Spark Terasort and CRAIL

www.crail.io

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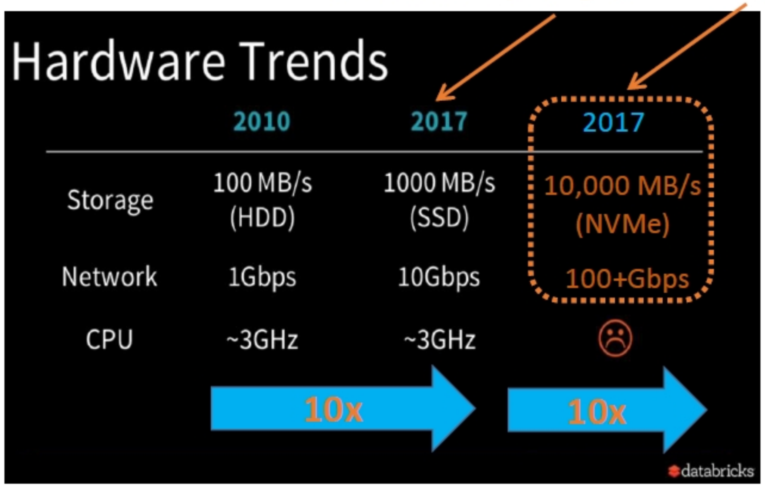
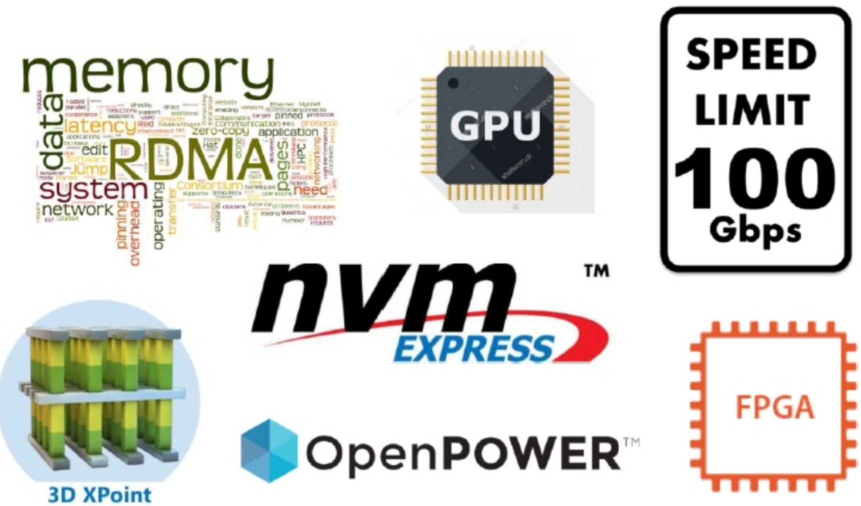
I/O Hardware Trends

Speed

community target
our target

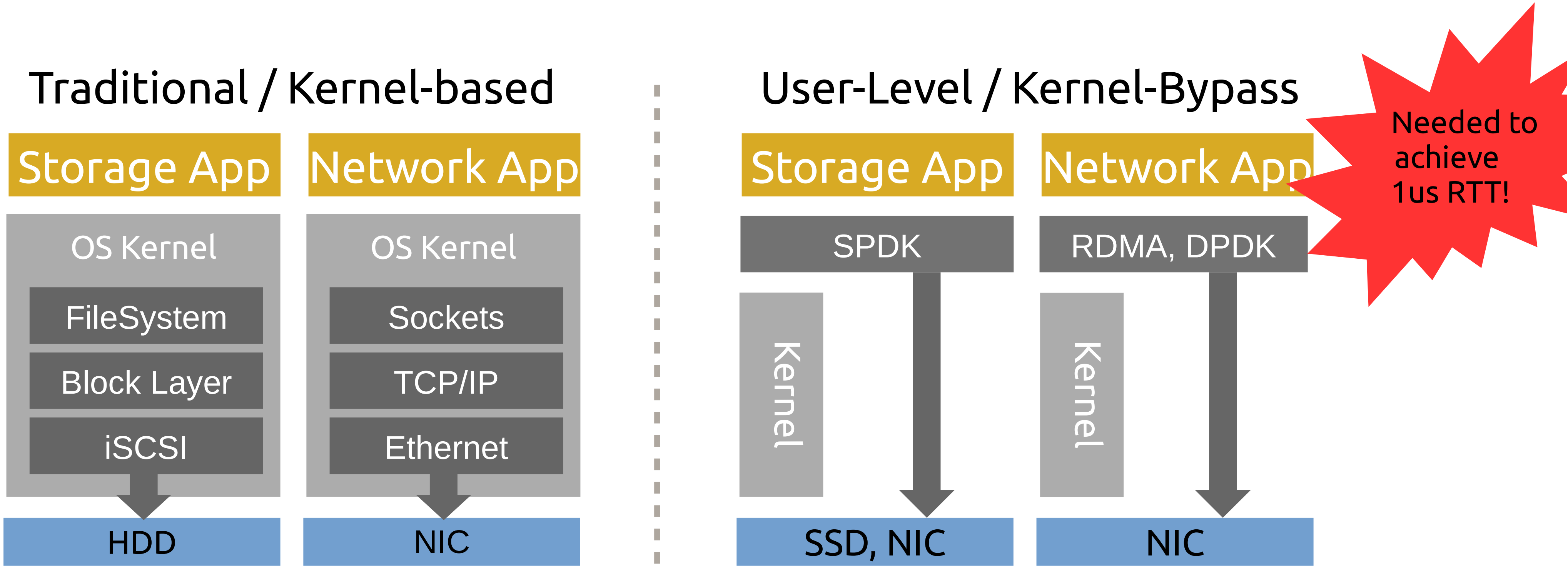


Diversity



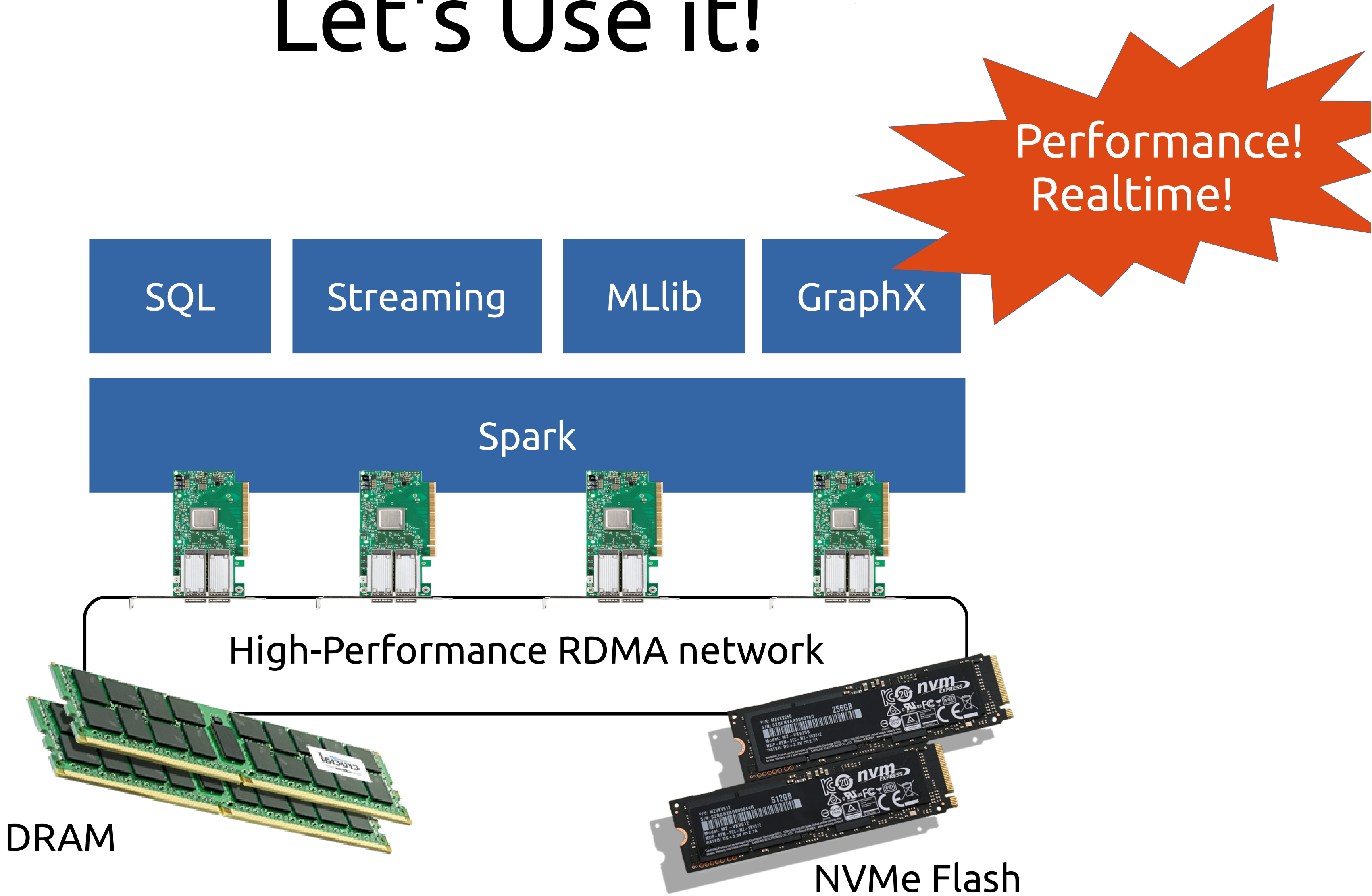
- Network interconnects have evolved from
  - Gbps bandwidth to 100Gbps
  - 100us delay to 1us delay
- Storage technology has evolved
  - Factor 100x-1000x

