



Streaming Report

Functional Comparison and Performance Evaluation

毛玮

王华峰

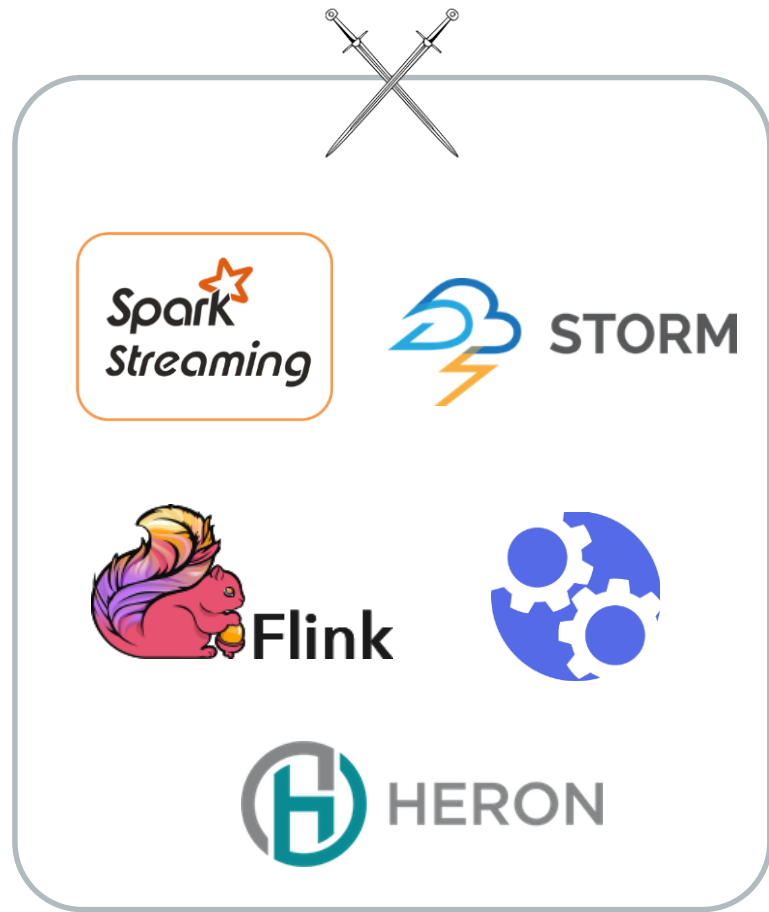
张天伦

2016/9/10

Overview

- Streaming Core
- MISC
- Performance Benchmark

Choose your weapon !



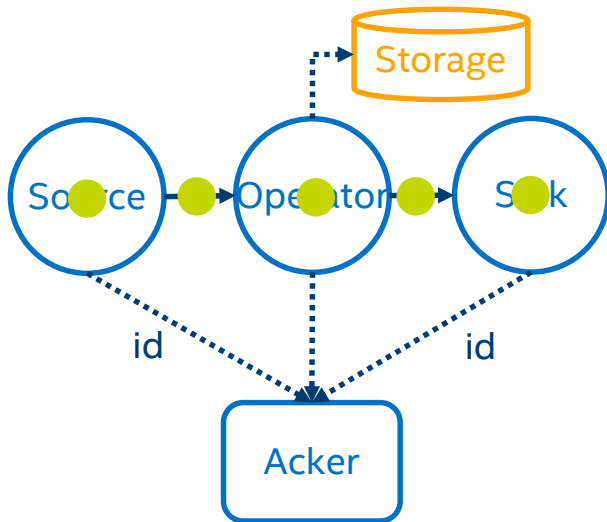
Execution Model + Fault Tolerance Mechanism

