NEPTUNE
Scheduling Suspendable Tasks for Unified Stream/Batch Applications

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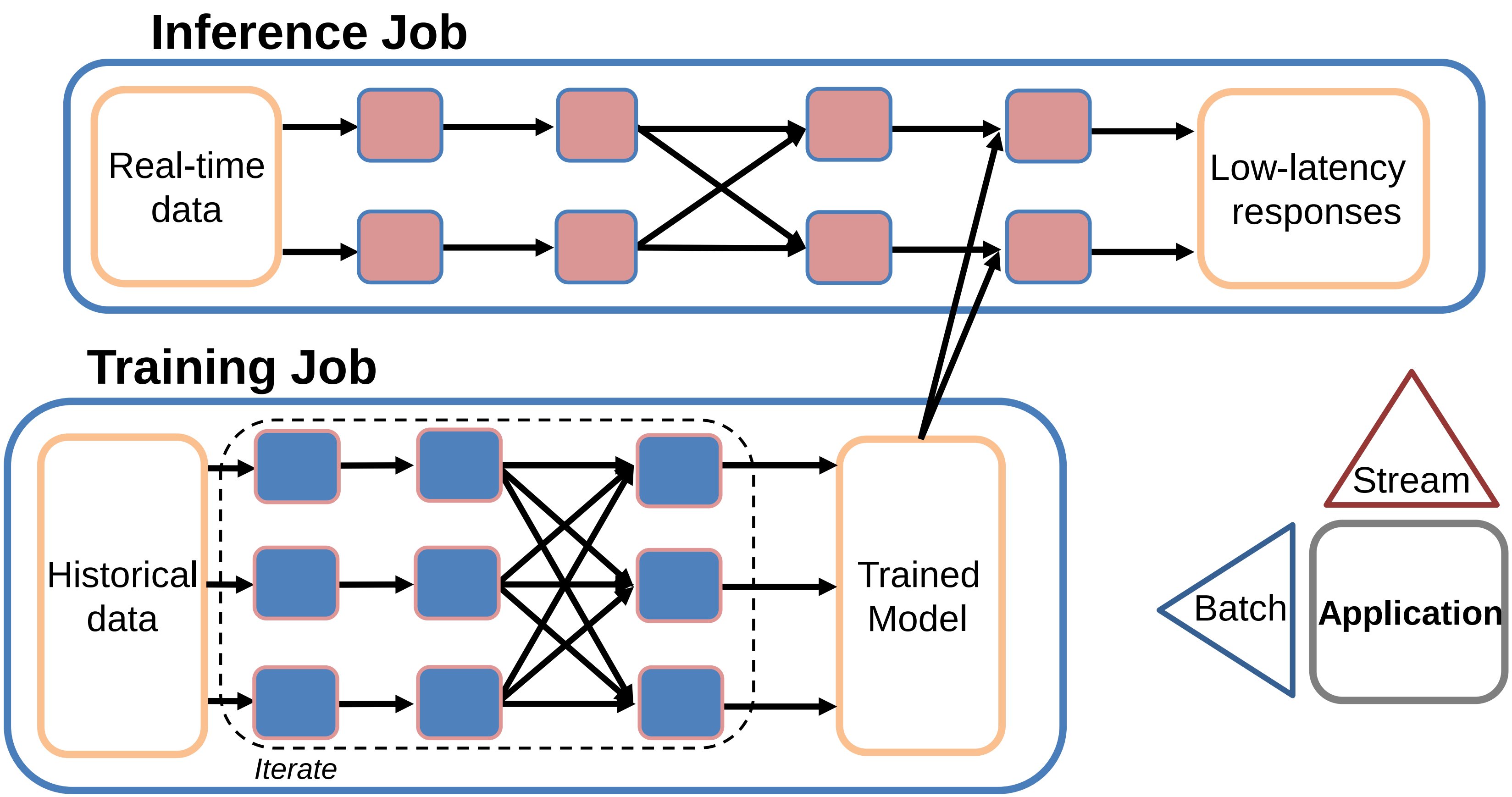
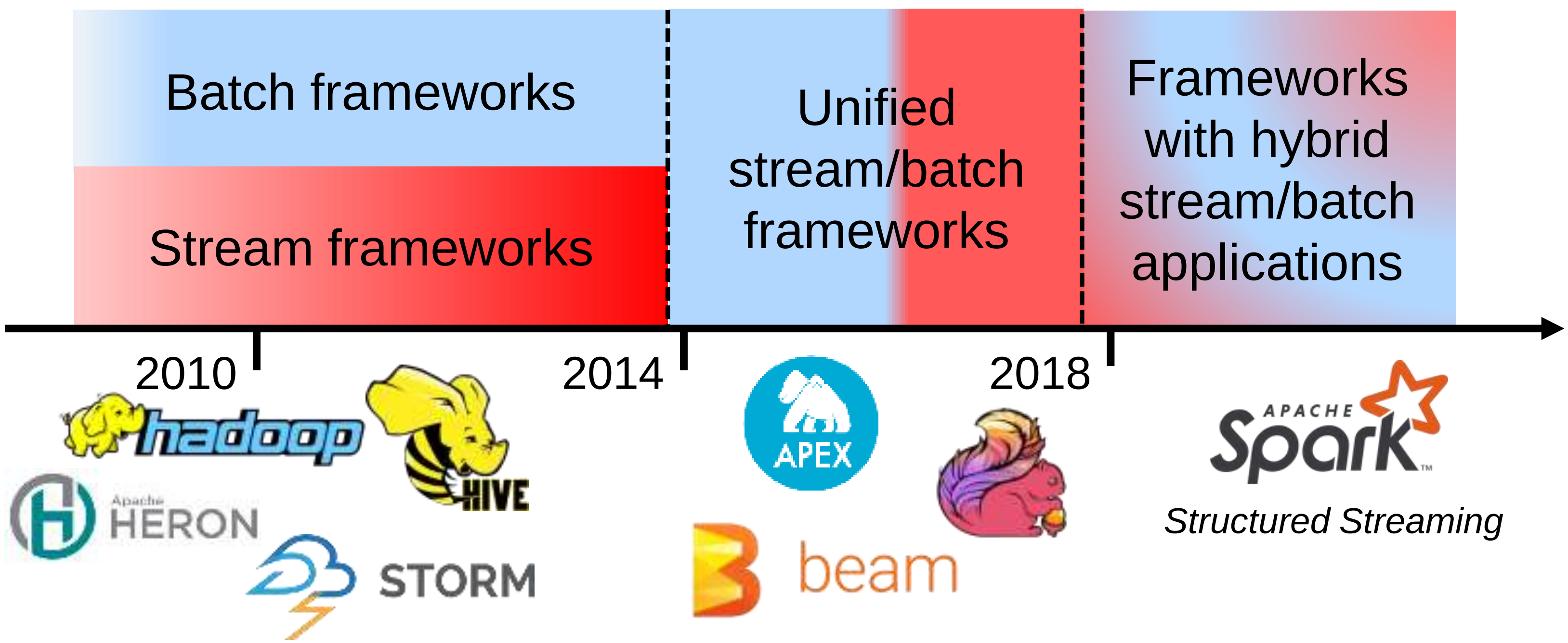
Unified application example