User-Level APIs

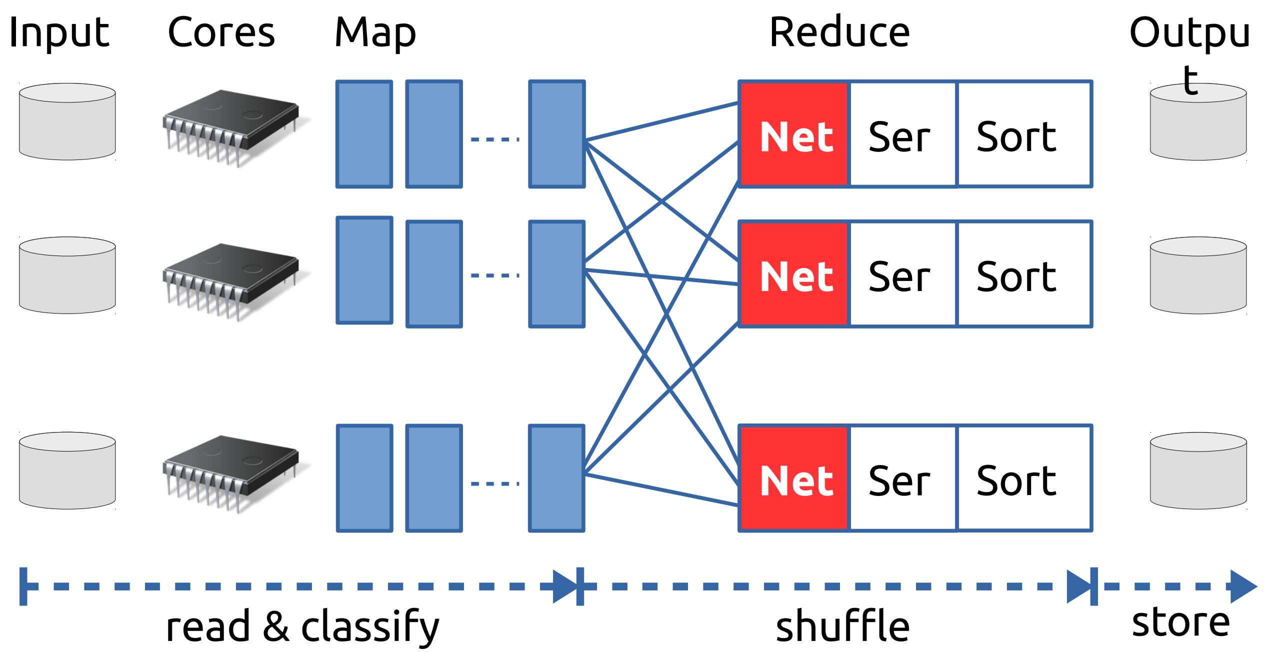


Modern APIs for Networking and Storage offer asynchronous non-blocking user-level access to hardware

Let's Use it!


Performance!
Realtime!
SQL
Streaming
MLlib
GraphX
Spark
High-Performance RDMA network
DRAM
NVMe Flash

Case Study: Sorting in Spark

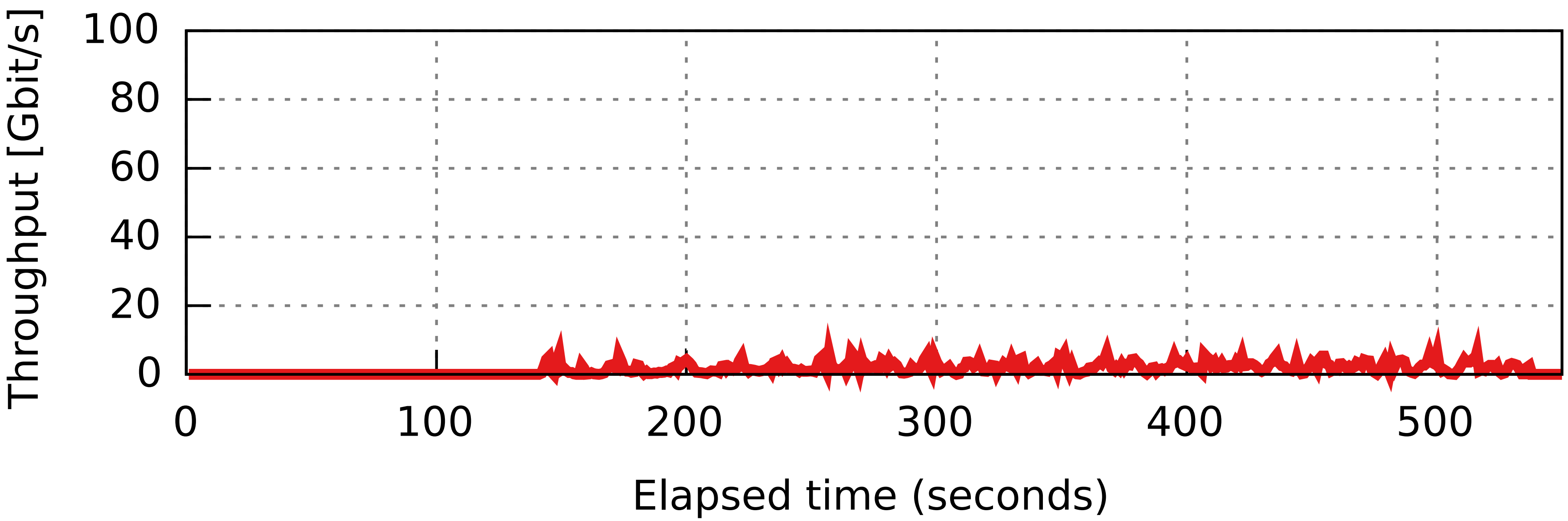


- Map task classify data into local files (typically absorbed by buffer cache)
- Reduce task fetch remote files over the network
- Sorting requires the entire data set to be shuffled over the network

Experiment Setup

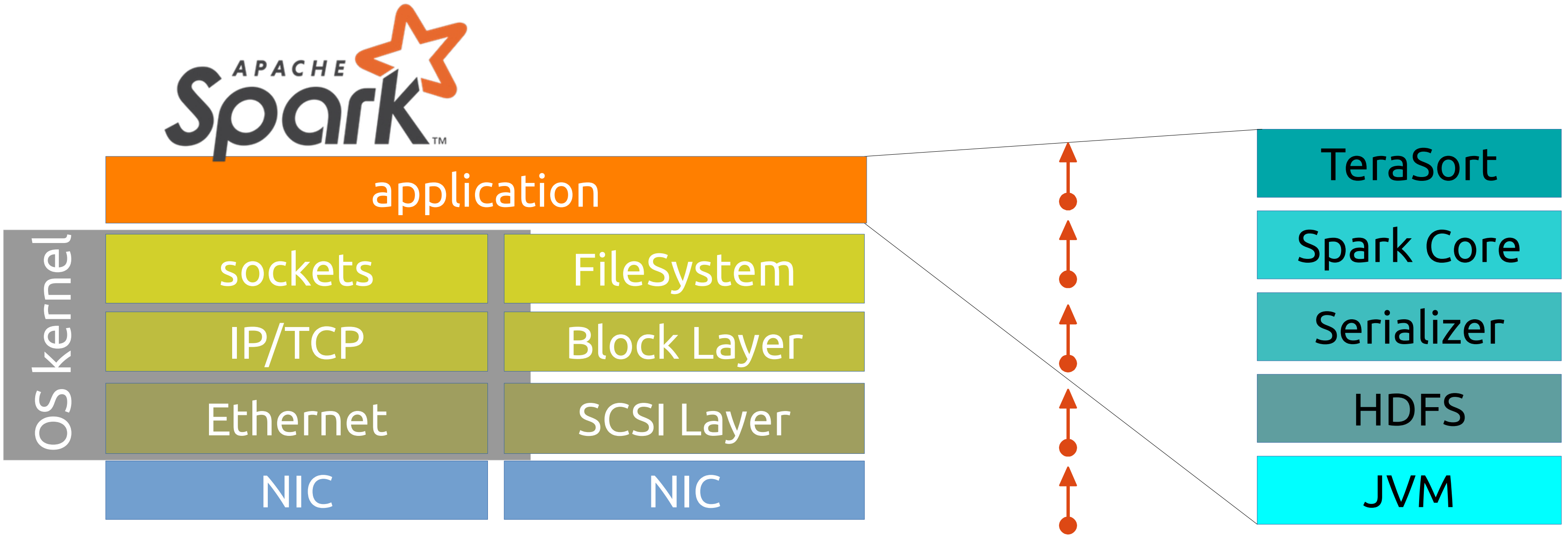
- Total data size: 12.8 TB
- Cluster size: 128 nodes
- Cluster hardware
  - DRAM: 512 GB DDR 4
  - Storage: 4x 1.2 TB NVMe SSD
  - Network: 100GbE Mellanox RDMA
- Software
  - Spark 2.0.0

How is the Network Used?



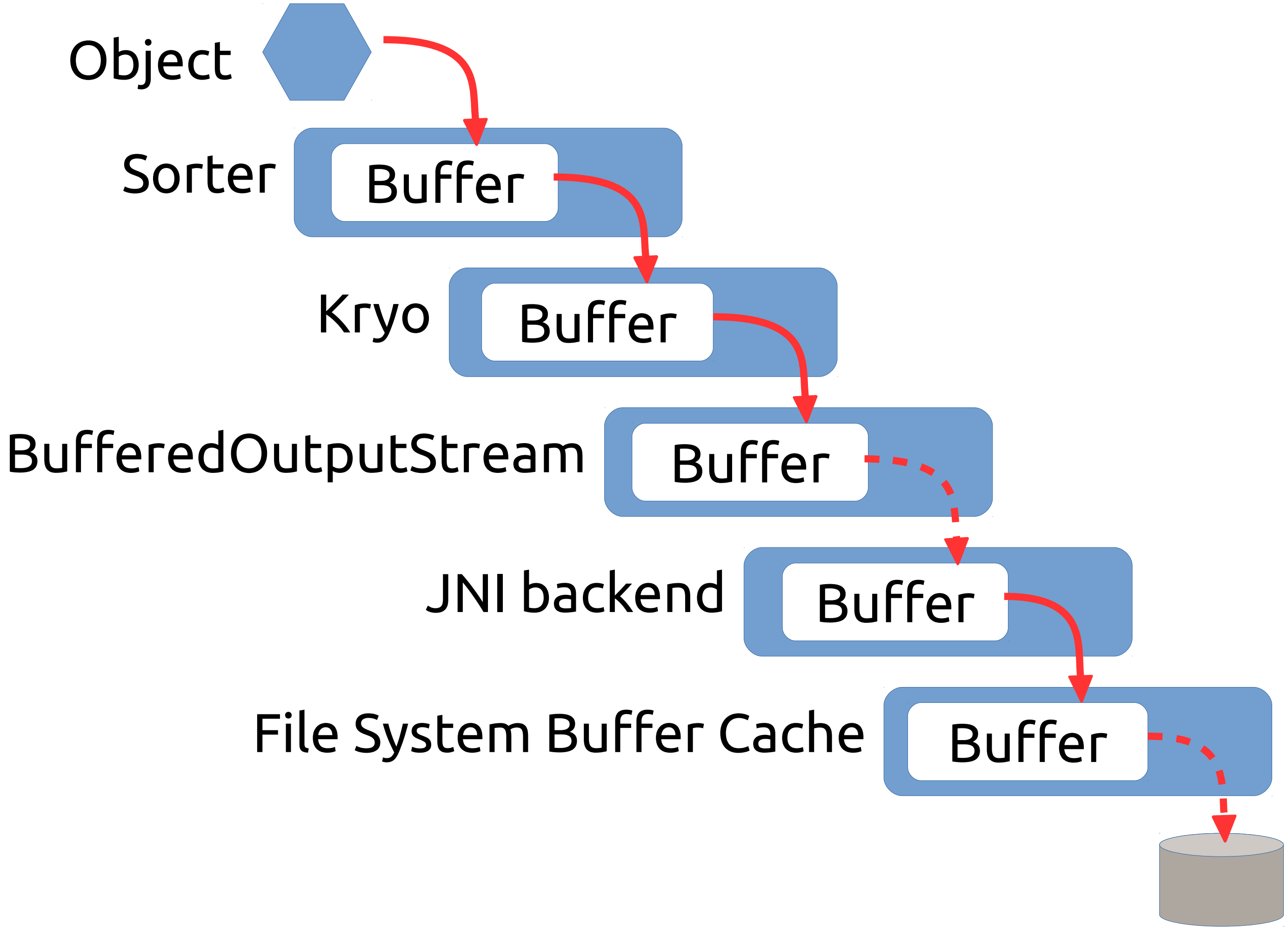
- Only 5-10 Gpbs of the network is being used

