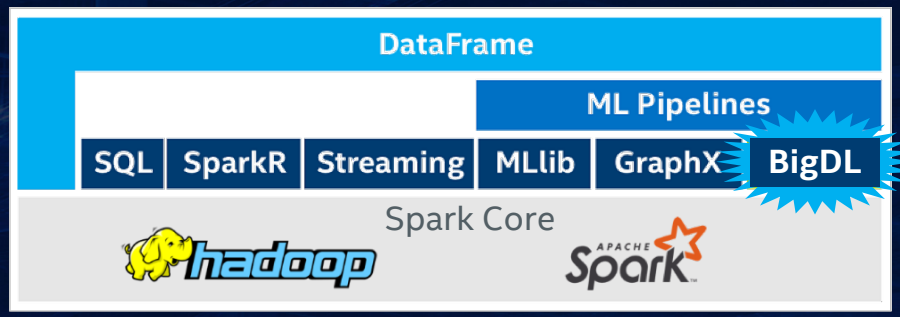
ACCELERATING DEEP LEARNING ON APACHE SPARK USING BIGDL WITH COARSE-GRAINED SCHEDULING

Shivaram Venkataraman (Microsoft Research, UC Berkeley)
Ding Ding (Intel)
Sergey Ermolin (Intel)

June 2018

BigDL

HIGH PERFORMANCE DEEP LEARNING FOR APACHE SPARK* ON CPU INFRASTRUCTURE



BigDL is an **open-source** distributed deep learning library for Apache Spark* that can run directly on top of existing Spark or Apache Hadoop* clusters

Ideal for DL Models TRAINING and INFERENCE

Designed and Optimized for Intel® Xeon®

No need to deploy costly accelerators, duplicate data, or suffer through scaling headaches!

Feature Parity & Model Exchange with TensorFlow*, Caffe*, Keras, Torch*

Lower TCO and improved ease of use with existing infrastructure

Deep Learning on Big Data Platform, Enabling **Efficient Scale-Out**

Powered by Intel® MKL and multi-threaded programming

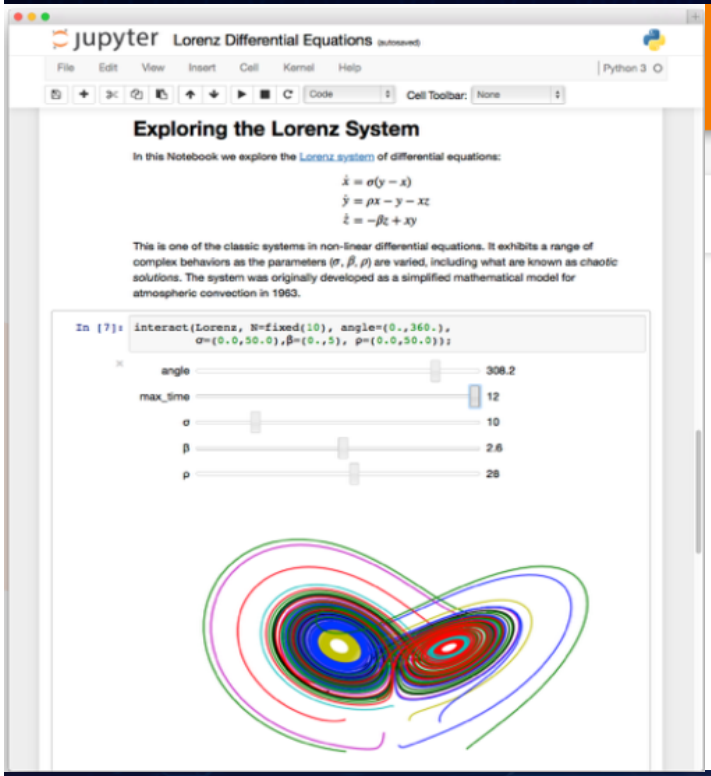
bigdl-project.github.io

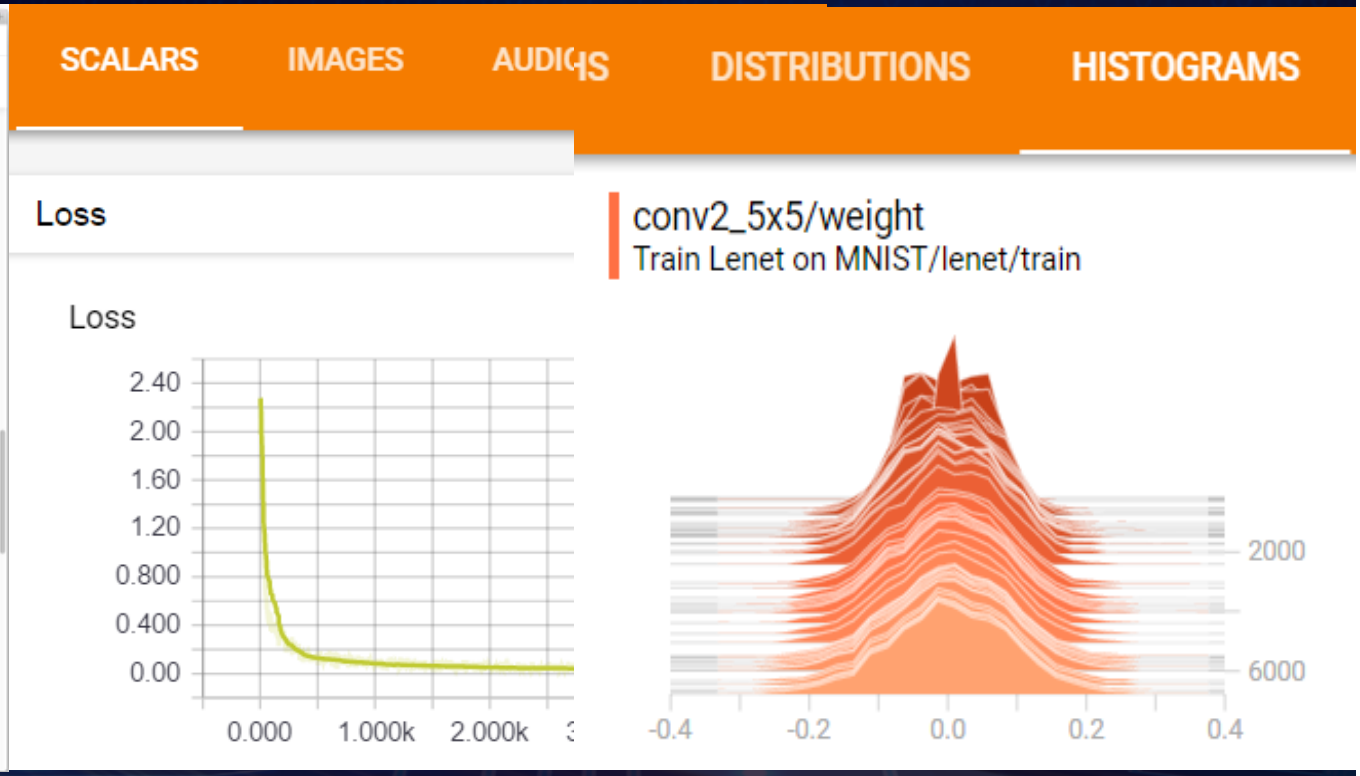
software.intel.com/bigdl

intel

BIGDL

Jupyter, Zeppelin notebooks and TensorBoard support





bigdl-project.github.io

software.intel.com/bigdl

BigDL

BUILDING & DEPLOYING WITH BIGDL

PLATFORMS

bluedata®

cloudera® INSIGHTEDGE

databricks

CRAY THE SUPERCOMPUTER COMPANY

DELL KINGSOFT

Qubole

Lightbend

CLOUD SERVICE PROVIDERS

Alibaba Cloud aliyun.com

aws

Azure

IBM Cloud

Google Cloud Platform

SOLUTIONS

JD.COM 京东

UnionPay 银联

GIGASPACES innovate with confidence

MLS LISTINGS

UCSF

Open Source Community support:
2496 STARS | 500+ FORKS | 50 CONTRIBUTORS

https://bigdl-project.github.io

And Many More...