Evolution of analytics frameworks



Stream/Batch application requirements

Requirements

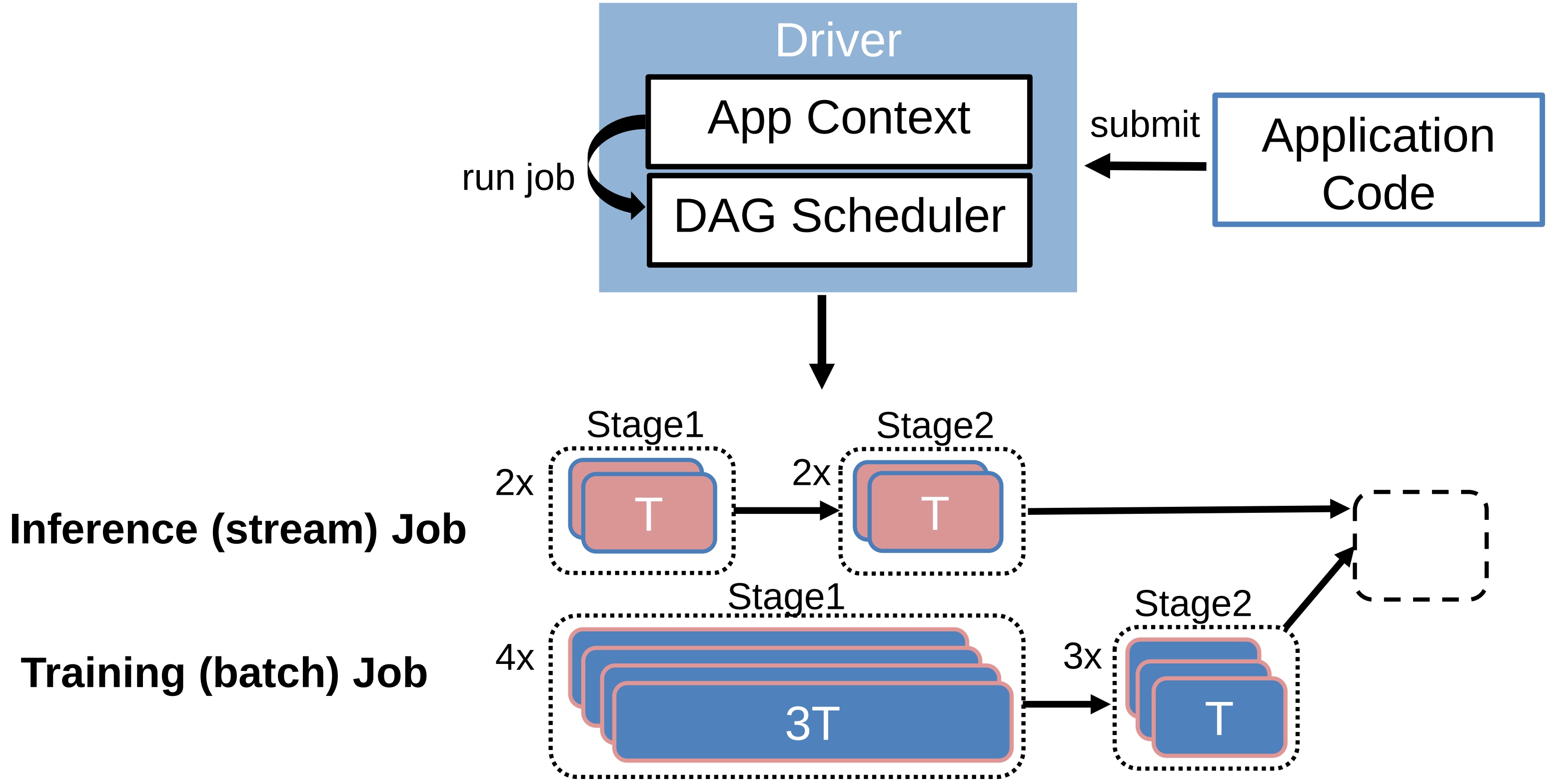
> **Latency:** Execute inference job with minimum delay

> **Throughput:** Batch jobs should not be compromised

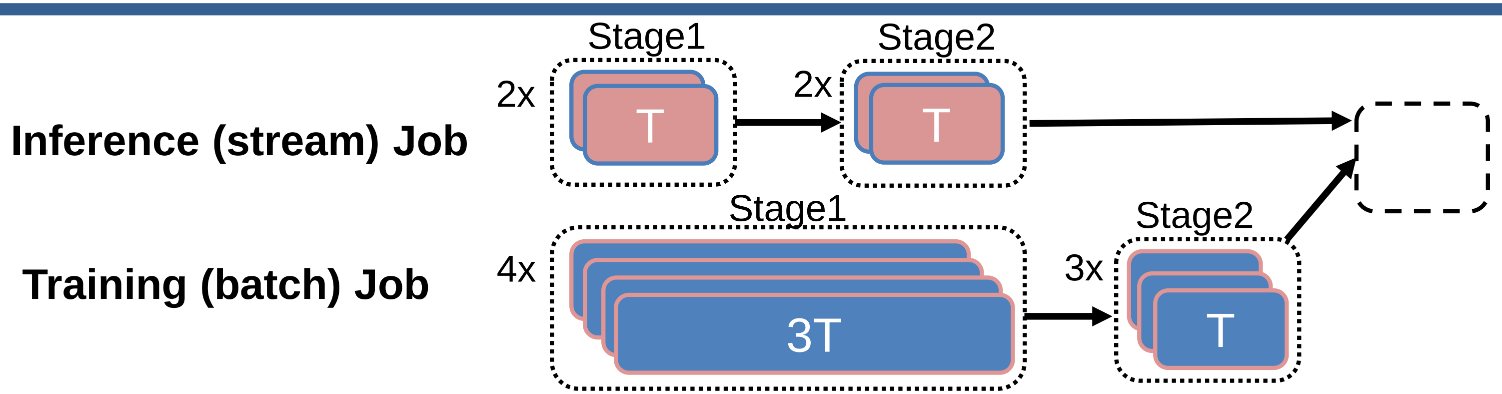
> **Efficiency:** Achieve high cluster resource utilization