Continuous Streaming

Ack per Record

Apache Storm*

Twitter Heron*

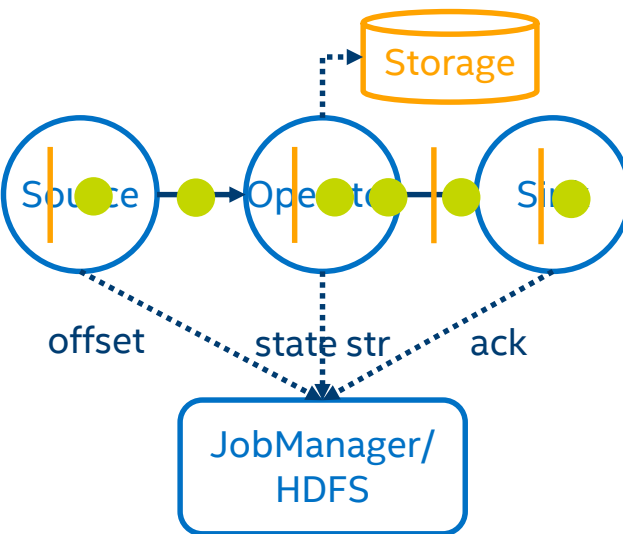


Continuous Streaming

Checkpoint "per Batch"

Aapche Flink*

Apache Gearpump*

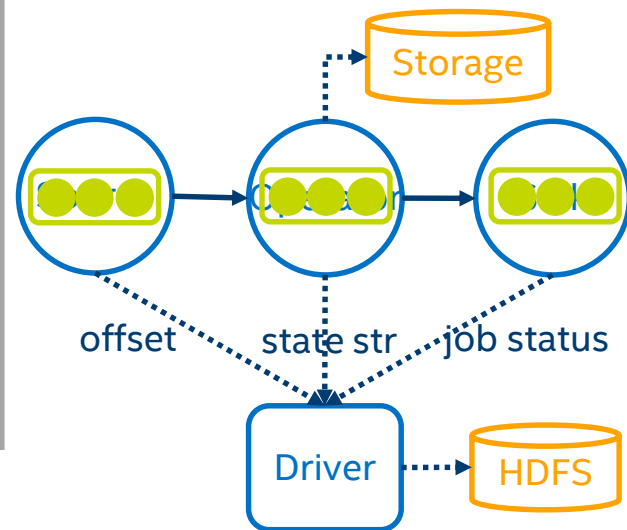


Micro-Batch

Checkpoint per Batch

Apache Spark Streaming*

Apache Storm Trident*



This is the **critical** part, as it affects many features

Continuous Streaming

Ack per Record

Apache Storm*

Twitter Heron*

Continuous Streaming

Checkpoint "per Batch"

Aapche Flink*

Apache Gearpump*

Micro-Batch

Checkpoint per Batch

Apache Spark Streaming*

Apache Storm Trident*

Low Latency

High Latency

High Overhead

Low Overhead

Low Throughput

High Throughput

Delivery Guarantee

Apache Storm*

Twitter Heron*

Apache Flink*

Apache Gearpump*

Apache Spark Streaming*

Apache Storm Trident*

At least once

- Ackers know about if a record is processed successfully or not. If it failed, replay it.
- There is no state consistency guarantee.

Exactly once

- State is persisted in durable storage
- Checkpoint is linked with state storage per Batch

Native State Operator

Apache
Storm*

Twitter
Heron*

Yes*

- Storm:
 - ✓ KeyValueState
- Heron:
 - X User Maintain

Apache
Flink*

Apache
Gearpump*

Yes

- Flink Java API:
 - ✓ ValueState
 - ✓ ListState
 - ✓ ReduceState
- Flink Scala API:
 - ✓ mapWithState
- Gearpump
 - ✓ persistState

Apache Spark
Streaming*

Apache Storm
Trident*

Yes

- Spark 1.5:
 - ✓ updateStateByKey
- Spark 1.6:
 - ✓ mapWithState
- Trident:
 - ✓ persistentAggregate
 - ✓ State