What is the Problem



- Application use the legacy APIs
- Applications themselves are heavily layered!
- Overhead during local file system writing
- Overhead during network processing
  - Data copies, context switches, cache pollution, etc

Example: Shuffle Writer (map)



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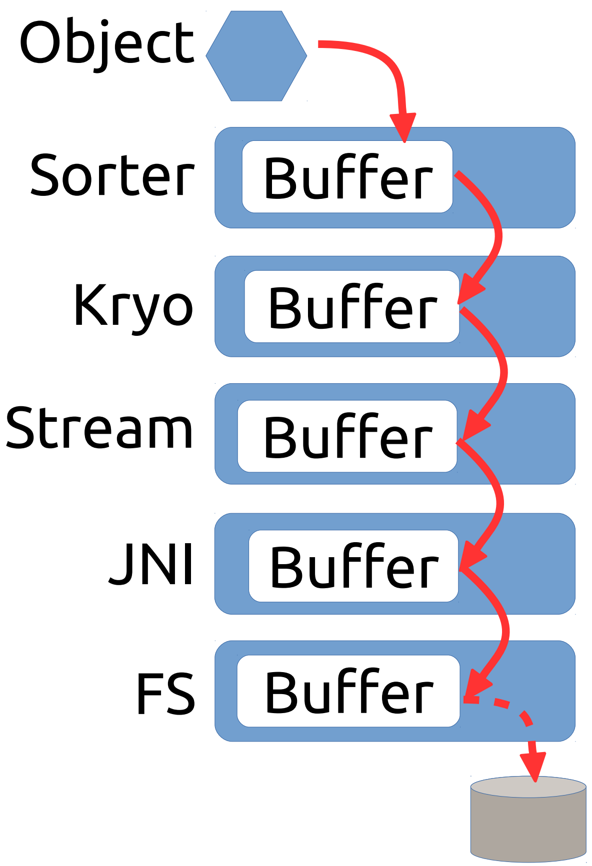

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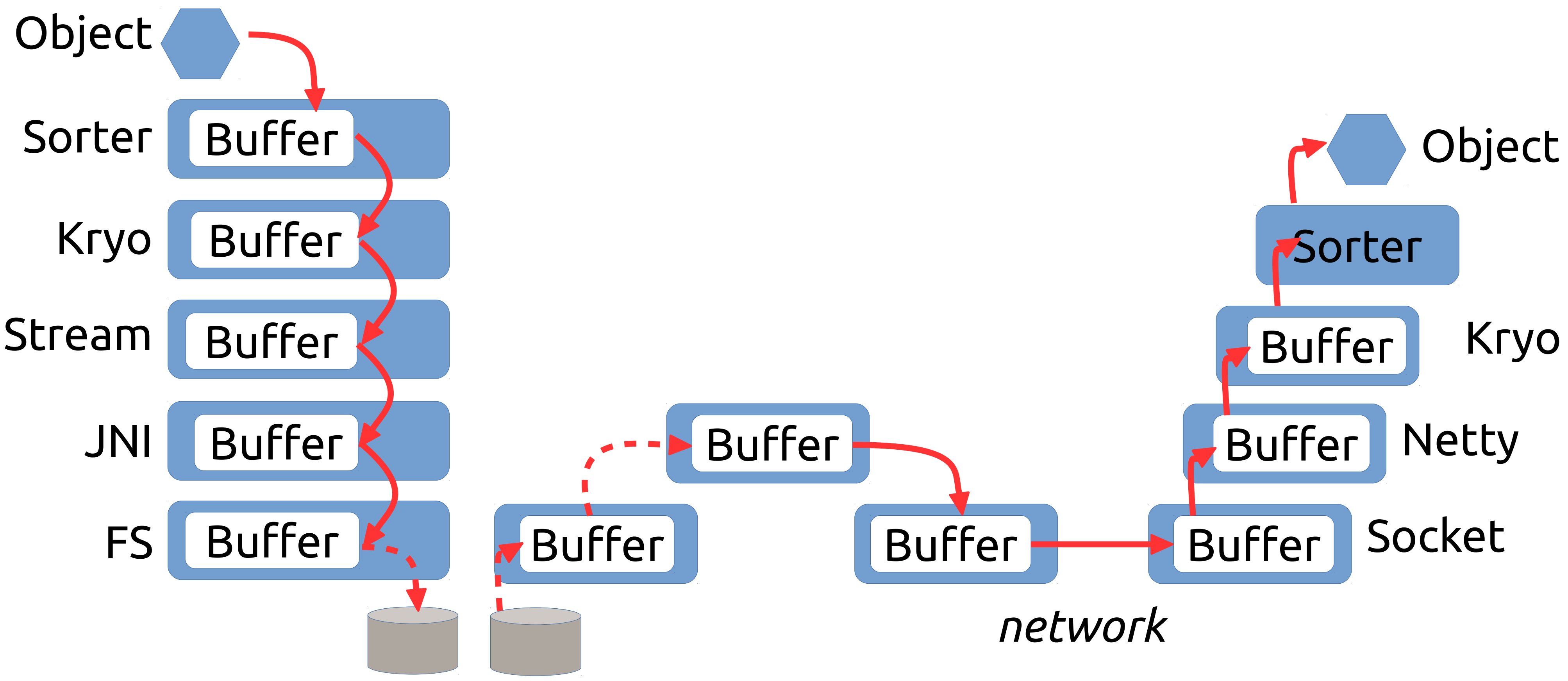

