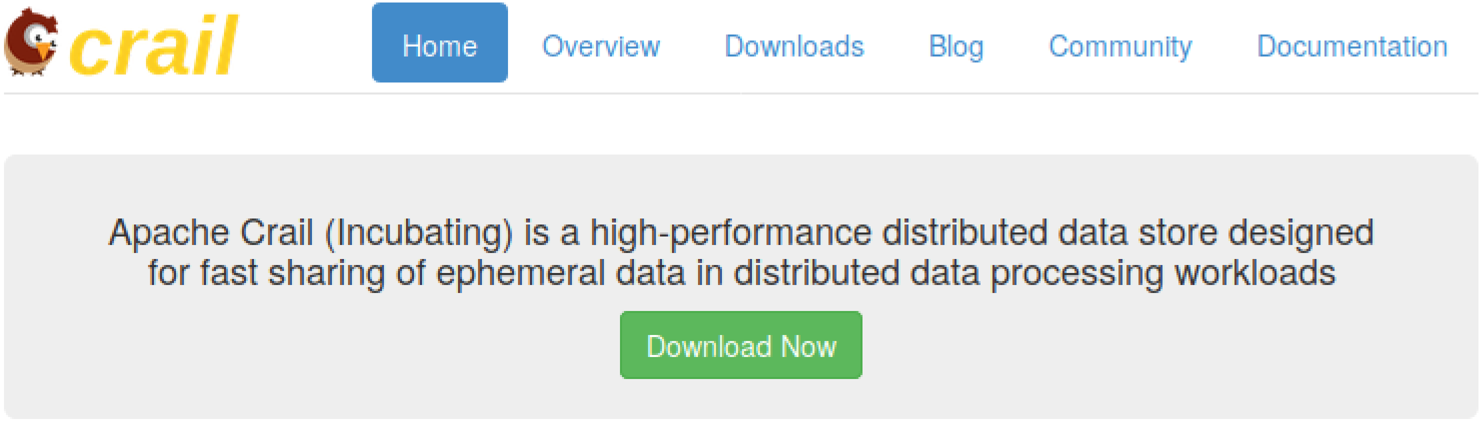
Data Processing at the Speed of 100 Gbps using Apache Crail

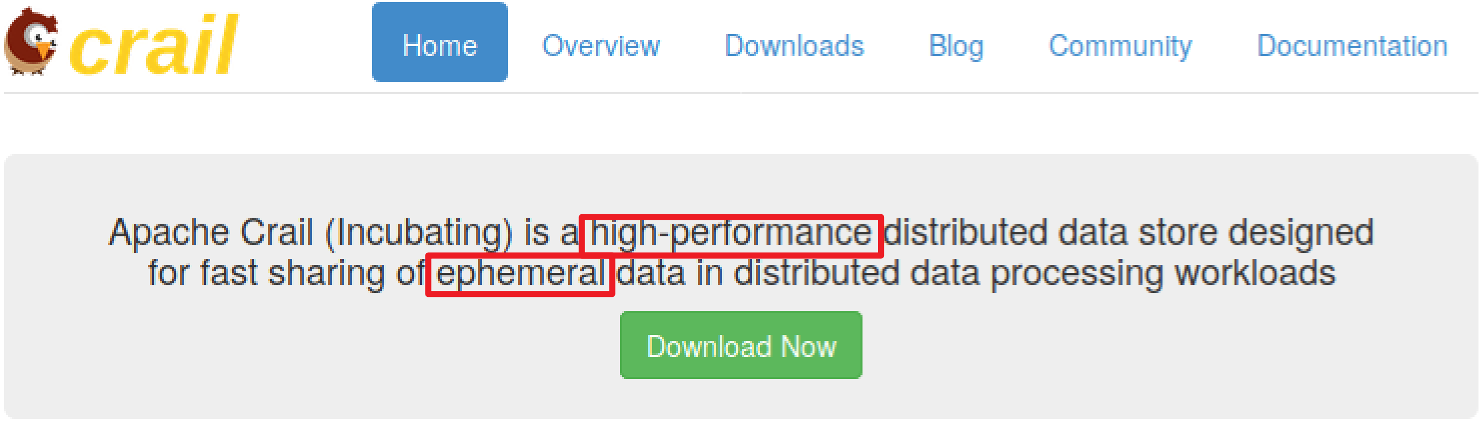
Patrick Stuedi
IBM Research

Apache Crail (crail.apache.org)



Apache Crail (Incubating) is a high-performance distributed data store designed for fast sharing of ephemeral data in distributed data processing workloads

Apache Crail (crail.apache.org)



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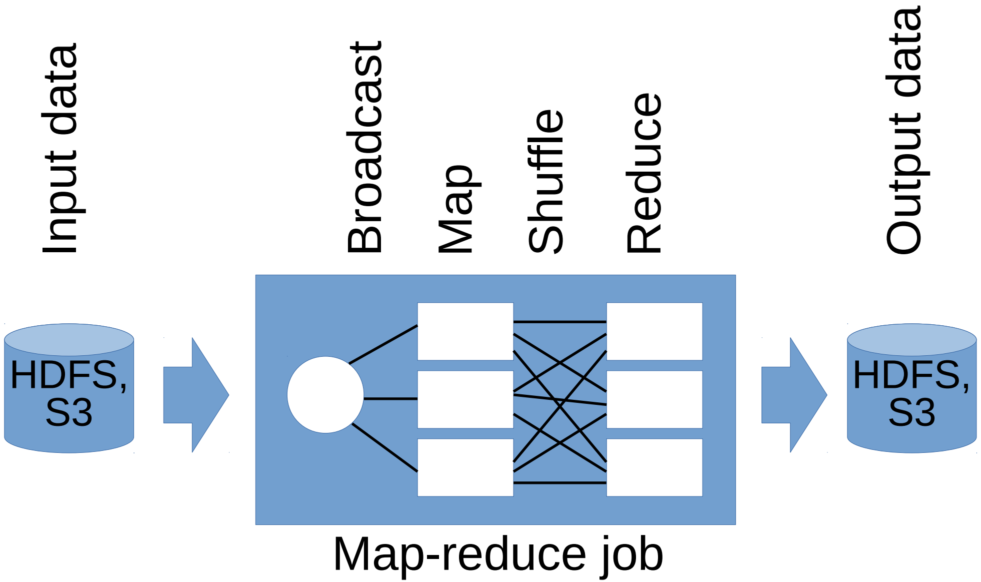
Ephemeral Data



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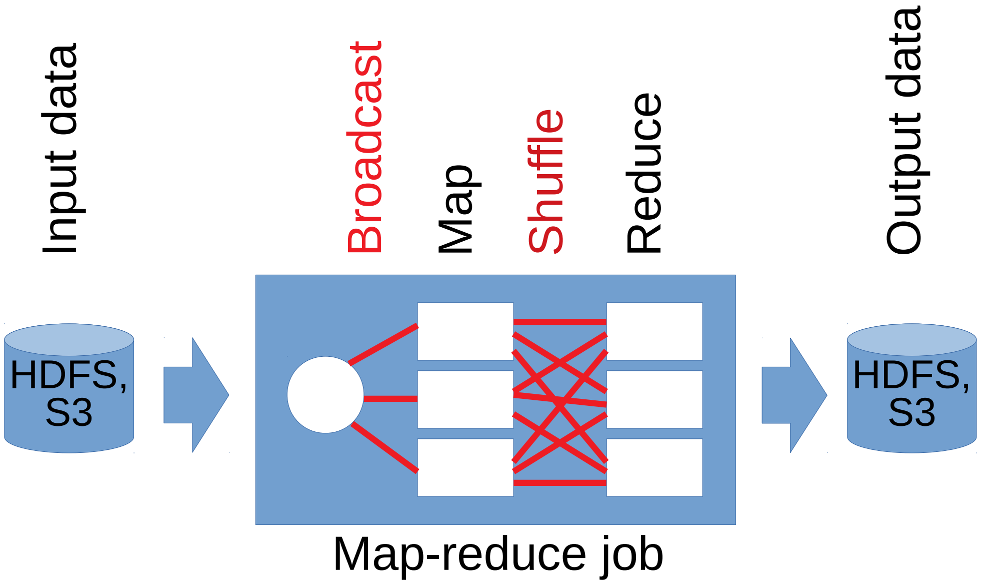

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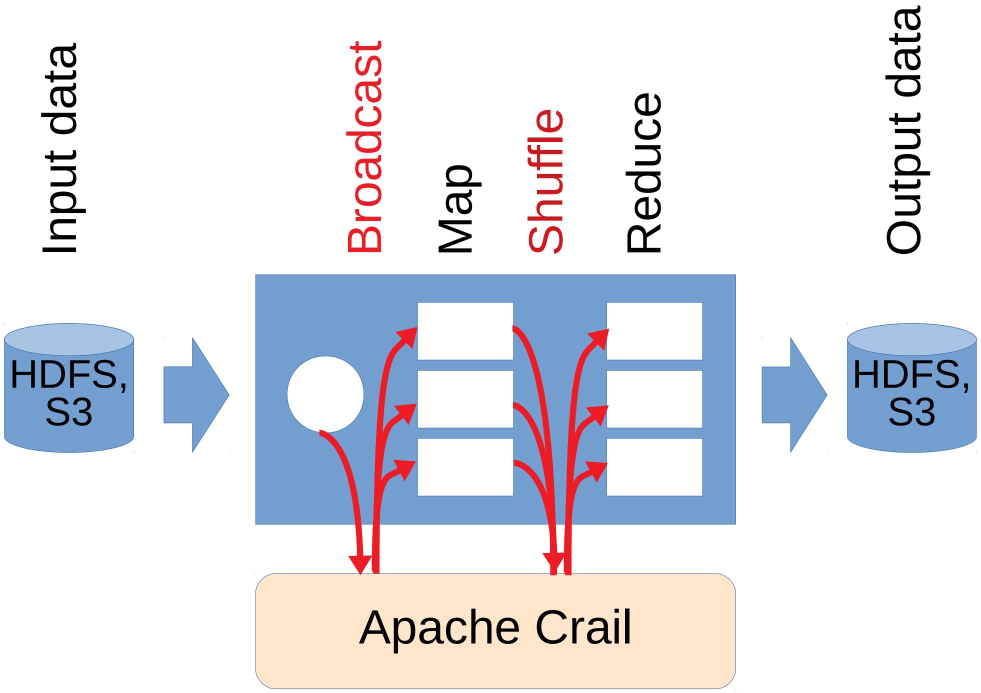