*Other names and brands may be claimed as the property of others.

intel

ANALYTICS ZOO

Analytics + AI Pipelines for Spark and BigDL

“Out-of-the-box” ready for use

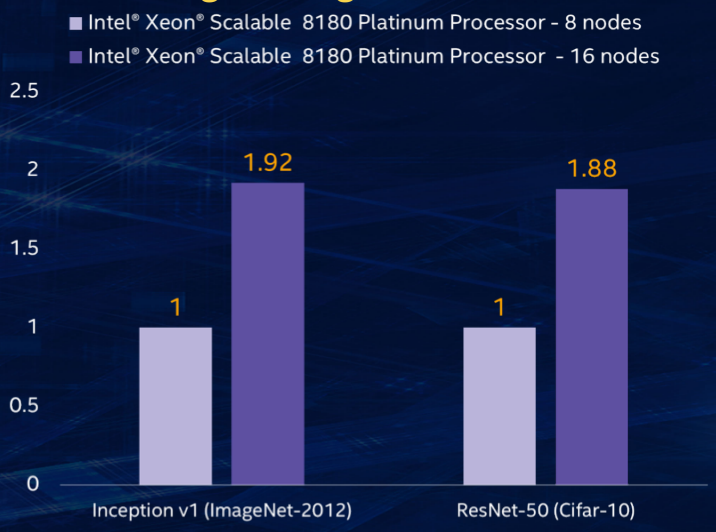
- Reference use cases
  - Fraud detection, time series prediction, sentiment analysis, chatbot, etc.
- Predefined models
  - Object detection, image classification, text classification, recommendations, etc.
- Feature transformations
  - Vision, text, 3D imaging, etc.
- High level APIs
  - DataFrames, ML Pipelines, Keras/Keras2, etc.

bigdl-project.github.io

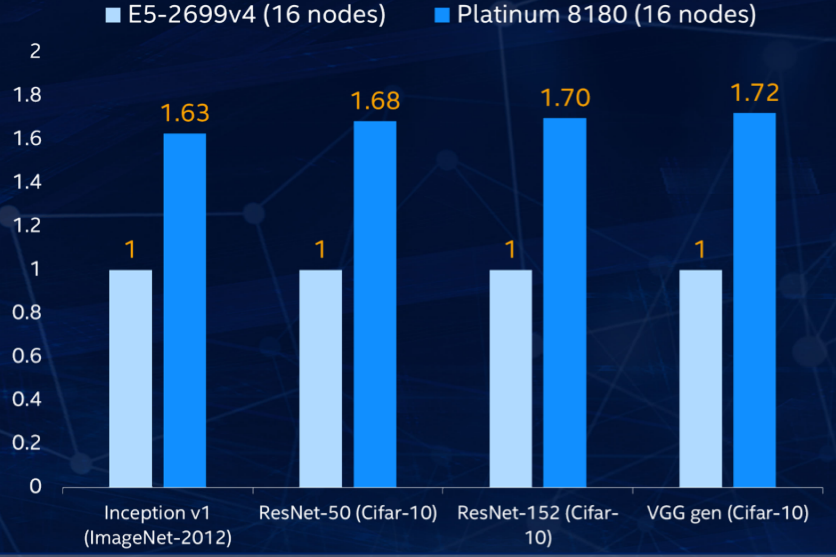
software.intel.com/bigdl

DEEP LEARNING WITH BIGDL/SPARK

Node Scaling with BigDL



Generational performance increase with BigDL

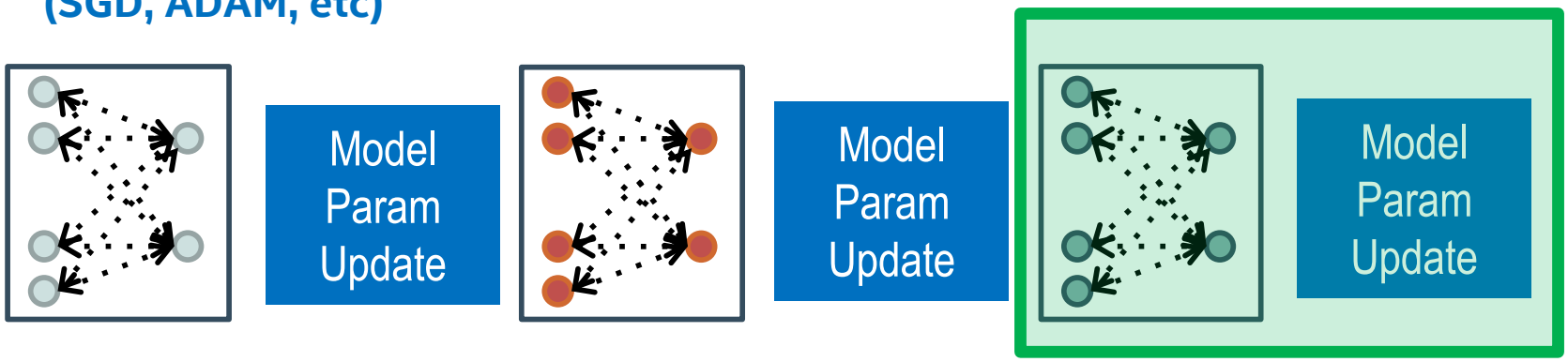


GET EXCELLENT MULTI-NODE SCALING AND GENERATIONAL PERFORMANCE WITH YOUR EXISTING HARDWARE

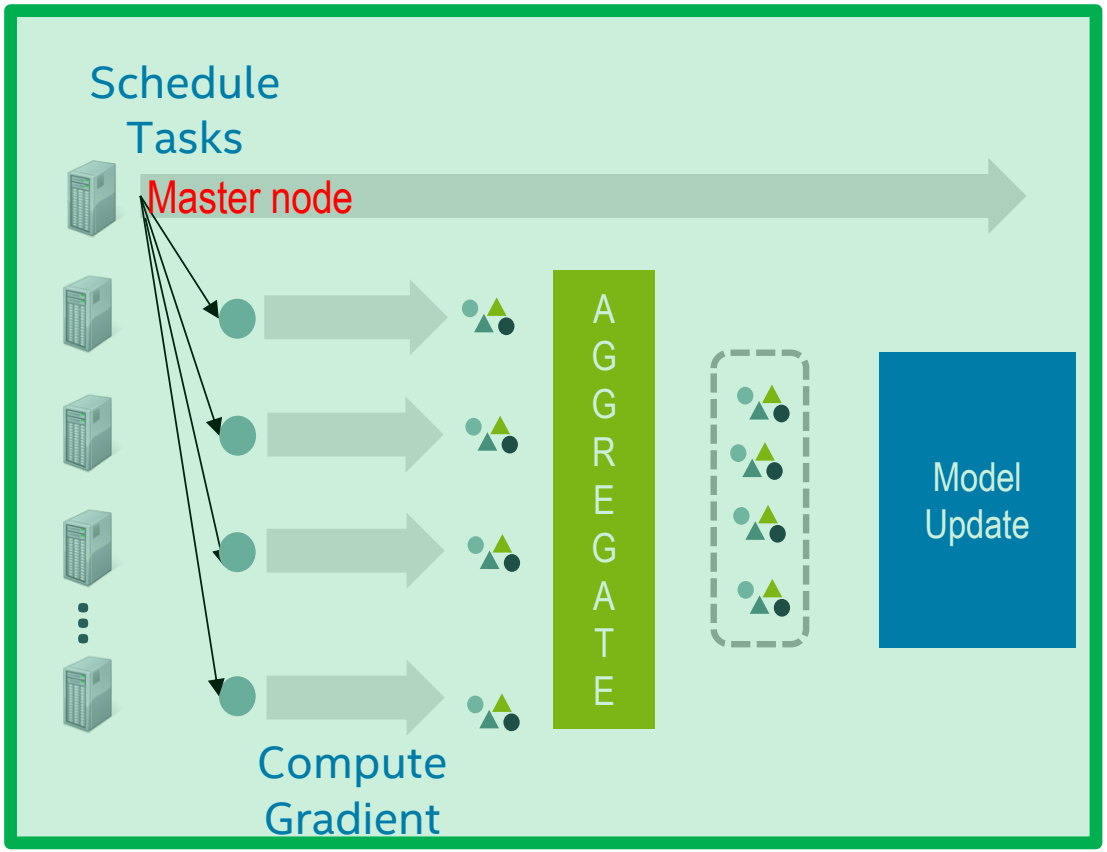
bigdl-project.github.io software.intel.com/bigdl intel

DEEP LEARNING TRAINING

All Iterative ML Algorithms exchange model parameters after each iterations (SGD, ADAM, etc)



