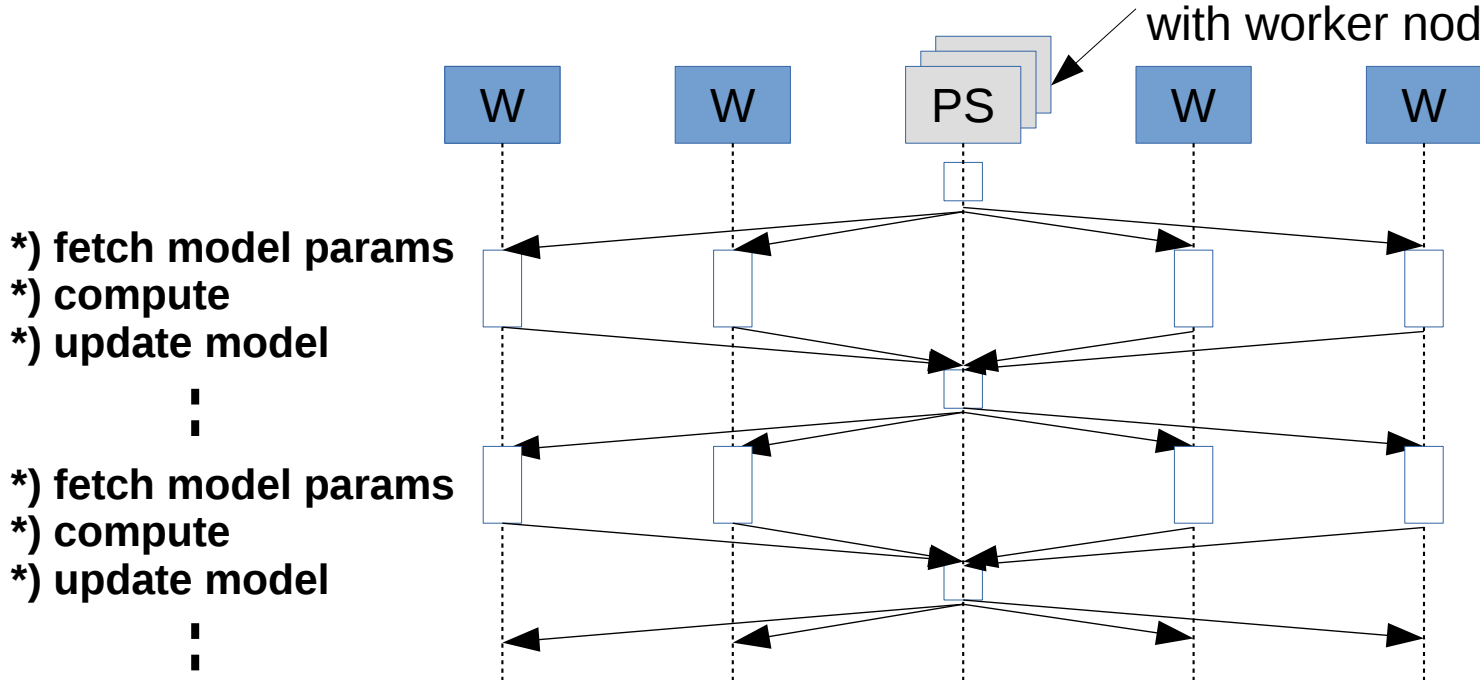
Example: SQL, Query 77 / TPC-DS benchmark



# What about other workloads?

Example: Iterative ML (e.g., linear regression)

could be co-located  
with worker nodes

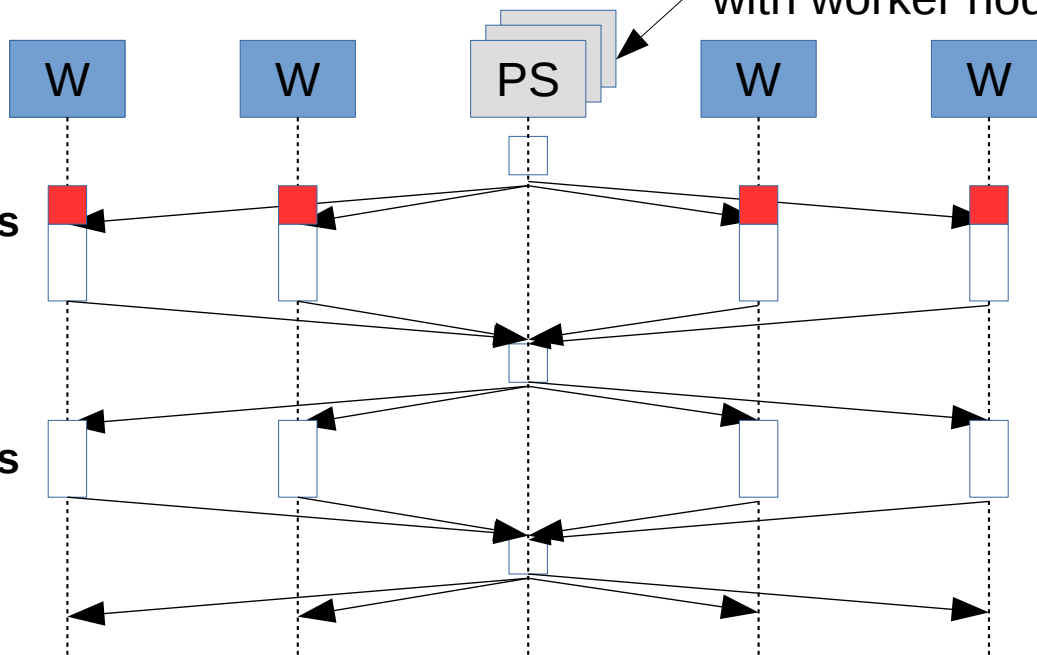




# What about other workloads?

Example: Iterative ML (e.g., linear regression)

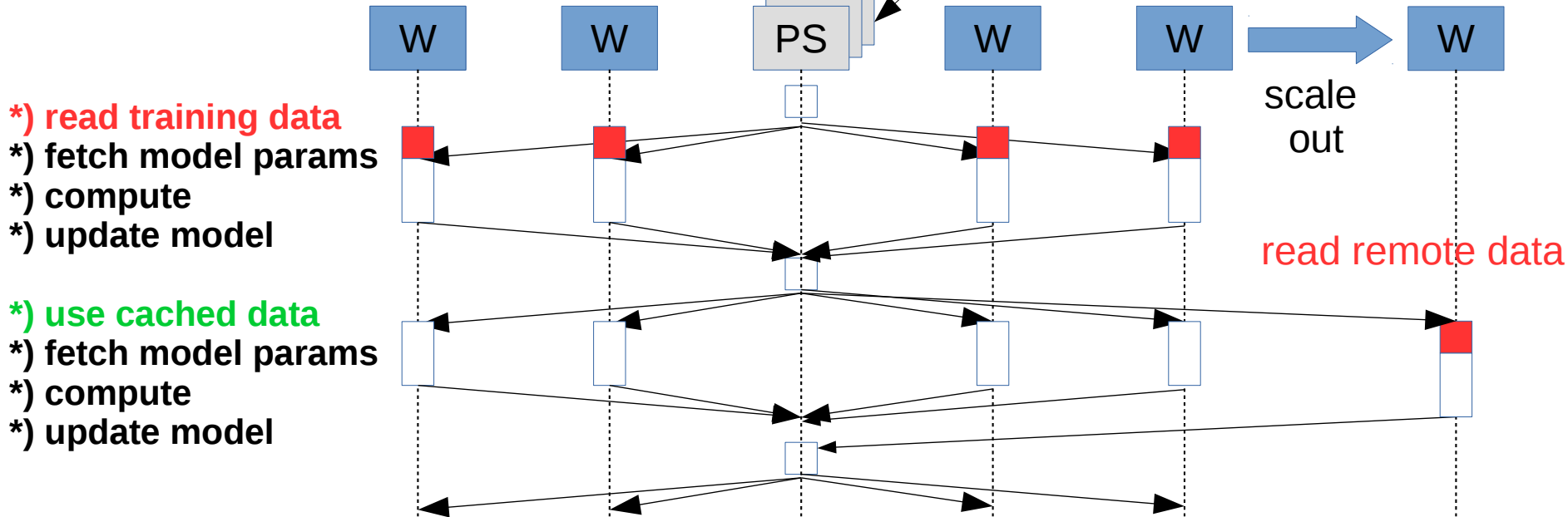
could be co-located  
with worker nodes



# What about other workloads?

Example: Iterative ML (e.g., linear regression)