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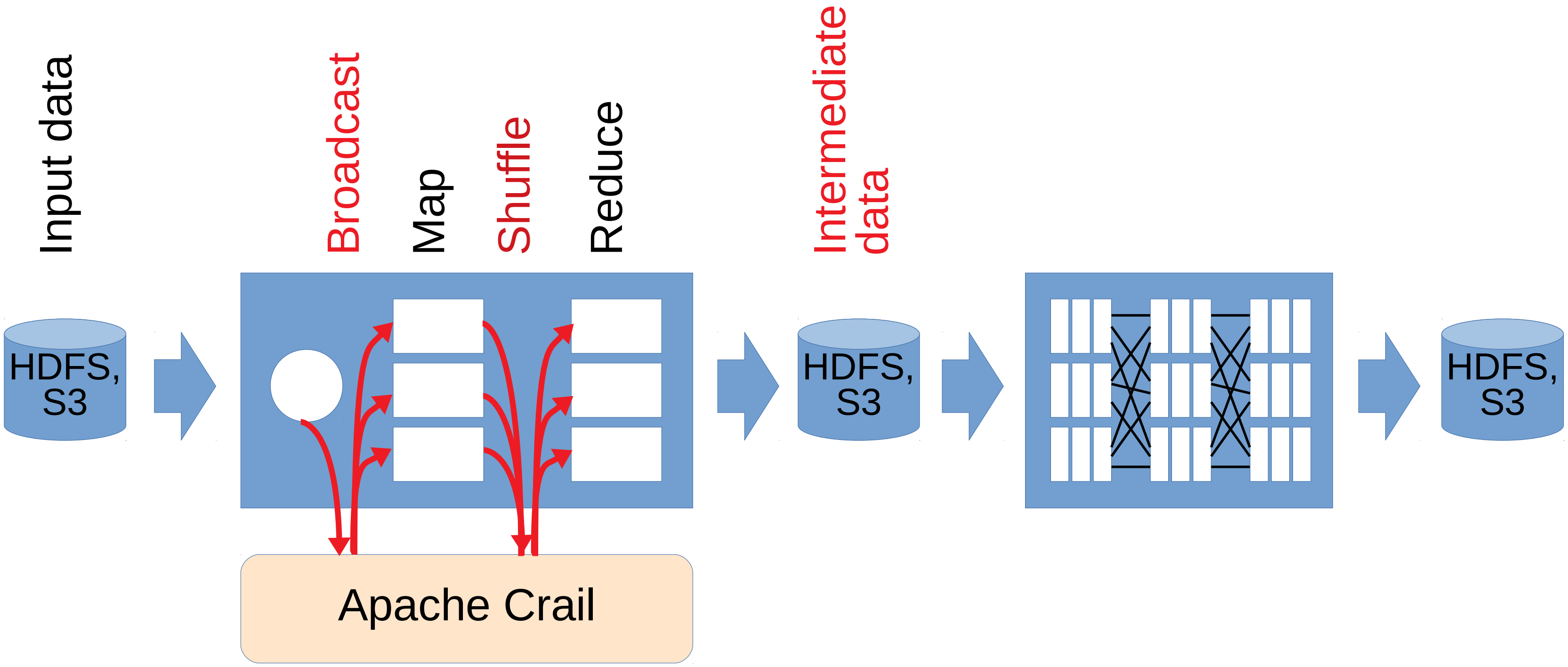

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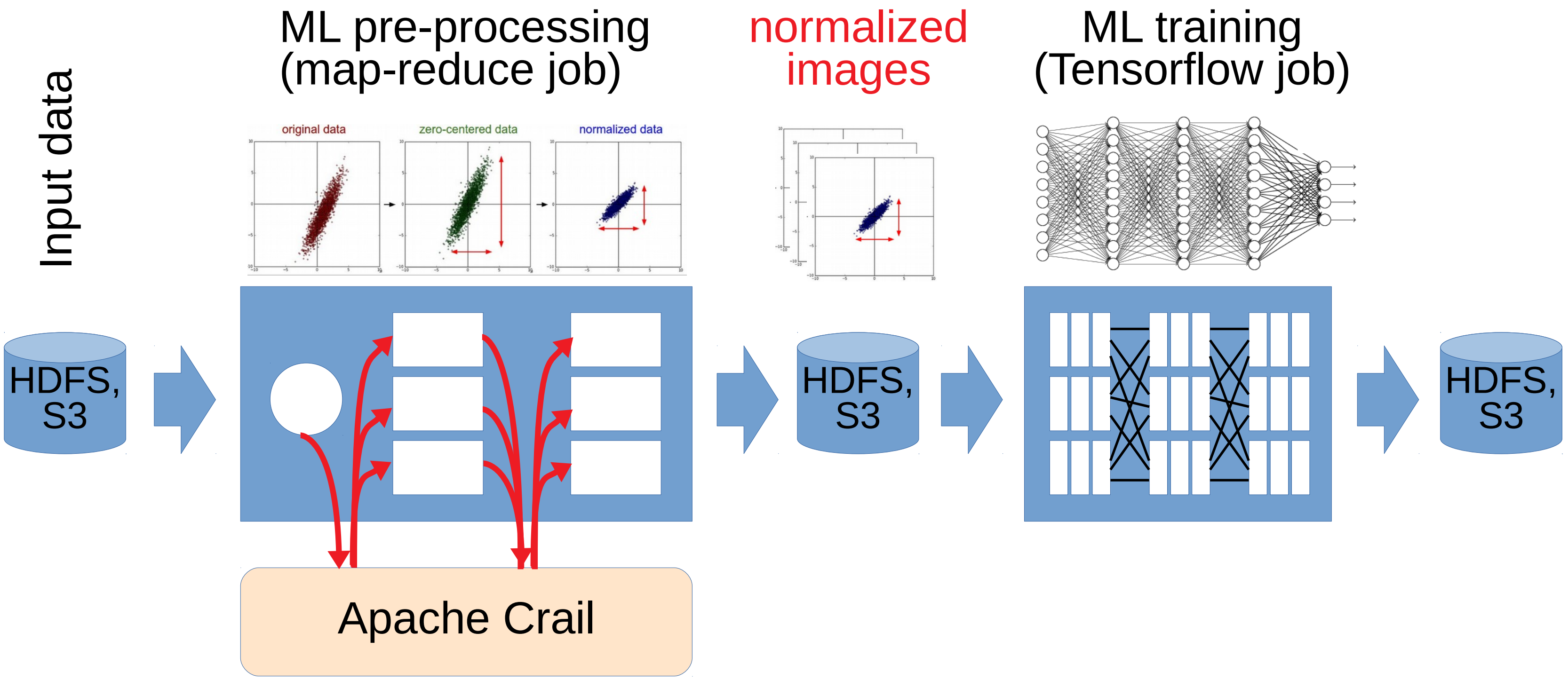


Input data

ML pre-processing (map-reduce job)

normalized images

ML training (Tensorflow job)