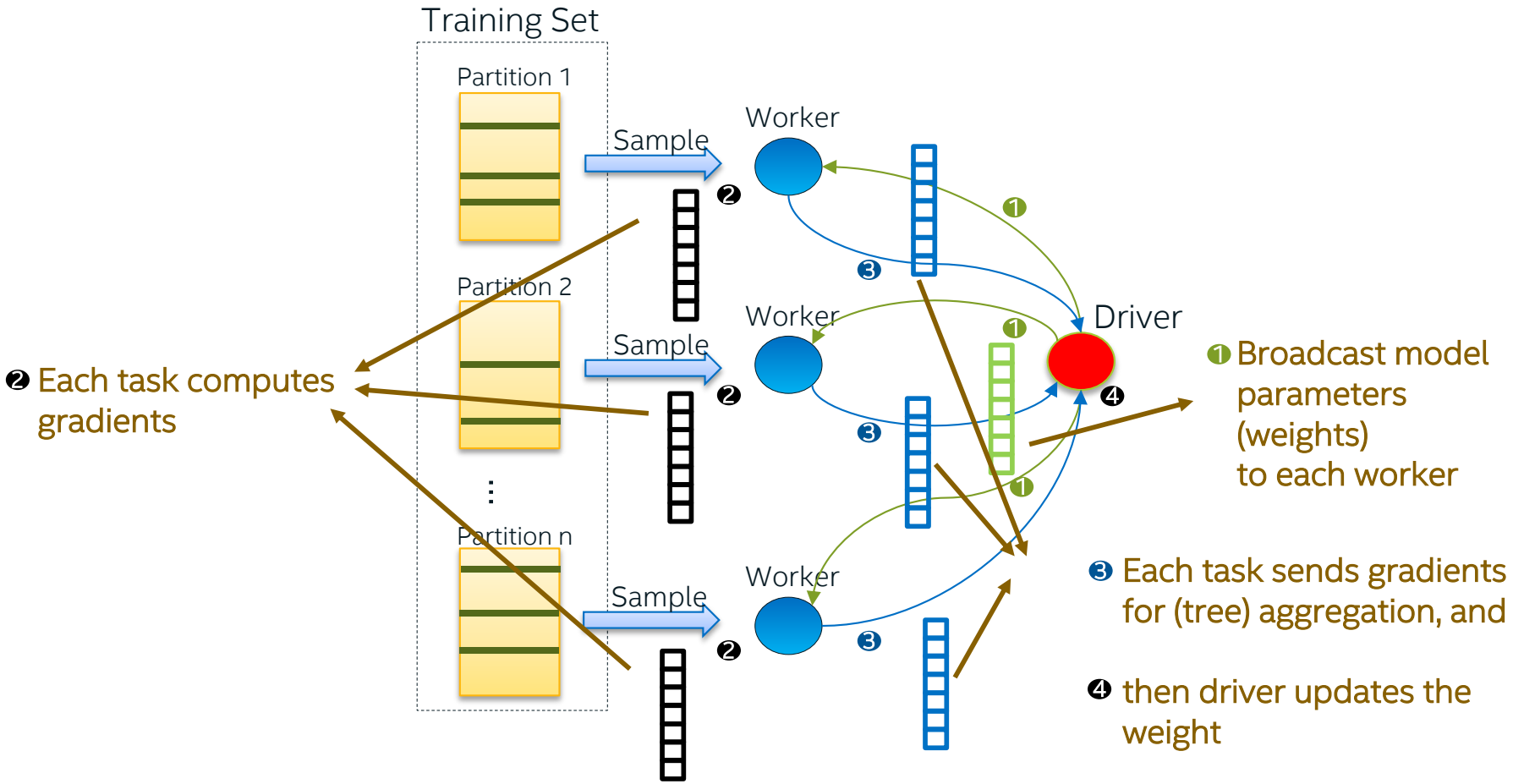
ZOOMING IN: INSIDE EACH ITERATION



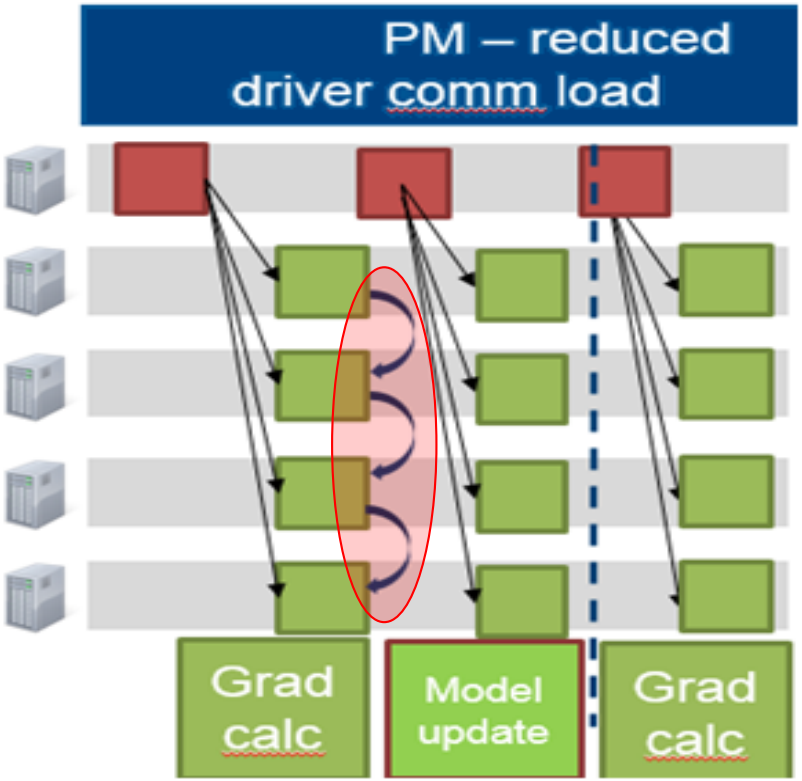
Training

```
for (i <- 1 to N) {
  batch = next_batch()
  output = model.forward(batch.input)
  loss = criterion.forward(output, batch.target)
  error = criterion.backward(output,
batch.target)
  model.backward(input, error)
   …
  optimMethod.optimize(model.weight,
model.gradient)
}
```

BASELINE: PARAMETER SYNCHRONIZATION IN SPARK MLLIB



SYNCHRONIZATION VIA PARAMETER MANAGER IN BIGDL

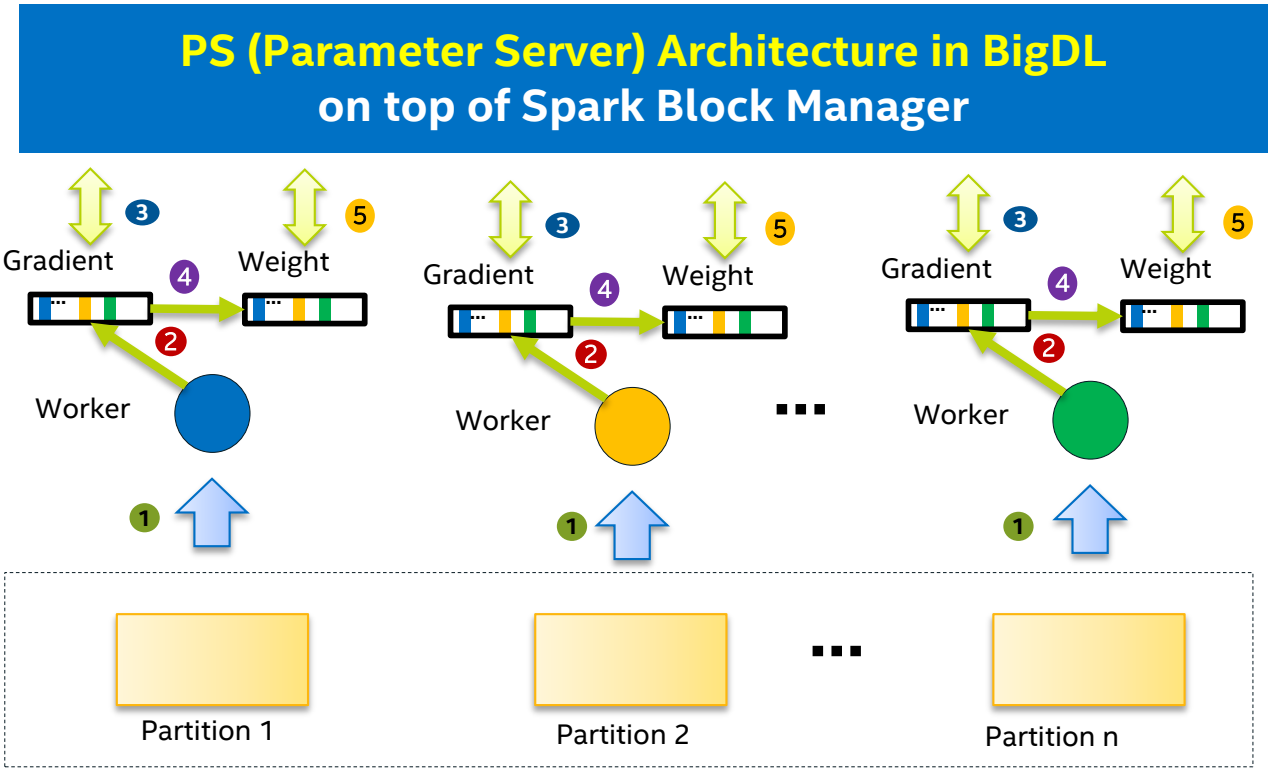


Distributed Parameter Manager aggregates gradients and updates model

Master Node is not involved!