Dynamic Load Balance & Recovery Speed

Apache Storm*

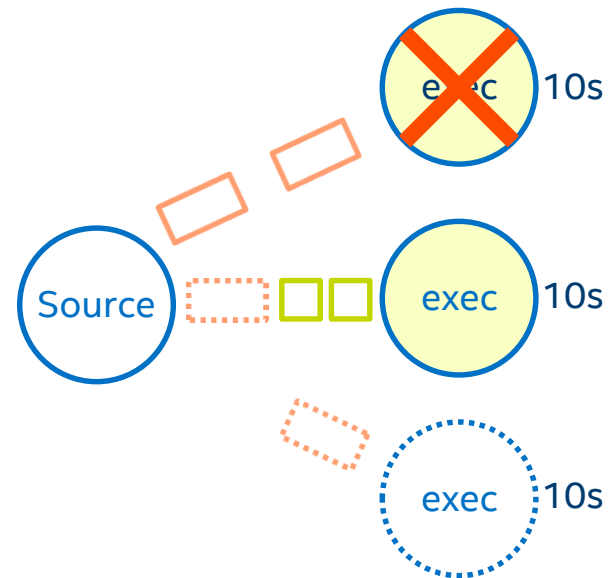
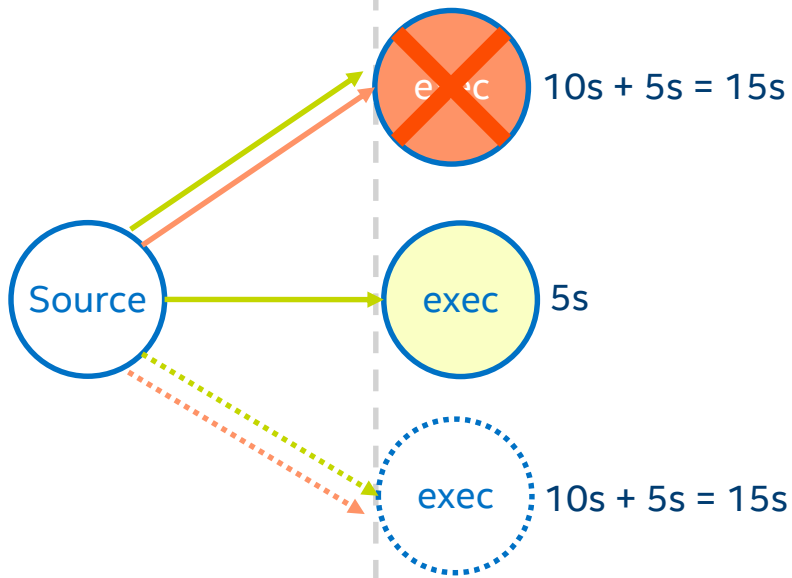
Twitter Heron*

Apache Flink*

Apache Gearpump*

Apache Spark Streaming*

Apache Storm Trident*

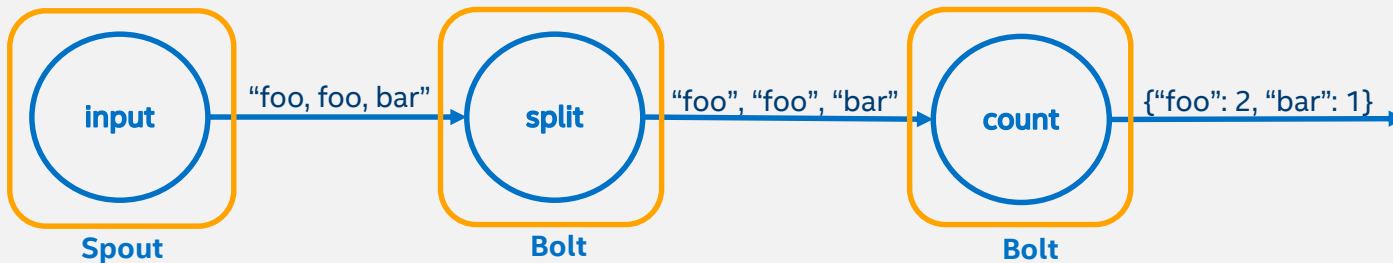


API

Compositional

- Highly customizable operator based on basic building blocks
- Manual topology definition and optimization

