2020 OFA Virtual Workshop

SPARKUCX – RDMA ACCELERATION PLUGIN FOR SPARK

Peter Rudenko, software engineer

Mellanox Technologies

APACHE SPARK

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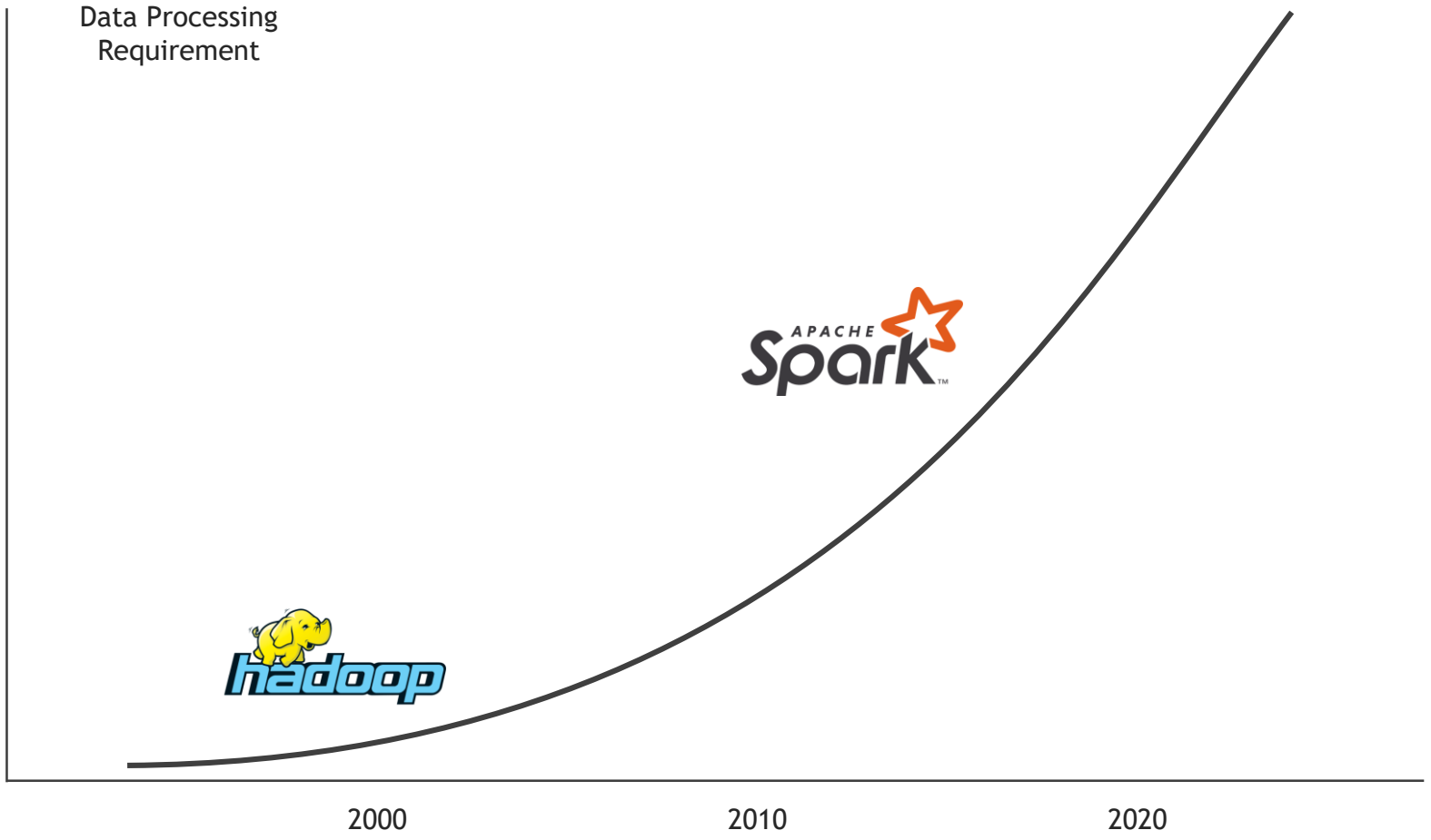
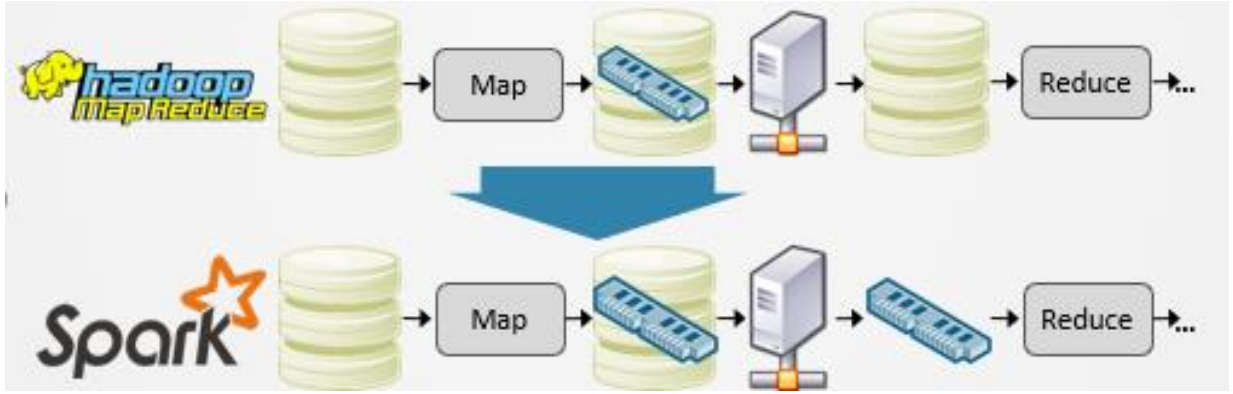
Leading Framework for Distributed, Scale-Out Data Analytics