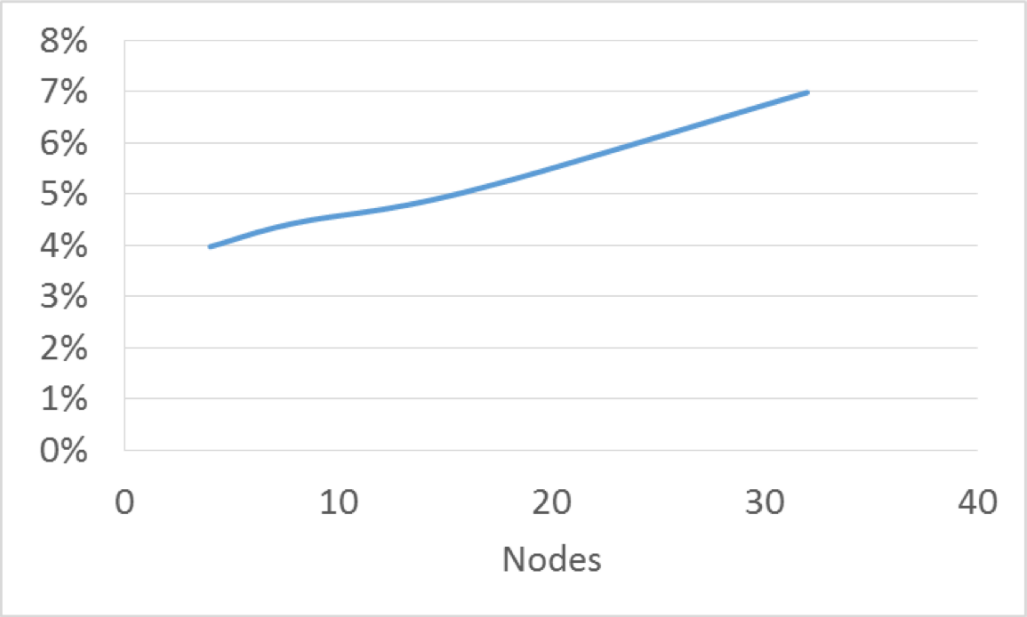
All-Reduce synchronization without hotspot and shuffle

SYNCHRONIZATION VIA PARAMETER MANAGER IN BIGDL



Peer-2-Peer All-Reduce synchronization

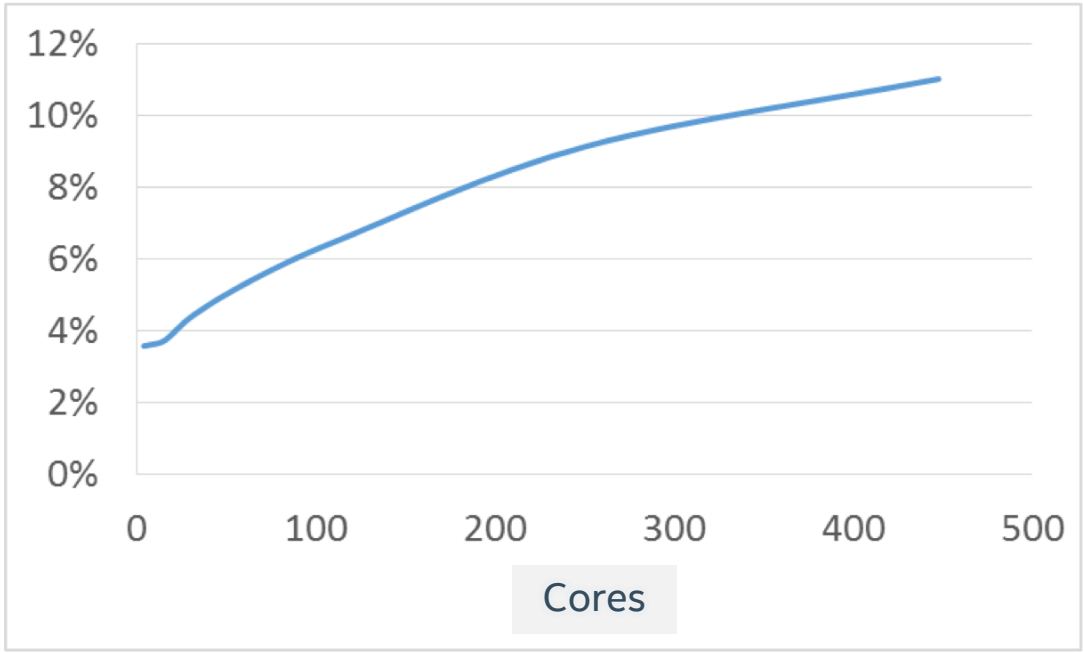
EFFECTS OF PARAMETER MANAGER IMPLEMENTATION IN BIGDL



Parameter synchronization time as a fraction of average compute time for Inception v1 training

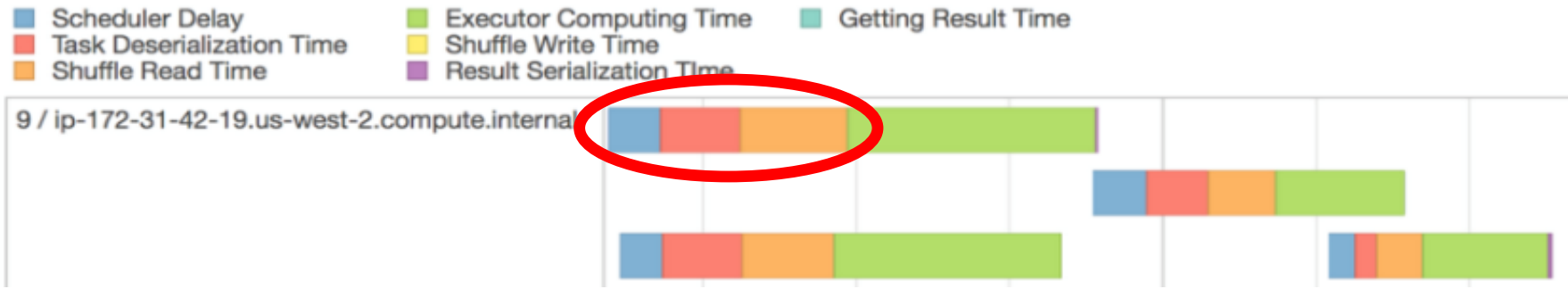
- Linear scaling
- 2x node increase – **only 1%** increase in parameter sync time

TASK SCHEDULING OVERHEAD



Total Spark overhead (task scheduling, task serdes, task fetch) as a fraction of average compute time for Inception-v1 training

FOCUS: CUTTING SPARK SCHEDULING AND COMMS OVERHEAD



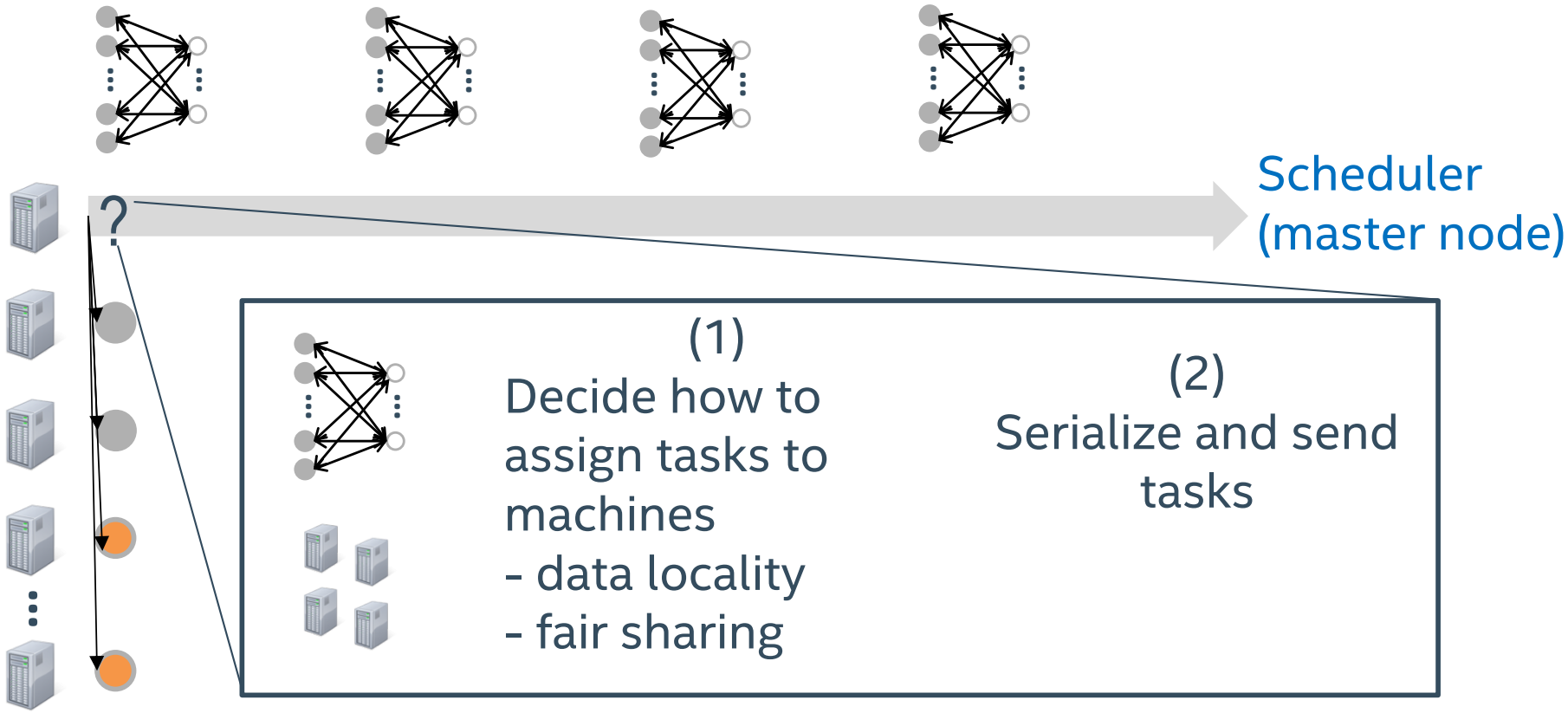
- Optimizing parameter synchronization and aggregation (PM)