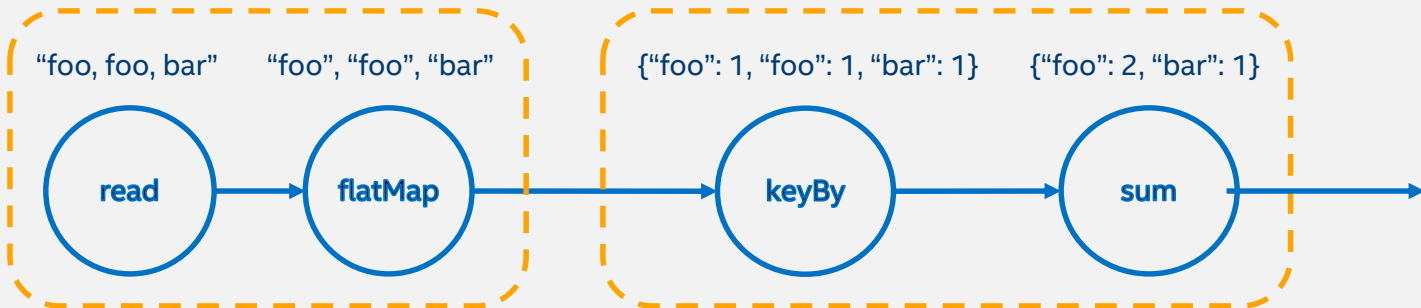
```
TopologyBuilder builder = new TopologyBuilder();  
builder.setSpout("input", new RandomSentenceSpout(), 1);  
builder.setBolt("split", new SplitSentence(), 3).shuffleGrouping("spout");  
builder.setBolt("count", new WordCount(), 2).fieldsGrouping("split", new Fields("word"));
```



Declarative

- Higher order function as operators (filter, mapWithState...)
- Logical plan optimization

```
DataStream<String> text = env.readTextFile(params.get("input"));  
DataStream<Tuple2<String, Integer>> counts = text.flatMap(new Tokenizer()).keyBy(0).sum(1);
```



Statistical

- Data scientist friendly
- Dynamic type

Apache Spark
Streaming*

Apache
Storm*

Twitter
Heron*

Python

```
lines = ssc.textFileStream(params.get("input"))
words = lines.flatMap(lambda line: line.split(","))
pairs = words.map(lambda word: (word, 1))
counts = pairs.reduceByKey(lambda x, y: x + y)
counts.saveAsTextFiles(params.get("output"))
```

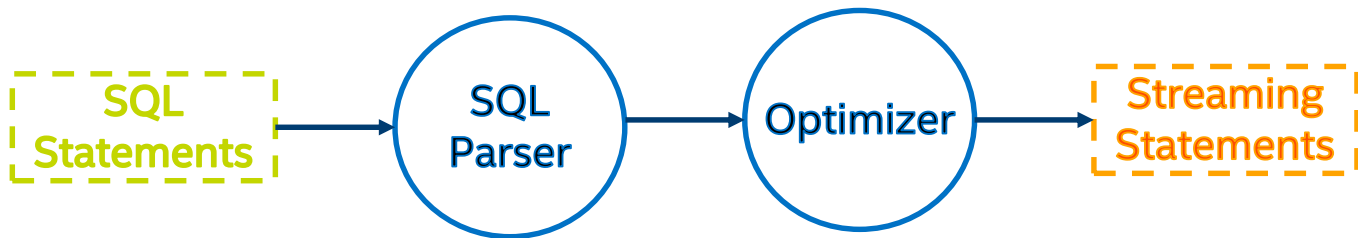
°Structured
Streaming*

°Apache
Storm*

R

```
lines <- textFile(sc, "input")
words <- flatMap(lines, function(line) {
  strsplit(line, " ")[[1]]
})
wordCount <- lapply(words, function(word) {
  list(word, 1L)
})
counts <- reduceByKey(wordCount, "+", 2L)
```