Challenge: schedule stream/batch jobs to satisfy their diverse requirements

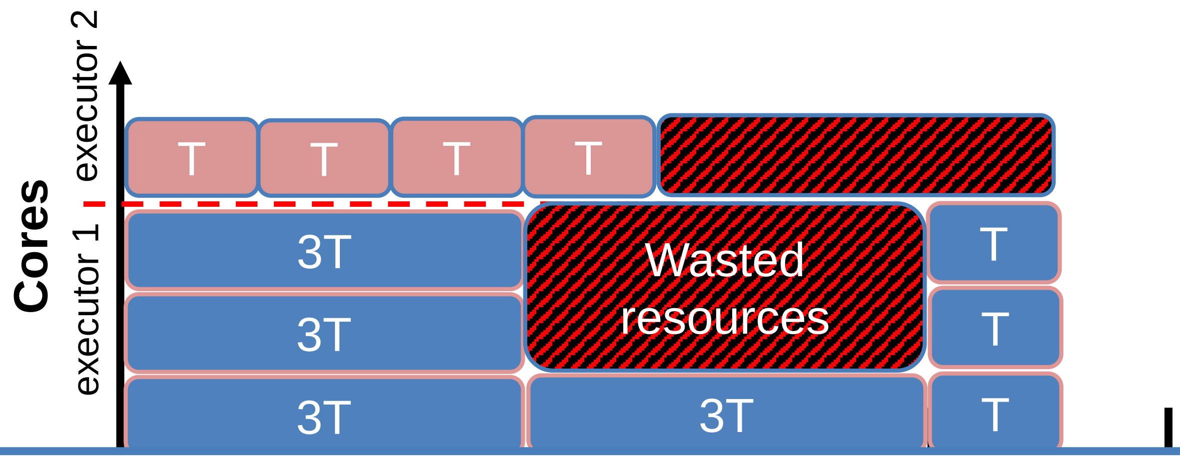
Stream/Batch application scheduling



Stream/Batch application scheduling

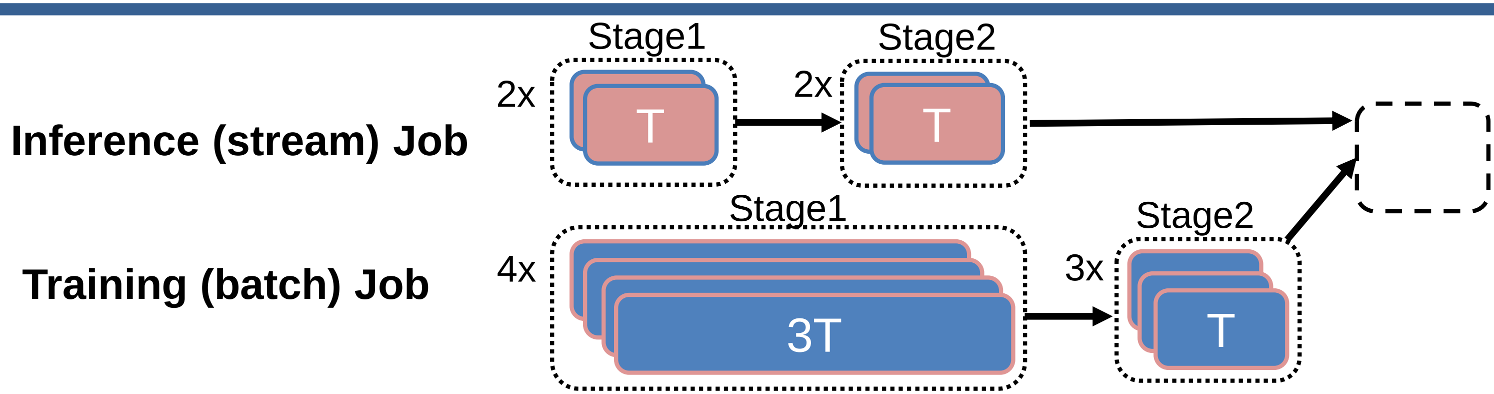


> **Static allocation:** dedicate resources to each job

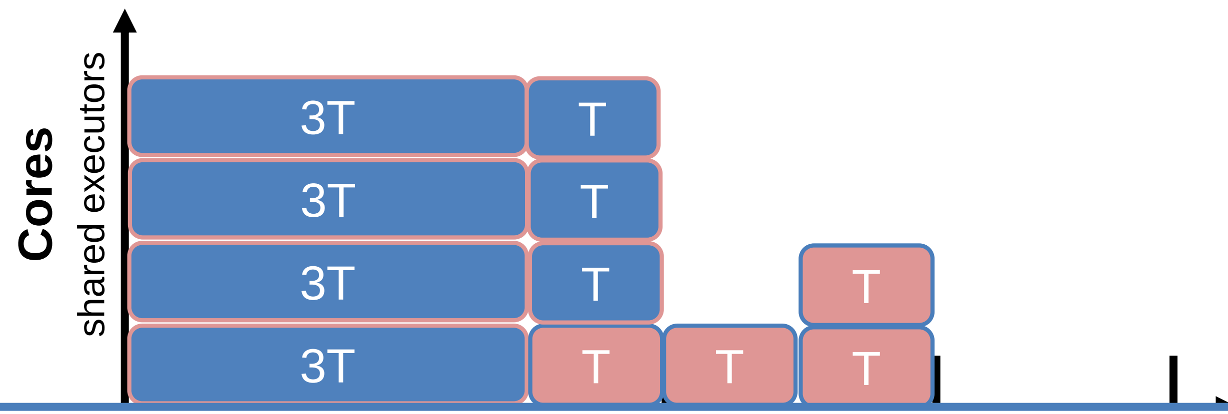


Resources can not be shared across jobs

Stream/Batch application scheduling

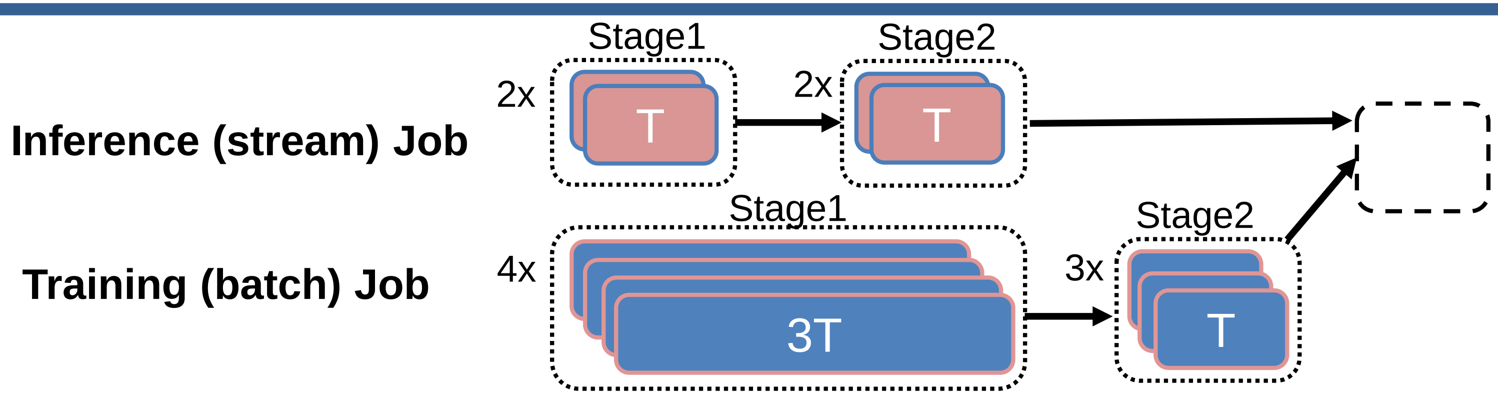


> **FIFO:** first job runs to completion

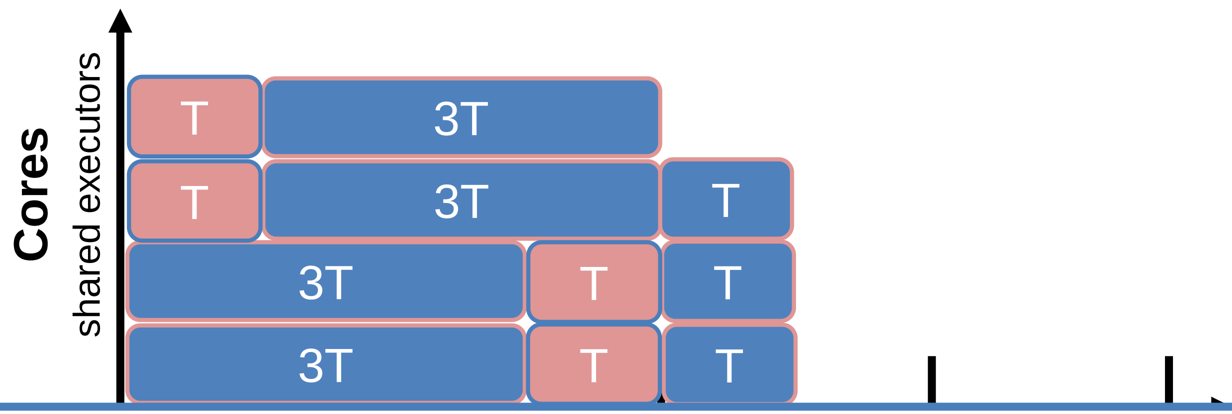


Long batch jobs increase stream job latency

Stream/Batch application scheduling

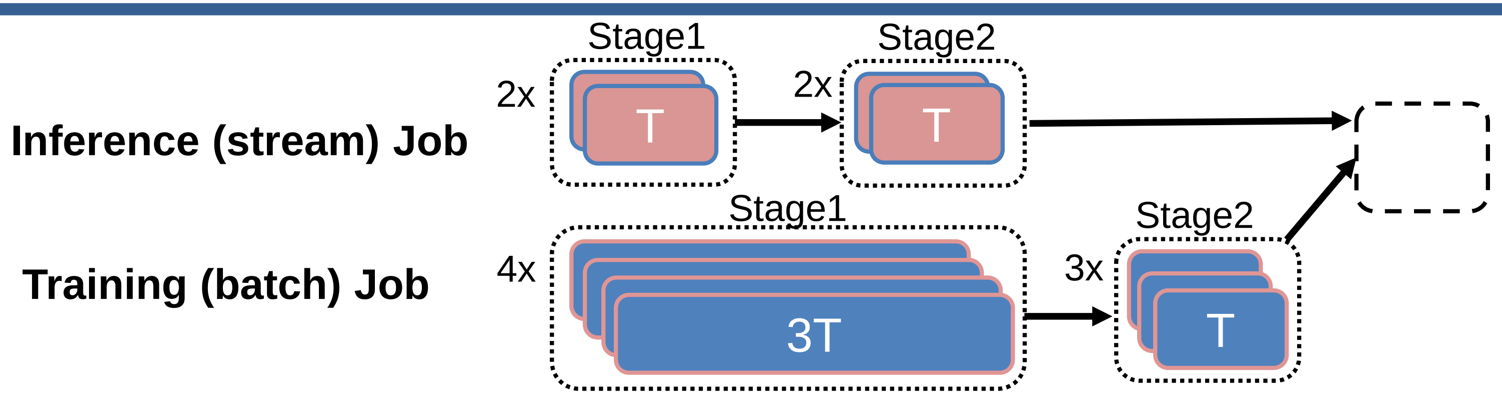


> **FAIR:** weight share resources across jobs

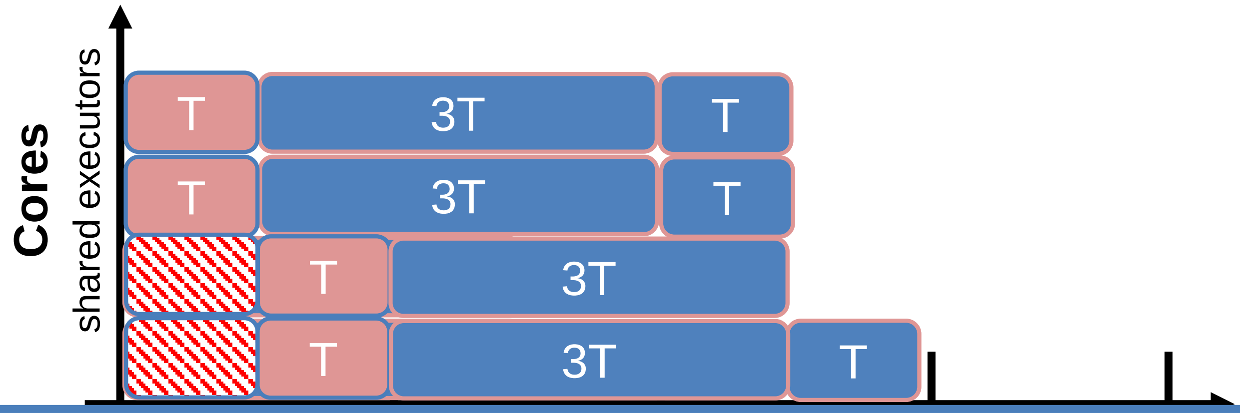