- **Optimizing task scheduling (Drizzle)**

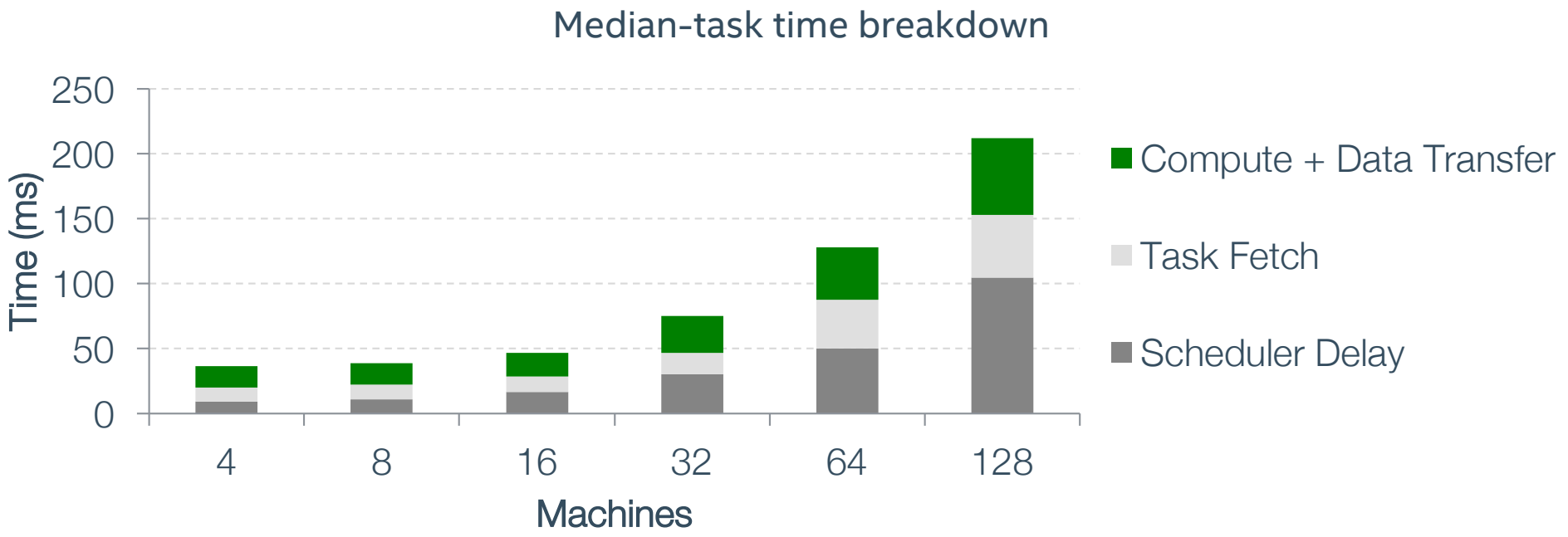
DL tasks are uniquely suited for Spark performance optimization:

- Heavy master node workload during model update
- **Repetitive in nature (reusable task scheduling decisions)**
- **Static data partitioning and cluster configuration**

INSIDE THE SCHEDULER



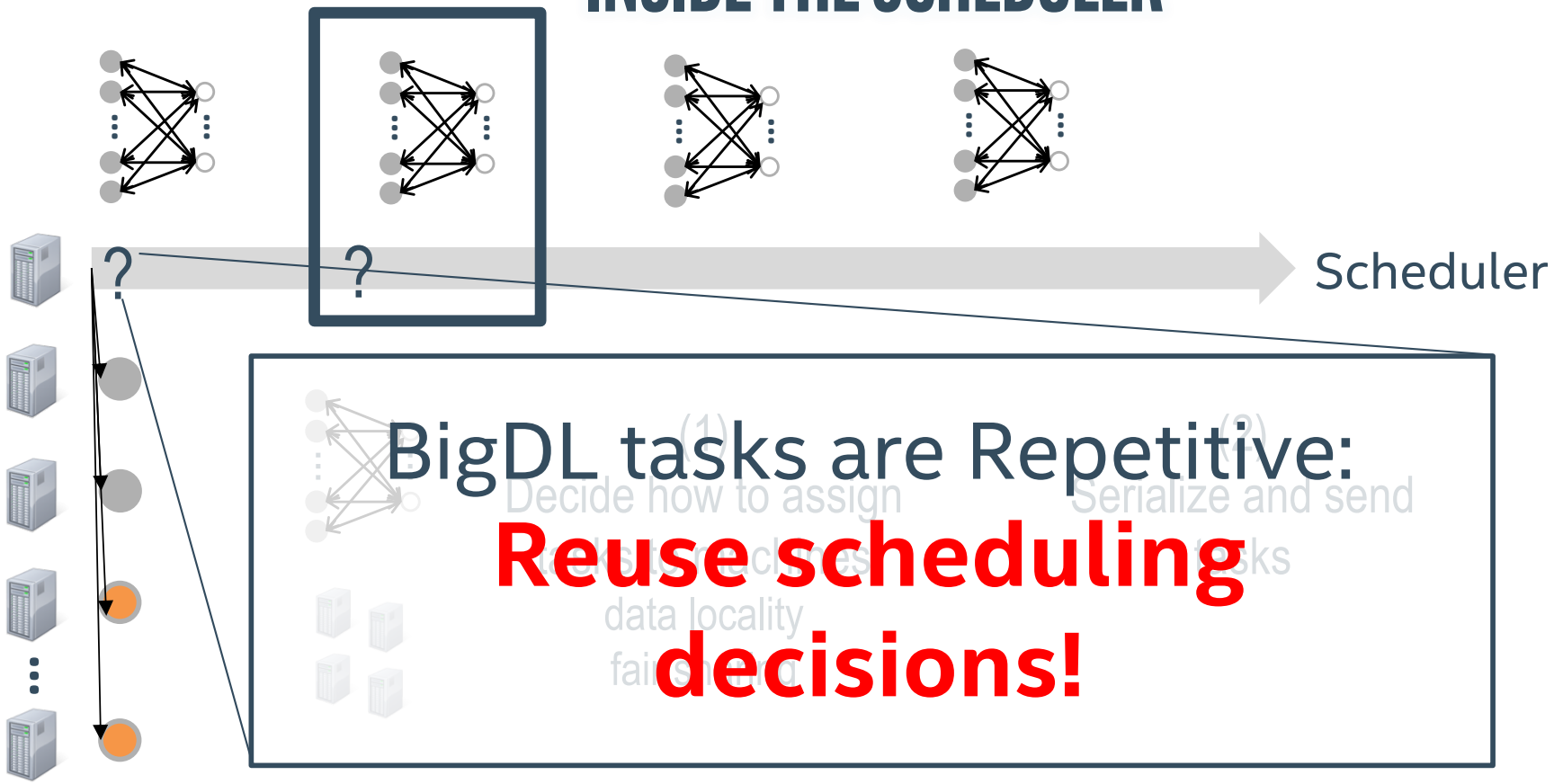
SCHEDULING OVERHEADS – SCALABILITY PROBLEM