SQL



Fusion Style

Apache Spark
Streaming*

Apache
Flink*

```
InputDStream.transform((rdd: RDD[Order], time: Time) =>
{
  import sqlContext.implicits._
  rdd.toDF.registerAsTempTable
  val SQL = "SELECT ID, UNIT_PRICE * QUANTITY
    AS TOTAL FROM ORDERS WHERE UNIT_PRICE *
    QUANTITY > 50"
  val largeOrderDF = sqlContext.sql(SQL)
  largeOrderDF.toRDD
})
```

Pure Style

Structured
Streaming

Apache Storm
Trident*

```
CREATE EXTERNAL TABLE
  ORDERS (ID INT PRIMARY KEY, UNIT_PRICE INT, QUANTITY
  INT)
  LOCATION 'kafka://localhost:2181/brokers?topic=orders'
  TBLPROPERTIES '{...}'

INSERT INTO LARGE_ORDERS SELECT ID, UNIT_PRICE *
  QUANTITY
  AS TOTAL FROM ORDERS WHERE UNIT_PRICE * QUANTITY >
  50
```

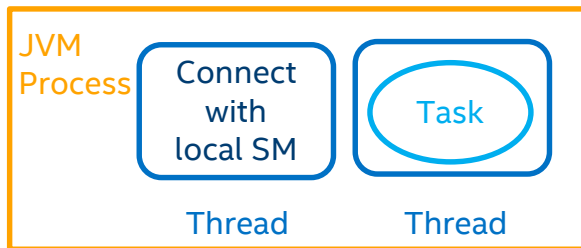
`bin/storm sql XXXX.sql`

Summary

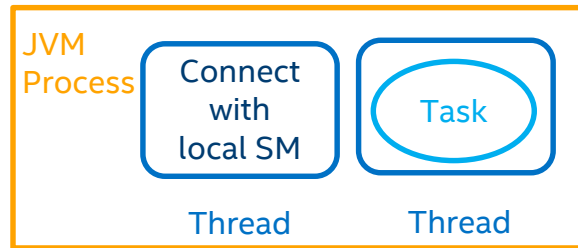
	Compositional	Declarative	Python/R	SQL
Apache Spark Streaming*	X	✓	✓	✓
Apache Storm*	✓	X	✓	NOT support aggregation, windowing and joining
Apache Storm Trident*	X	✓	X	
Apache Gearpump*	✓	✓	X	X
Apache Flink*	X	✓	X	Support select, from, where, union
Twitter Heron*	✓	X	✓°	X