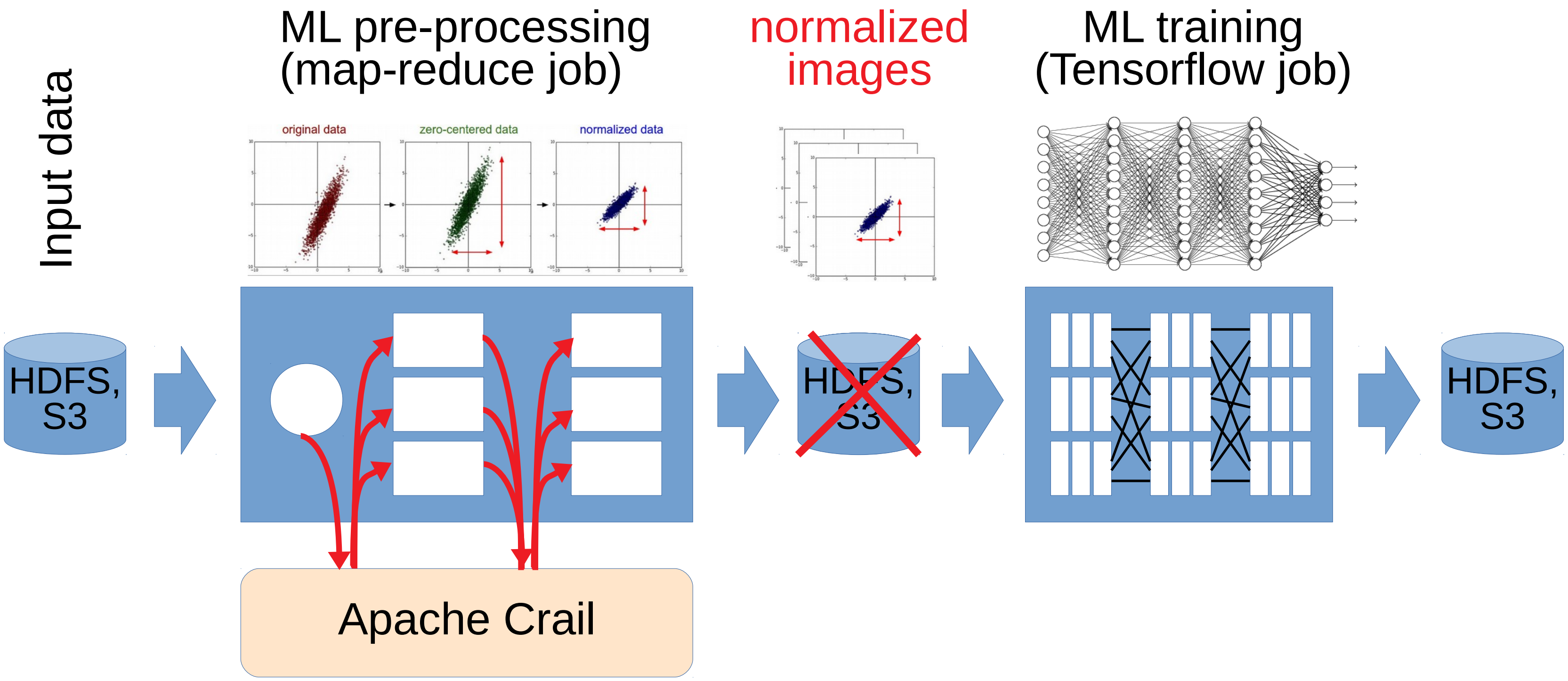
HDFS, S3

HDFS, S3

HDFS, S3

Apache Crail

Ephemeral Data



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HDFS,
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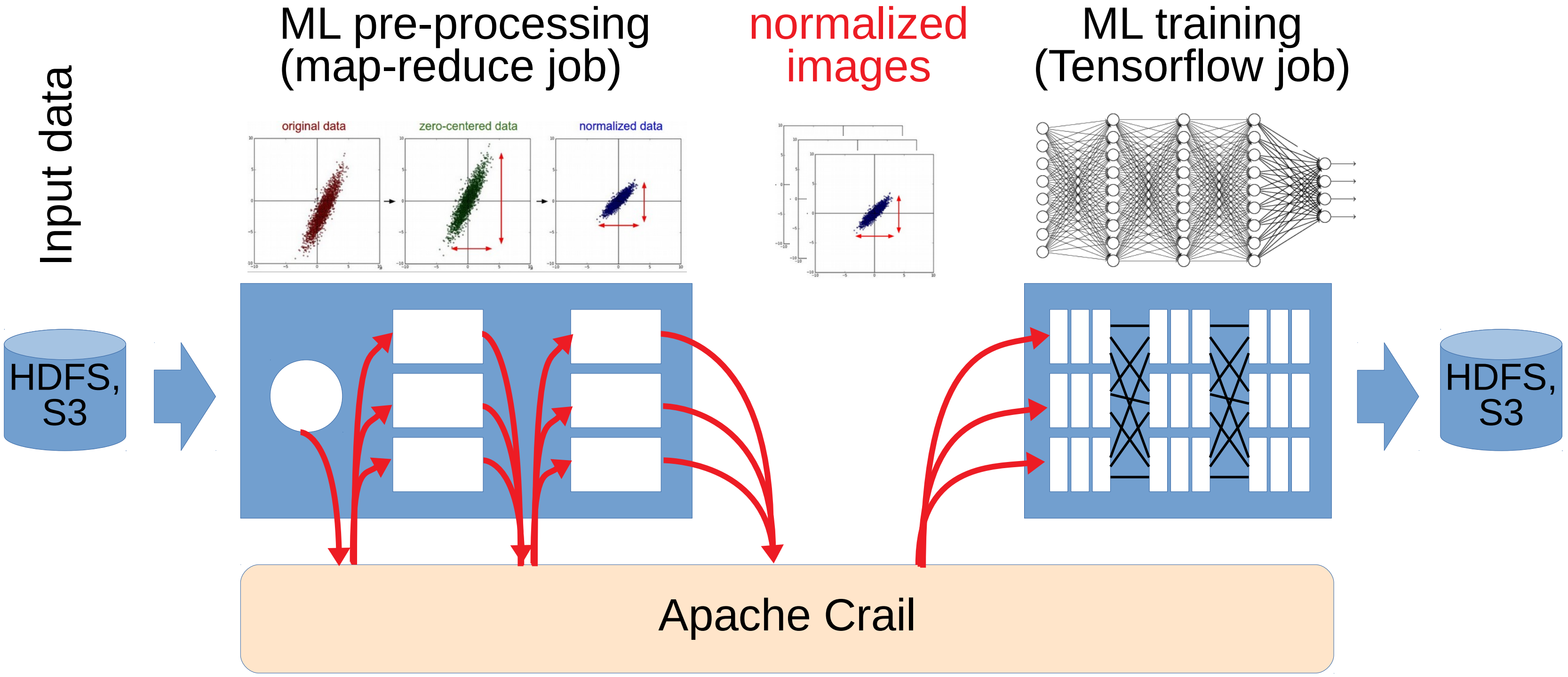
Apache Crail

Ephemeral Data



Input data

ML pre-processing (map-reduce job)

normalized images

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HDFS, S3

Apache Crail

HDFS, S3

Why/when to use Crail

HDD

10 Gb/s Ethernet

Why/when to use Crail

No Crail needed

HDD

10 Gb/s Ethernet

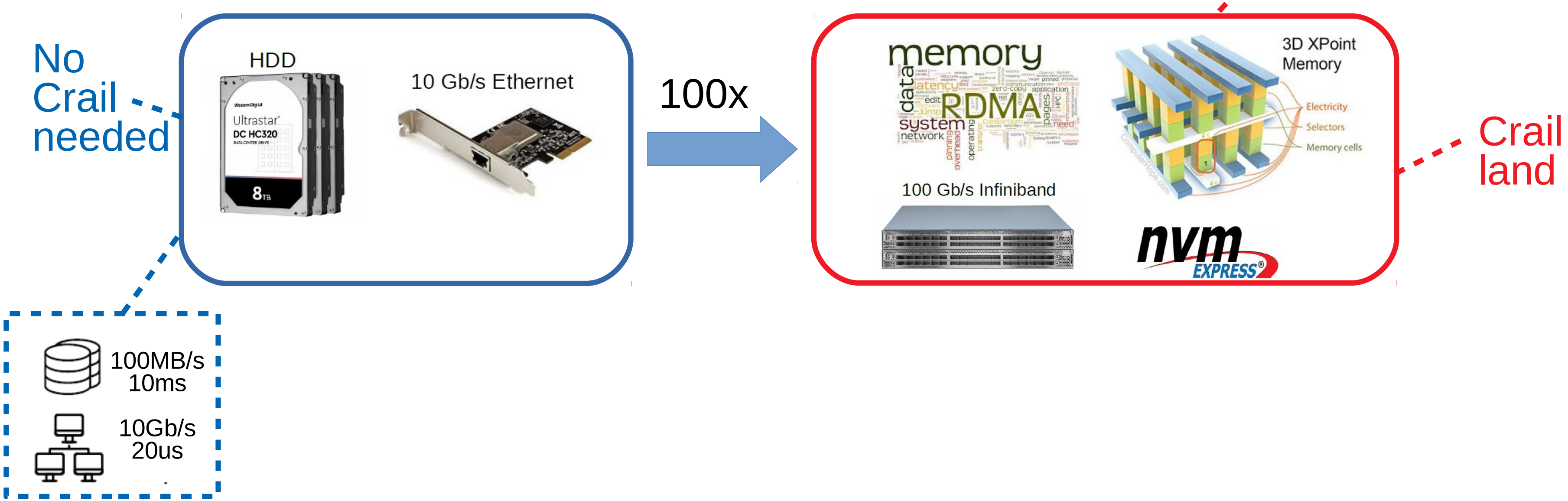
100MB/s
10ms

10Gb/s
20us

Why/when to use Crail

10GB/s
10us

200Gb/s
1us



No Crail needed

HDD

10 Gb/s Ethernet

100x

100 Gb/s Infiniband

Crail land

100MB/s
10ms

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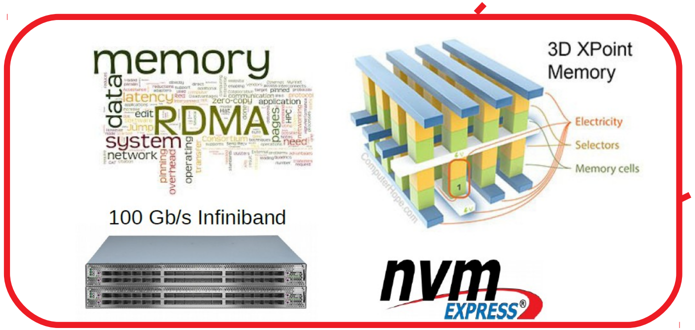

Crail
land

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10ms

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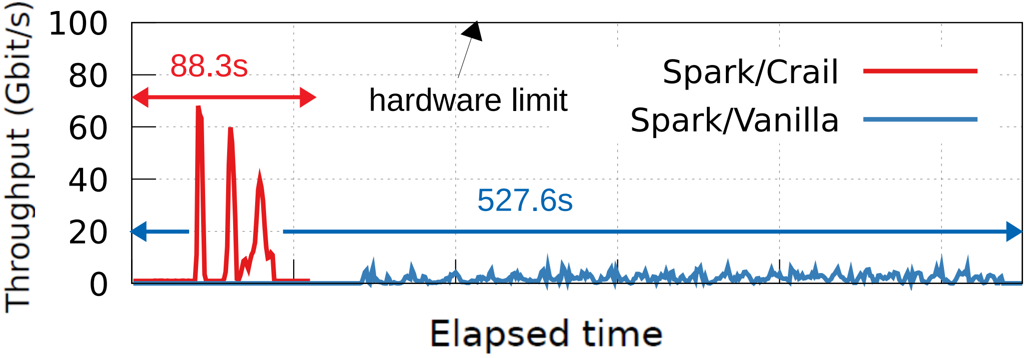
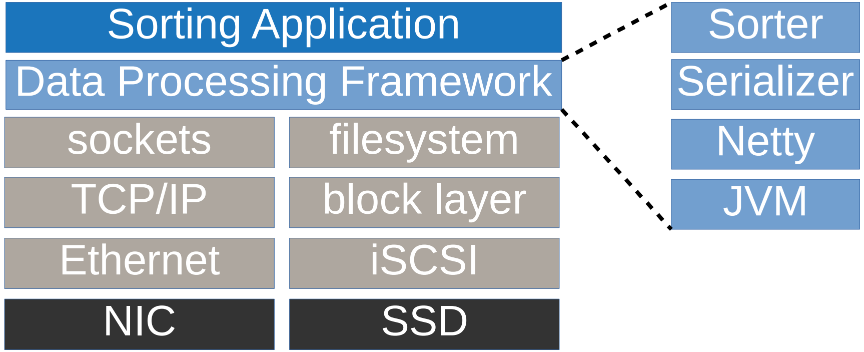