Better packing with non-optimal latency

Stream/Batch application scheduling

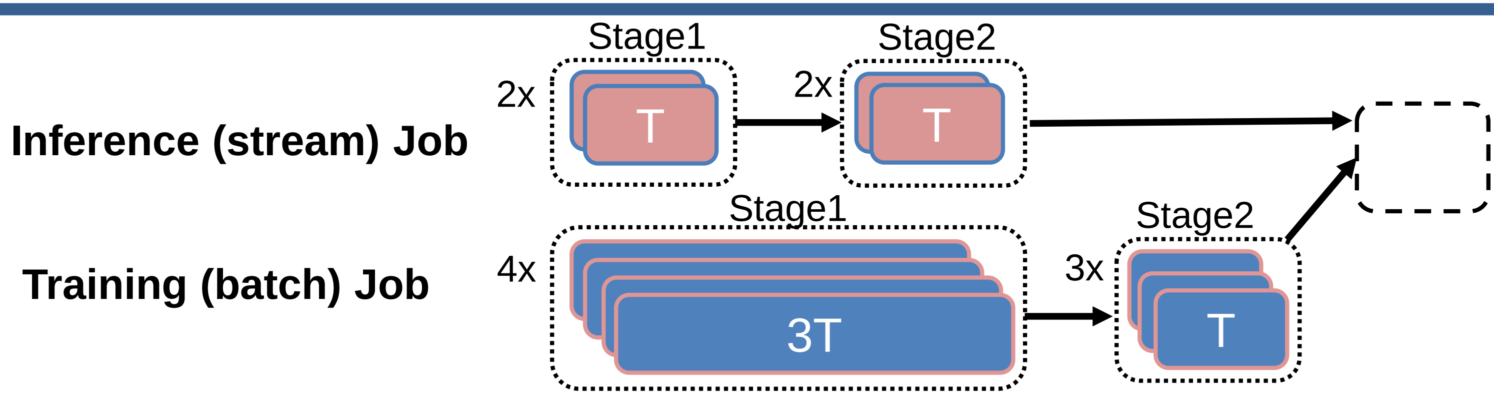


> **KILL:** avoid queueing by preempting batch tasks

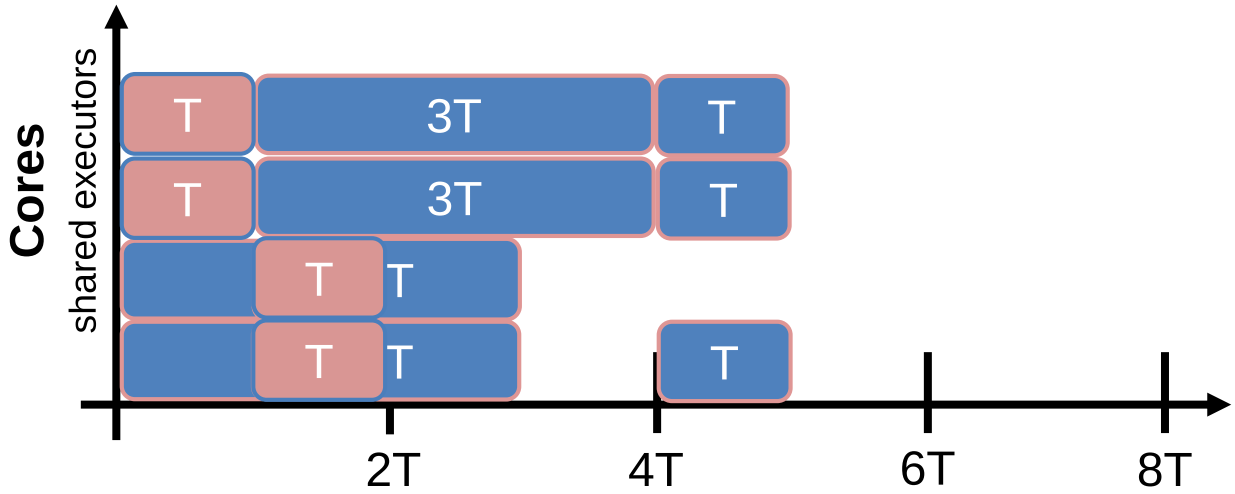


Better latency at the expense of extra work

Stream/Batch application scheduling



> **NEPTUNE:** minimize queueing and wasted work!



Challenges

> How to minimize queuing for latency-sensitive jobs and wasted work?

> How to natively support stream/batch applications?

> How to satisfy different stream/batch application requirements and high-level objectives?

NEPTUNE

Execution framework for Stream/Batch applications

- How to minimize queuing for latency-sensitive jobs and wasted work?
  - Support suspendable tasks

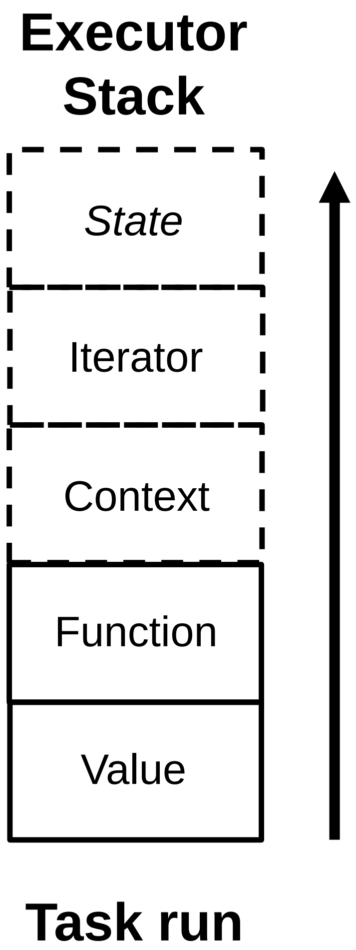