- 100s of 1000s of data scientists and over 16,000 enterprises use Spark
- Spark is 100x faster at processing data than Hadoop
- 1000+ contributors across 250+ companies
- Databricks platform alone spins up 1 million virtual machines per day



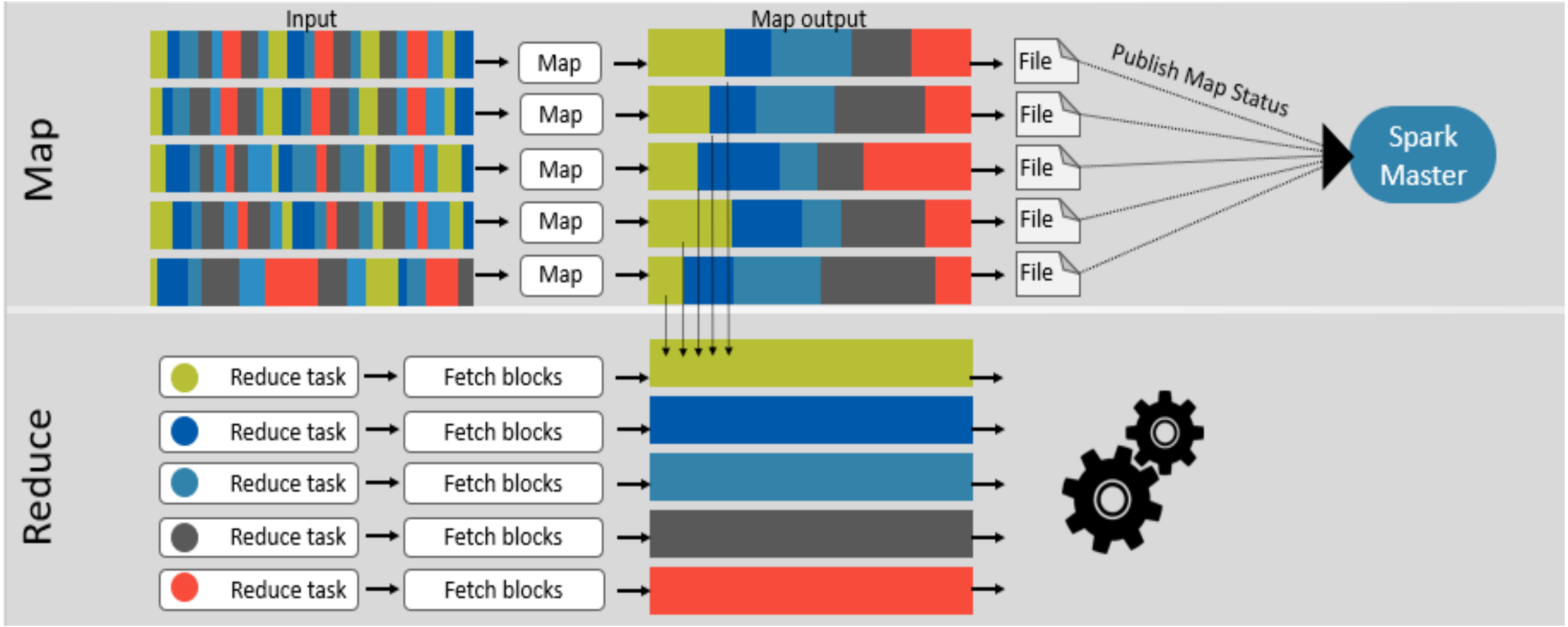
HADOOP'S MAPREDUCE VS. APACHE SPARK

- Spark's in-memory model completely changed how shuffle is done
- In both Spark and Hadoop, map output is saved on the local disk
- In Hadoop, map output is then copied over the network to the destined reducer's local disk
- In Spark, map output is fetched from the network, on-demand, to the reducer's memory



Memory-to-network-to-memory? RDMA/RoCE is a perfect fit!

SPARK'S SHUFFLE BASICS



THE COST OF SHUFFLING

- **Shuffling is very expensive in terms of CPU, RAM, disk and network**
- **Spark users try to avoid shuffles as much as they can**
- **Speedy shuffles can relieve developers of such concerns, and simplify applications**

MELLANOX SPARK SHUFFLE ACCELERATION

- **2017 SparkRDMA shuffle plugin open sourced https://github.com/Mellanox/SparkRDMA**
  - Based on disni library (thin wrapper over verbs)
  - Promote RDMA technology in Spark community (AI Spark summit talks Accelerating Shuffle: A Tailor-Made RDMA Solution for Apache Spark, Accelerated Spark on Azure: Seamless and Scalable Hardware Offloads in the Cloud)
  - Initial customers POC, collected requirements and feedback.

- **2019 SparkUCX shuffle plugin https://github.com/openucx/sparkucx**
  - Java wrapper for UCX library implementation
  - Fixes architectural bottlenecks in SparkRDMA

- **2020 Nvidia Rapids for Spark (to be open sourced)**
  - Based on UCX java library for communication
  - GPU + RDMA acceleration

UNIFIED COMMUNICATION **X (UCX)**

UCX

- UCX is a framework for network APIs and stacks
- UCX aims to unify the different network APIs, protocols and implementations into a single framework that is portable, efficient and functional
- UCX doesn’t focus on supporting a single programming model, instead it provides APIs and protocols that can be used to tailor the functionalities of a particular programming model efficiently
- When different programming paradigms and applications use UCX to implement their functionality, it increases their portability. As just implementing a small set of UCX APIs on top of a new hardware ensures that these applications can run seamlessly without having to implement it themselves