Runtime Model

- Single Task on Single Process

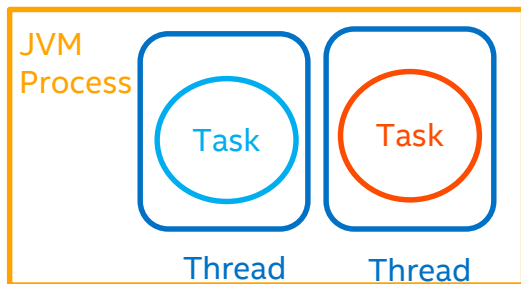


Twitter
Heron*

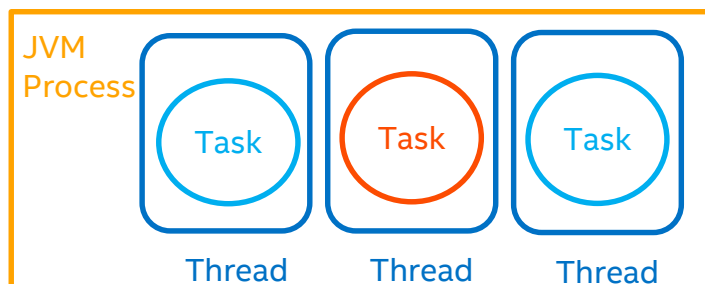


- Multi Tasks of Multi Applications on Single Process

Apache
Flink*



Task task from application A

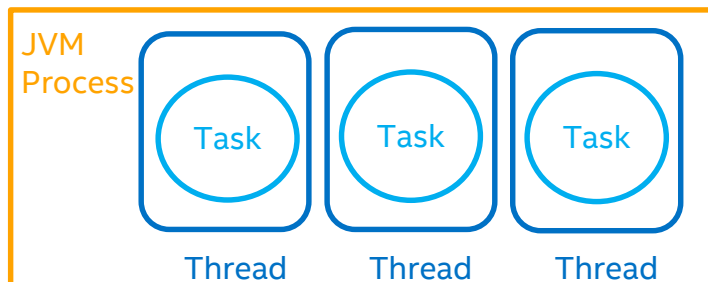
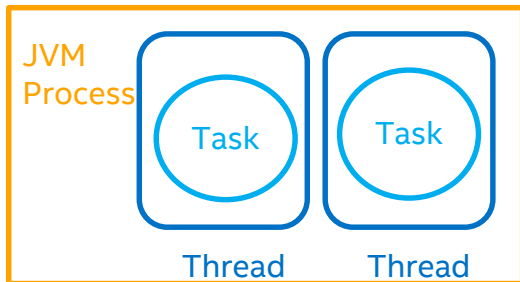


Task task from application B

- Multi Tasks of Single application on Single Process

- Single task on single thread

Apache Spark
Streaming*

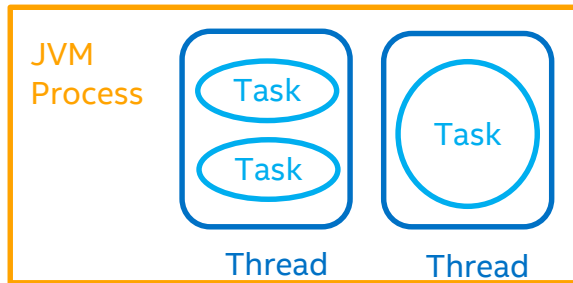
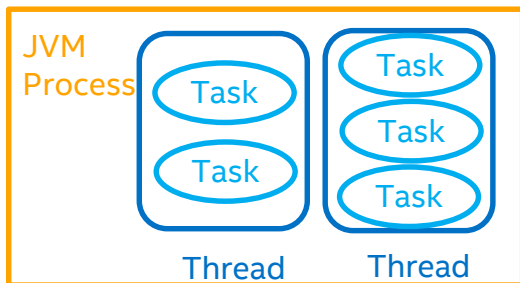


- Multi tasks on single thread

Apache
Storm*

Apache Storm
Trident*

Apache
Gearpump*



MISC

- Window Support
- Out-of-order Processing
- Memory Management
- Resource Management
- Web UI
- Community Maturity

Window Support

- Sliding Window 
- Count Window 
- Session Window 

	Sliding Window	Count Window	Session Window
Apache Spark Streaming*	✓	✗	✗°
Apache Storm*	✓	✓	✗
Apache Storm Trident*	✓	✓	✗
Apache Gearpump*	✓°	✗	✗
Apache Flink*	✓	✓	✓
Apache Heron*	✗	✗	✗

Out-of-order Processing

	Processing Time	Event Time	Watermark
Apache Spark Streaming*	✓	✓°	X°
Apache Storm*	✓	✓	✓
Apache Storm Trident*	✓	X	X
Apache Gearpump*	✓	✓	✓
Apache Flink*	✓	✓	✓
Twitter Heron*	✓	X	X

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

Memory Management

	JVM Manage	Self Manage on-heap	Self Manage off-heap
Apache Spark Streaming*	√	√°	√°
Aapche Flink*	√	√	√
Apache Storm*	√	X	X
Apache Gearpump*	√	X	X
Twitter Heron*	√	X	X

Resource Management

	Standalone	YARN	Mesos
Apache Spark Streaming*	✓	✓	✓
Apache Storm*	✓	✓°	✓°
Apache Storm Trident*	✓	✓°	✓°
Apache Gearpump*	✓	✓	X
Aapche Flink*	✓	✓	X
Twitter Heron*	✓	✓	✓