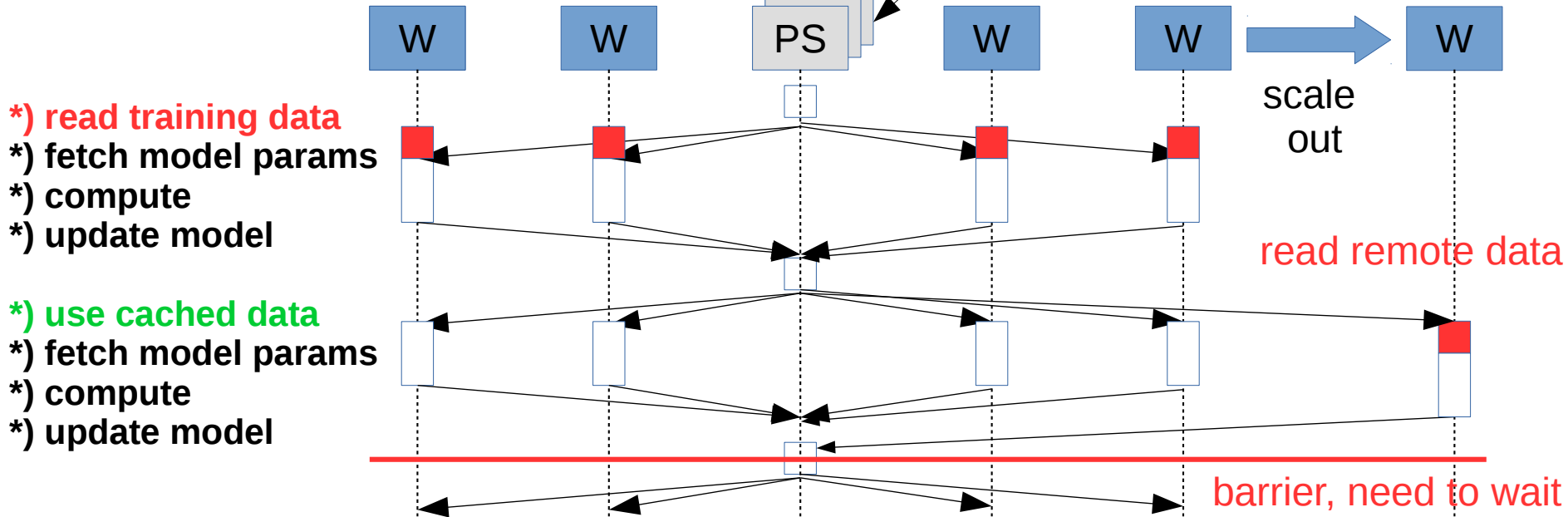
~~could be co-located  
with worker nodes~~ Needs to be  
remote



# What about other workloads?

Example: Iterative ML (e.g., linear regression)

~~could be co-located with worker nodes~~ Needs to be remote



# Can we..

- ..use Spark to run such workloads in a serverless fashion?
  - Dynamic scaling of compute nodes while jobs are running
  - No cluster configuration
  - No startup time overhead
- ..eliminate the performance overheads?
  - Workloads should run as fast as on a dedicated cluster

# Design Options

- **Scheduling:**

- 1 Use serverless framework to schedule executors
- 2 Use serverless framework to schedule tasks
- 3 Enable sharing of executors among different applications

- **Intermediate data:**

- 1 Executors cooperate with scheduler to flush data remotely
- 2 Consequently store all intermediate state remotely

# Design Options

- **Scheduling:**

High startup  
Latency!

- 1 Use serverless framework to schedule executors
- 2 Use serverless framework to schedule tasks
- 3 Enable sharing of executors among different applications

- **Intermediate data:**

- 1 Executors cooperate with scheduler to flush data remotely
- 2 Consequently store all intermediate state remotely

# Design Options

- **Scheduling:**

- ① Use serverless framework to schedule executors
- ② Use serverless framework to schedule tasks
- ③ Enable sharing of executors among different applications

High startup  
Latency!

Slow!

- **Intermediate data:**

- ① Executors cooperate with scheduler to flush data remotely
- ② Consequently store all intermediate state remotely

# Design Options

- **Scheduling:**

- 1 Use serverless framework to schedule executors
- 2 Use serverless framework to schedule tasks
- 3 Enable sharing of executors among different applications

High startup  
Latency!

Slow!

- **Intermediate data:**

- 1 Executors cooperate with scheduler to flush data remotely
- 2 Consequently store all intermediate state remotely



# Design Options

- **Scheduling:**

- 1 Use serverless framework to schedule executors
- 2 Use serverless framework to schedule tasks
- 3 Enable sharing of executors among different applications

High startup  
Latency!

Slow!

- **Intermediate data:**

- 1 Executors cooperate with scheduler to flush data remotely
- 2 Consequently store all intermediate state remotely

Complex!

# Design Options

- **Scheduling:**

- ① Use serverless framework to schedule executors
- ② Use serverless framework to schedule tasks
- ③ Enable sharing of executors among different applications

High startup  
Latency!