UCX GOALS

Unified API

Applications driven, simple, extendable, HW-agnostic

Focus on performance

Fast, scalable, highly optimized low latency high bandwidth messaging framework

Production quality

Multi-tier testing, used by top Mellanox customers in production

Open source

Collaboration between industry, laboratories, and academia

Innovation

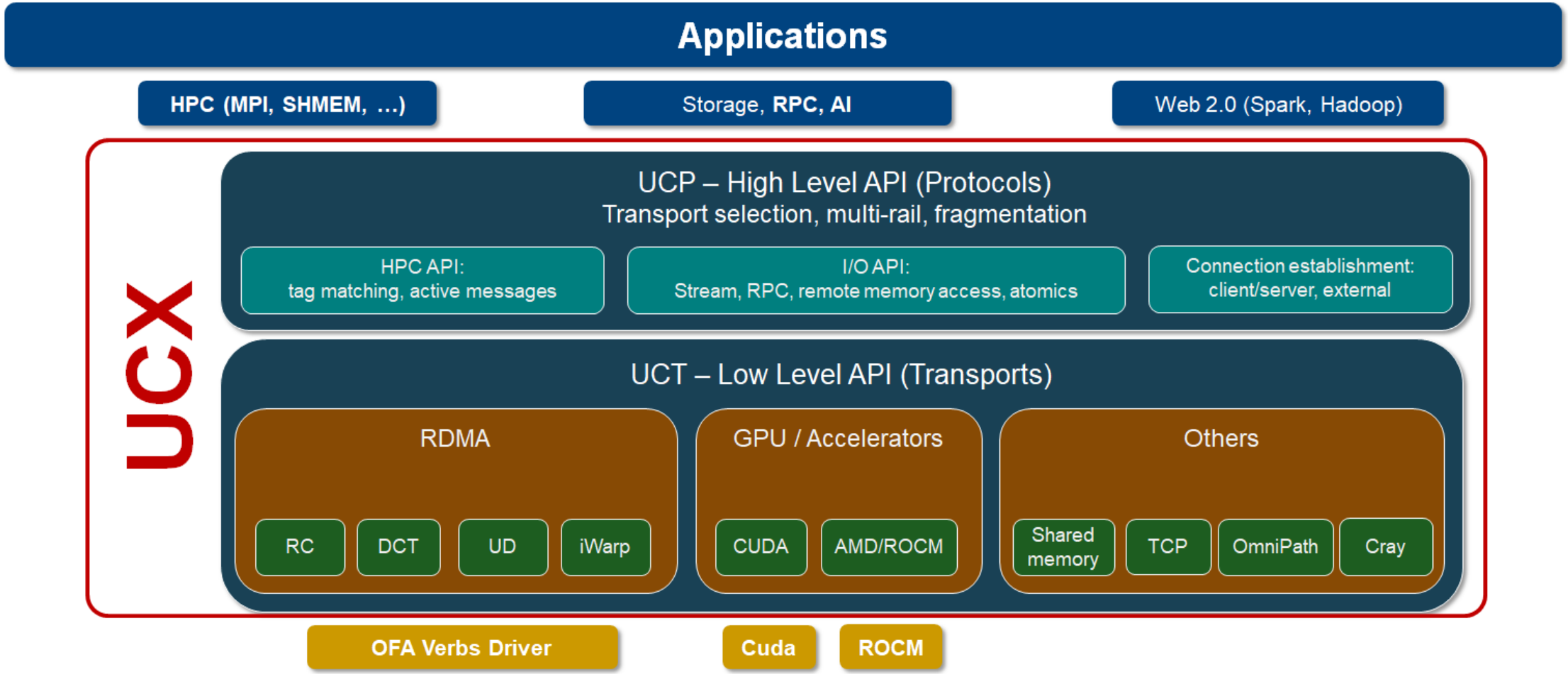
Concepts and ideas from research in academia and industry