Terasort
12.8 TB data
128 nodes

Performance Challenge

	1 Gbps	HDD	100 Gbps	Flash
Bandwidth	117 MB/s	140 MB/s	12.5 GB/s	3.1 GB/s
cycle/unit	38,400	10,957	360	495



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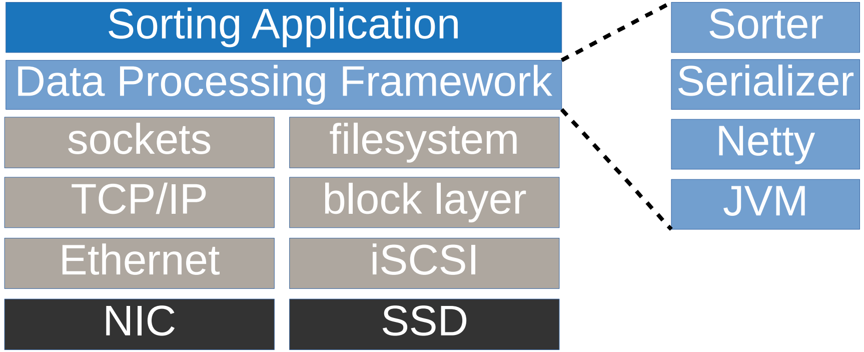
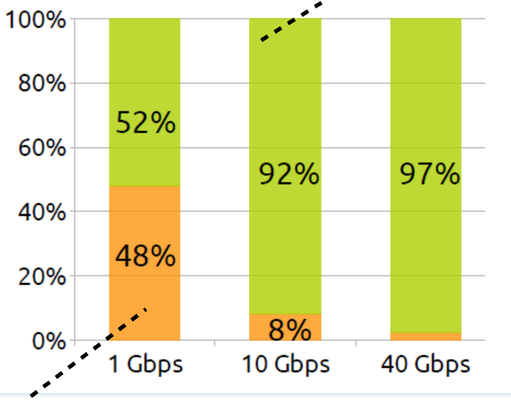


Process chunk
In reduce task



Fetch chunk
Over the network

HotNets'16

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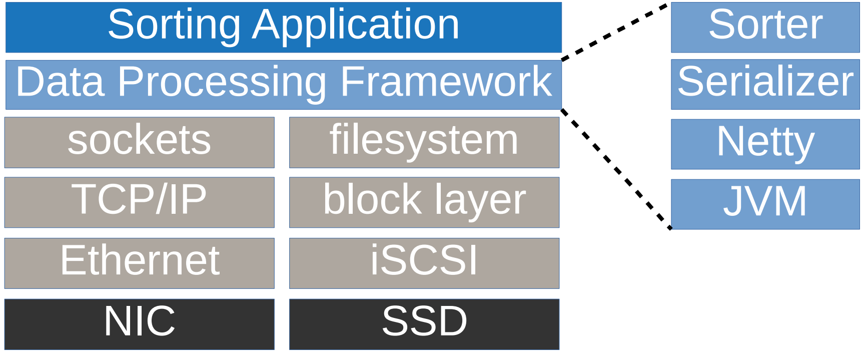


Sorting Application

Data Processing Framework

sockets | filesystem

TCP/IP | block layer

Ethernet | iSCSI

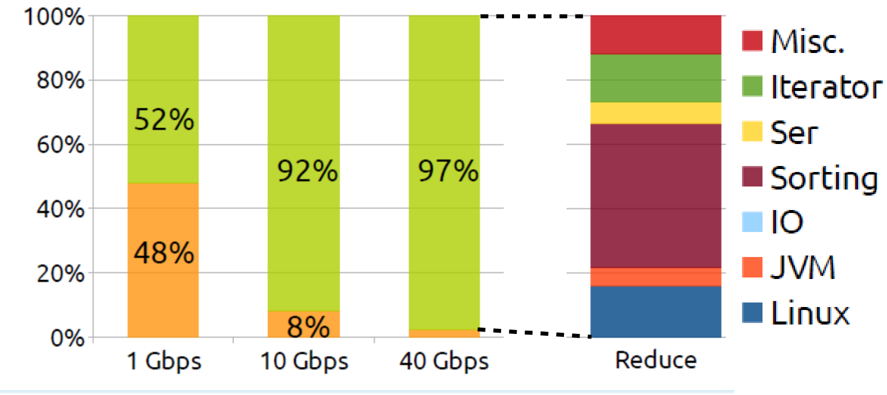
NIC | SSD

Sorter

Serializer

Netty

JVM



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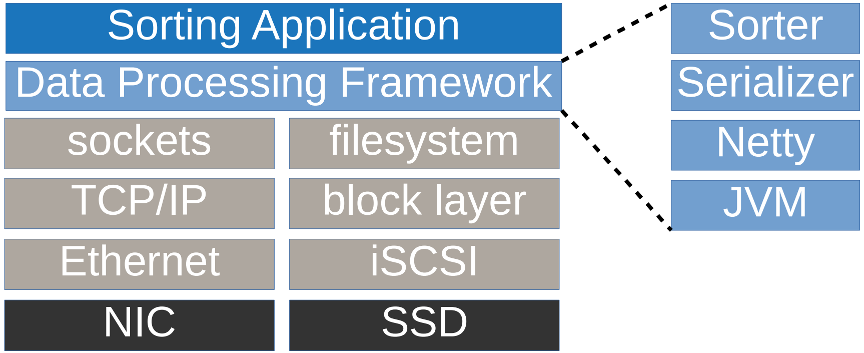
software overhead
are spread
over the entire
stack



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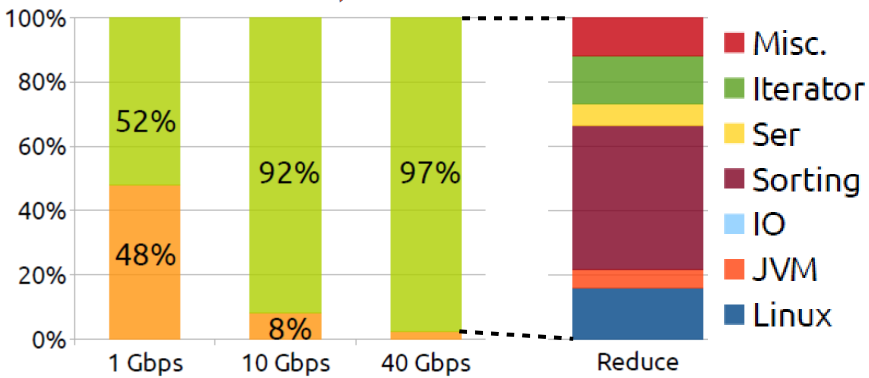
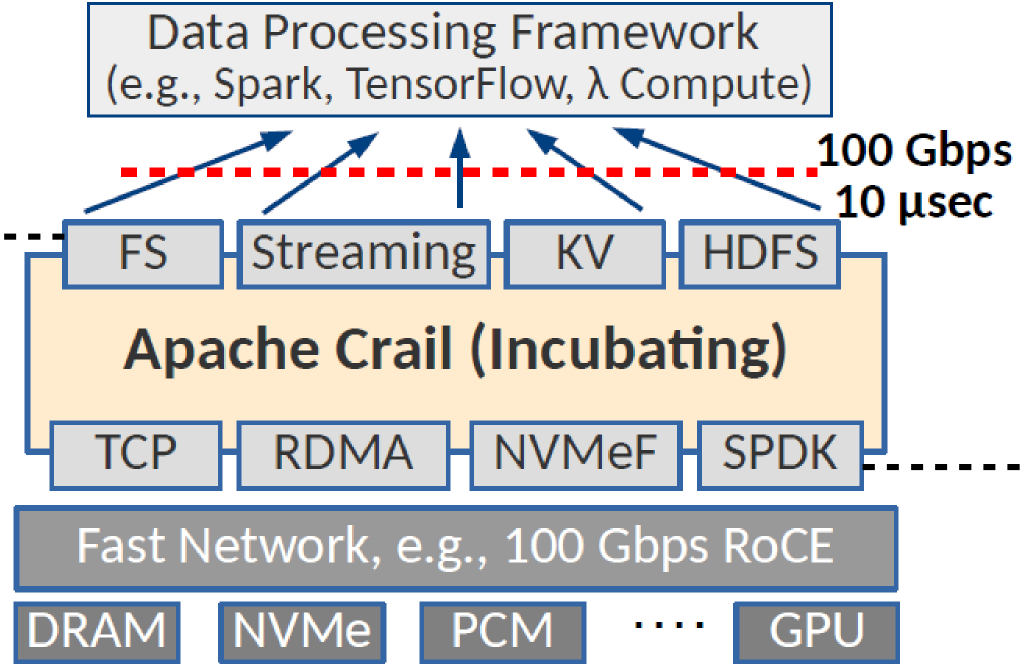


HotNets’16

Crail Overview



Data Processing Framework
(e.g., Spark, TensorFlow, λ Compute)

100 Gbps
10 µsec

FS | Streaming | KV | HDFS

Apache Crail (Incubating)

TCP | RDMA | NVMeF | SPDK

Fast Network, e.g., 100 Gbps RoCE

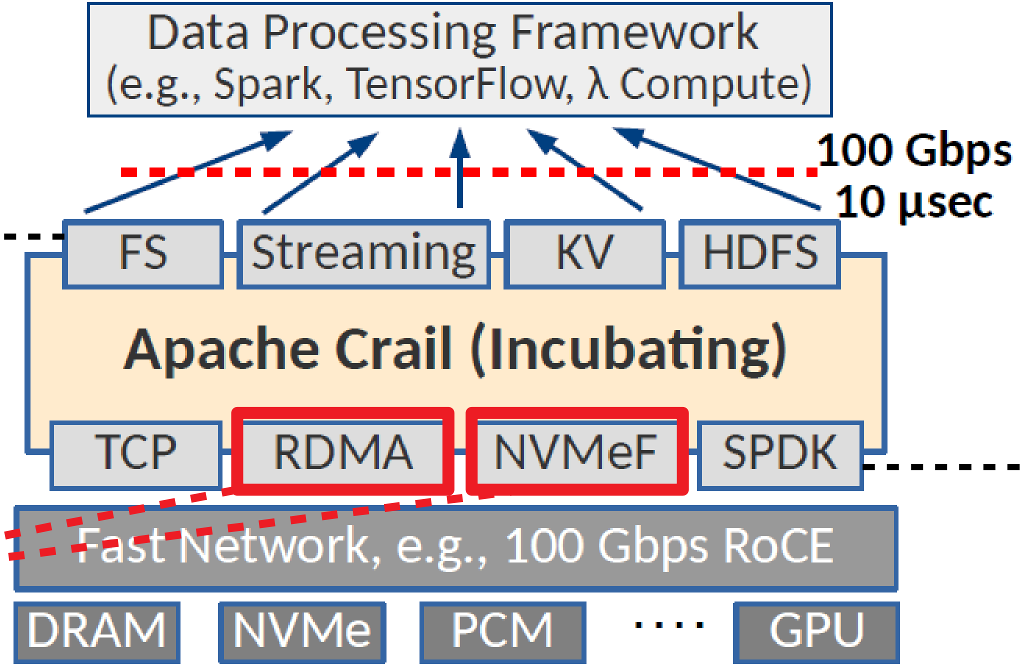
DRAM | NVMe | PCM | .... | GPU

Multiple interfaces

Multiple storage backends
(pluggable, open interface)