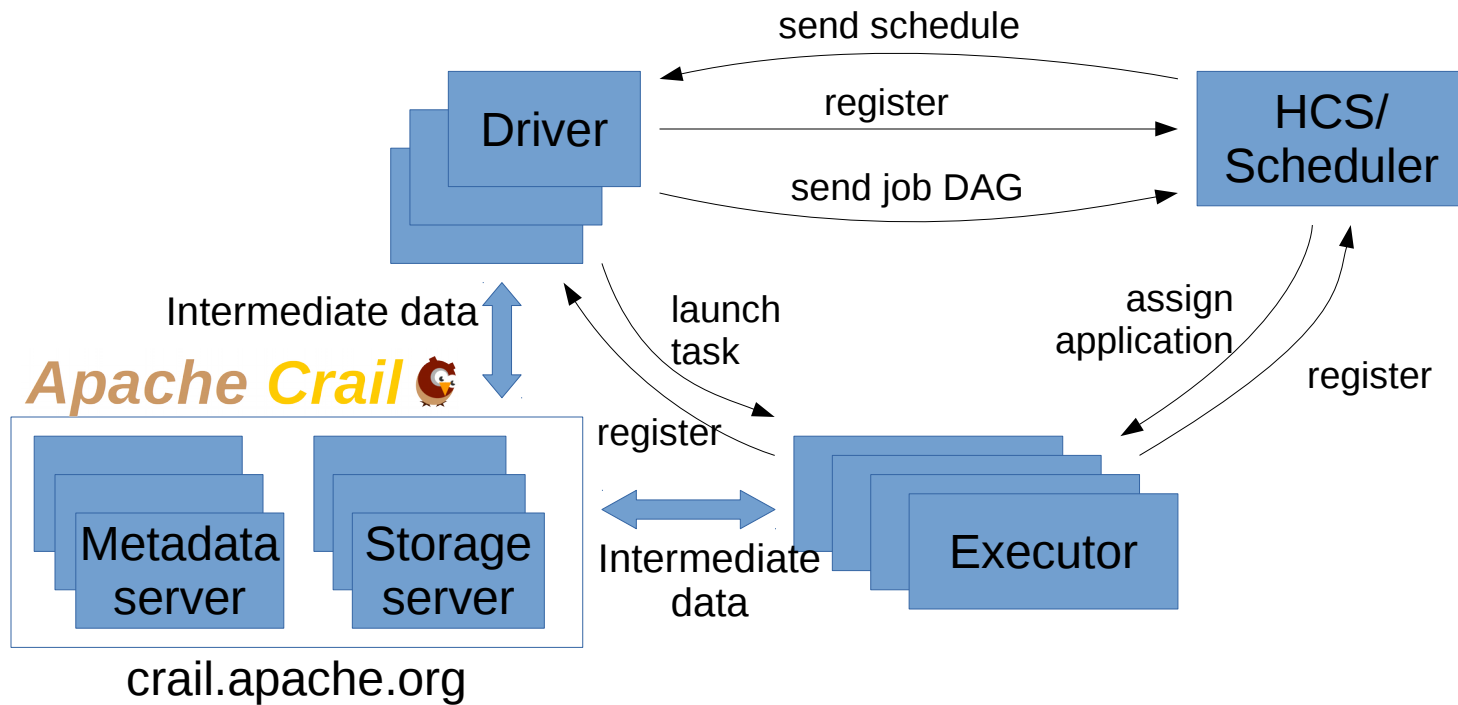
Slow!

- **Intermediate data:**

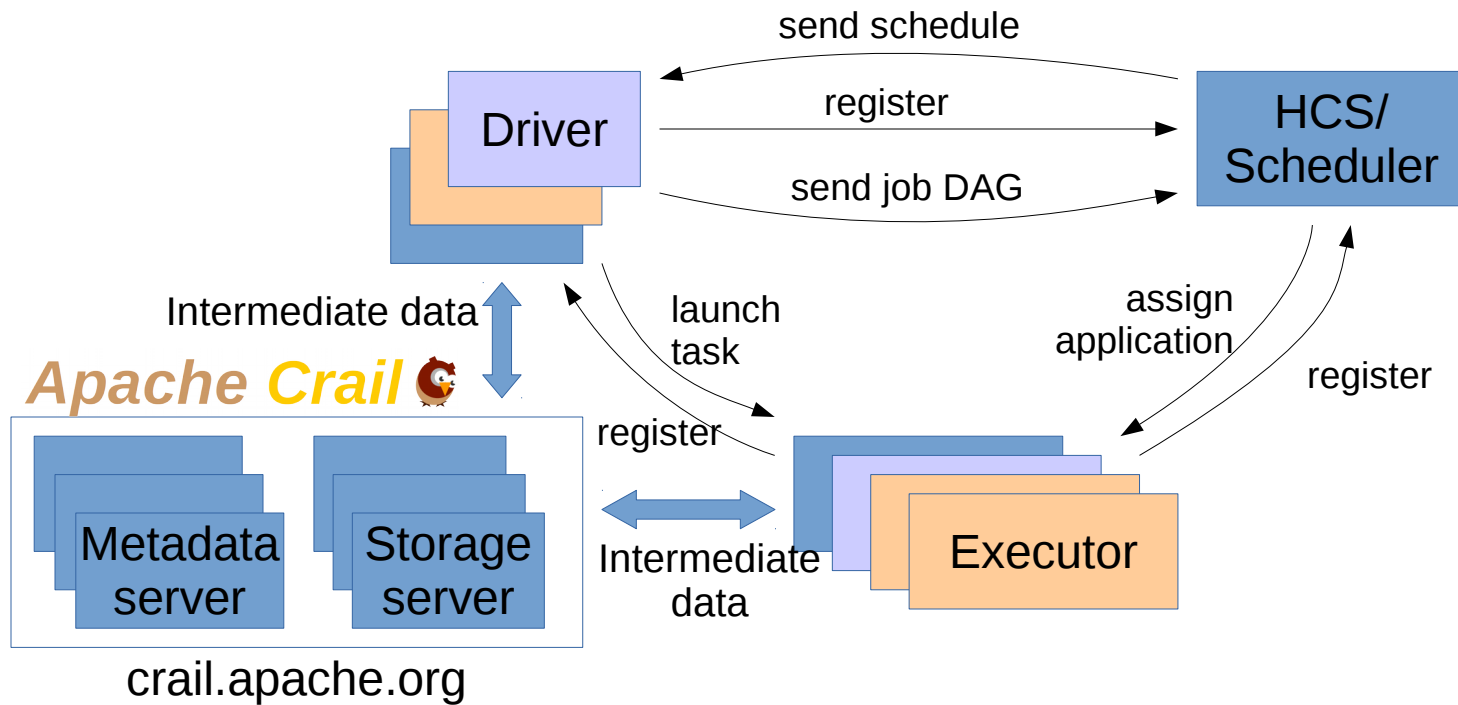
- ① Executors cooperate with scheduler to flush data remotely
- ② Consequently store all intermediate state remotely

Complex!