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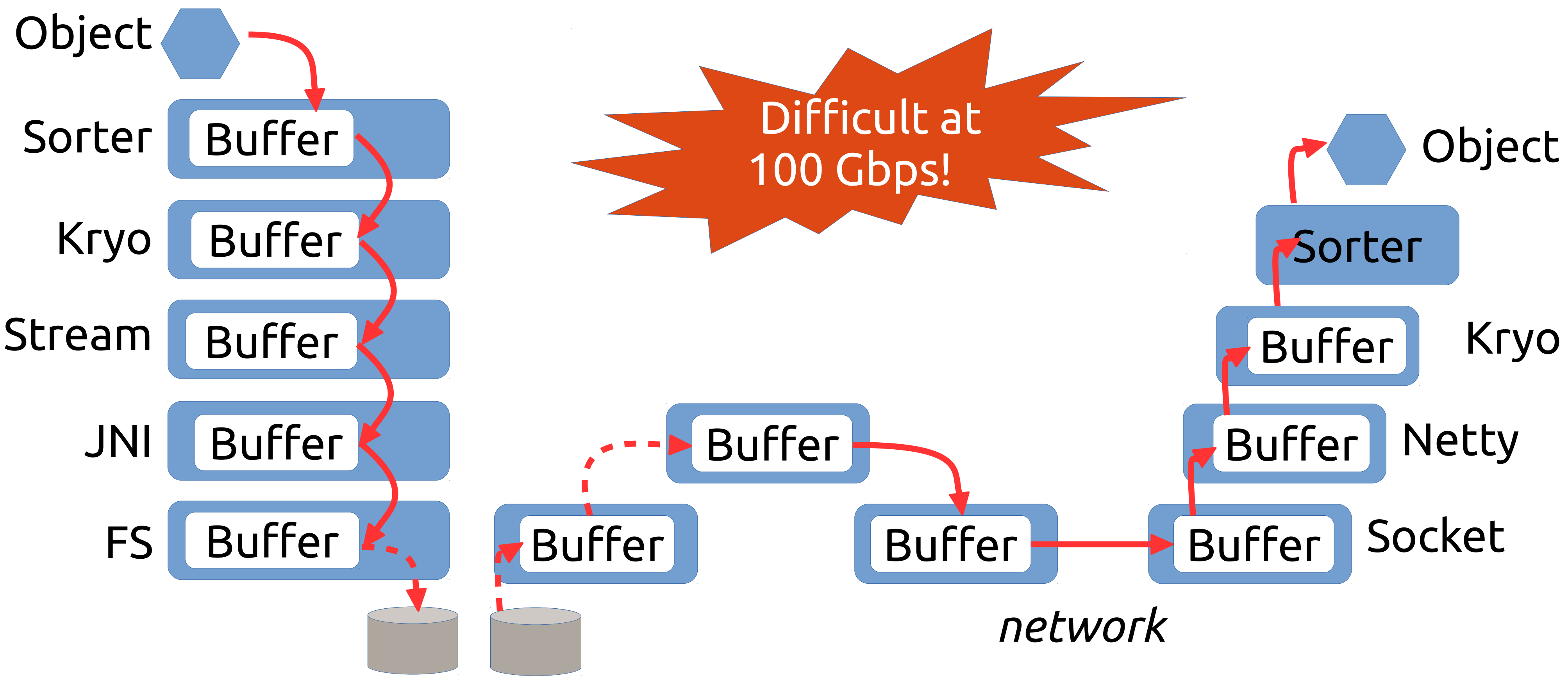
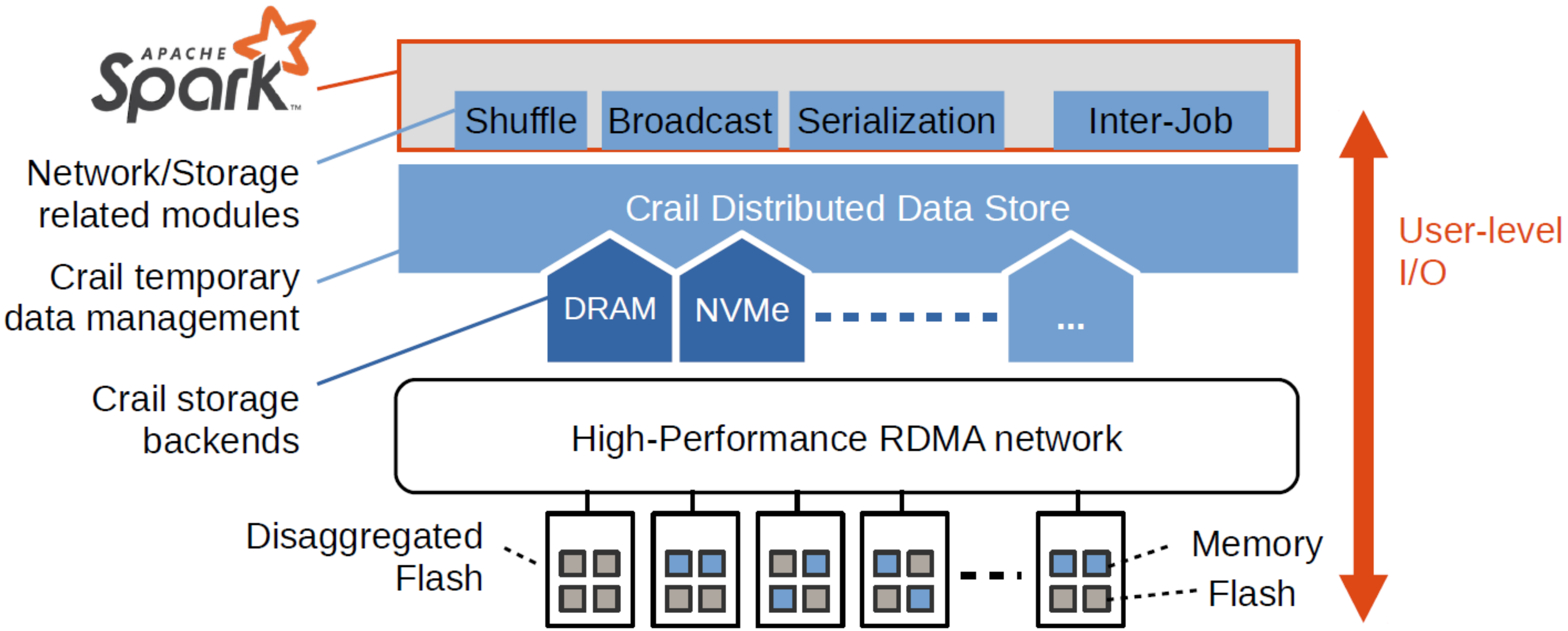


How can we fix this...

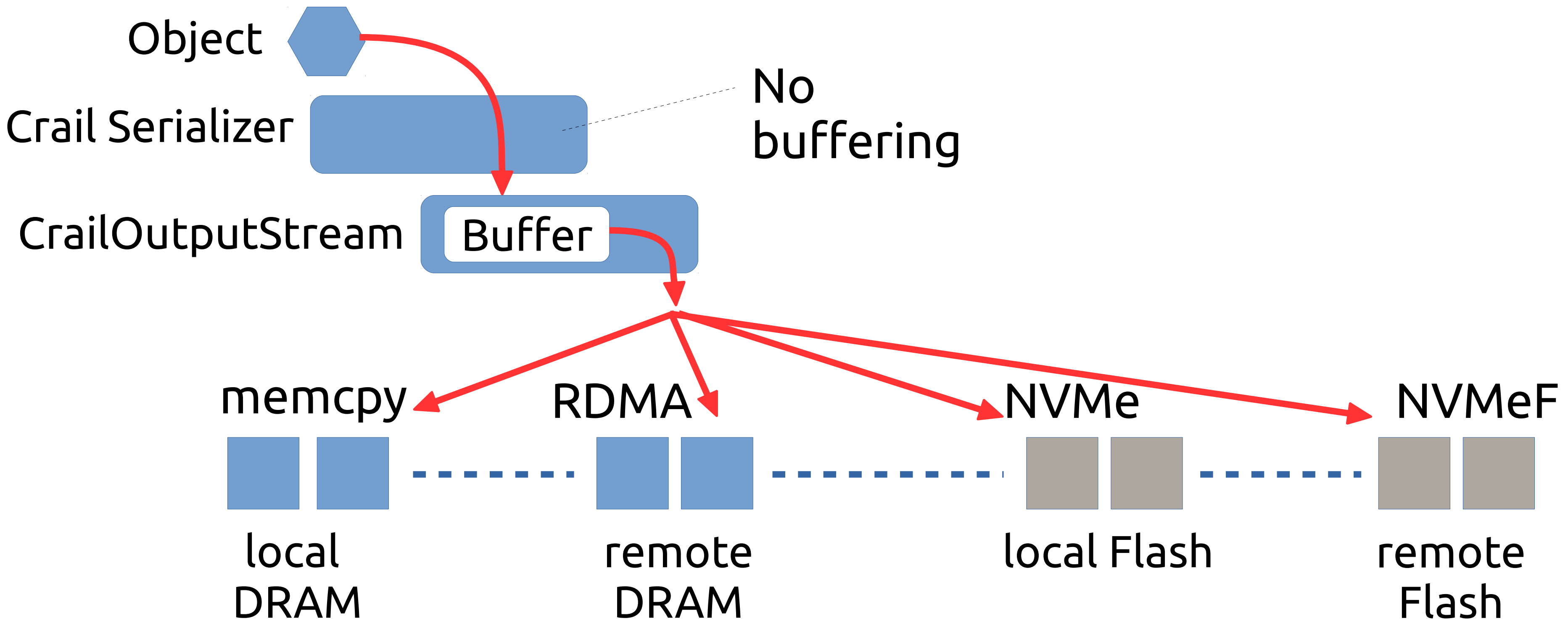
- Not just for shuffle
  - For broadcast, RDD transport, inter-job sharing, etc.
- Not just for RDMA and NVMe
  - For any future high-performance I/O hardware
- Not just for co-located compute/storage
  - Also for disaggregated storage, heterogeneous resource distribution, etc.
- Not just improve things
  - Make it perform at the hardware limit

The CRAIL Approach



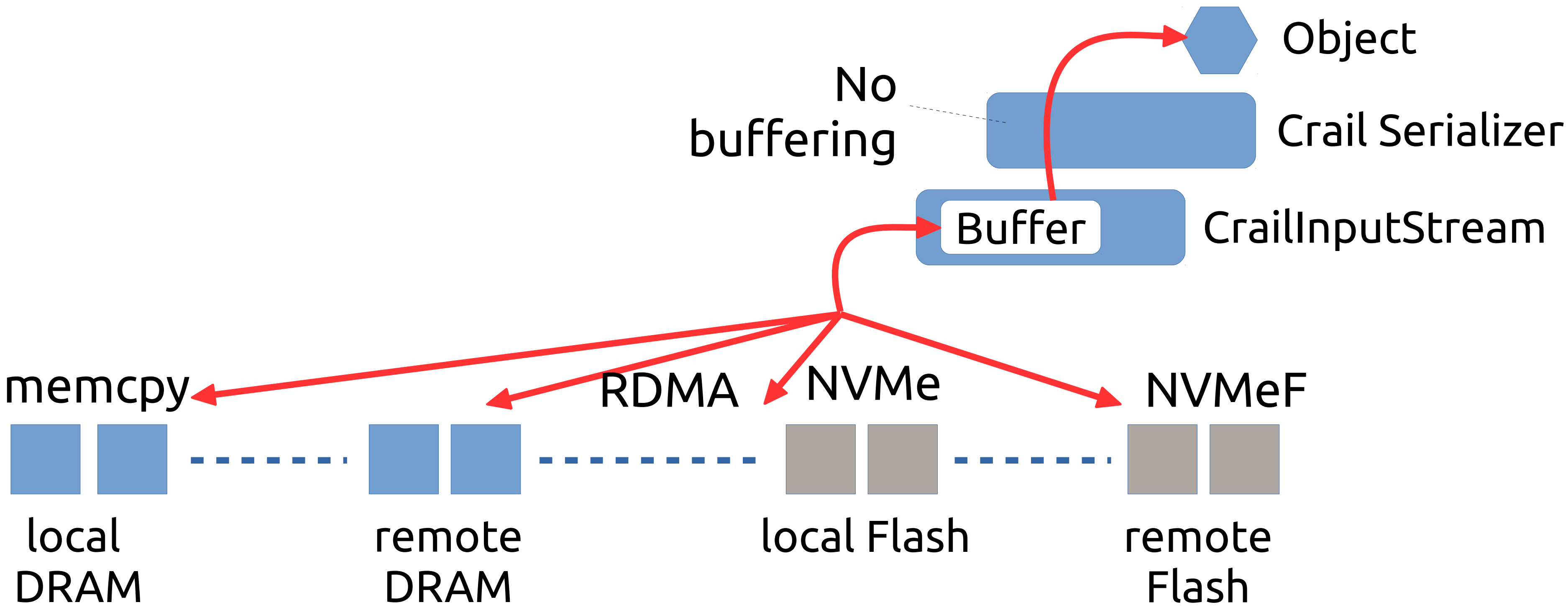
Re-think how I/O is handled in case of fast networking and storage hardware

Example: Crail Shuffle (map)