Multi arch/transports

RoCE, InfiniBand, Cray, TCP, shared memory, GPUs, x86, ARM, POWER

Co-design of Network APIs

UCX GOALS



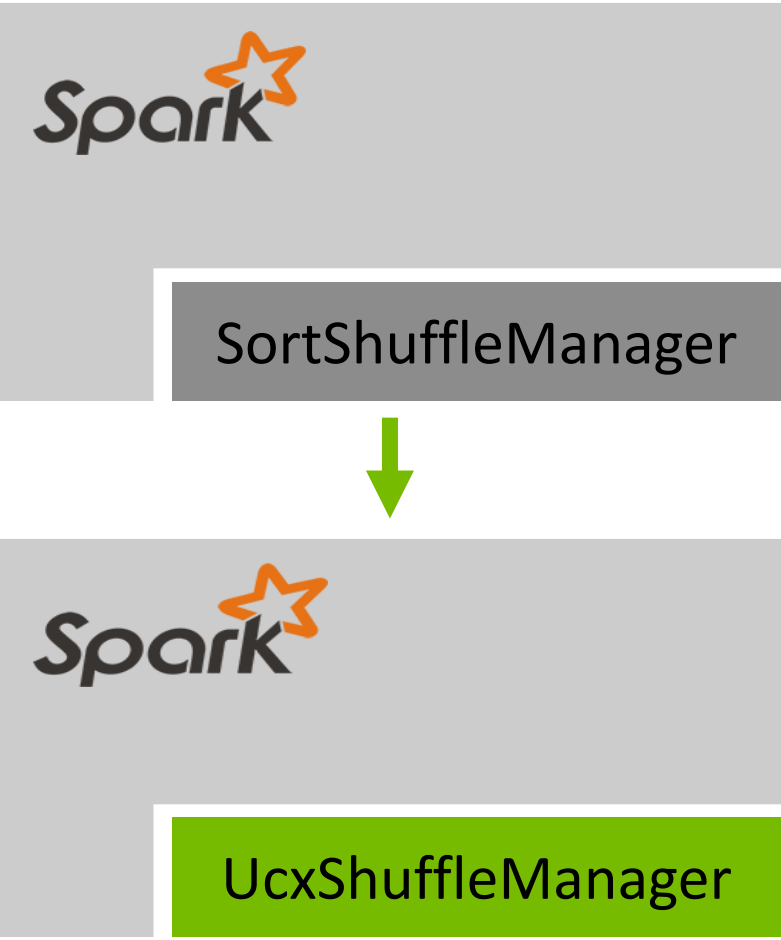
UCX OVERVIEW

- **APIs**
  - Socket-like stream send/receive, RPC
  - Remote memory access and atomic operations
  - Client/server connection establishment
  - Fully non-blocking
- **Advanced features**
  - Full support for GPU and GPU Direct
  - Multi-rail and fault tolerance
  - Direct verbs for minimal software overhead
  - Thread-safety with separate resources per-thread
  - Interrupt and polling-based progress
  - Smart data transfer protocols (eager, rendezvous, bcopy, zcopy, …)

APACHE SPARK + UCX = ACCELERATED SHUFFLE

SHUFFLE MANAGER PLUGIN

- **Spark allows for external implementations of ShuffleManagers to be plugged in**
  - Configurable per-job using: “spark.shuffle.manager”
- **The plugin interface allows proprietary implementations of Shuffle Writers and Readers, and essentially defers the entire Shuffle process to the new component**
- **SparkUCX utilizes this interface to introduce RDMA in the Shuffle process**



SPARK+UCX OPERATION FLOW

- **Initialization:**
  - Spark driver allocates global metadata buffer per shuffle stage, to hold addresses and memory keys of data and index files on mappers.

- **Mapper phase:**
  - mmap() and register index and data files
  - Publish {address, rkey} to driver metadata buffer (ucp_put).

- **Reduce phase:**
  - Fetch metadata from driver (ucp_get)
  - For each block:
    - Fetch offset in data file, from index file (ucp_get).
    - Fetch block contents from data file (ucp_get).

JUCX API EXAMPLE IN SPARK

1. Instantiate ucp context:

UcpConetxt context = new UcpContext(new UcpParams().requestRmaFeature());

2. Register memory on context:

UcpMemory memoryRegion = context.memoryMap(new UcpMemMapParams().setLength(length).allocate())

3. Instantiate ucp worker:

UcpWorker worker = context.newWorker(new UcpWorkerParams().setCpu(0).requestWakeupRMA());

4. Instantiate ucp endpoint:

UcpEndpoint endpoint = worker.newEndpoint(new UcpEndpointParams().setSocketAddress(InetSocketAddress("1.2.3.4:1234"));

5. Perform get/put/send/recv operation on endpoint:

UcxRequest request = endpoint.getNonBlocking(remoteAddress, remoteKey, localBuffer, callback);

6. Progress request until it's completed:

worker.progressRequest(request)