Web UI

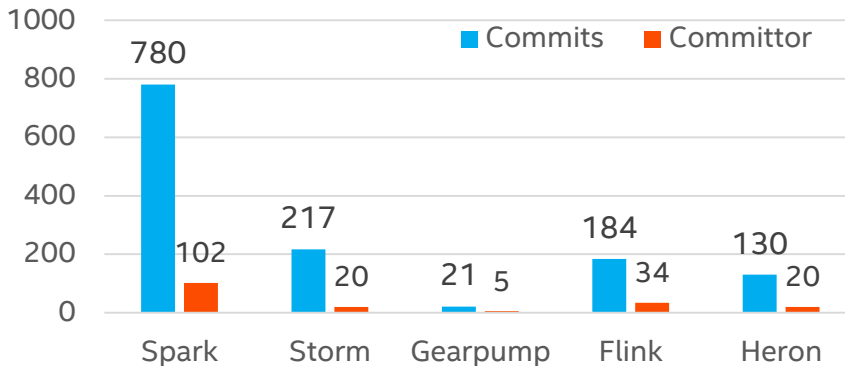
	Submit Jobs	Cancel Jobs	Inspect Jobs	Show Statistics	Show Input Rate	Check Exceptions	Inspect Config	Alert
Apache Spark Streaming*	X	✓	✓	✓	✓	✓	✓	X
Apache Storm*	X	✓	✓	✓	✓°	✓	✓	X
Apache Gearpump*	✓	✓	✓	✓	✓°	✓	✓	X
Apache Flink*	✓	✓	✓	✓	X	✓	✓	X
Twitter Heron*	X	X	✓	✓	✓°	✓	✓	X

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

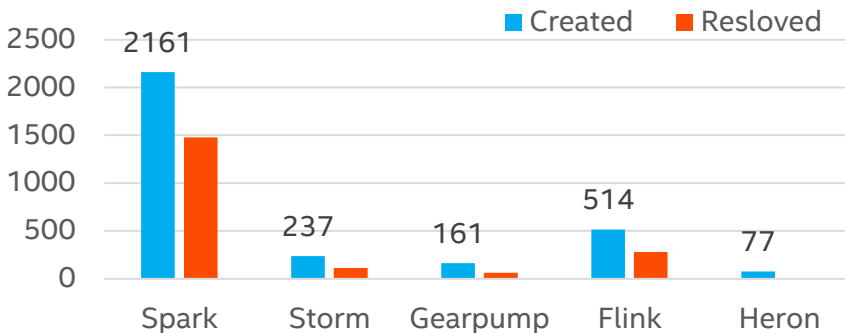
Community Maturity

	Initiation Time	Apache Top Project	Contributors
Apache Spark Streaming*	2013	2014	926
Apache Storm*	2011	2014	219
Apache Gearpump*	2014	Incubator	21
Apache Flink*	2010	2015	208
Twitter Heron*	2014	N/A	44

Past 1 Months Summary on GitHub



Past 3 Months Summary on JIRA



Performance Benchmark

HiBench 6.0

Test Philosophical

- “Lazy Benchmarking”
- Simple test case infer practical use case

The Setup

Name	Version
Java	1.8
Scala	2.11.7
Apache Hadoop*	2.6.2
Apache Zookeeper*	3.4.8
Apache Kafka*	0.8.2.2
Apache Spark*	1.6.1
Apache Storm*	1.0.1
Apache Flink*	1.0.3
Apache Gearpump*	0.8.1

- Apache Heron* require specific Operation System (Ubuntu / CentOS / Mac OS)
- Structured Streaming doesn't support Kafka source yet (Spark 2.0)