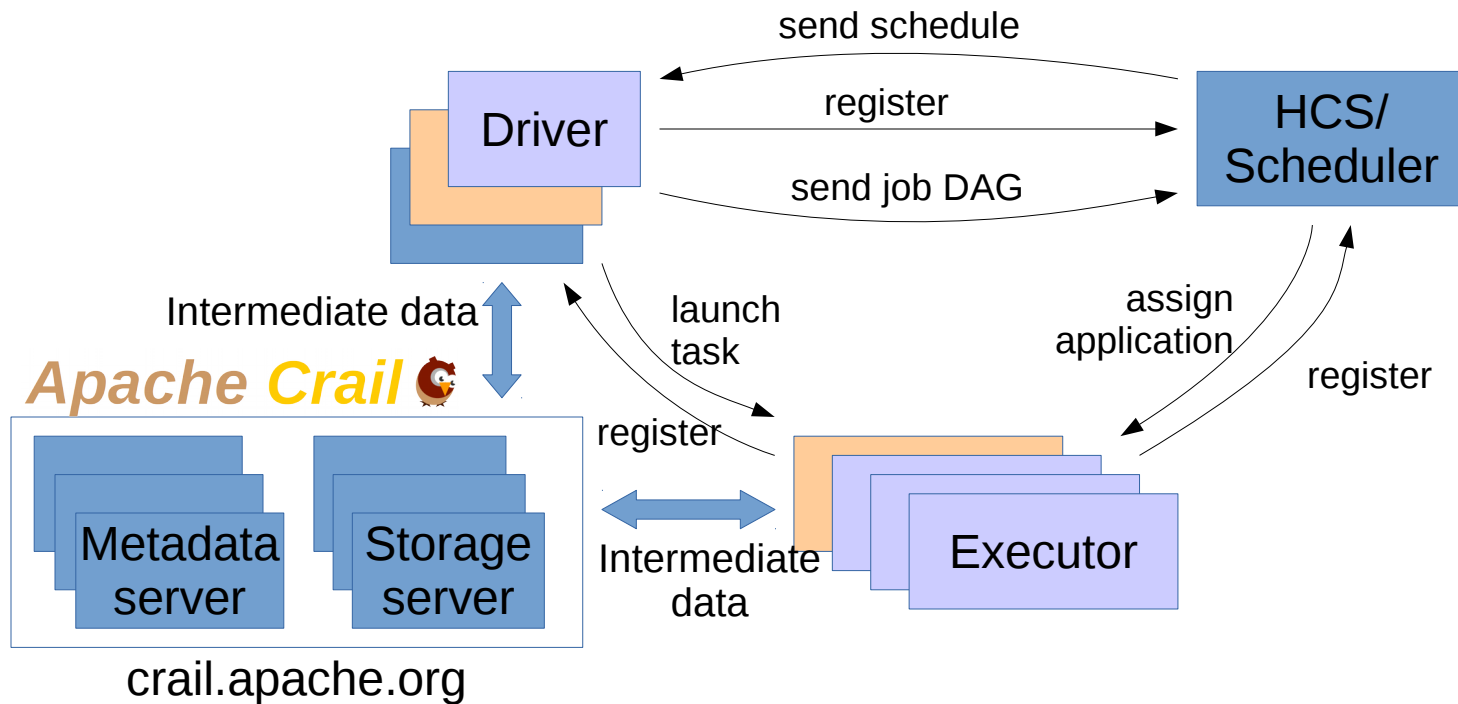
# Architecture Overview



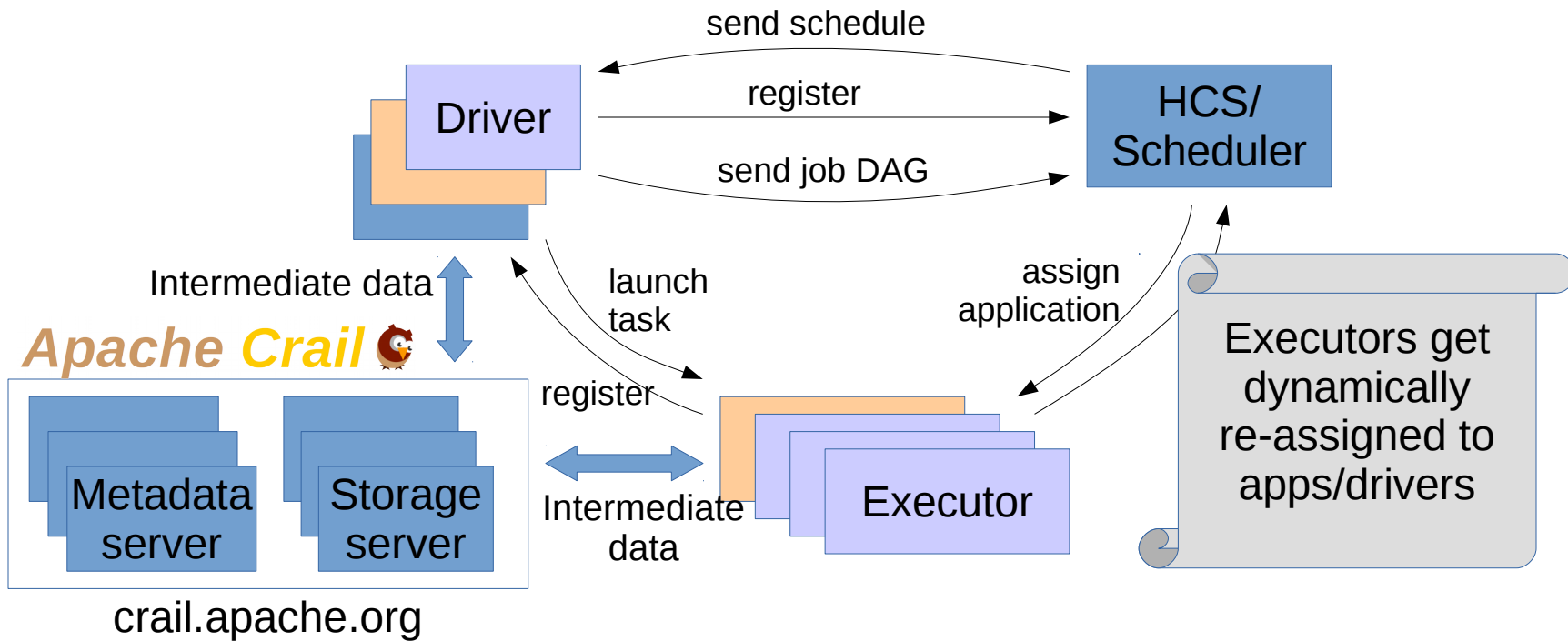
# Architecture Overview



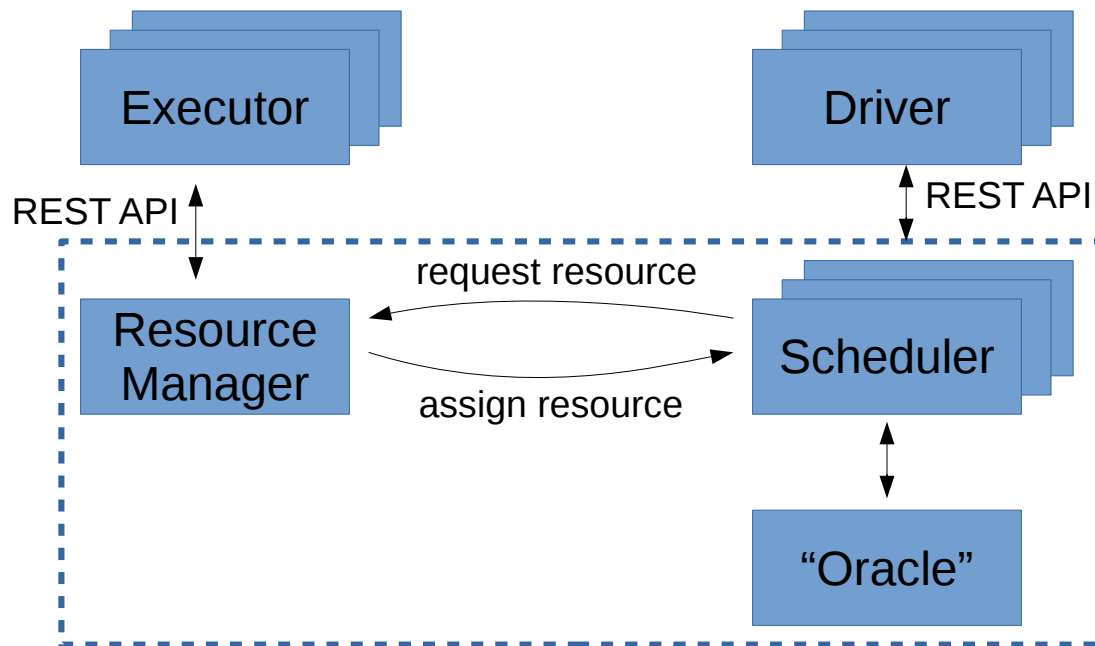