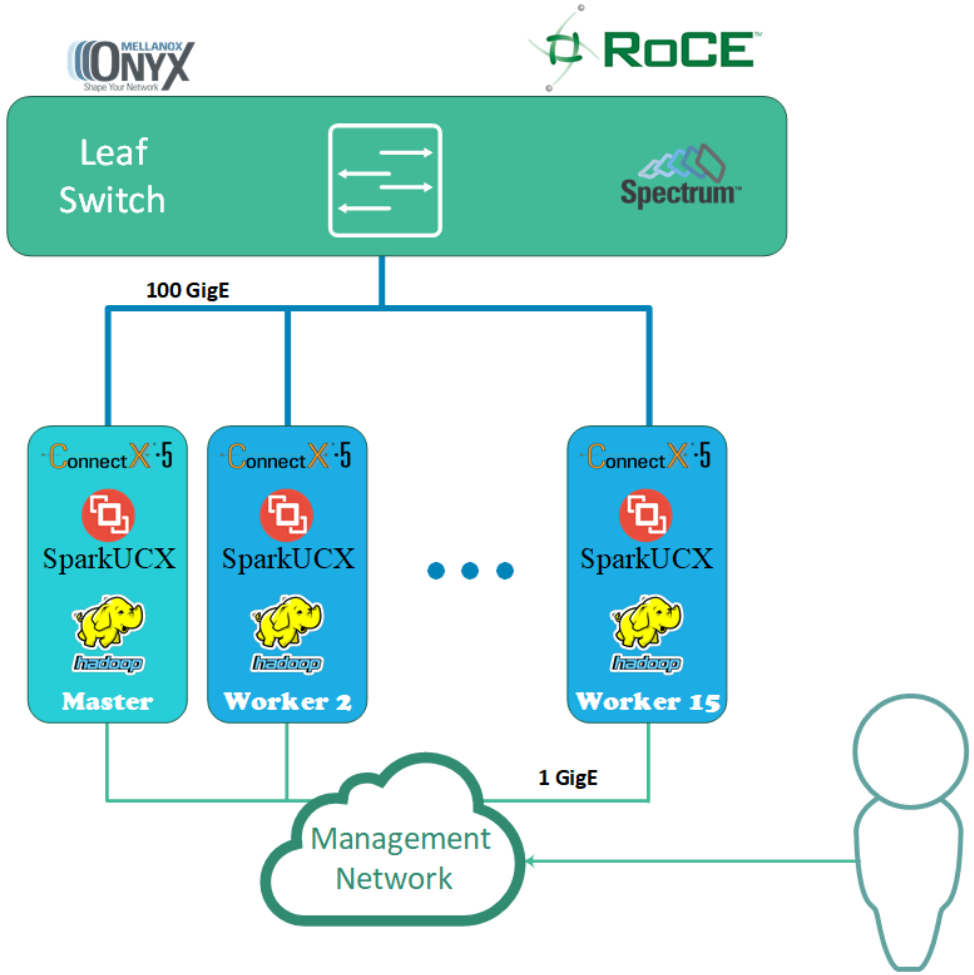
SPARK+UCX BENEFITS

- **Accelerating Spark**
  - Lower Block transfer times (latency and total transfer time)
  - Lower Memory consumption and management
  - Lower CPU utilization
  - GPU Direct
- **Easy to deploy and configure**
  - Packed into a single JAR file