Crail Overview

Multiple interfaces



Data Processing Framework
(e.g., Spark, TensorFlow, λ Compute)
100 Gbps
10 µsec
FS
Streaming
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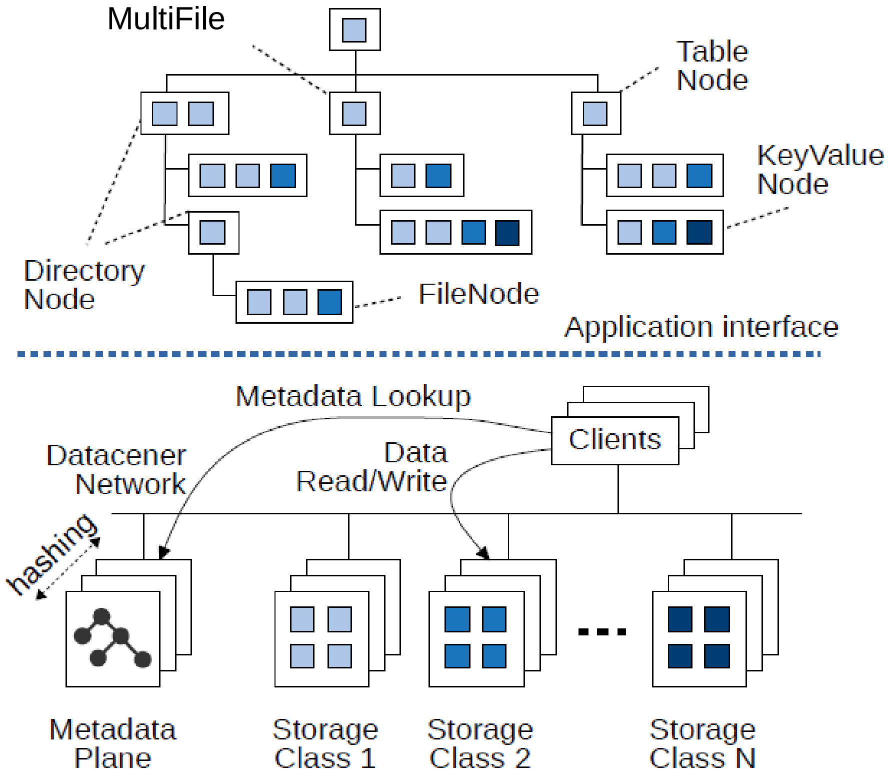
Apache Crail (Incubating)
TCP
RDMA
NVMeF
SPDK
Fast Network, e.g., 100 Gbps RoCE
DRAM
NVMe
PCM
....
GPU

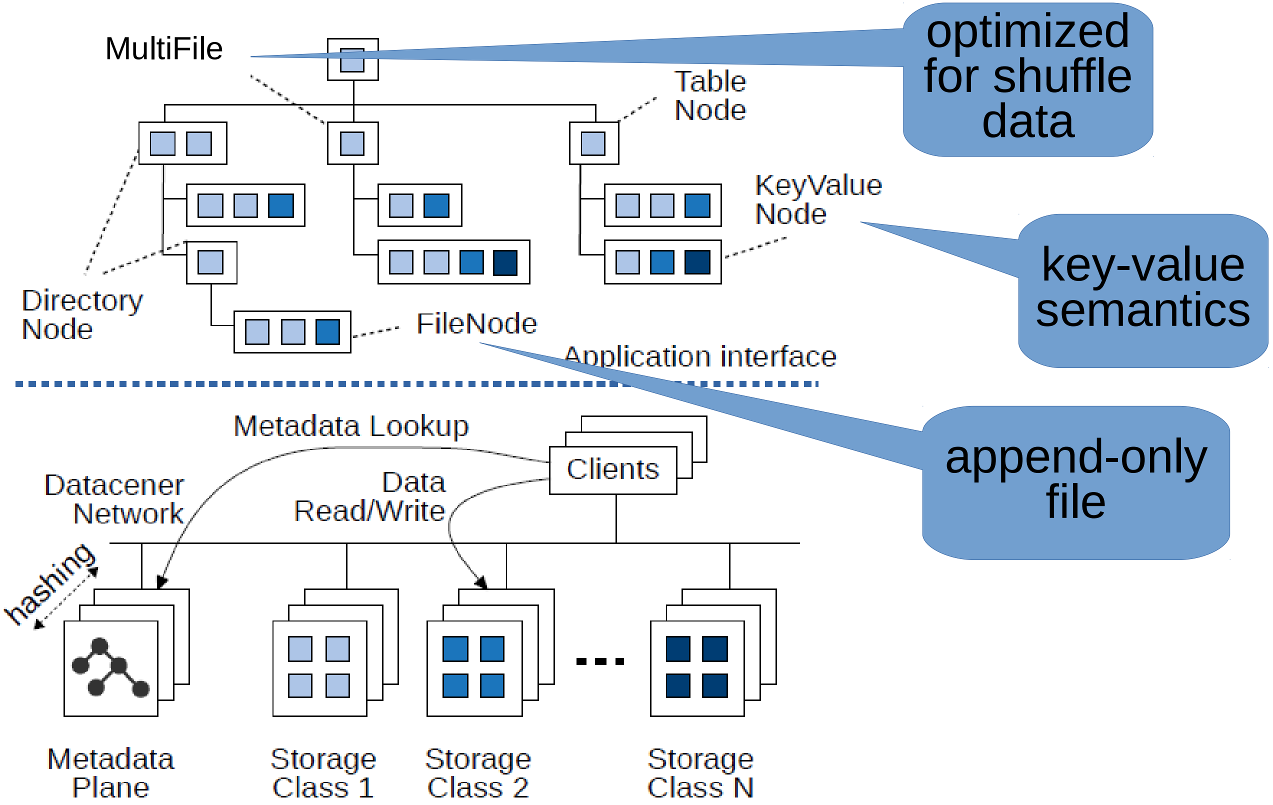
Multiple storage backends (pluggable, open interface)

primary high-performance storage backends

Crail Architecture & API



Crail Architecture & API

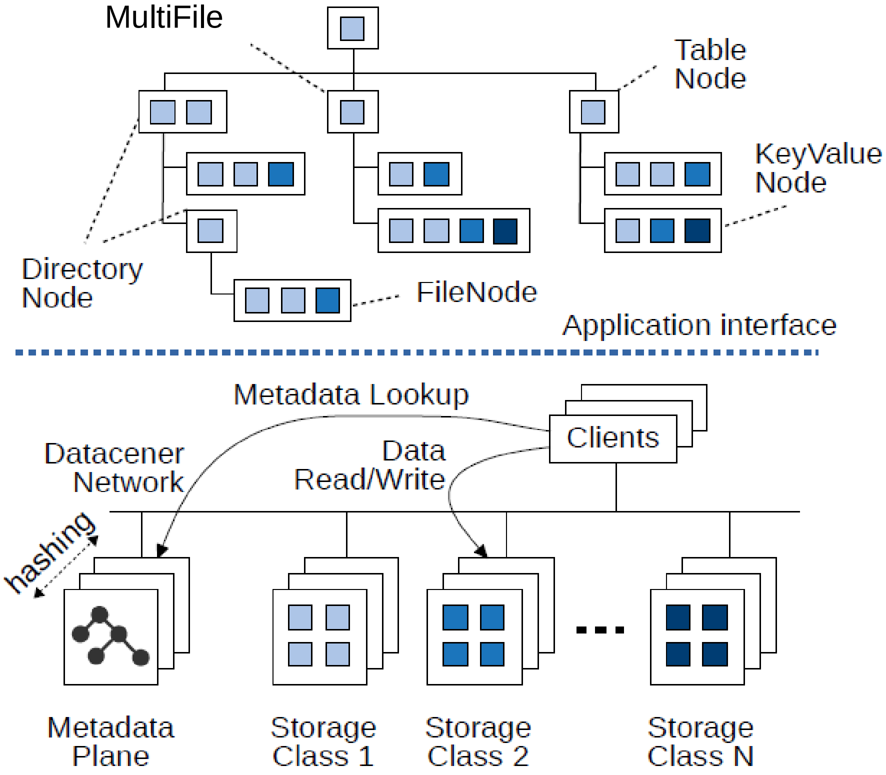


optimized for shuffle data

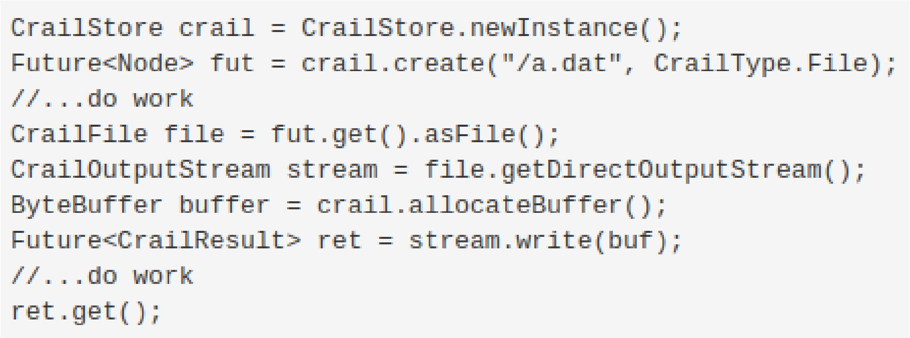
key-value semantics

append-only file

Crail Architecture & API

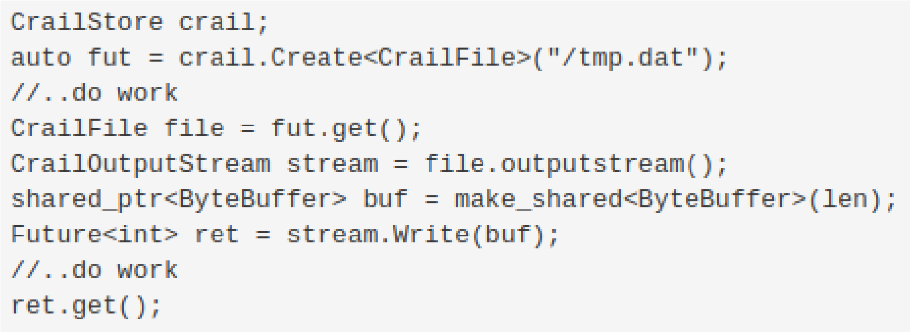


Java:



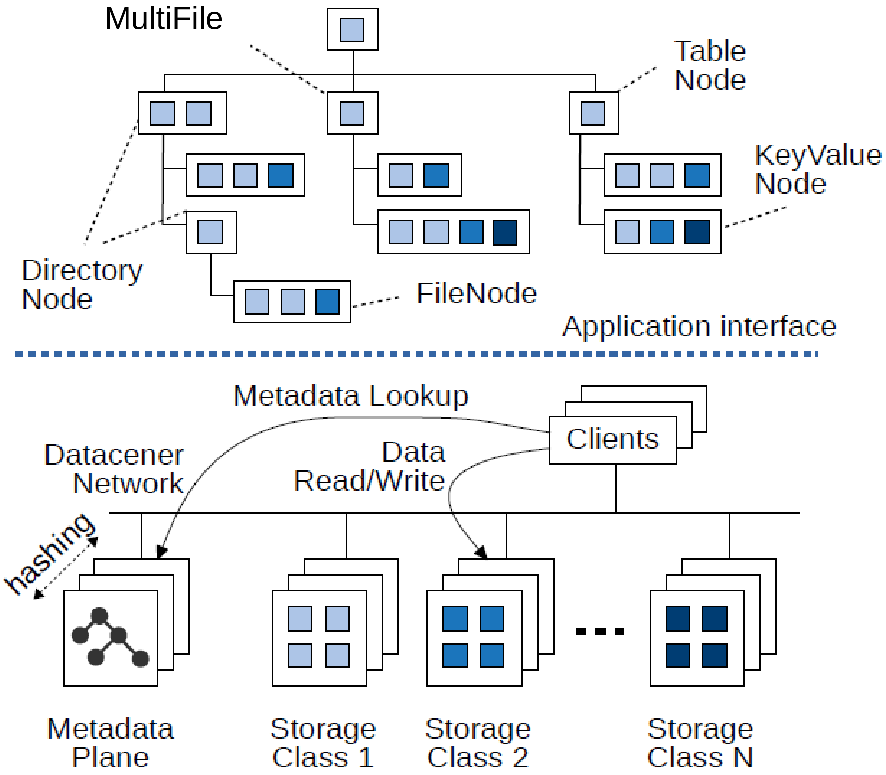
```
CrailStore crail = CrailStore.newInstance();
Future<Node> fut = crail.create("/a.dat", CrailType.File);
//...do work
CrailFile file = fut.get().asFile();
CrailOutputStream stream = file.getDirectOutputStream();
ByteBuffer buffer = crail.allocateBuffer();
Future<CrailResult> ret = stream.write(buf);
//...do work
ret.get();
```

C++:



```
CrailStore crail;
auto fut = crail.Create<CrailFile>("/tmp.dat");
//..do work
CrailFile file = fut.get();
CrailOutputStream stream = file.outputstream();
shared_ptr<ByteBuffer> buf = make_shared<ByteBuffer>(len);
Future<int> ret = stream.Write(buf);
//..do work
ret.get();
```

Crail Architecture & API



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Node type

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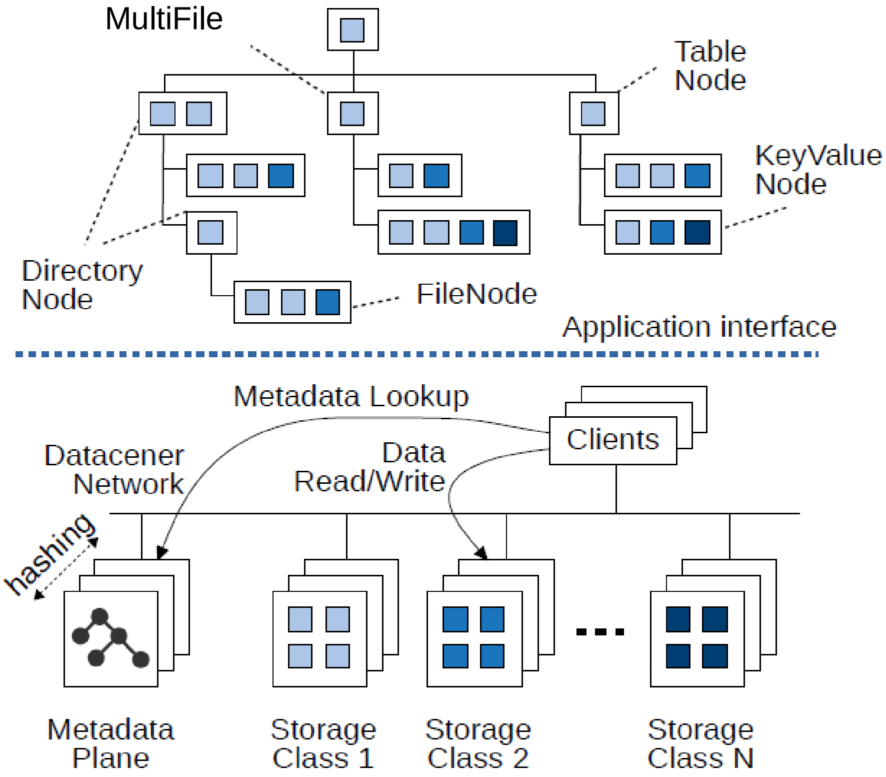

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```

non-blocking & asynchronous

C++:

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Where does the performance come from?

User-Level I/O: Metadata

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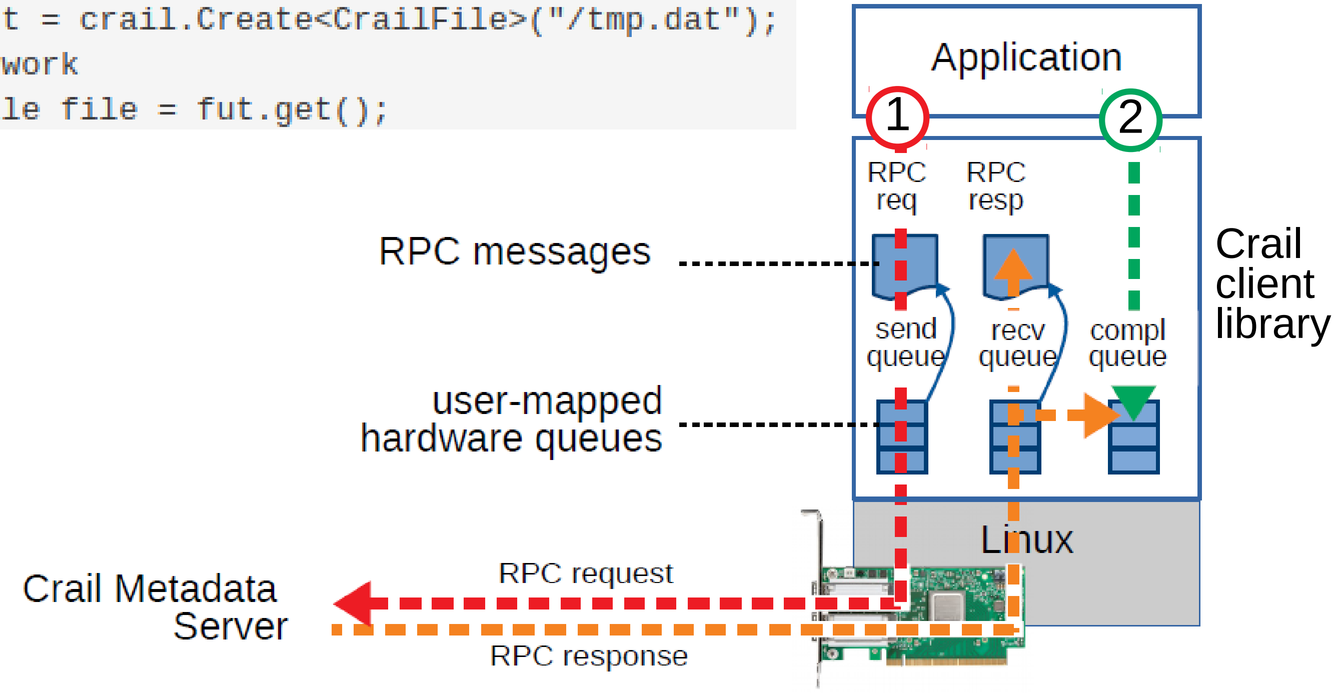