# Architecture Overview



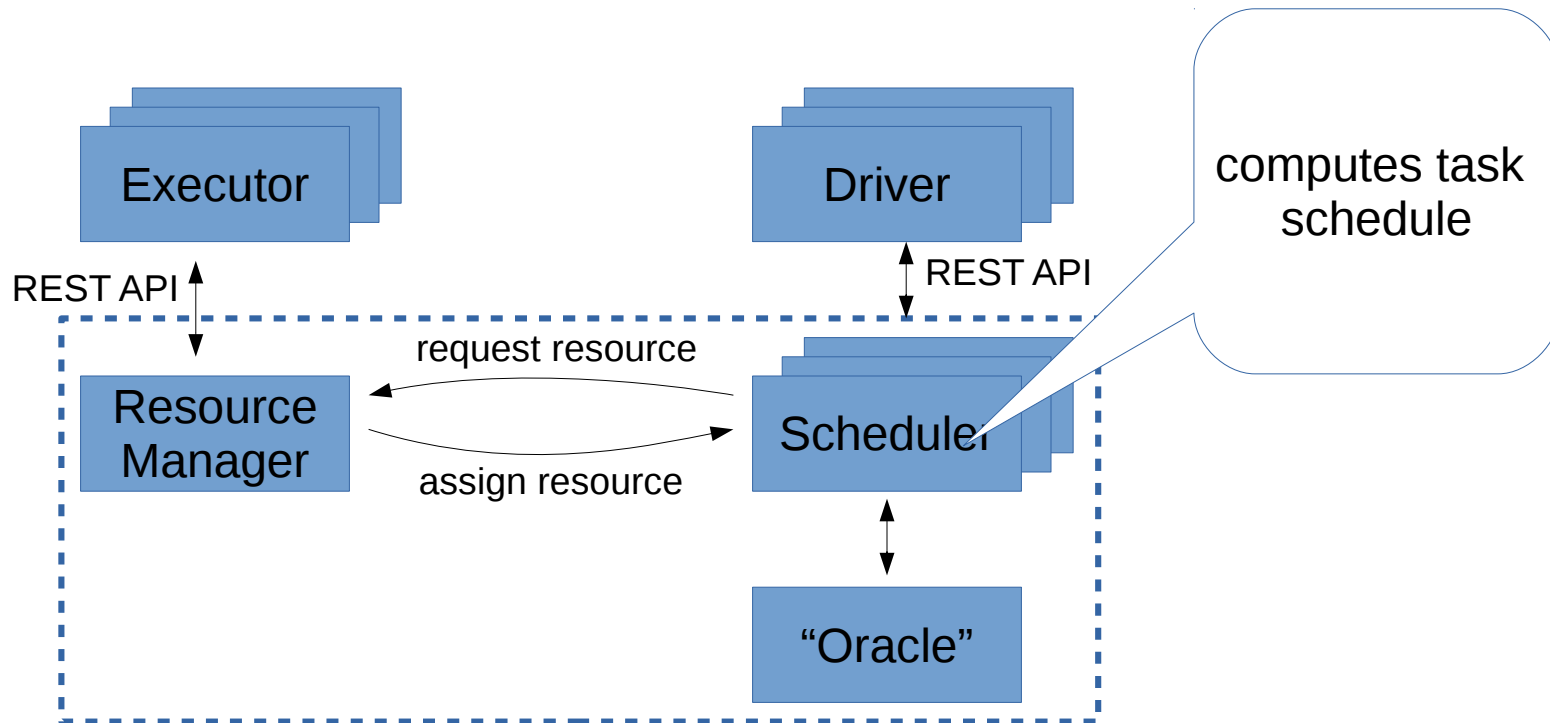
# Architecture Overview



# HCS Scheduler

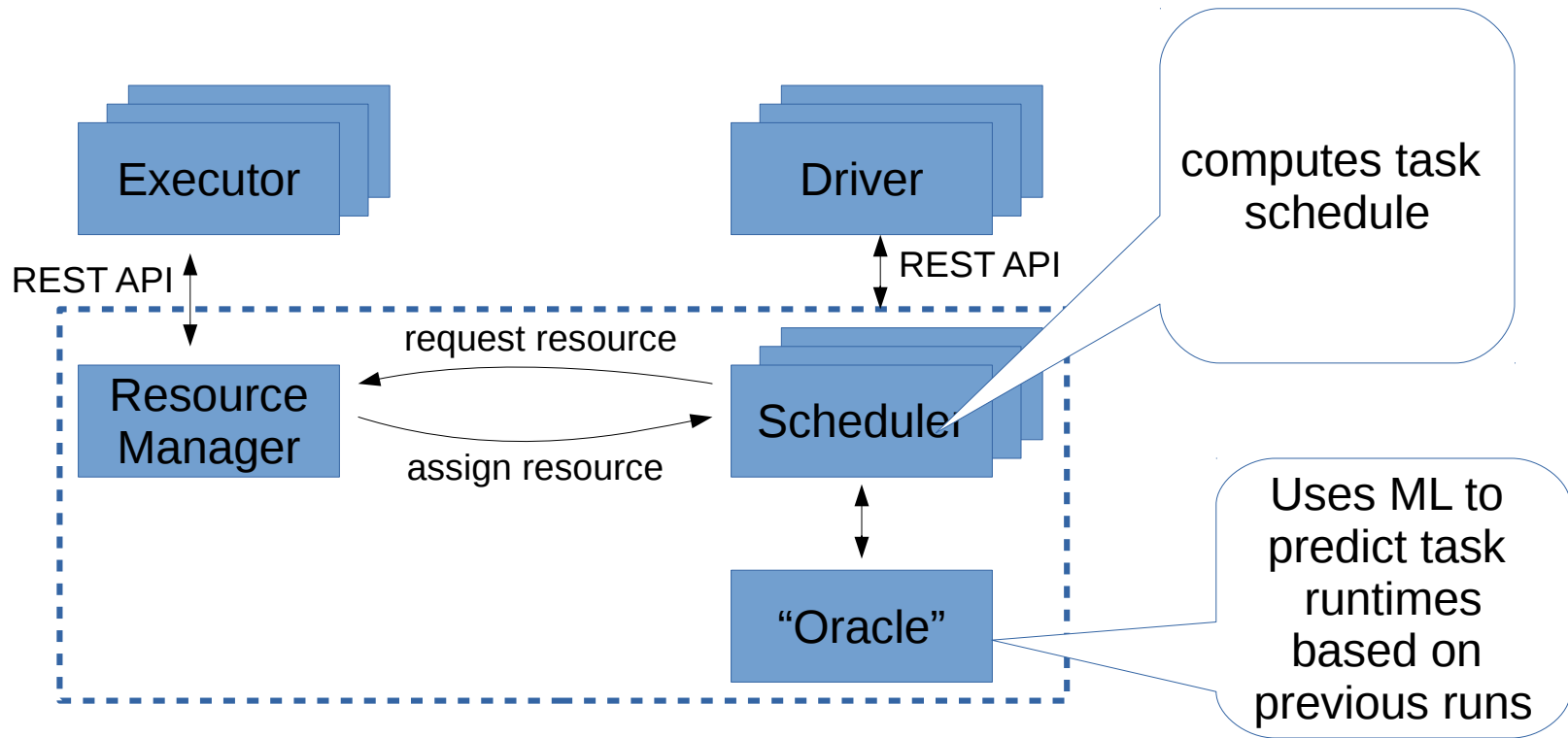


# HCS Scheduler

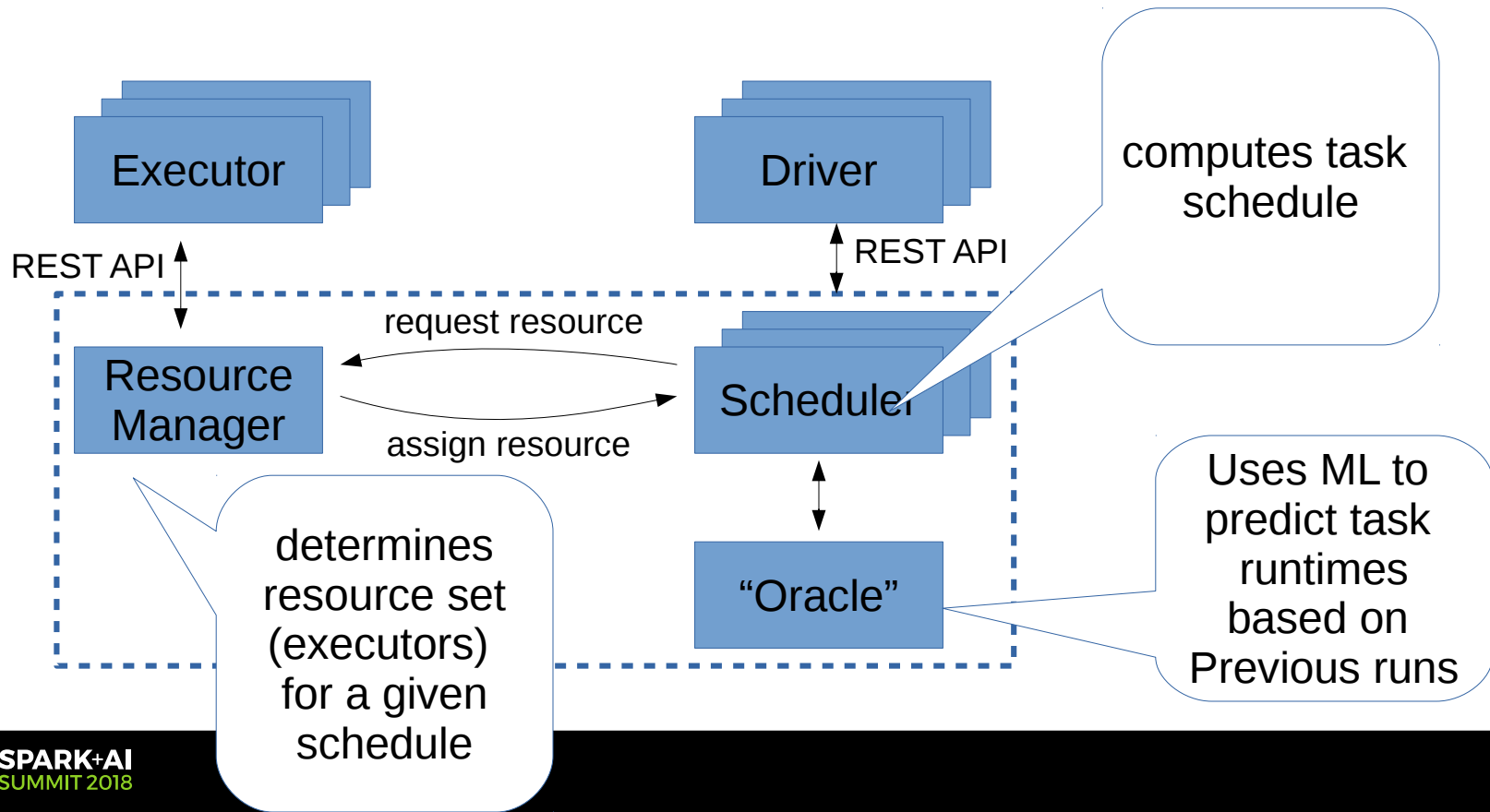