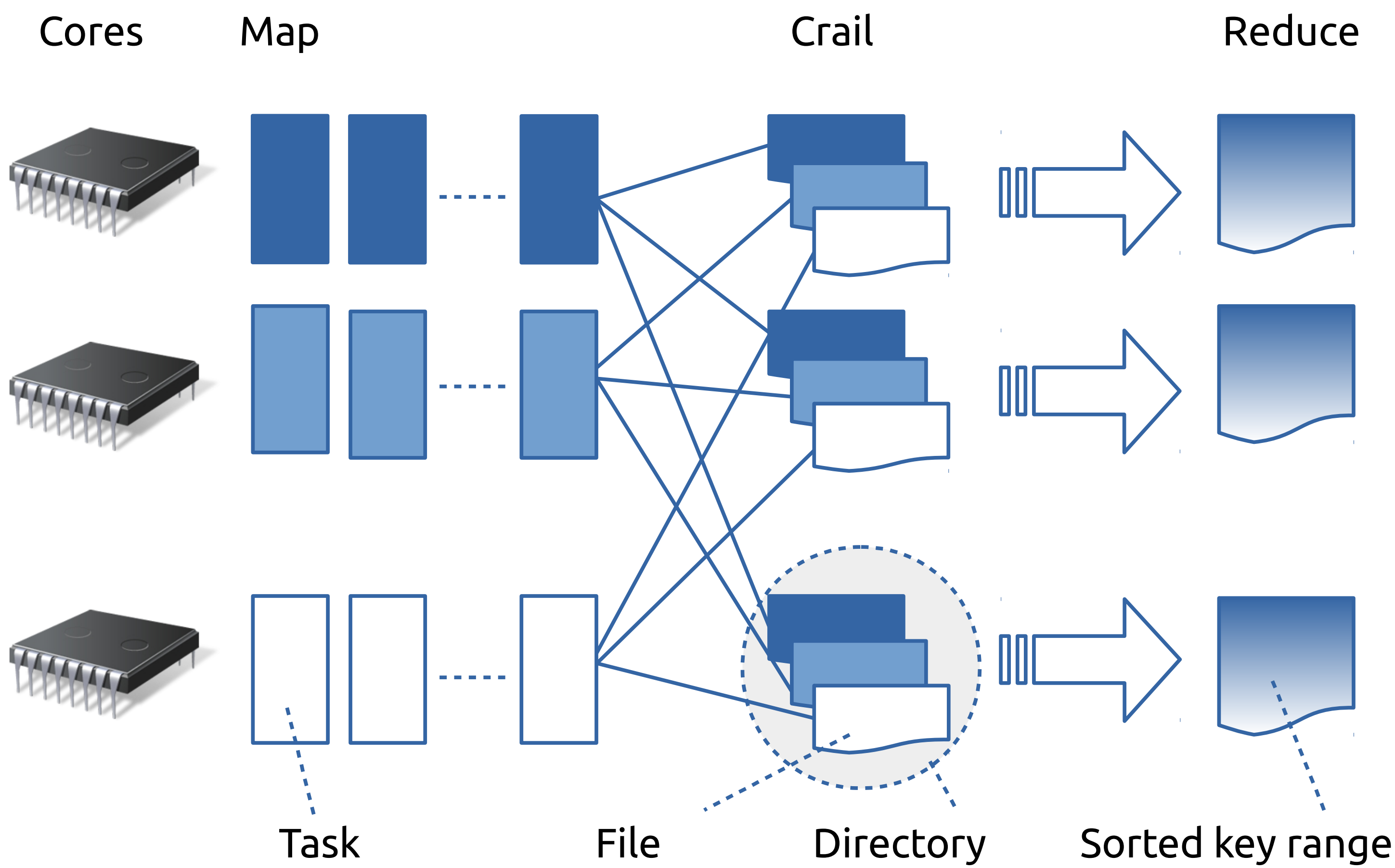
Higher-performing tiers are filled up across the cluster prior to using lower performing tiers

Example: Crail Shuffle (reduce)



Other Spark I/O operations such as broadcast, SQL join, etc., are implemented similarly

Crail Shuffle: File System Layout



Evaluation – Terasort

128 nodes OpenPOWER cluster

- 2 x IBM POWER8 10-core @ 2.9 GHz
- DRAM: 512GB DDR4
- 4 x 1.2 TB NVMe SSD
- 100GbE Mellanox ConnectX-4 EN (RoCE)
- Ubuntu 16.04 (kernel 4.4.0-31)
- Spark 2.0.2

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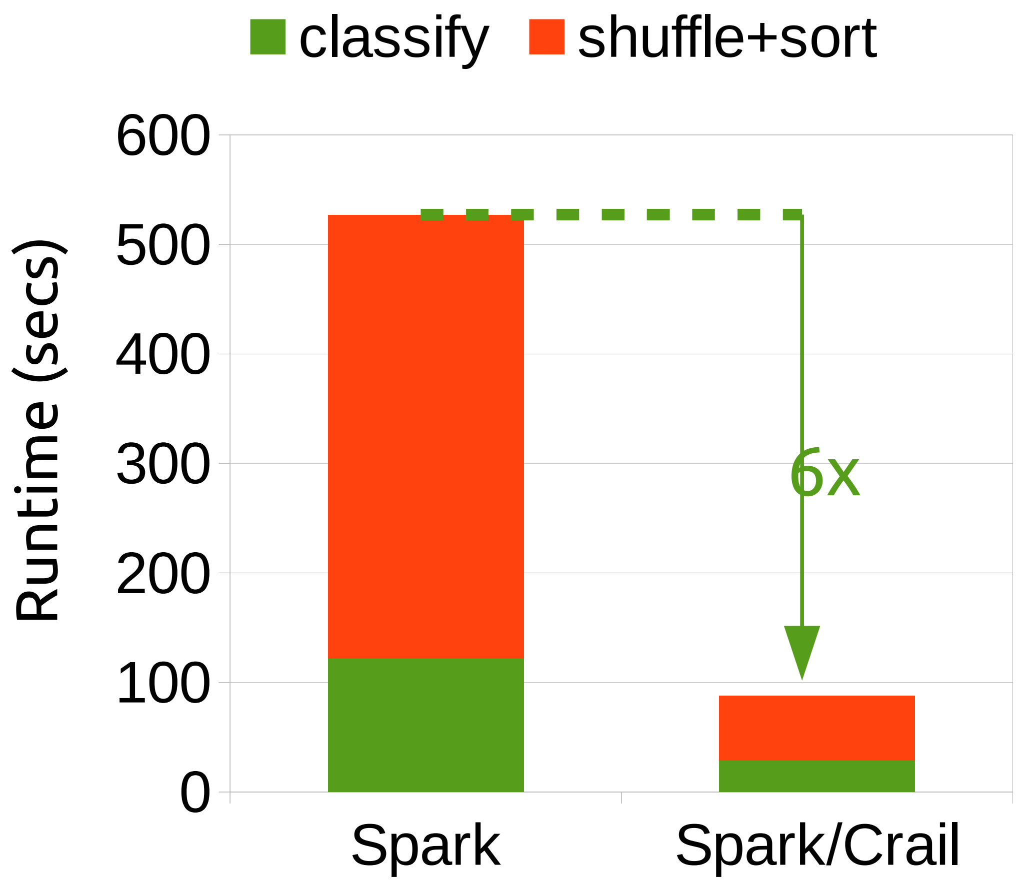
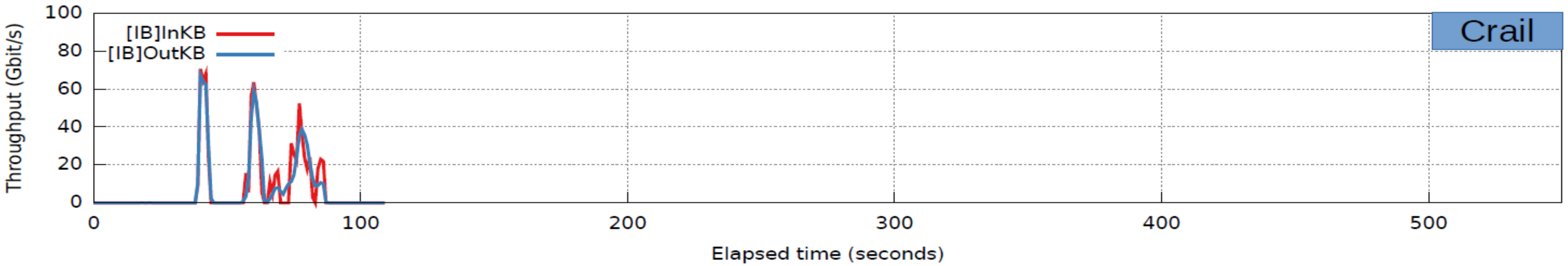
Performance gain: 6x

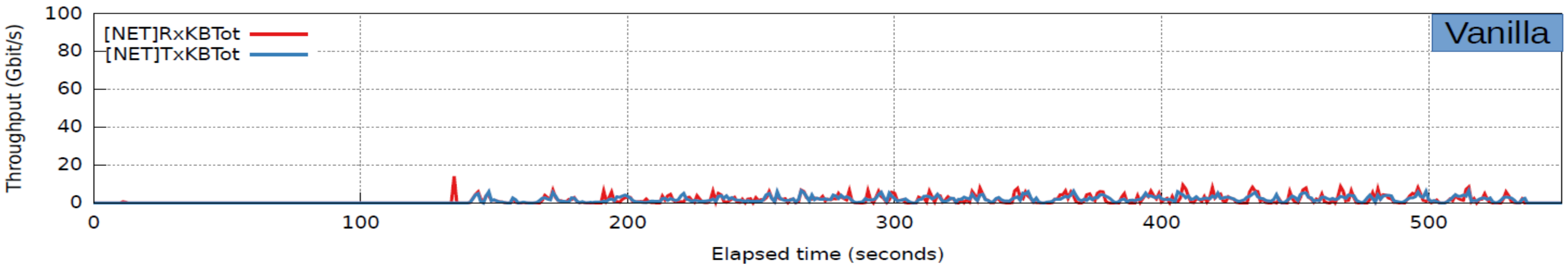
- Most gain from reduce phase:
  - Crail shuffler much faster than Spark build-in
  - Dramatically reduced CPU involvement
  - Dramatically improved network usage
- Map phase: all activity local
  - Still faster than vanilla Spark