User-Level I/O: Metadata

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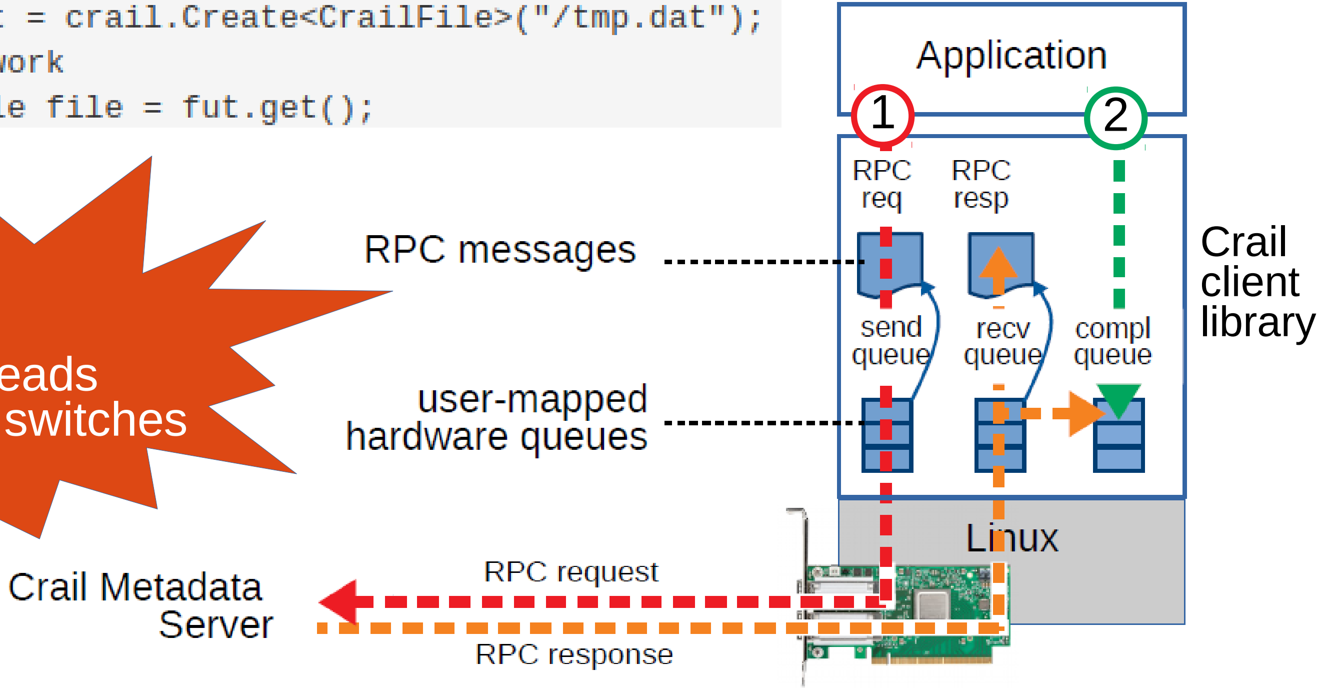
```

No threads
No context switches



RPC messages

user-mapped hardware queues

Crail Metadata Server

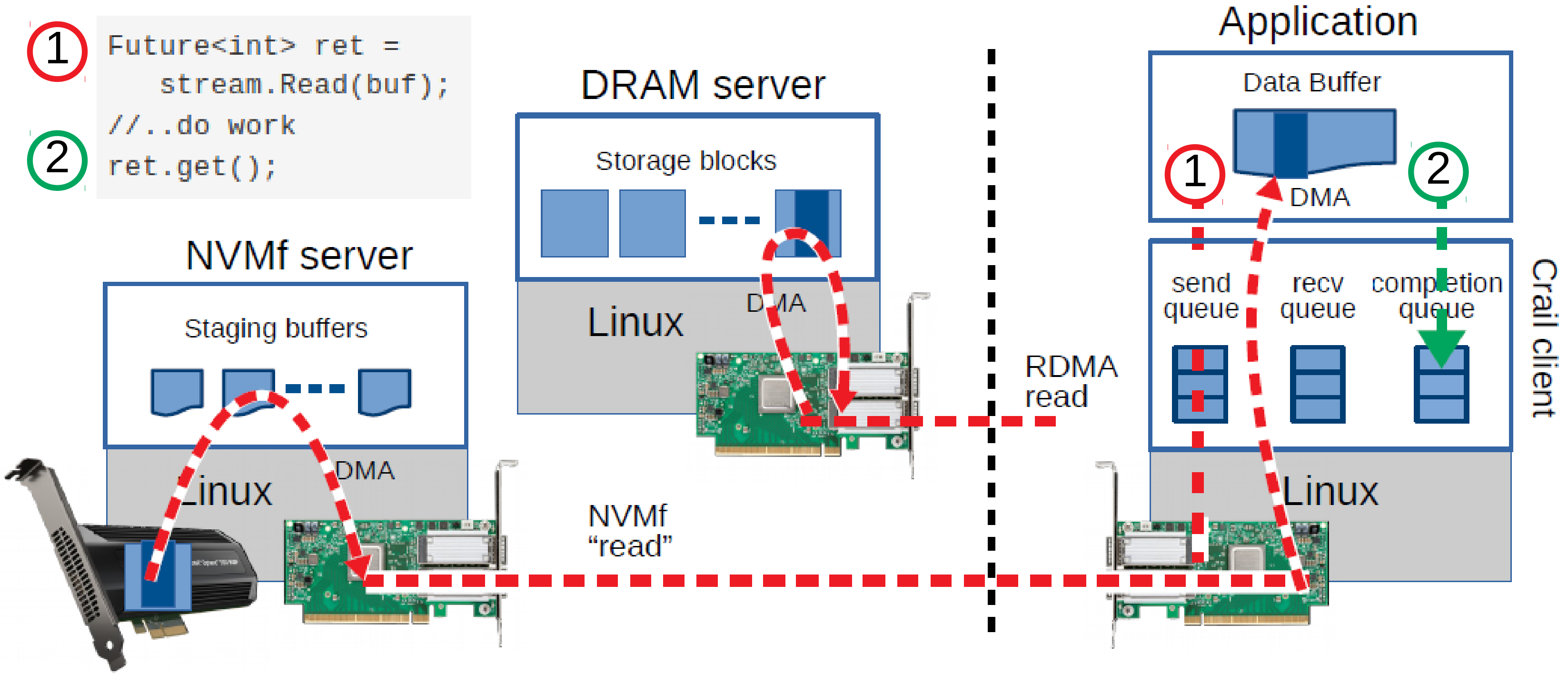
User-Level I/O: Data

1

```
Future<int> ret =
    stream.Read(buf);
//..do work
```

2

```
ret.get();
```



User-Level I/O: Data

zero-copy, transfer only data that is requested

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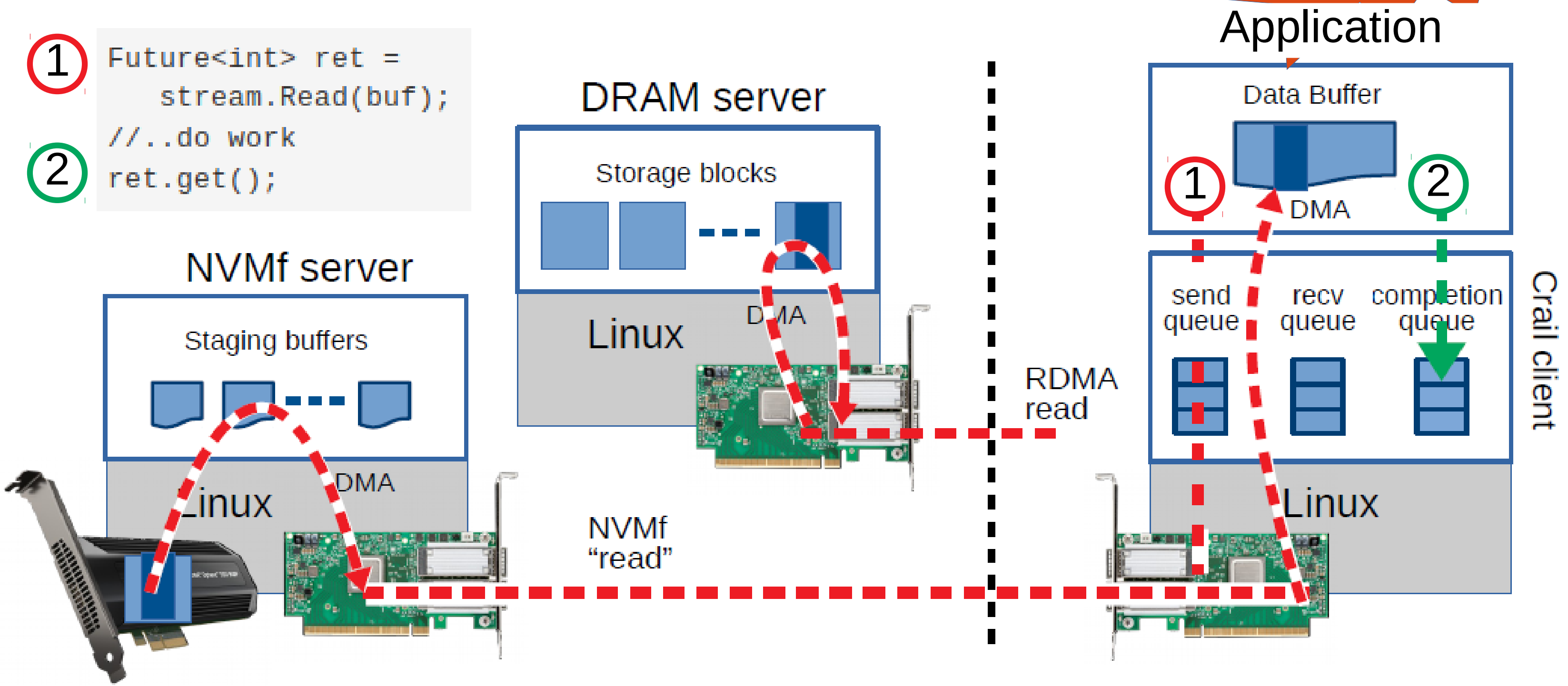
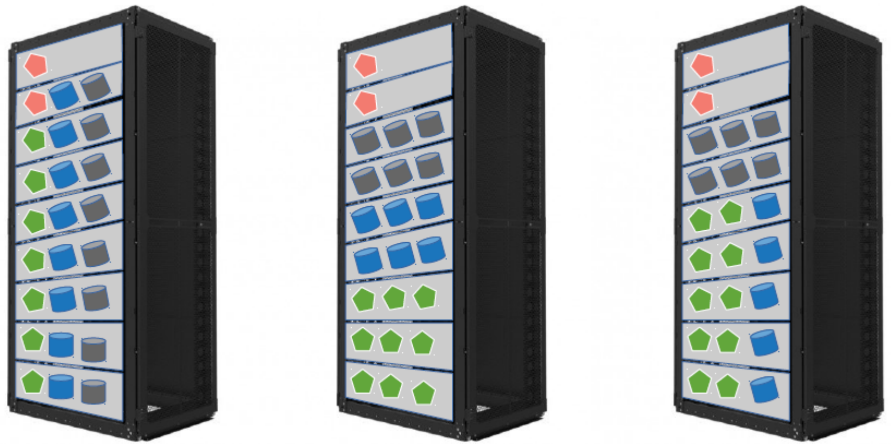
//..do work
ret.get();
```