# HCS Scheduler

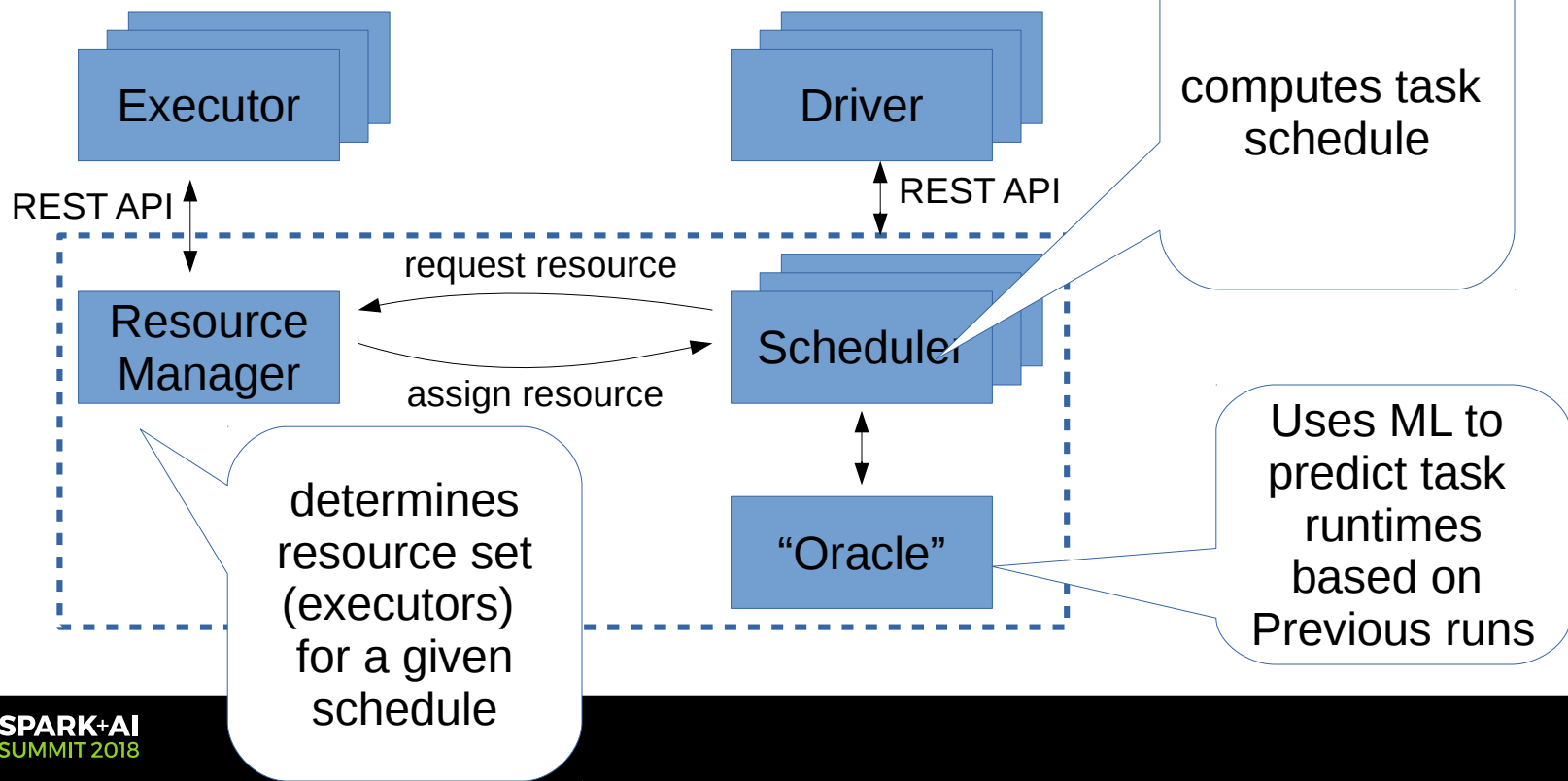


# HCS Scheduler



# HCS Scheduler

“The HCI Scheduler:  
Going all-in on Heterogeneity”,  
Michael Kaufmann et al., HotCloud’17