12.8 TB data set, TeraSort

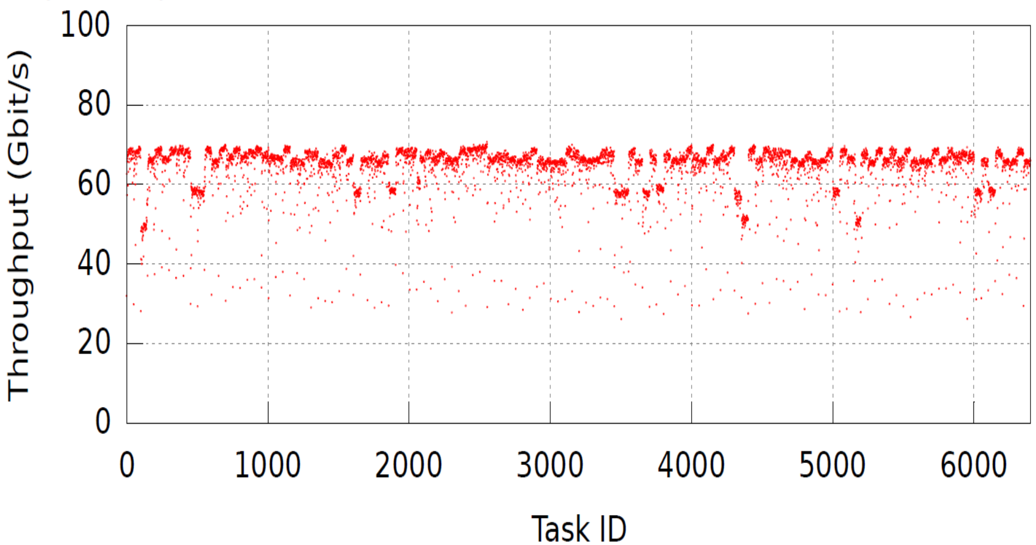
Evaluation – Network IO





- Vanilla Spark runs on 100GbE
- Spark/Crail runs on 100Gb RoCE/RDMA

- Vanilla Spark peaks at ~10Gb/s
- Spark/Crail shuffle delivers ~70Gb/s

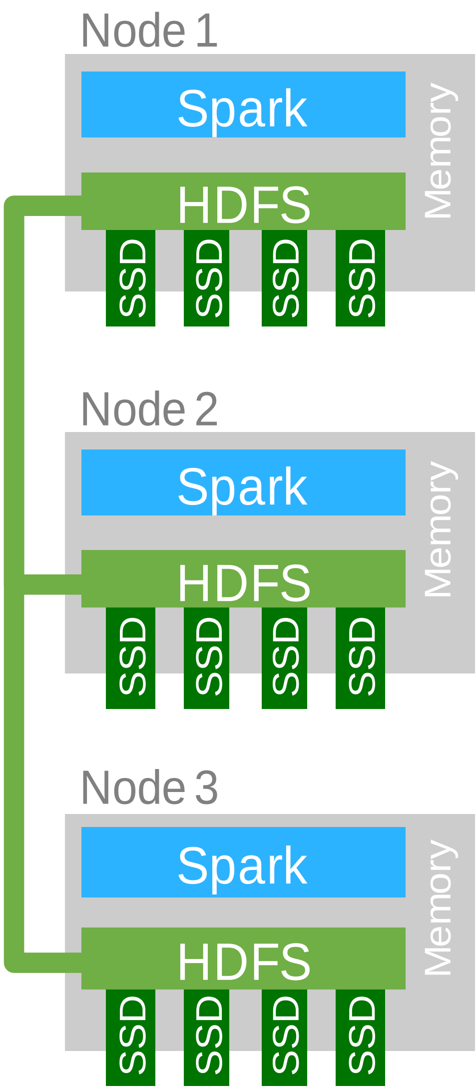


Sorting Comparison

	Spark + Crail	Spark 2.0.2	Winner 2014	Winner 2016
Size TB	12.8		100	
Time sec	98	527	1406	98.6
Cores	2560		6592	10240
Nodes	128		206	512
NW Gb/s	100		10	100
Rate TB/min	7.8	1.4	4.27	44.78
Rate/core GB/min	3.13	0.58	0.66	4.4

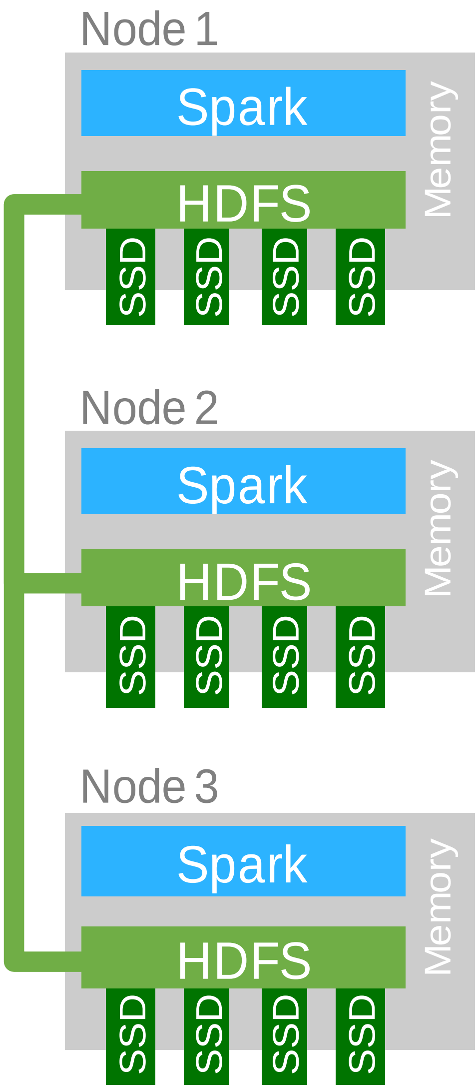
- Spark/Crail CPU efficiency is close to 2016 sorting benchmark winner: **3.13 vs. 4.4 GB/min/core**
- 2016 winner runs native C code!

Storage Disaggregation



- Why disaggregation?
  - Independent scaling of compute and storage
  - Higher utilization due to less fragmentation
  - Easier maintenance
- Challenges:
  - Systems like Hadoop/Spark have been designed for local storage
  - But: new fast networks may permit storage disaggregation

Storage Disaggregation



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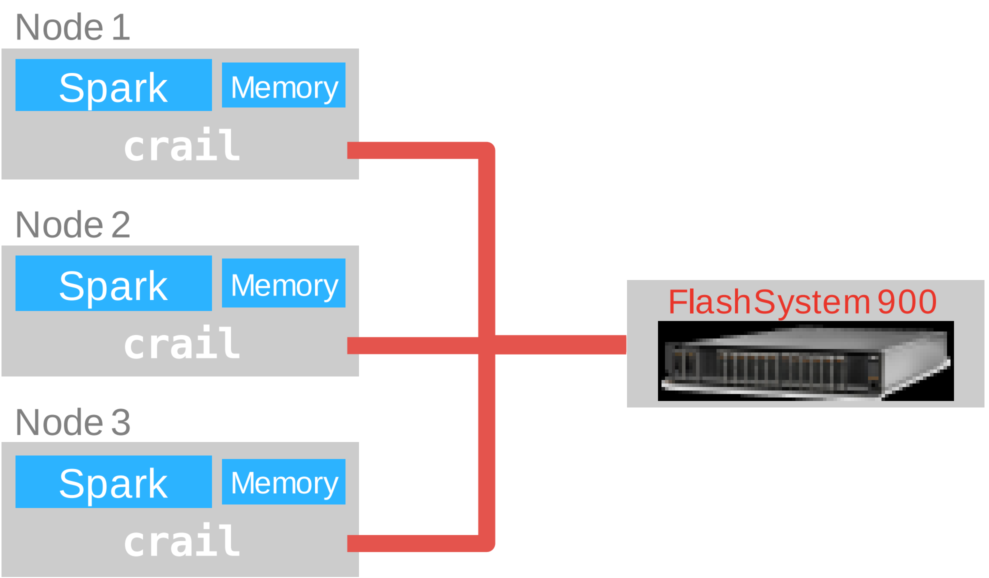
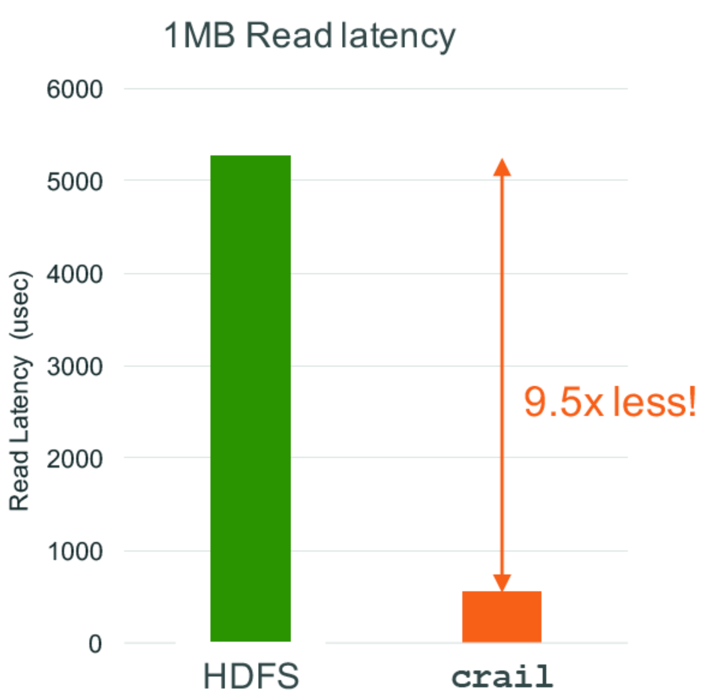
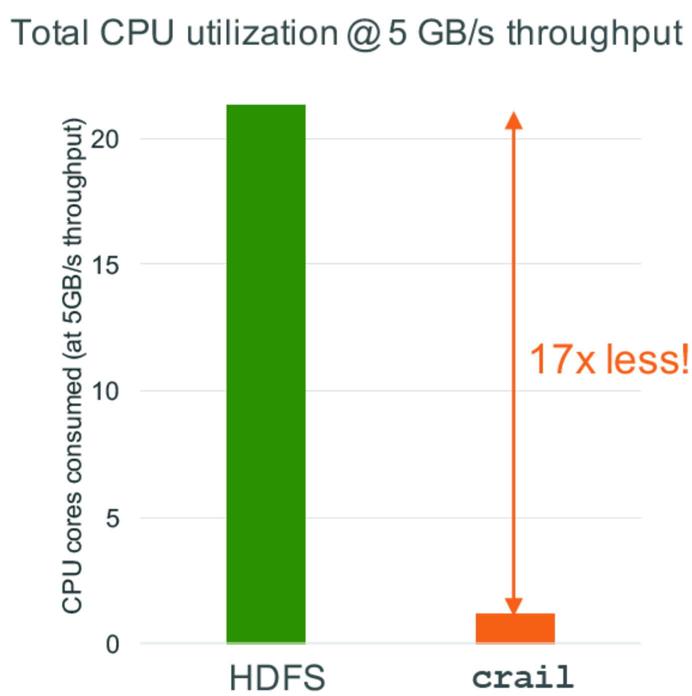