  - Plugin is enabled through a simple configuration handle
  - Allows finer tuning with a set of configuration handles
- **Configuration and deployment are on a per job basis**
  - Can be deployed incrementally

SPARK SHUFFLE PERFORMANCE (CPU)

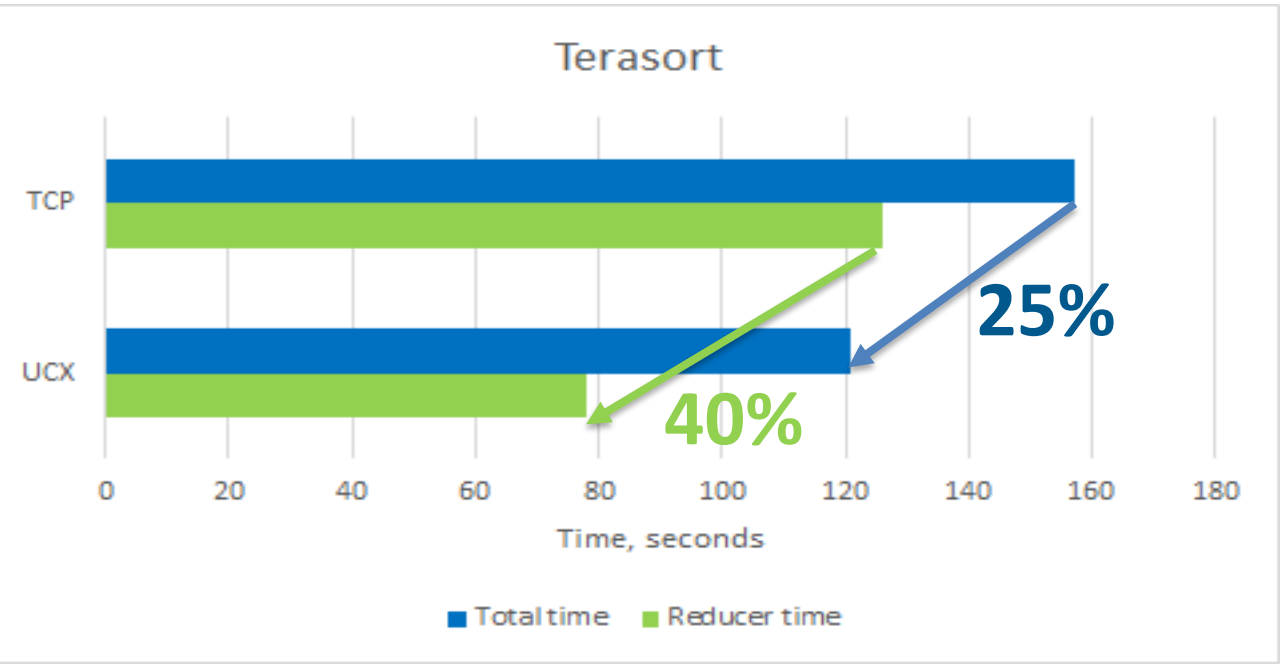
Using default TCP vs SparkUCX (RoCE)