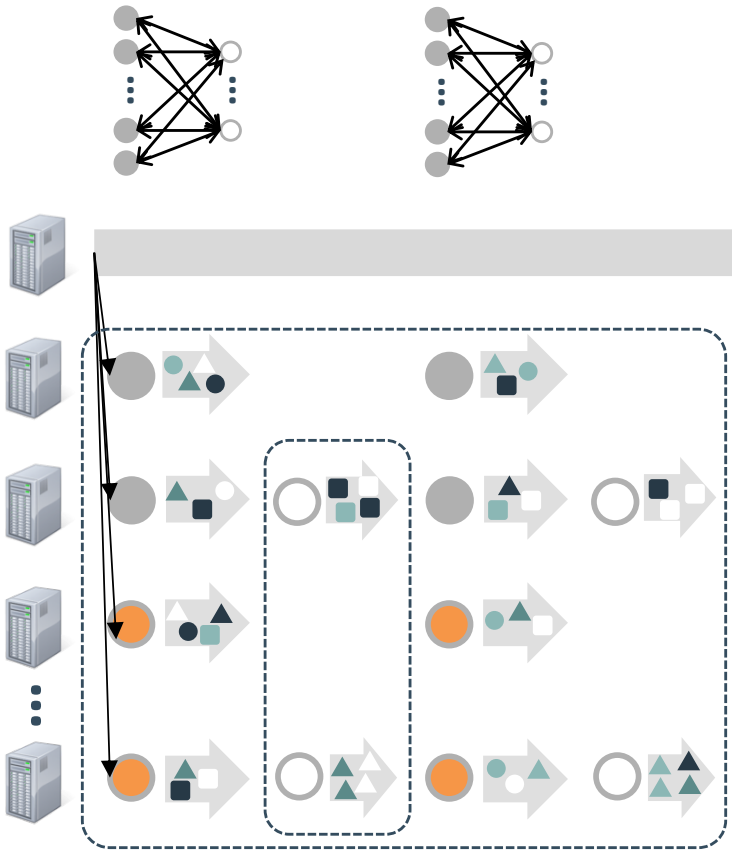
Cluster: 4 core, r3.xlarge machines

Workload: Sum of 10k numbers per-core

INSIDE THE SCHEDULER



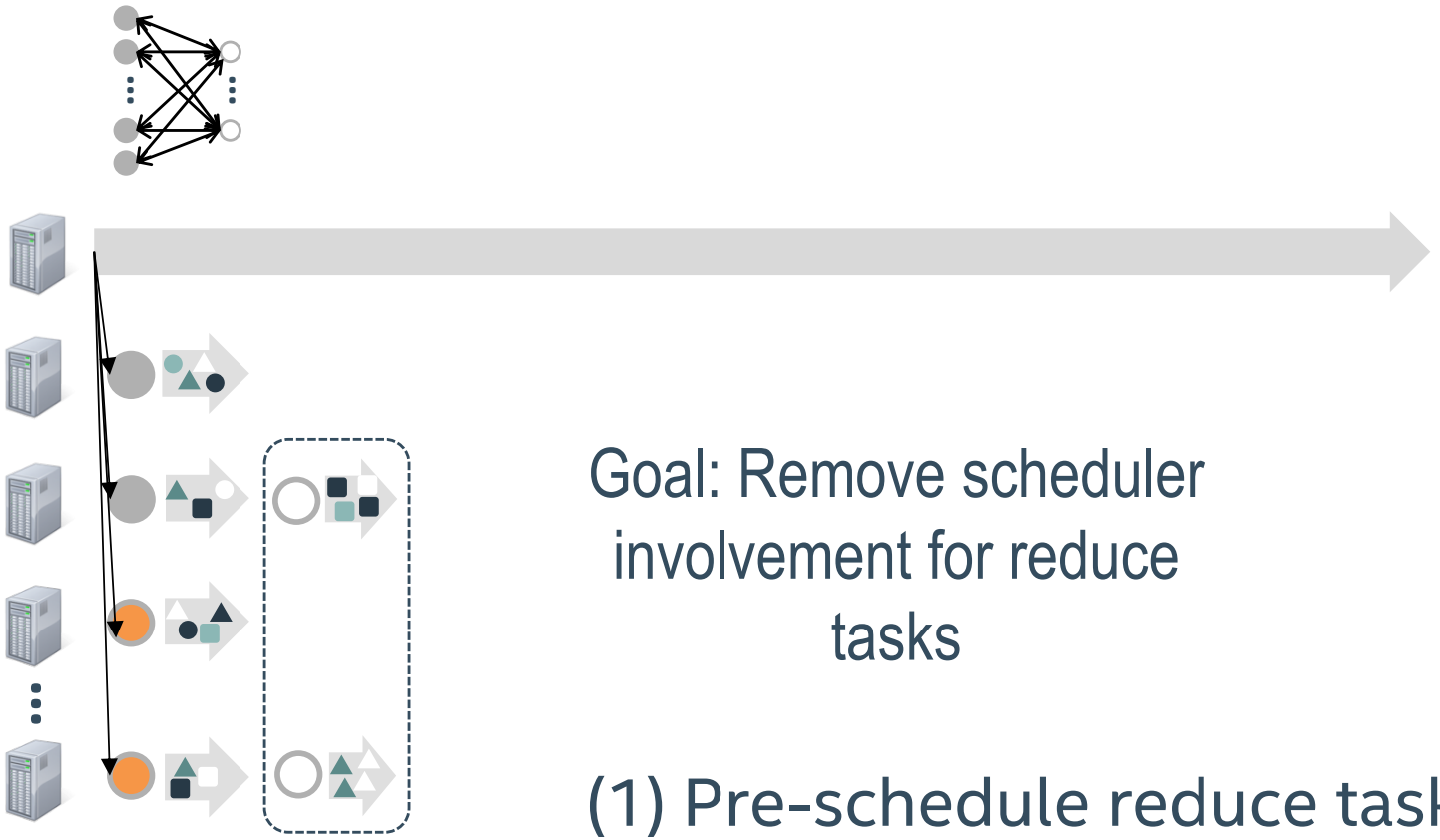
DRIZZLE



Goal:
remove frequent
scheduler
interaction

(2) Group
schedule
iterations

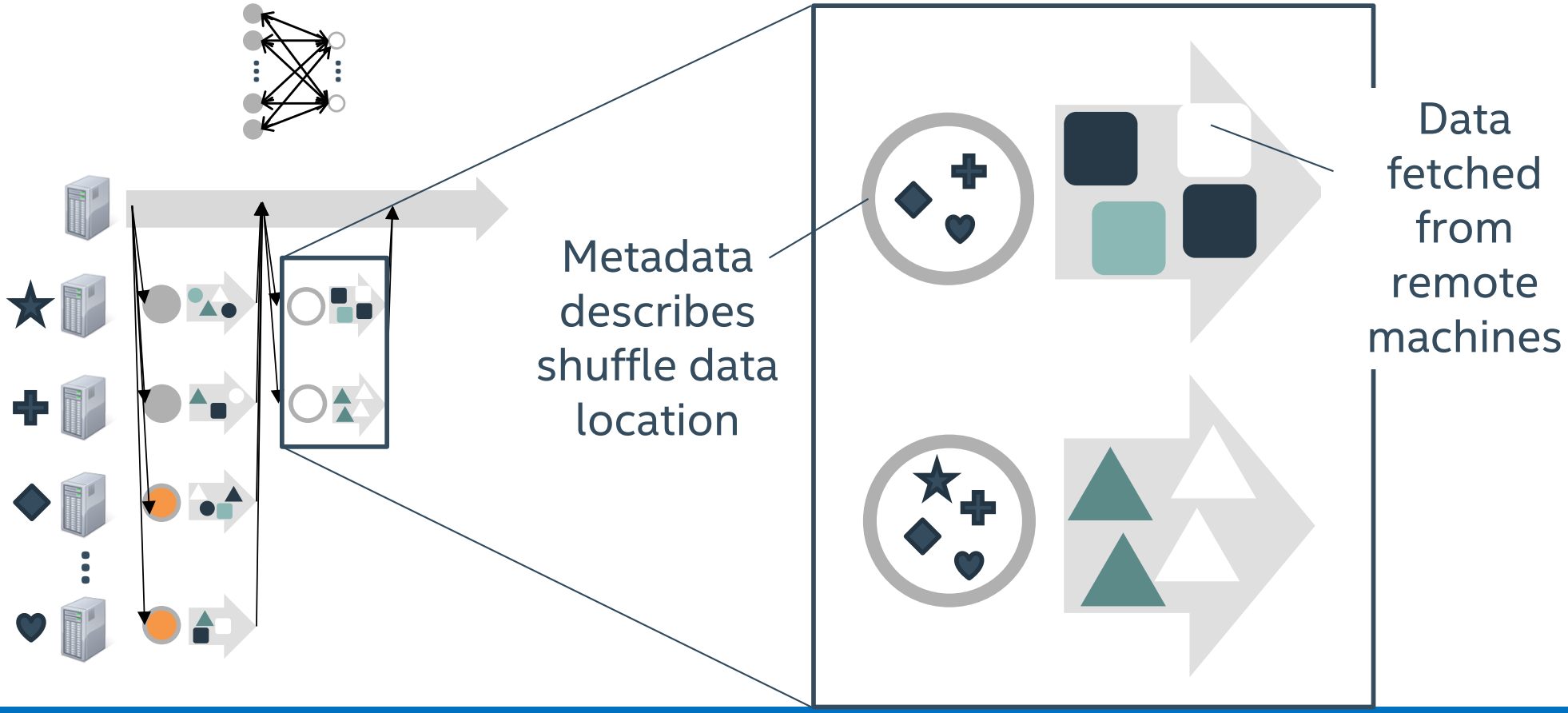
(1) Pre-schedule reduce tasks



Goal: Remove scheduler involvement for reduce tasks

(1) Pre-schedule reduce tasks

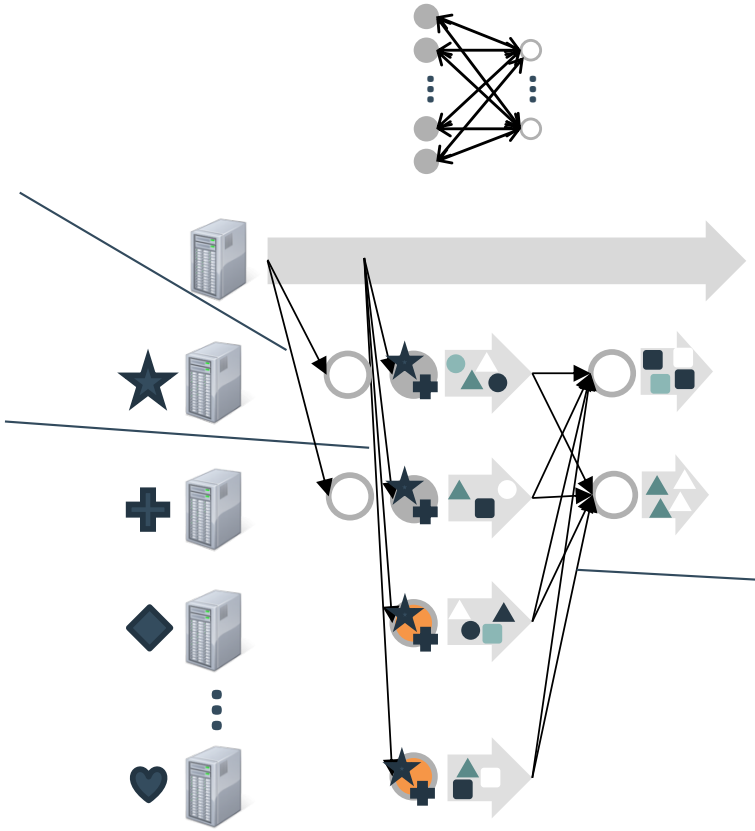
COORDINATING SHUFFLES: EXISTING SYSTEMS



COORDINATING SHUFFLES: PRE-SCHEDULING

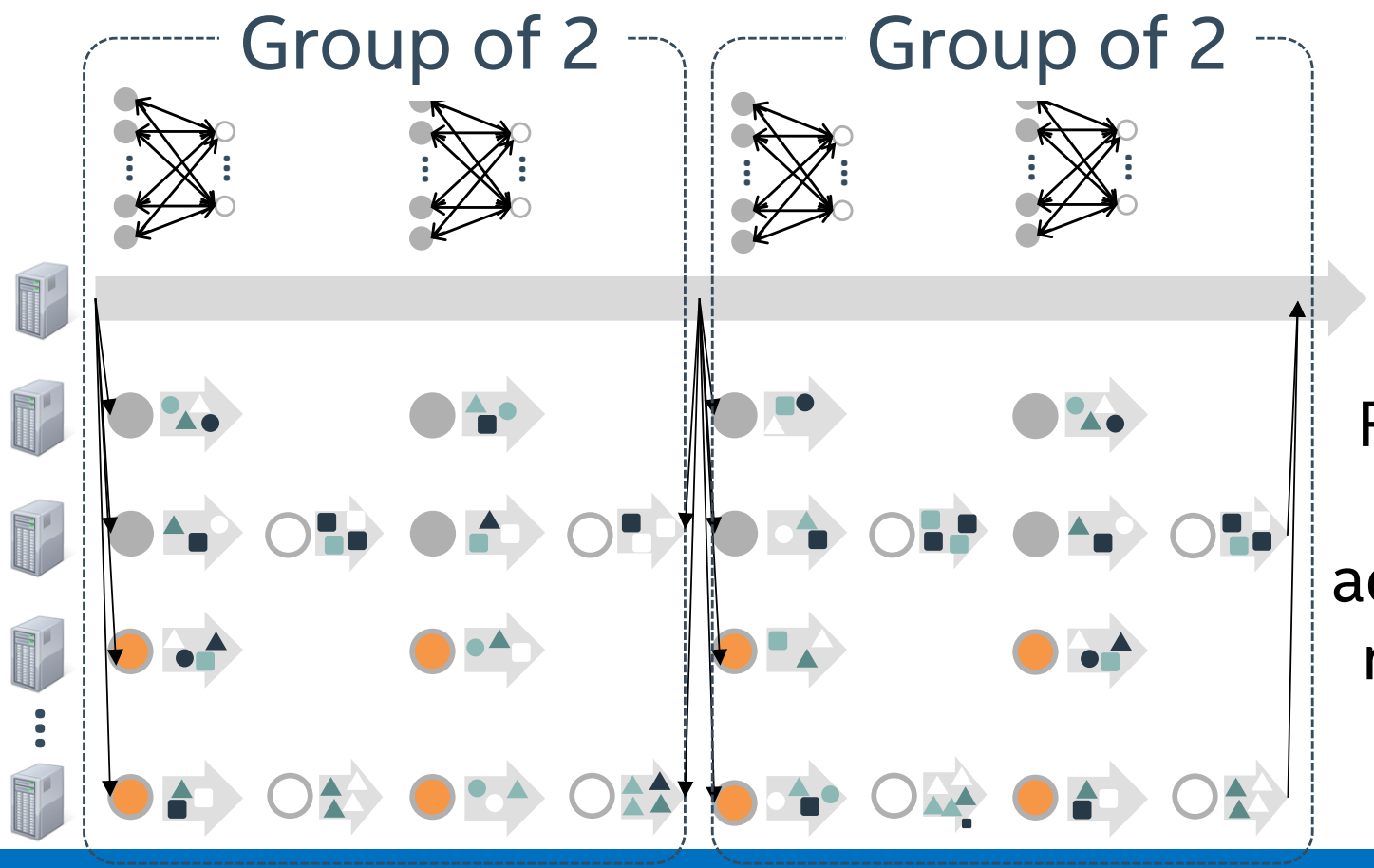
(1) Pre-schedule reducers

(2) Mappers get metadata



(3) Mappers trigger reducers

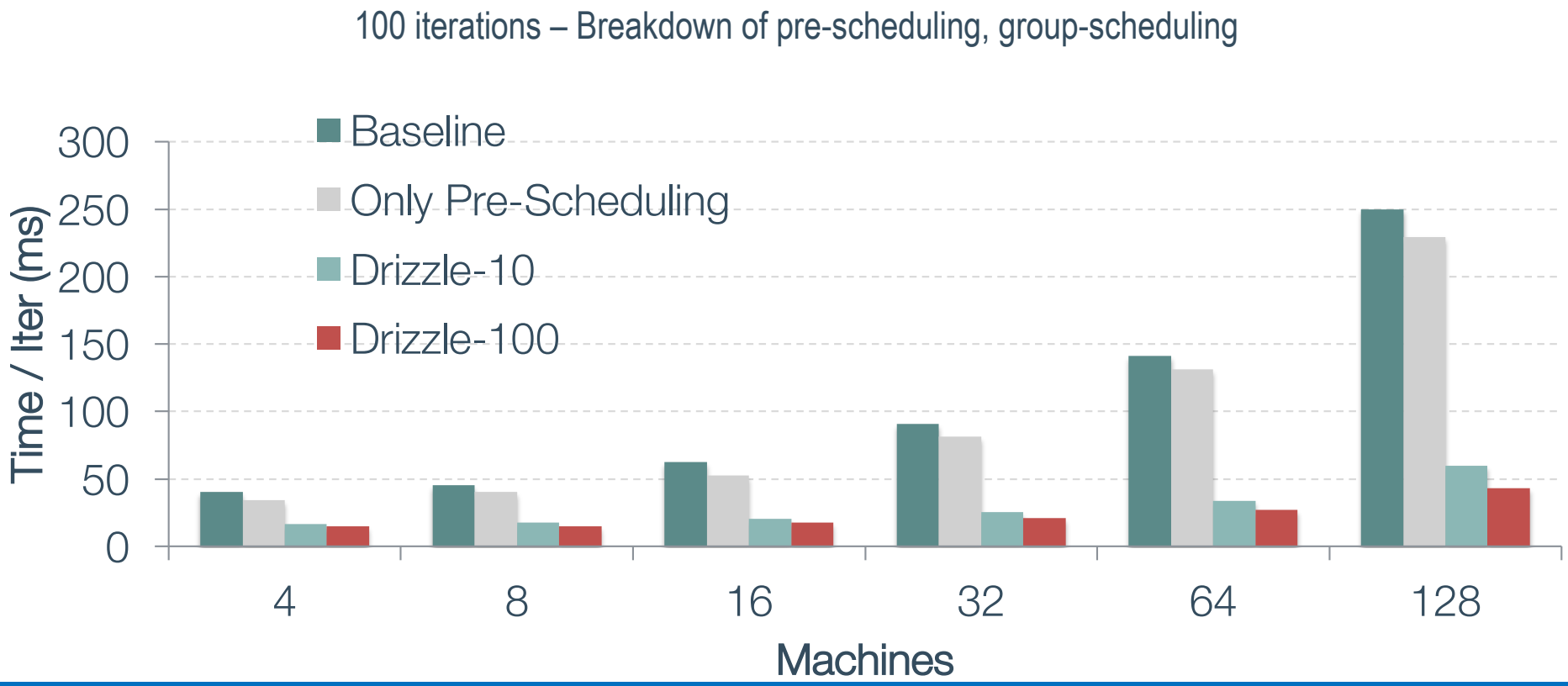
GROUP SCHEDULING



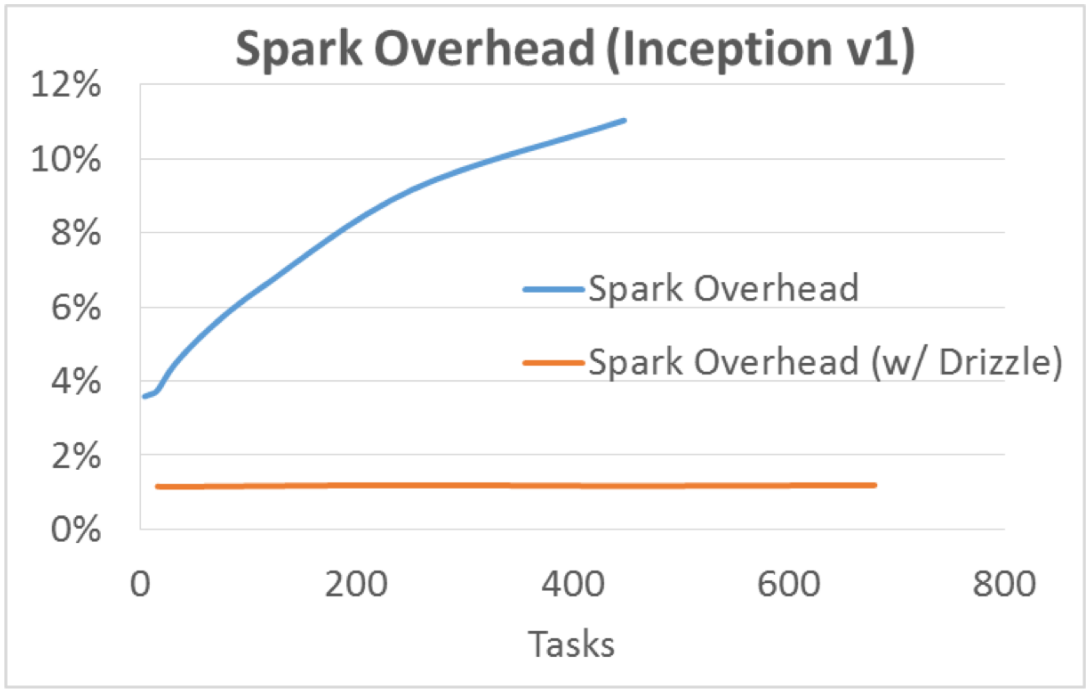
Schedule **group** of iterations at once

Fault tolerance, scheduling, adding/removing nodes at group boundaries

MICRO-BENCHMARK: 2-STAGES



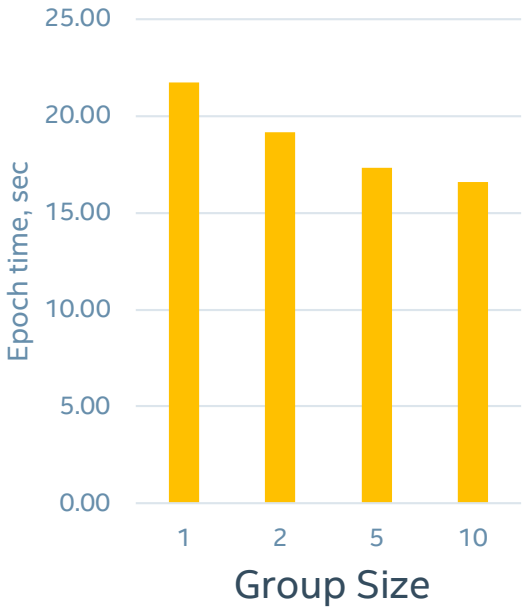
REDUCING SCHEDULING OVERHEADS WITH DRIZZLE



DRIZZLE – BIGDL PERFORMANCE IMPROVEMENT

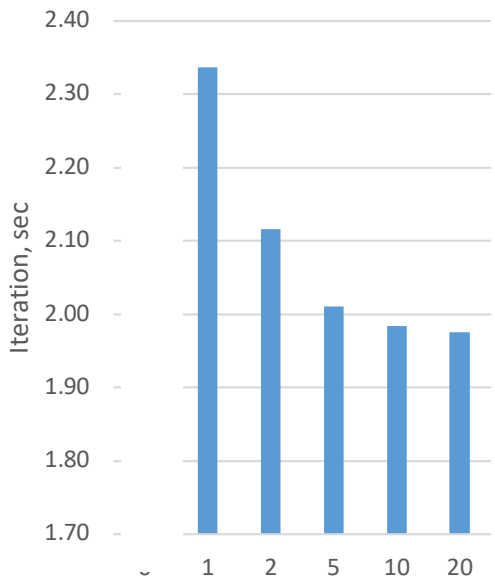
YOUR MILEAGE WILL VARY...

LeNet, 32 nodes, 16 cores



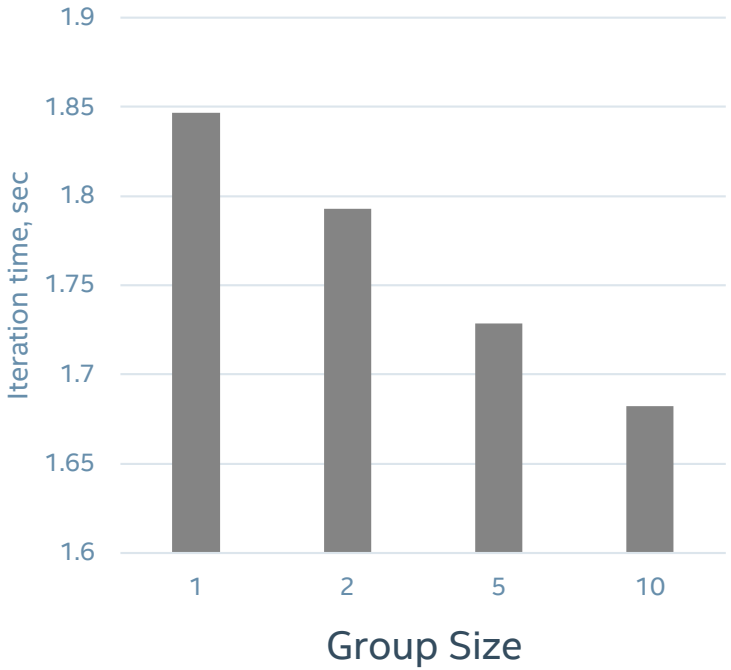
15% improvement

CIFAR, 32 nodes, 4cores, EC2



24% improvement

ImageNet, 64 nodes, 16 cores