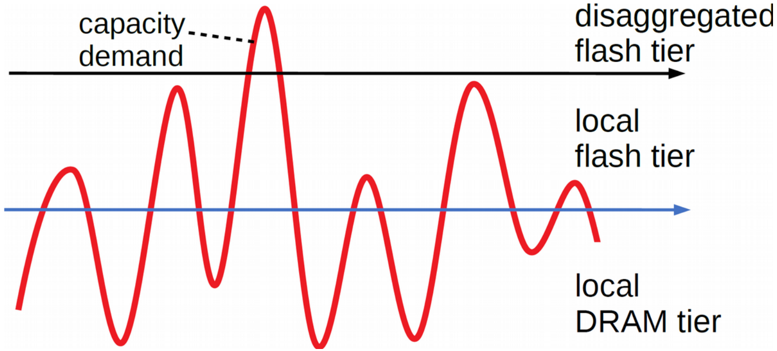
Crail Deployment Modes



compute/storage
co-located

storage
disaggregation

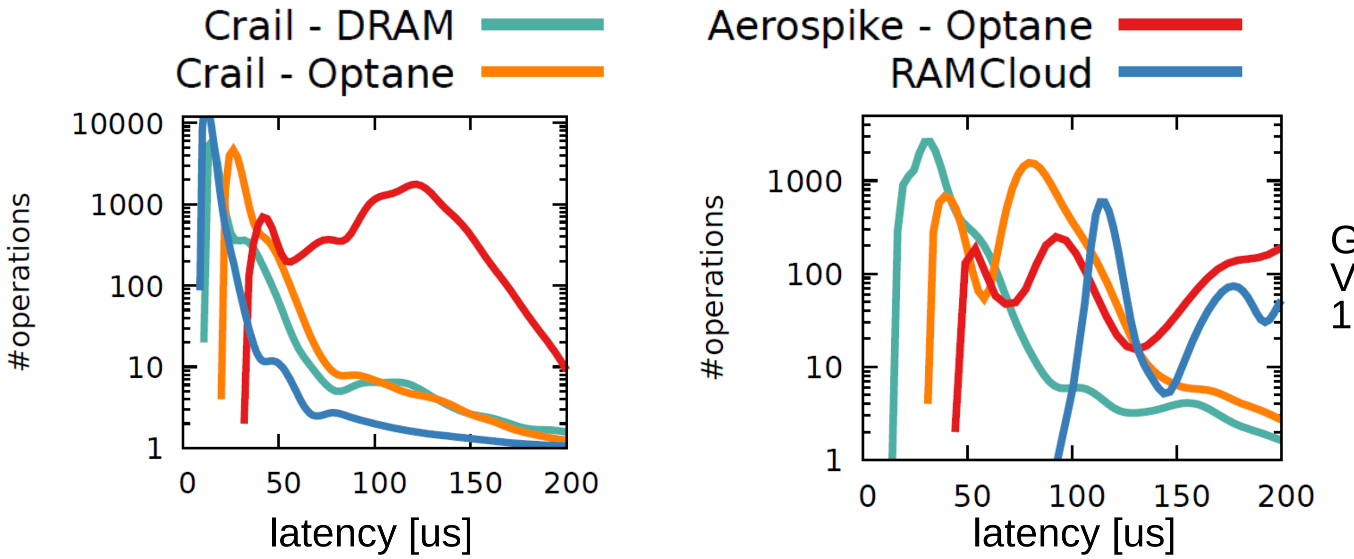
flash storage
disaggregation



- ⬟ Metadata server
- ⛁ Flash storage server
- ⛁ DRAM storage server
- ⬟ Application compute

YCSB KeyValue Workload

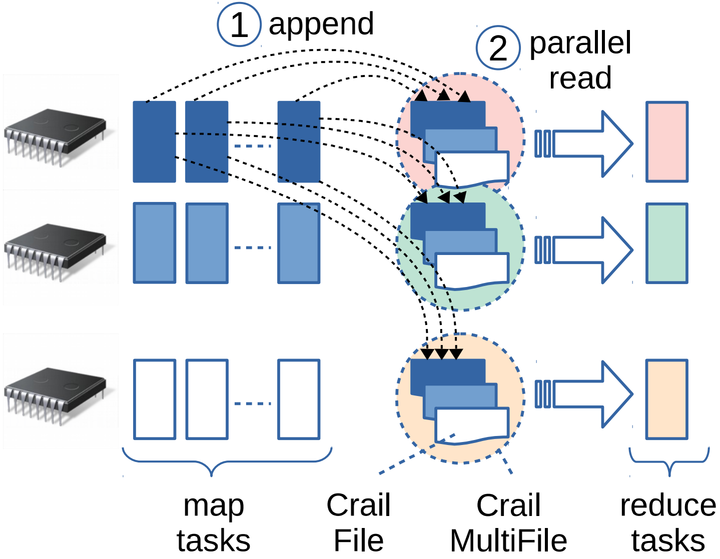
GET
Value size:
1KB

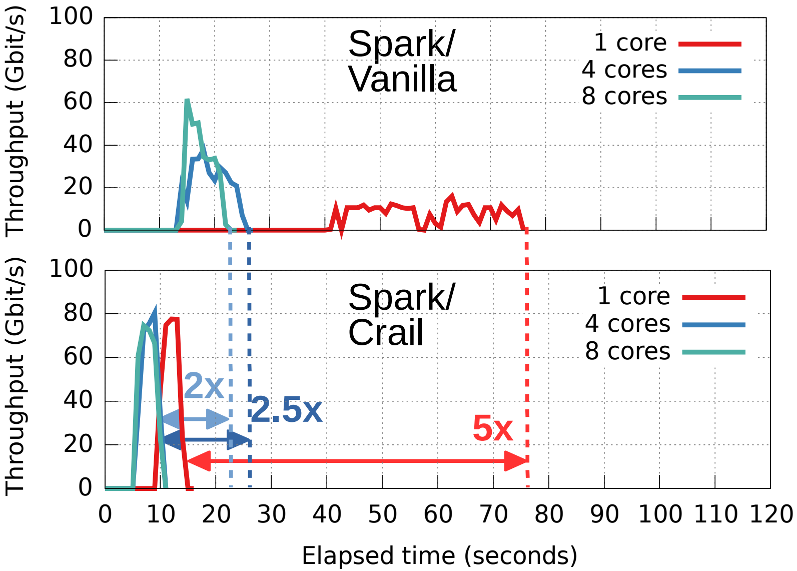


GET
Value size:
100KB

Crail offers Get latencies of ~12us and 30us for DRAM and NVM for 100 byte KV pairs
Crail offers Get latencies of ~30us and 40us for DRAM and NVM for 1000 byte KV pairs

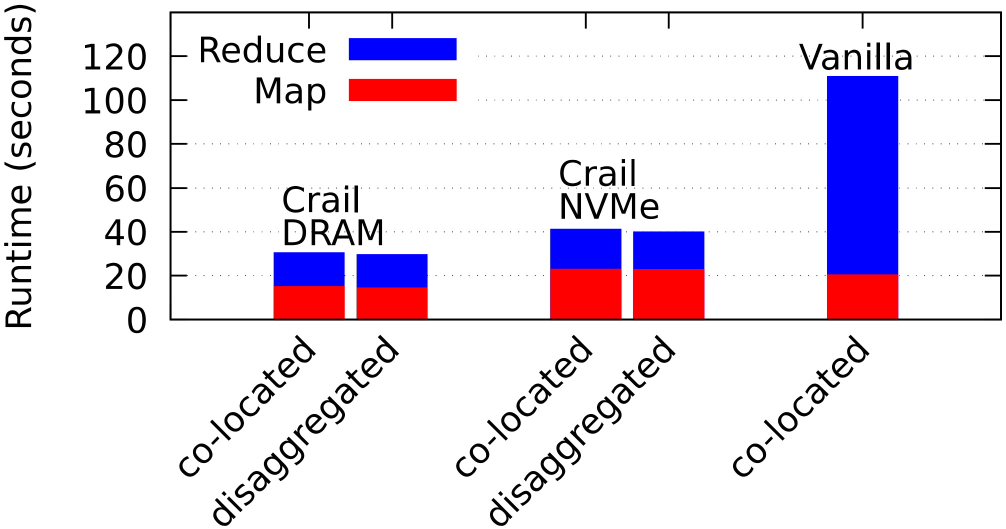
Spark GroupBy (80M keys, 4K)





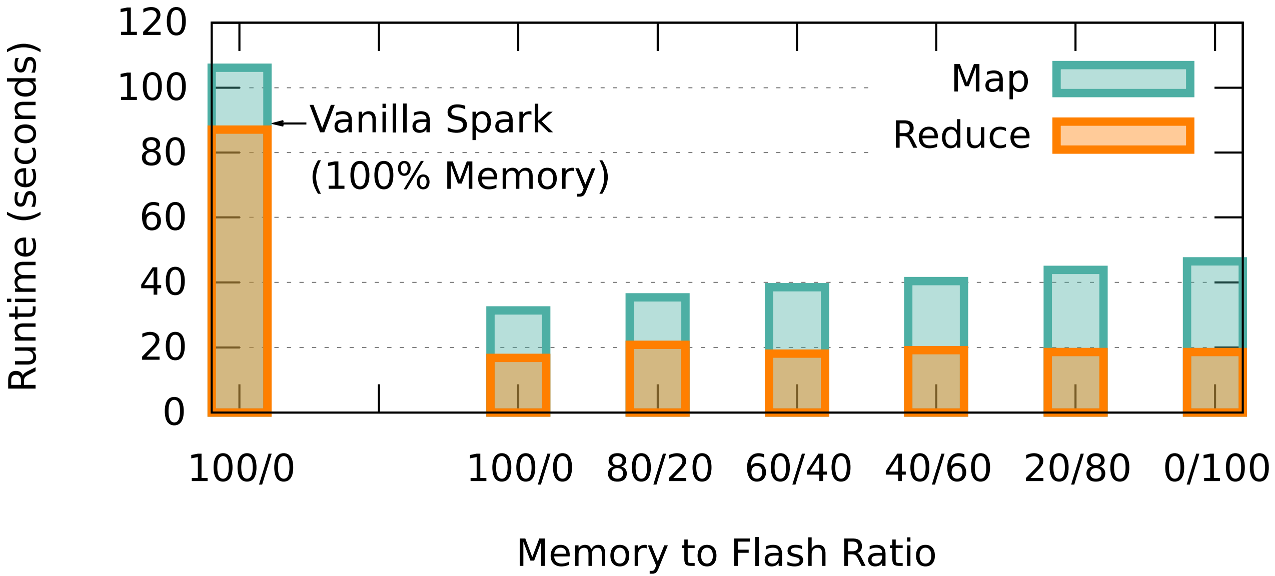
Spark shuffling via Crail on a single core is 2x faster
than vanilla Spark on 8 cores per executor (8 executors)

DRAM & Flash Disaggregation



Crail enables disaggregation of temporary data at no cost

DRAM/Flash Tiering



Using flash only increases the sorting time by around 48%

Conclusions

- Apache Crail: Fast distributed “tmp”
  - User-level I/O
  - Storage disaggregation
  - Memory/flash convergence
- Applications
  - Intra-job scratch space (shuffle, broadcast, etc.)
  - Multi-job pipelines
- Coming soon
  - Native Crail (C++)
  - Tensorflow-Crail