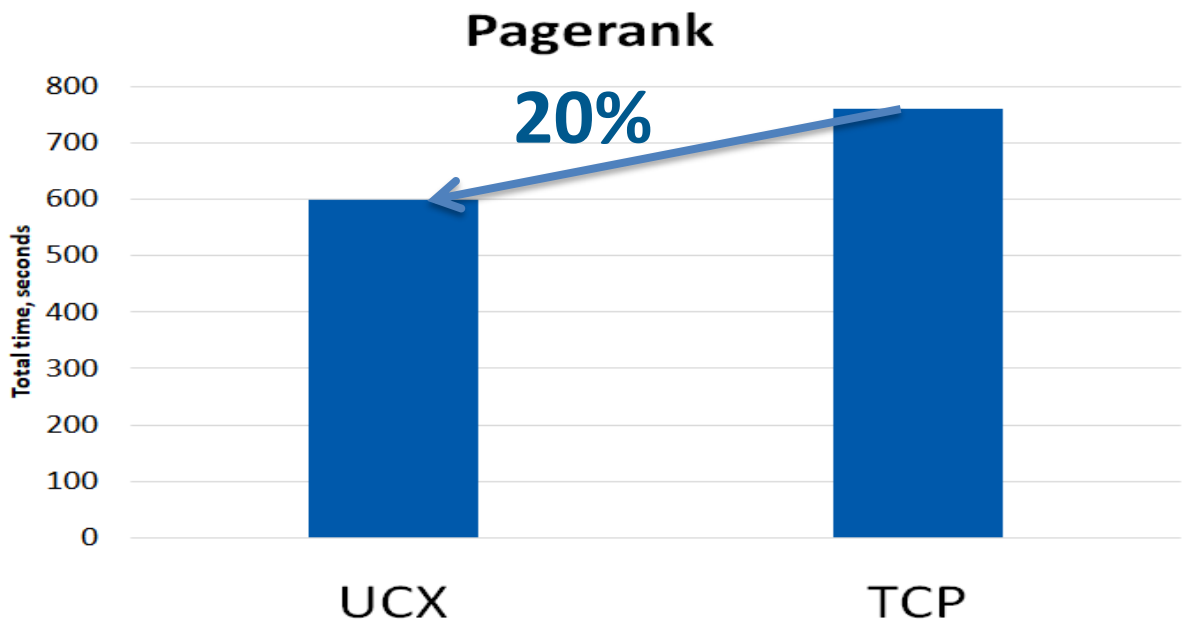
- **Benchmarks: Terasort + Pagerank**
  - https://github.com/Intel-bigdata/HiBench
- **Terasort:**
  - 1.2 TB input, 10K mappers, 15k reducers
- **Pagerank:**
  - Bigdata Hibench workload (600 Gb), 5K mappers, 15K reducers
- **15 nodes: Broadwell @ 2.60GHz, 250GB RAM, 500GB HDD**
- **ConnectX-5: Infiniband: 100G EDR. TCP device: IPoIB 100G**
- **Red Hat Enterprise Linux Server release 7.5 (Maipo) (kernel: 3.10.0-862.el7.x86_64)**
- **MLNX_OFED_LINUX-4.6-1.0.1.1.**
- **Spark-2.4.3, Hadoop-2.9.2, UCX v1.8.0**
- **Deployment guide: https://docs.mellanox.com/pages/releaseview.action?pageId=19819236**



SPARK SHUFFLE PERFORMANCE (CPU)

Using default TCP vs SparkUCX (RoCE)