- How to natively support stream/batch applications?
  - Unified execution framework on top of Apache Spark

Structured Streaming

- How to satisfy different stream/batch application requirements and high-level objectives?
  - Introduce pluggable scheduling policies

Typical tasks

- **Tasks:** apply a function to a partition of data
- Subroutines that run in executor to completion
- Preemption problem:
  - Loss of progress (kill)
  - Unpredictable preemption times (checkpointing)

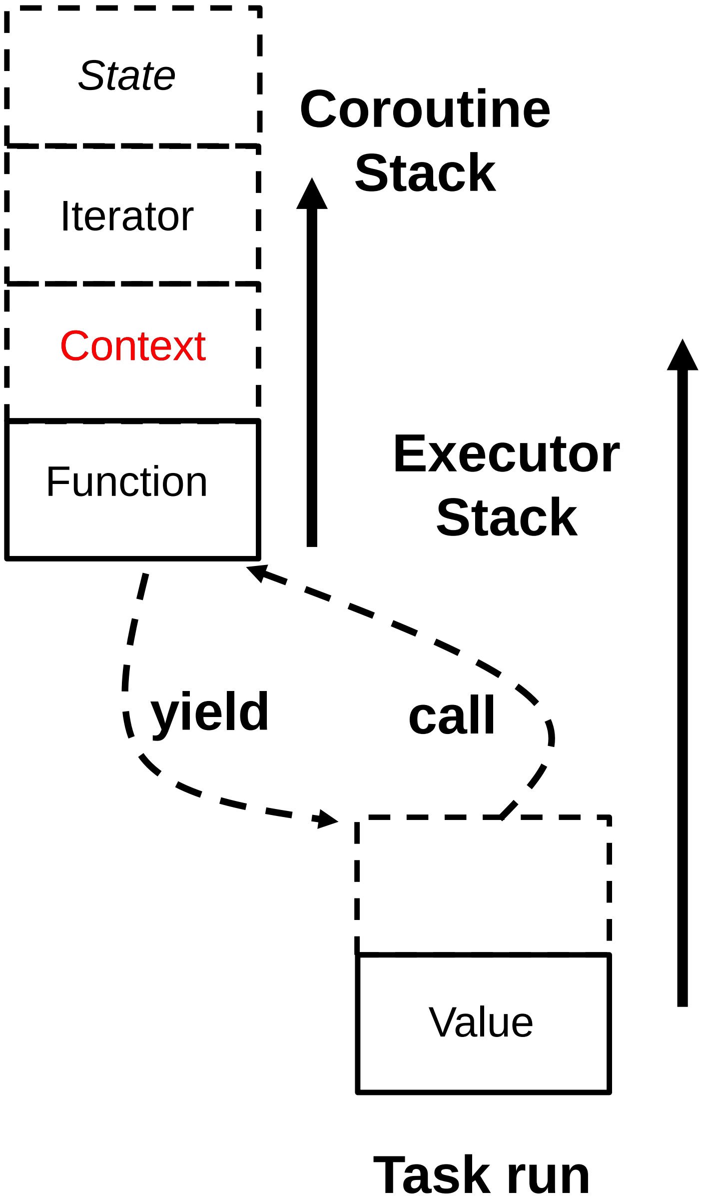


Suspendable tasks

- **Idea:** use coroutines
  - Separate stacks to store task state
  - Yield points handing over control to the executor

- Cooperative preemption:
  - Suspend and resume in *milliseconds*
  - Work-preserving