IBM Flashsystem: Crail vs HDFS





HDFS setup

- 10 node cluster
- 56 Gbit Infiniband network
- 2 x 1TB SSDs / node
- No replication

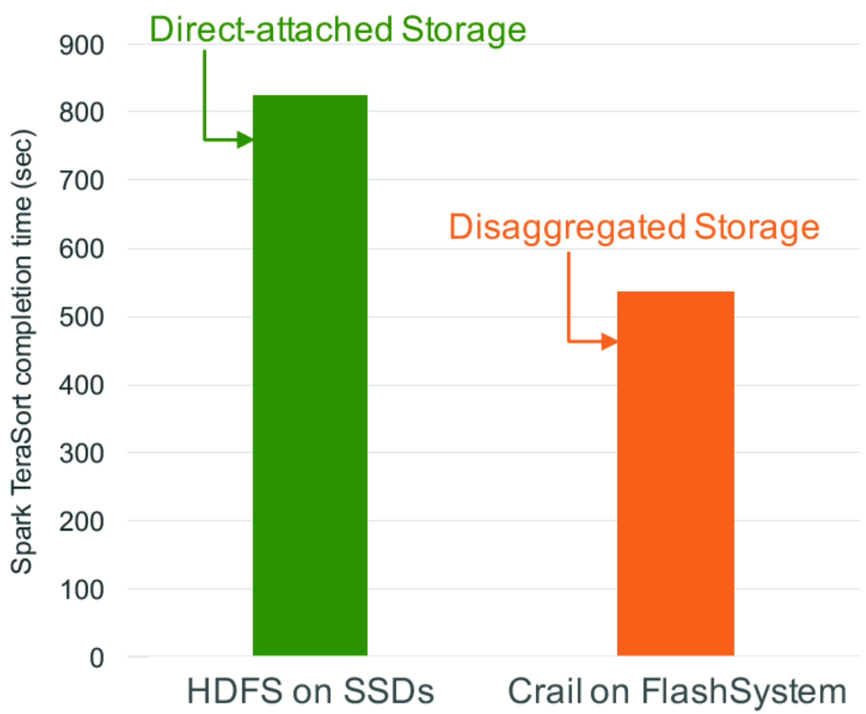
`crail` setup

- 10 node cluster
- 56 Gbit Inifiniband network
- 1 x FlashSystem 840
  - 8 Flash cards
  - 23TB usable capacity

The two systems have the same bandwidth from Flash (~10 GB/s) and about the same total capacity.

Crail + FlashSystem enables efficient, high-performance disaggregated storage for Hadoop & Spark

IBM Flashsystem: TeraSort with HDFS vs Crail



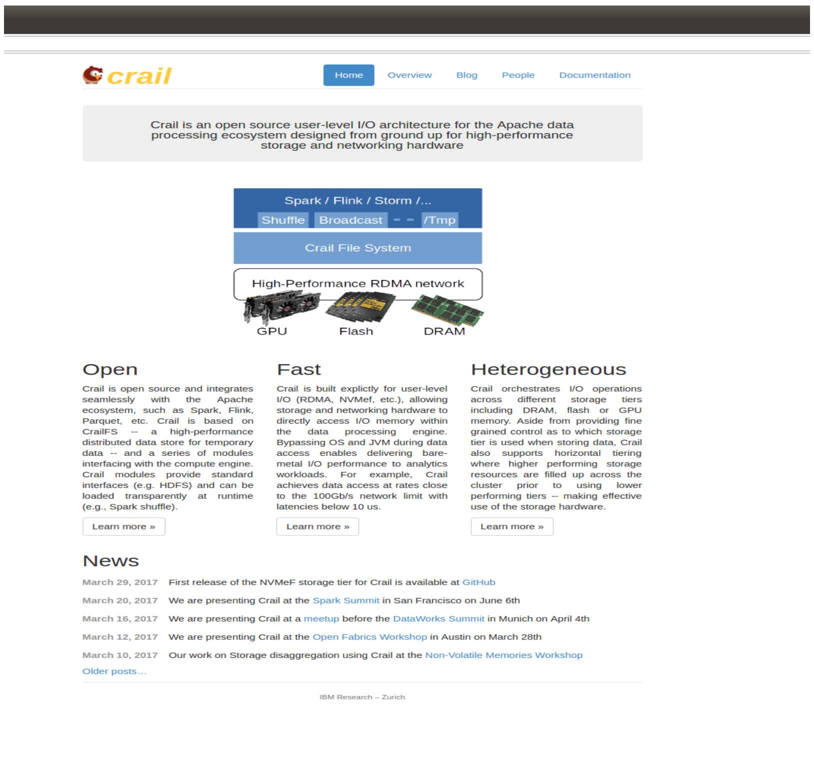
Experimental Setup

- Sorting 400GB of data using Spark
- HDFS setup
  - 10 node cluster, 56 Gbit Infiniband network
  - 2 x 1TB SSDs / node, 2-way replication
  - HDFS is using host memory (OS page cache)
- `crail` setup
  - 10 node cluster, 56 Gbit Inifiniband network
  - 1 x FlashSystem 840 (8 Flash cards, 23TB usable)
  - Crail is not using host memory
- The two systems have the same bandwidth from Flash (~10 GB/s) and about the same total Flash capacity.

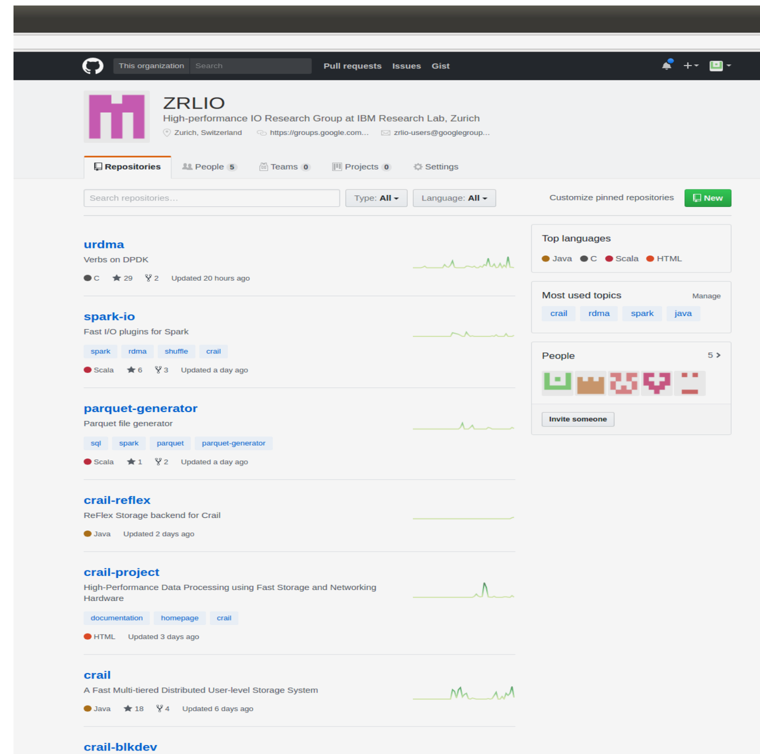
Crail + FlashSystem achieves 40% performance improvement with lower TCO and all the benefits of disaggregation

Crail is Open Source!

www.crail.io



https://github.com/zrlio



Related Work

Three classes of related work:

- New Data Processing Systems for High-Performance Network & Storage Hardware
  - FARM, RamCloud, HERD, etc

    Fast, but mostly academic, proprietary interfaces
- Updates/patches to existing Systems
  - Ohio Spark/Hadoop Distro

    Slow because no radical changes possible: fetrofitting RDMA/Flash integration into existing file/socket based I/O stacks
- Memory/Flash caches/stores
  - Example: Tacyon

    Slow because not designed for high-performance hardware

Conclusion

Today's open source analytics stacks:

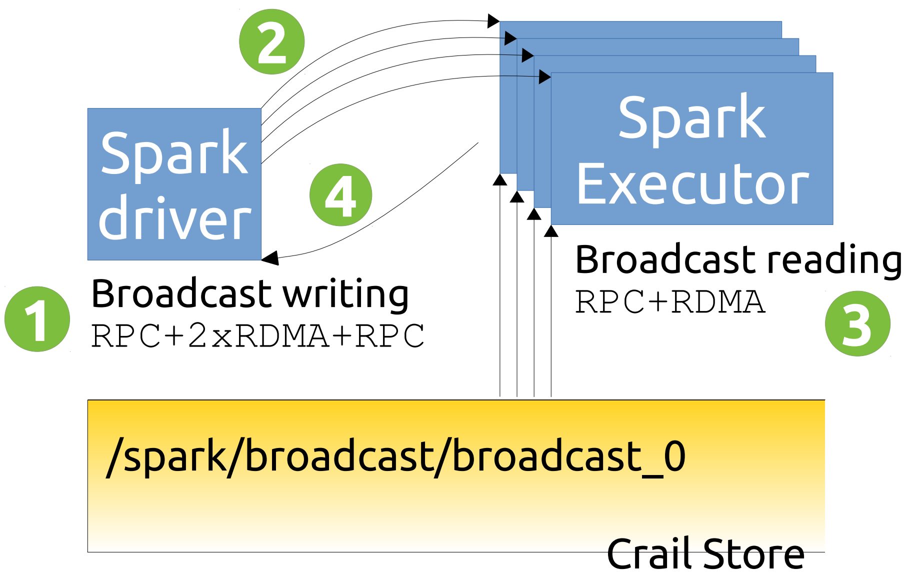
- Existing analytics stacks designed for yesterday's commodity hardware
- Performance on high-end hardware inhibited by heavy-layered stack architecture