# Video: Putting things together

Application 1:  
GridSearch

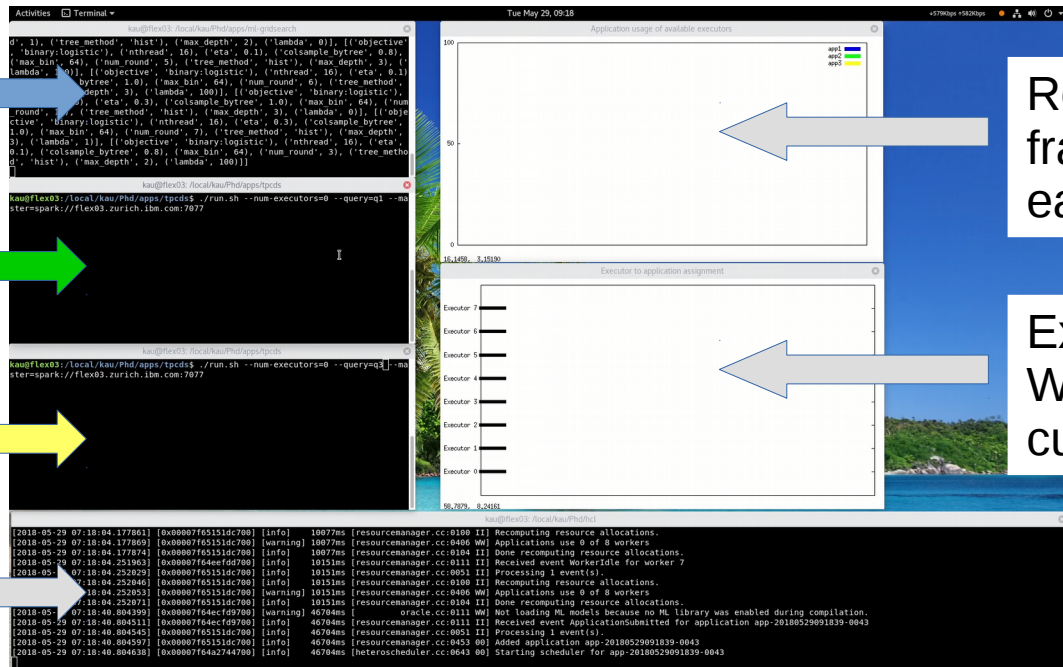
Application 2:  
SQL TPC-DS

Application 3:  
SQL TPC-DS

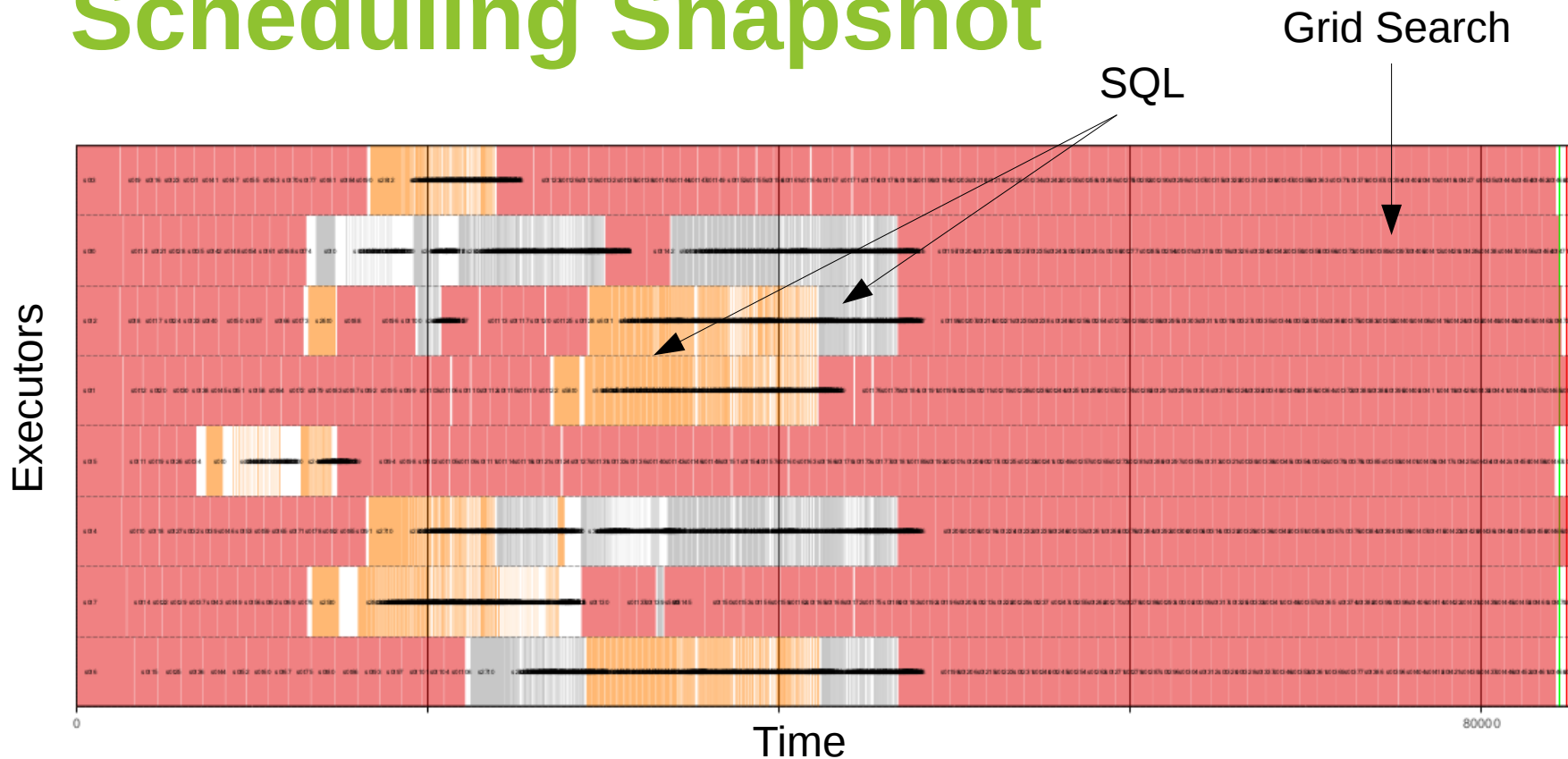
HCL  
Scheduler

Resource view:  
fraction of resources  
each app consumes

Executor view:  
Which app an executor  
currently runs



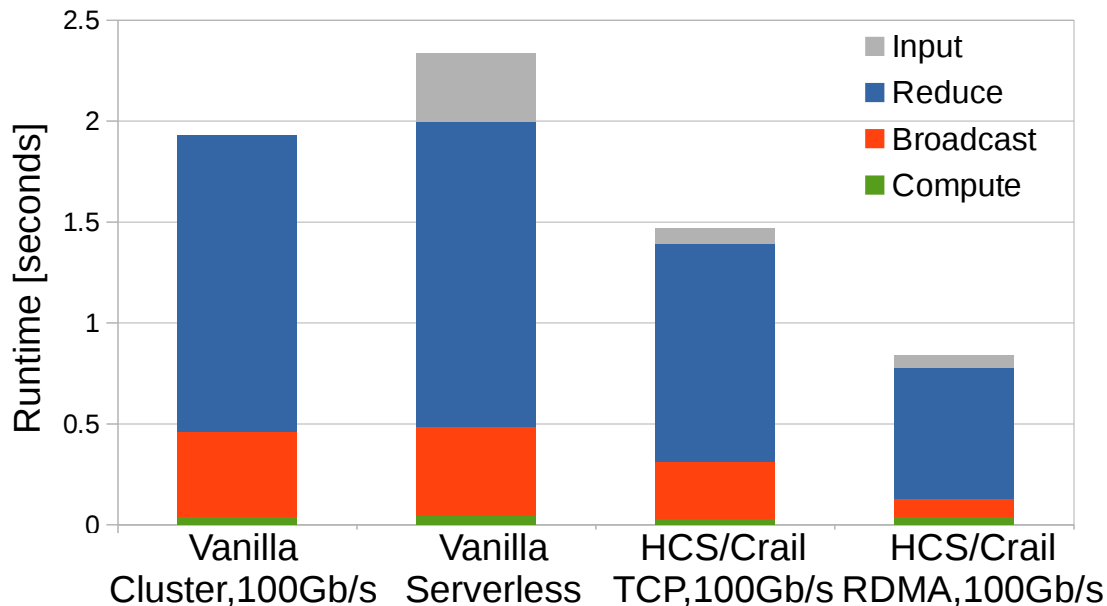
# Scheduling Snapshot



# Let's look at performance...

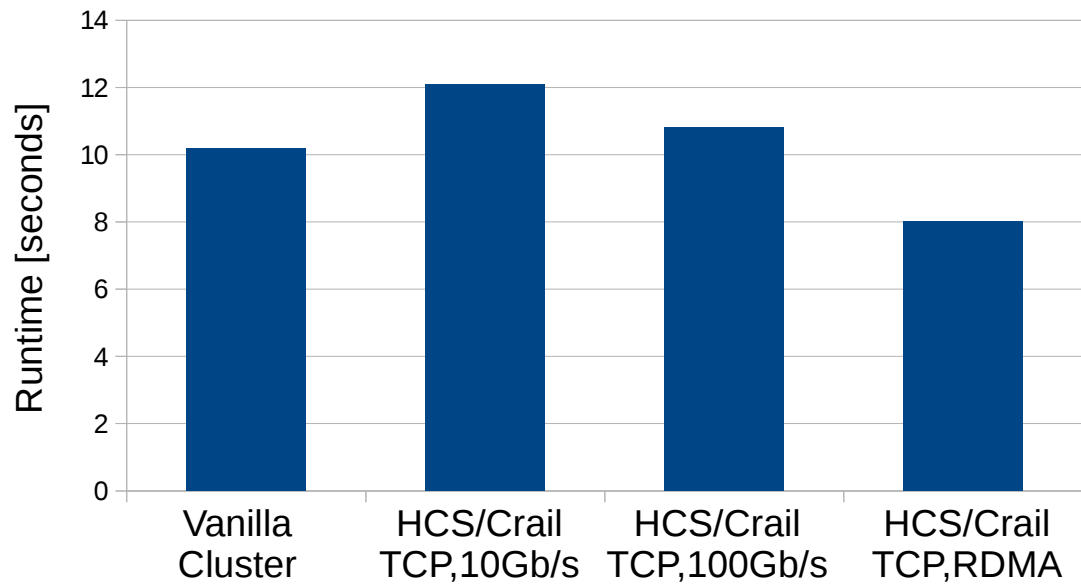
- Compute cluster size: 8 nodes: IBM Power8 Minsky
- Storage cluster size: 8 nodes, IBM Power8 Minsky
- Cluster hardware:
  - DRAM: 512 GB
  - Storage: 4x 1.2 TB NVMe SSD
  - Network: 10Gb/s Ethernet, 100Gb/s RoCE
  - GPU: NVIDIA P100, NVLink
- Workloads
  - ML: Logistic Regression using the CoCo framework
  - SQL: TCP-DS

# ML: Logistic Regression



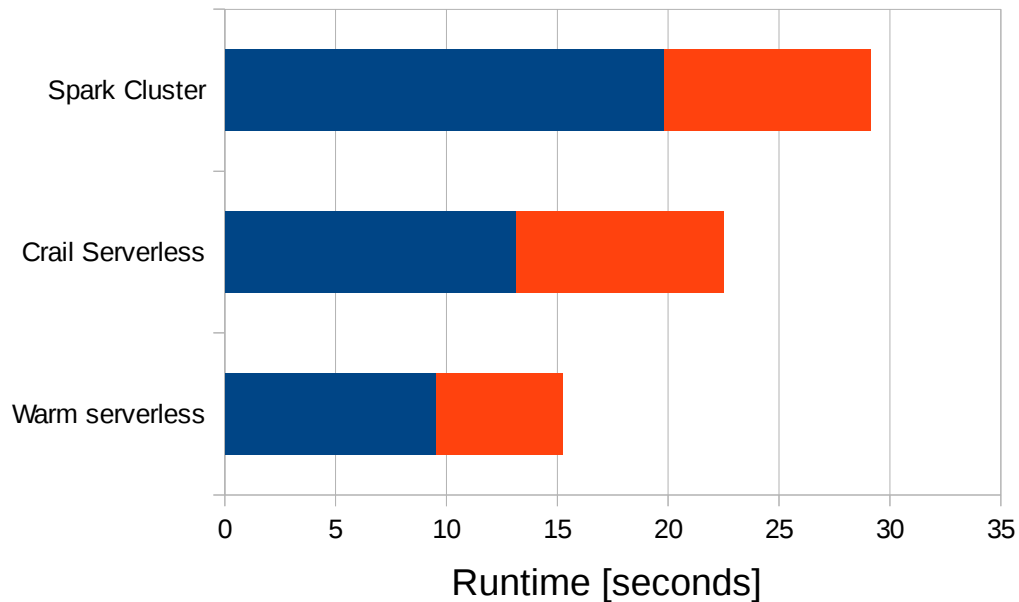
KDDA data set  
6.5 GB

# TPC-DS: Query #87





# TPC-DS: Query #3




# Conclusion

- Efficient serverless computing is challenging
  - Local state (e.g. shuffle, cached input, network state) is lost as compute cloud scales up/down
- This talk: turning Spark into a serverless framework by
  - Implementing HCS, a new serverless scheduler
  - Consequently storing compute state remotely using Apache Crail
- Supports arbitrary Spark workloads with almost no performance overhead
  - MapReduce, SQL, Iterative Machine Learning
- Implicit support for fast network and storage hardware
  - e.g, RDMA, NVMe, NVMe-oF

# Future Work

- Containerize the platform
- Add support for dynamic re-partitioning on scale events
- Add support for automatic caching
- Add more sophisticated scheduling policies

# Links

 Running Apache Spark on a High-Performance Cluster Using RDMA and NVMe Flash, Spark Summit'17, <https://tinyurl.com/yd453uzq>

 Apache Crail, <http://crail.apache.org>

 HCS Scheduler, [github.com/zrlio/hcs](https://github.com/zrlio/hcs)

 Spark-HCS, [github.com/zrlio/spark-hcs](https://github.com/zrlio/spark-hcs)

 Spark-IO, [github.com/zrlio/spark-io](https://github.com/zrlio/spark-io)

# Thanks to

Michael Kaufmann, Adrian Schuepbach, Jonas Pfefferle,  
Animesh Trivedi, Bernard Metzler, Ana Klimovic, Yawen  
Wang