- Transparent to the user

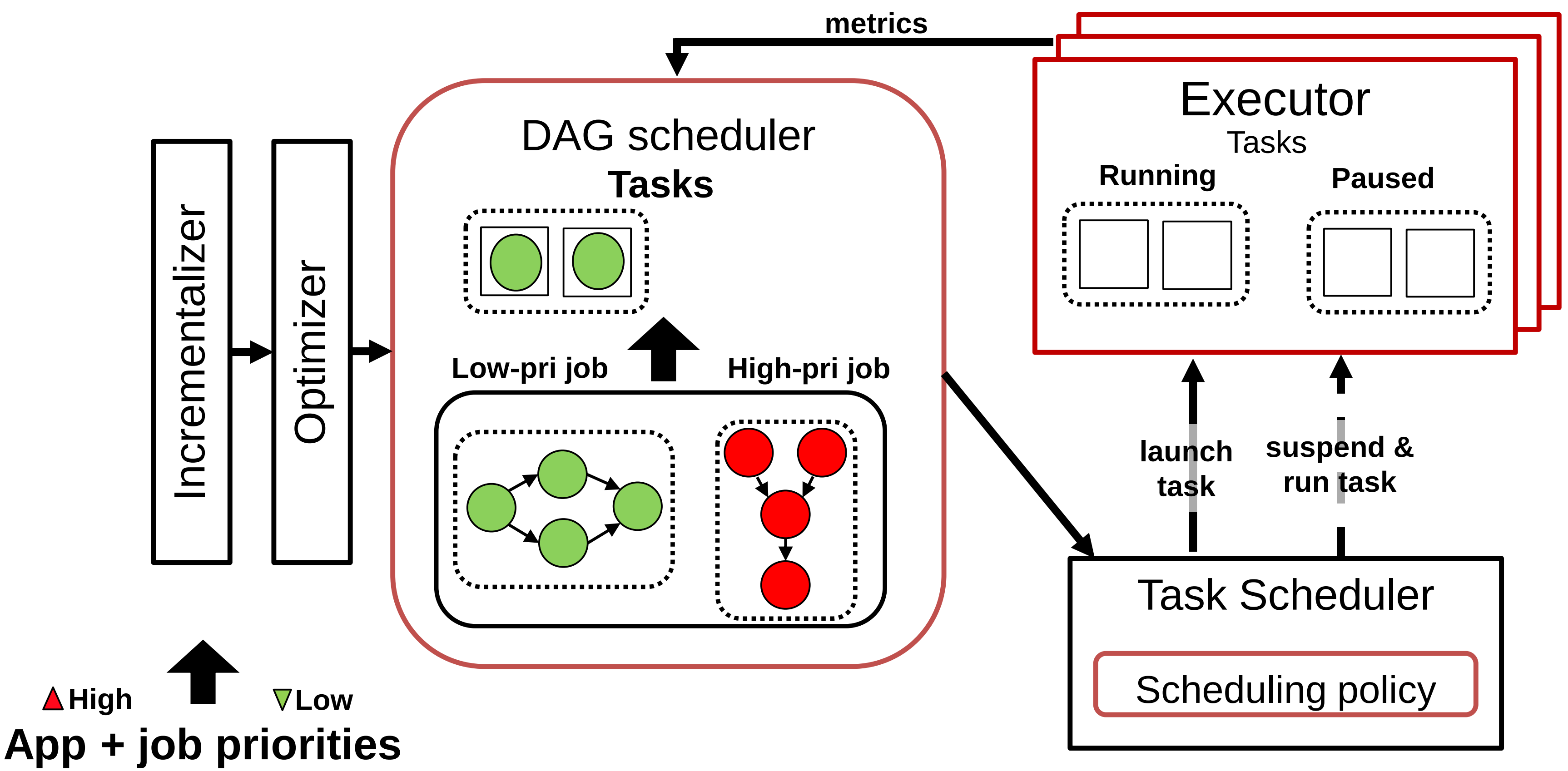


 https://github.com/storm-enroute/coroutines

Execution framework

> **Problem**: not just assign but also suspend and resume

> **Idea**: centralized scheduler with pluggable policies



Scheduling policies

- **Idea**: policies trigger task suspension and resumption
  - Guarantee that stream tasks bypass batch tasks
  - Satisfy higher-level objectives i.e. balance cluster load
  - Avoid starvation by suspending up to a number of times

- Load-balancing (LB): takes into account executors' memory conditions and equalize the number of tasks per node

- Locality- and memory aware (LMA): respect task locality preferences in addition to load-balancing

Implementation

> Built as an extension to Apache Spark **2.4.0** (https://github.com/lsds/Neptune)

> Ported all ResultTask, ShuffleMapTask functionality across programming interfaces to coroutines

> Extended Spark's DAG Scheduler to allow job stages with different requirements (priorities)

> Added additional Executor performance metrics as part of the heartbeat mechanism