TCP

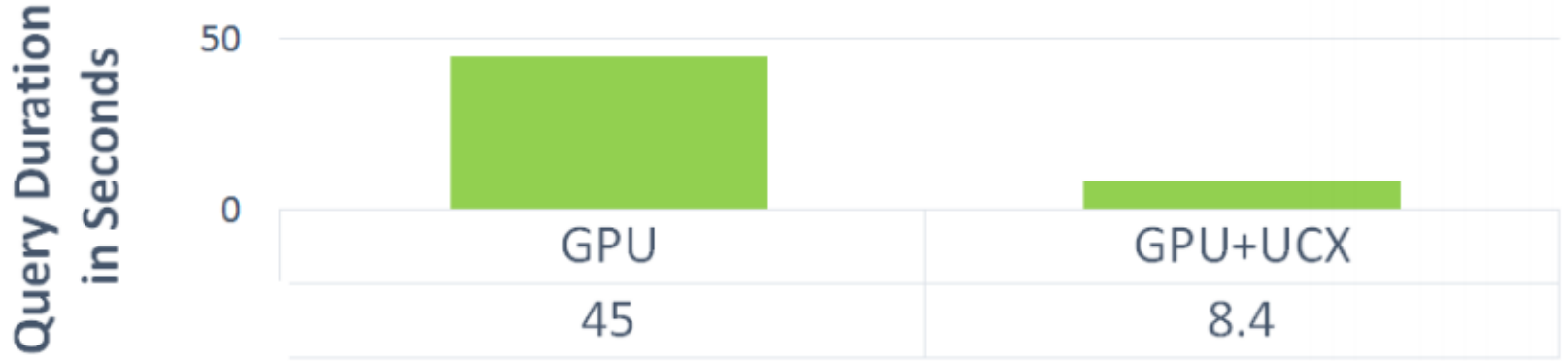
Stage Id	Description		Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
1	count at TeraSort.scala:153	+details	2019/10/10 17:05:05	2.3 min	15000/15000			1777.0 GB	

UCX

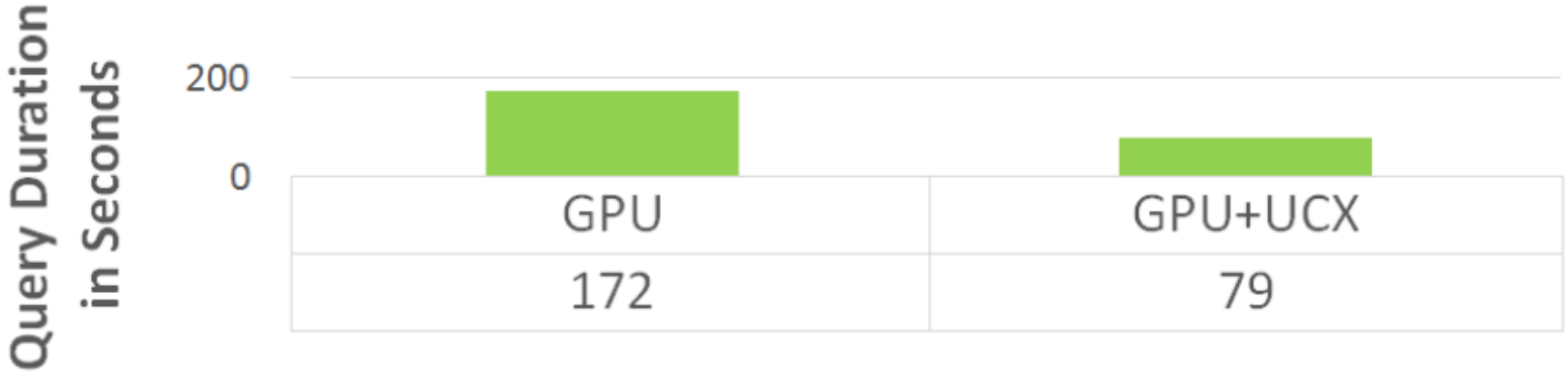
Stage Id	Description		Duration	Tasks: Succeeded/Total	Input	Output	Shuffle Read	Shuffle Write
1	count at TeraSort.scala:153	+details	2019/10/10 17:13:32	1.4 min	15000/15000			1777.0 GB	

SPARK SHUFFLE PERFORMANCE GPU

Inventory Pricing Queries: >5X time reduction



ETL for Logistical Regression Model: >2X time reduction



https://developer.download.nvidia.com/video/gputechconf/gtc/2020/presentations/s22674-accelerating-apache-spark-3.0-with-rapids-and-gpus.pdf

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THANK YOU

Peter Rudenko, software engineer

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