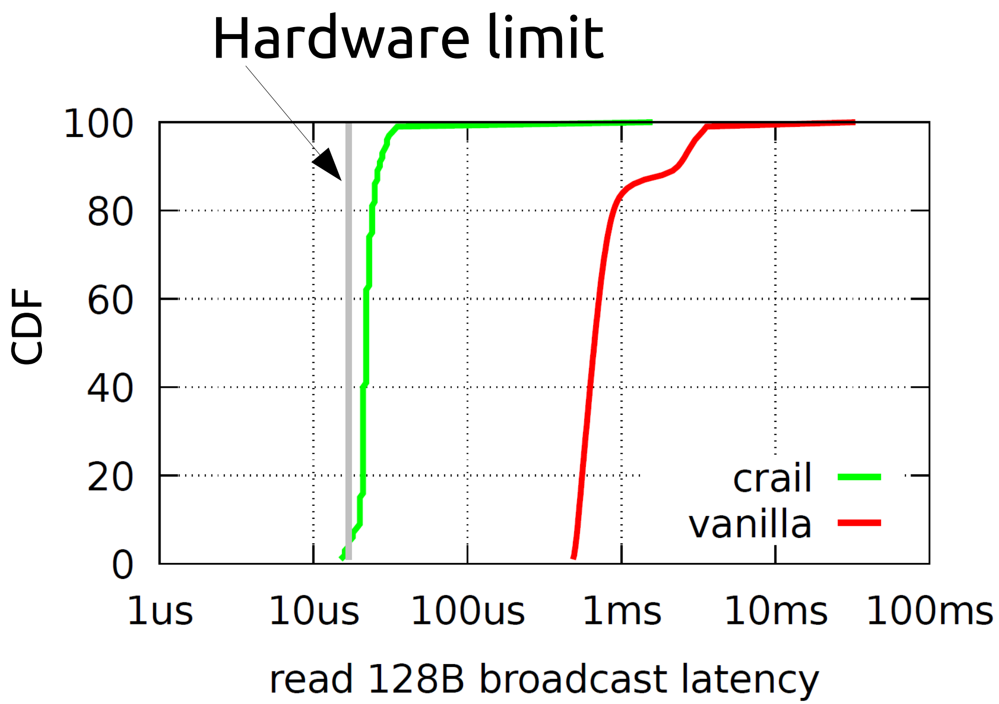
The Crail Approach:

- Radical re-design of I/O (network & storage) for analytics by exploiting modern hardware
  - RDMA, NVMe & NVMe over fabrics
- Enable high-performance disaggregated storage for analytics
- Extend Spark operation to take advantage of Crail
- Crail is open source: www.crail.io

Backup

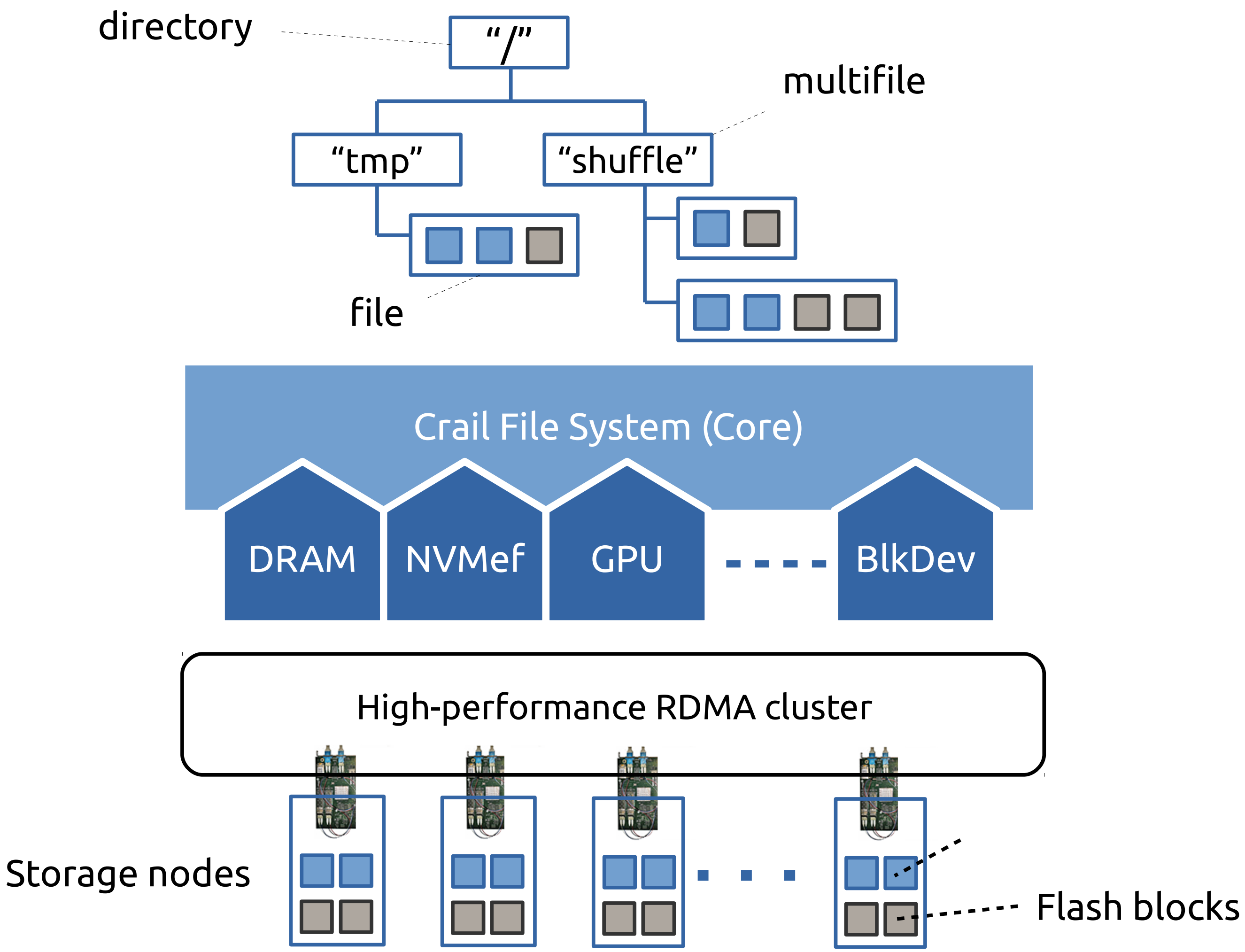
Spark/Crail Broadcast



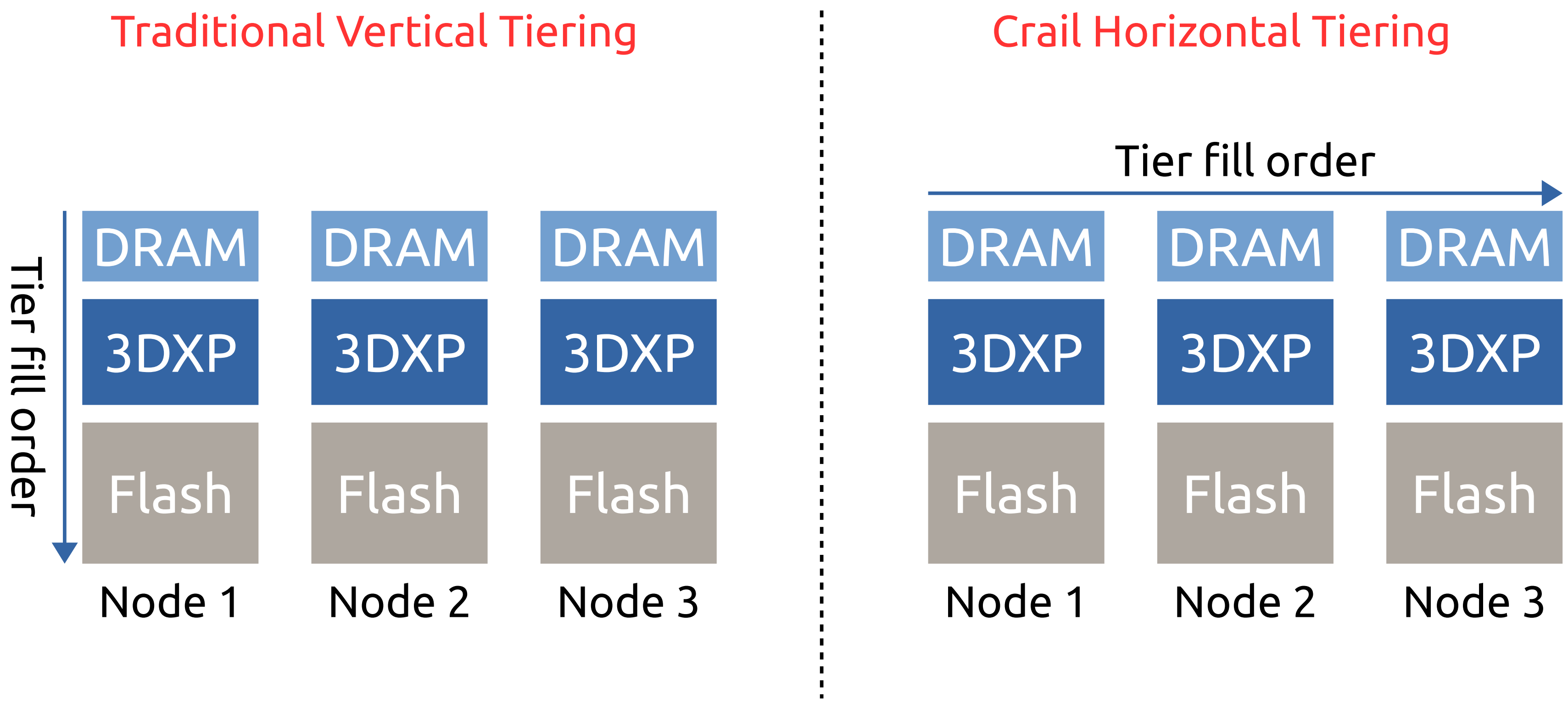



```
val bcVar = sparkContext.Broadcast(new Array[Byte](128))
sparkContext.parallelize(1 to tasks, tasks).map(_ => {
  bcVar.value.length
}).count
```

The Crail Store



Crail Storage Tiering



With horizontal tiering, higher-performing tiers are filled up across the cluster prior to using lower performing tiers