Azure deployment

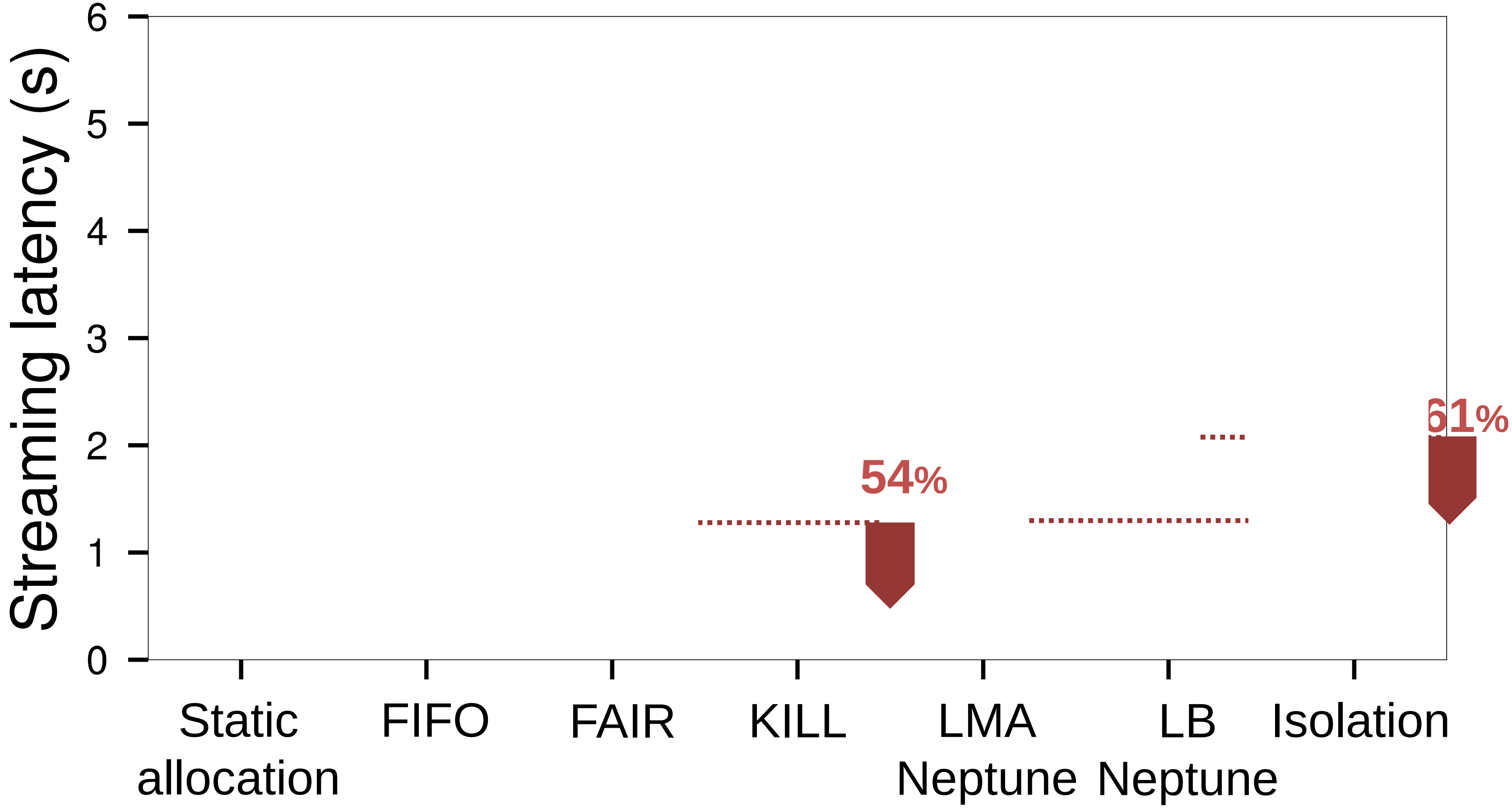
> Cluster

- 75 nodes with 4 cores and 32 GB of memory each

> Workloads

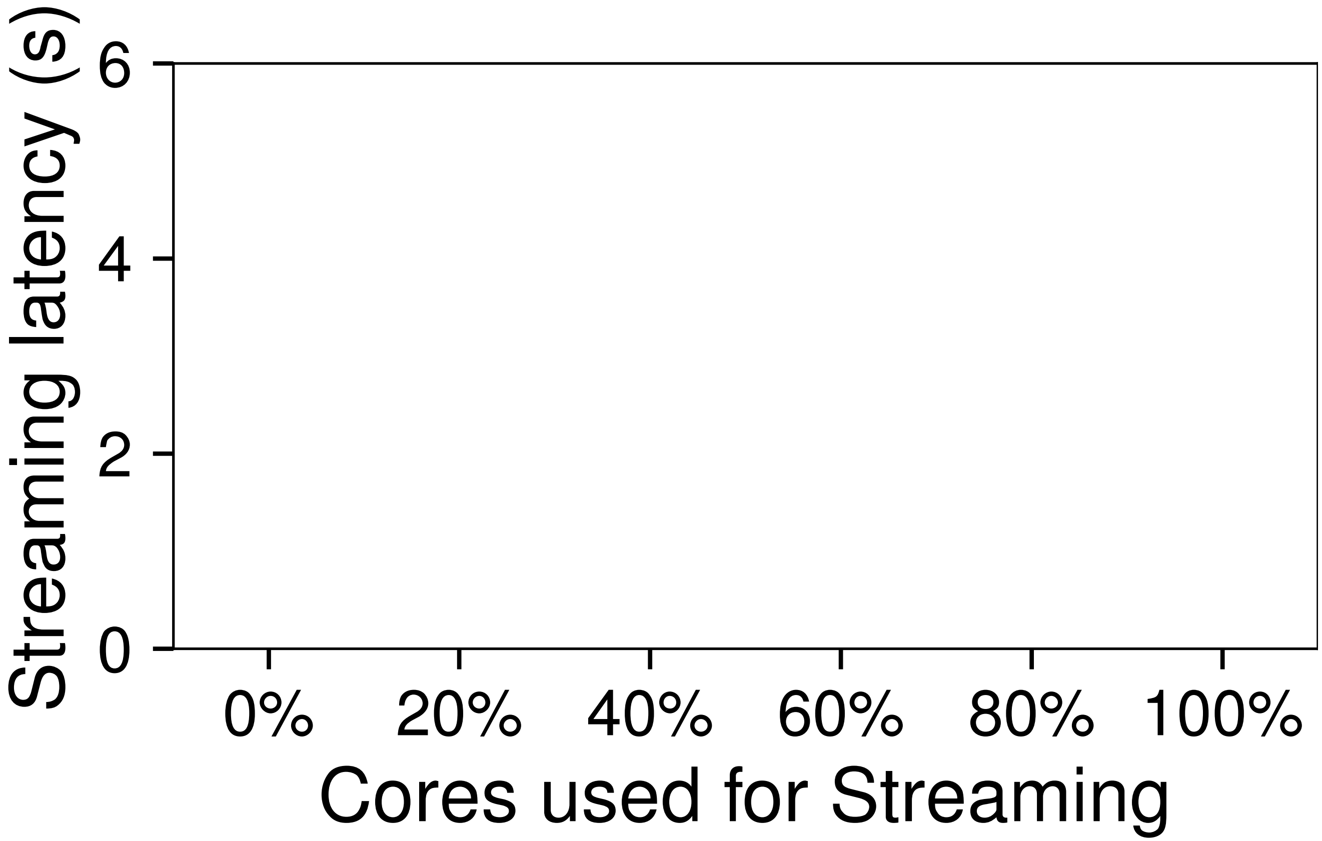
- **LDA**: ML training/inference application uncovering hidden topics from a group of documents
- **Yahoo Streaming Benchmark**: ad-analytics on a stream of ad impressions
- **TPC-H** decision support benchmark

Benefit of NEPTUNE in stream latency



NEPTUNE achieves latencies comparable to the ideal for the latency-sensitive jobs

Impact of resource demands in performance



Past to future

Efficiently share resources with low impact on throughput

Summary

NEPTUNE supports complex unified applications with diverse job requirements!

- Suspendable tasks using coroutines
- Pluggable scheduling policies
- Continuous unified analytics

https://github.com/lsds/Neptune

Thank you!
Questions?