10% improvement

https://bigdl-project.github.io https://software.intel.com/bigdl

CONCLUSION

- Deep Learning Spark jobs are somewhat unique
  - Heavy master node load for large model parameter update
  - Relatively short execution tasks (for fast model conversion)
  - Scheduling/Comms sometimes takes ~50% of total task execution.

- Deep Learning tasks are uniquely suited for optimization
  * Distributed Parameter Manager to offload Master compute.
  * Drizzle takes advantage of repetitive nature of the tasks and static data partitioning.

* Need Spark committers community involvement

FURTHER READING ☺

https://github.com/intel-analytics/BigDL/tree/new_parametermanager_drizzle

https://github.com/amplab/drizzle-spark

http://shivaram.org/publications/drizzle-sosp17.pdf


intel®
https://bigdl-project.github.io
https://software.intel.com/bigdl
intel

LEGAL NOTICES & DISCLAIMERS

This document contains information on products, services and/or processes in development. All information provided here is subject to change without notice. Contact your Intel representative to obtain the latest forecast, schedule, specifications and roadmaps.

Intel technologies' features and benefits depend on system configuration and may require enabled hardware, software or service activation. Learn more at intel.com, or from the OEM or retailer. No computer system can be absolutely secure.

Tests document performance of components on a particular test, in specific systems. Differences in hardware, software, or configuration will affect actual performance. Consult other sources of information to evaluate performance as you consider your purchase. For more complete information about performance and benchmark results, visit http://www.intel.com/performance.

Cost reduction scenarios described are intended as examples of how a given Intel-based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction.

Statements in this document that refer to Intel's plans and expectations for the quarter, the year, and the future, are forward-looking statements that involve a number of risks and uncertainties. A detailed discussion of the factors that could affect Intel's results and plans is included in Intel's SEC filings, including the annual report on Form 10-K.

The products described may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

Intel, the Intel logo, Pentium, Celeron, Atom, Core, Xeon and others are trademarks of Intel Corporation in the U.S. and/or other countries.
*Other names and brands may be claimed as the property of others.