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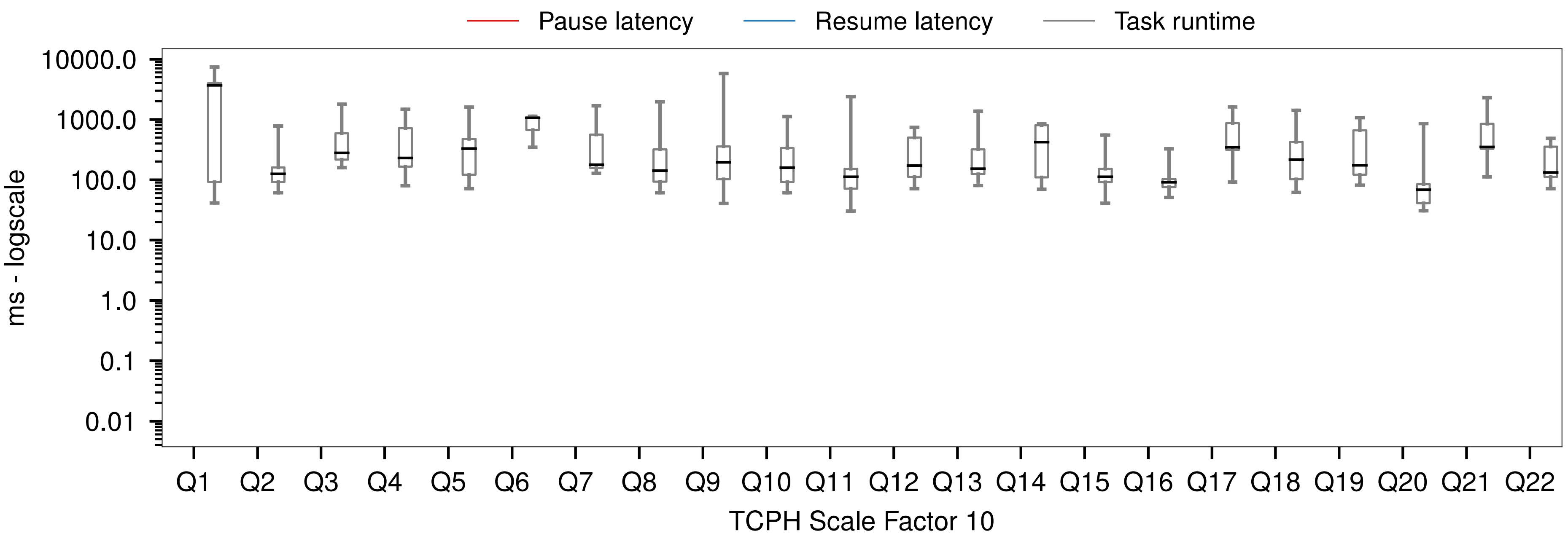
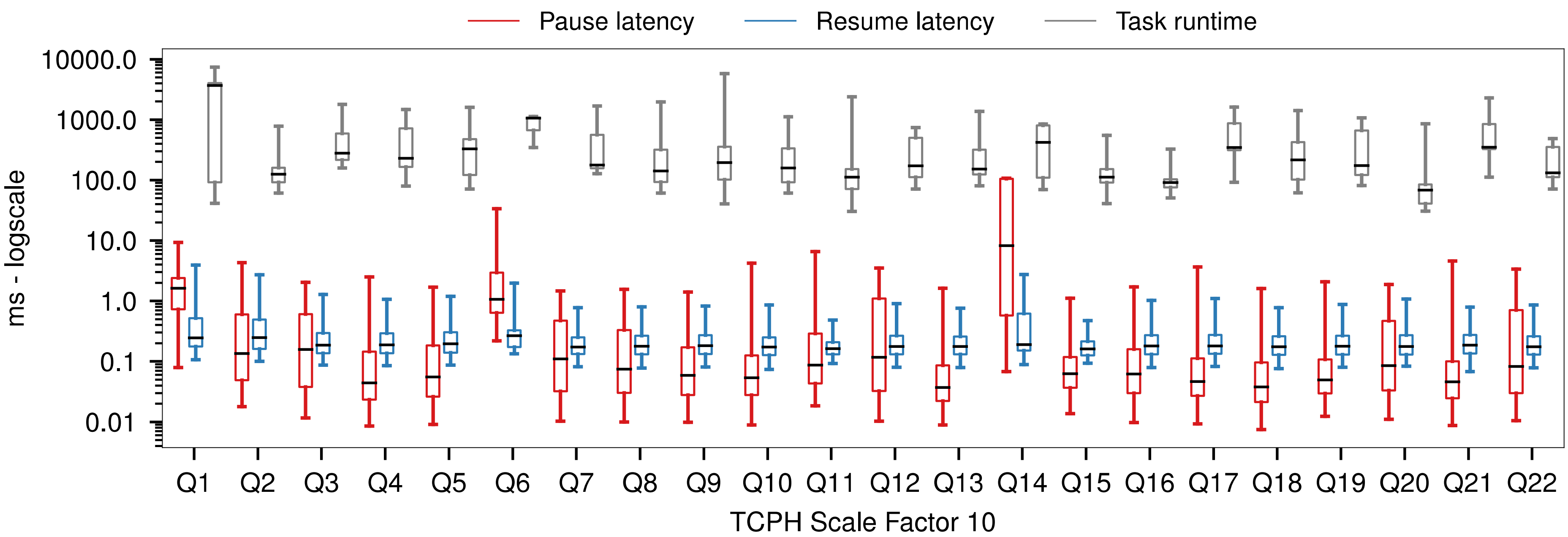
BACKUP SLIDES

Suspension mechanism effectiveness



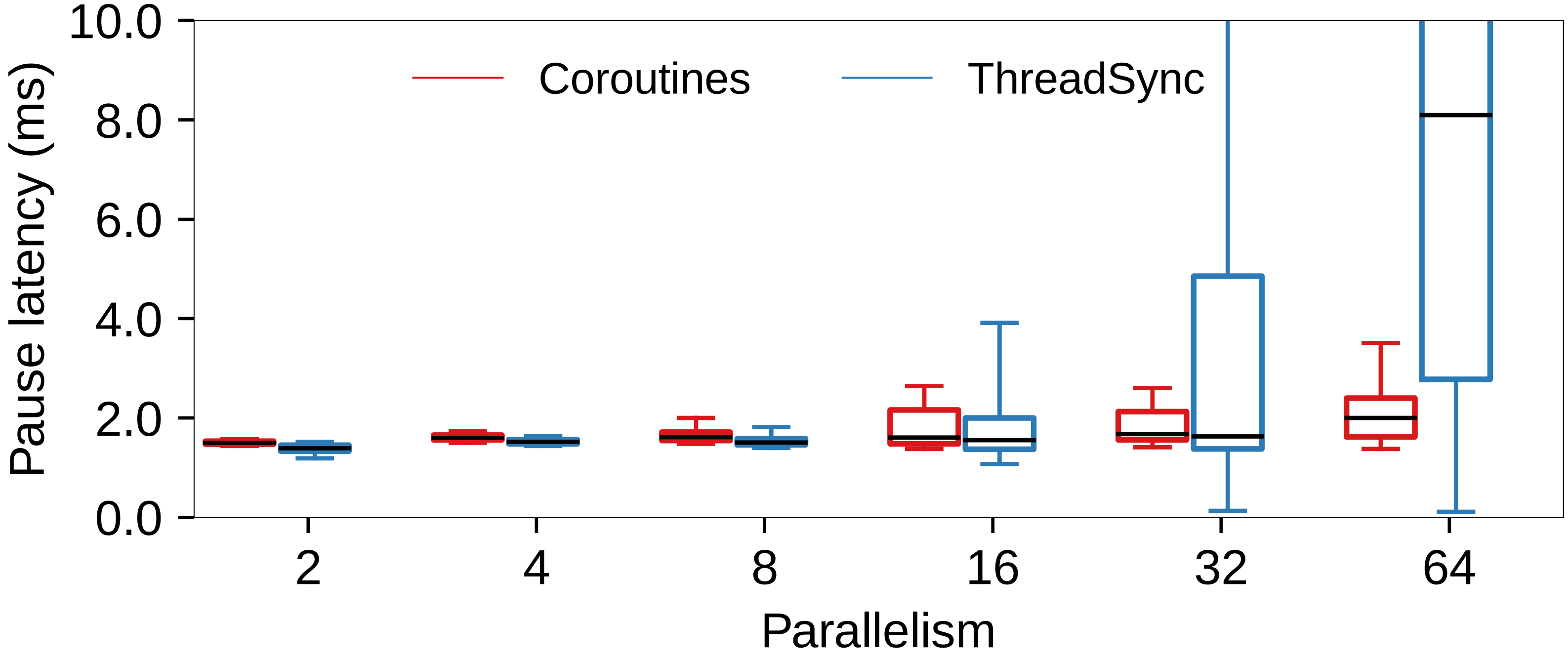
> **TPCH:** Task runtime distribution for each query ranges from 100s of milliseconds to 10s of seconds

Suspension mechanism effectiveness



Suspendable tasks effectively pause and resume with sub-millisecond latencies

Suspension mechanism effectiveness



Coroutine tasks have minimal performance overhead by bypassing the OS

Demo

- Run a simple **unified** application with
  - A **high-priority** latency-sensitive job
  - A **low-priority** latency-tolerant job
  - Schedule them with default **Spark** and **Neptune**

- **Goal**: show benefit of Neptune and ease of use

Suspendable tasks

Subroutine

```
val collect (TaskContext, Iterator[T]) =>
(Int, Array[T]) = {
	val result = new
mutable.ArrayBuffer[T]
	while (itr.hasNext) {
		result.append(itr.next)
	}
	result.toArray
}
```

Coroutine

```
val collect (TaskContext, Iterator[T]) => (Int, Array[T]) ={
 coroutine {(context: TaskContext, itr: Iterator[T]) => {
	val result = new mutable.ArrayBuffer[T]
	while (itr.hasNext) {
		result.append(itr.next)
		if (context.isPaused())
			yieldval(0)
	}
	result.toArray
} }
```