Apache Kafka* Cluster

- **CPU:** 2 x Intel(R) Xeon(R) CPU E5-2699 v3@ 2.30GHz
- **Mem:** 128 GB
- **Disk:** 8 x HDD (1TB)
- **Network:** 10 Gbps

x3

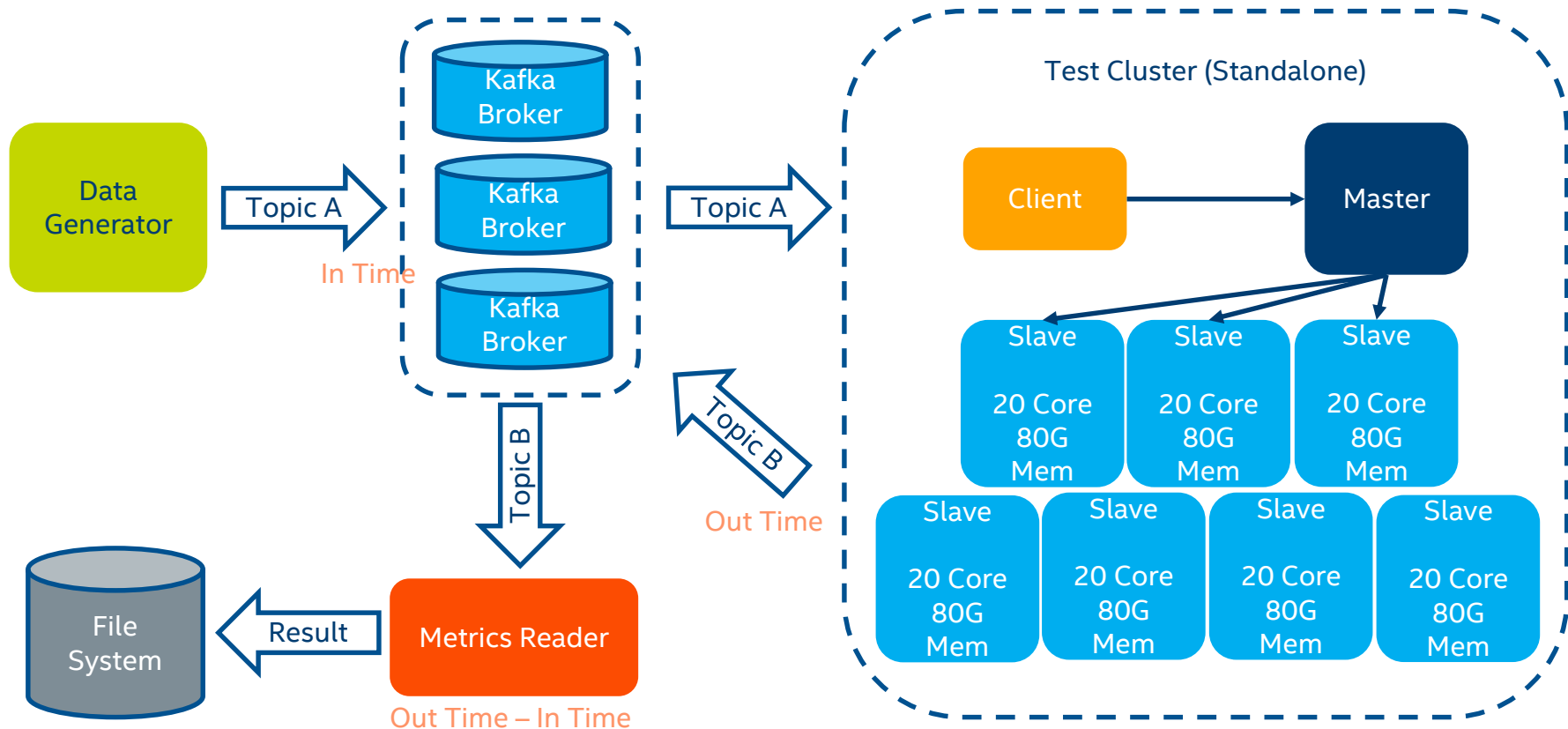


x7

Test Cluster

- **CPU:** 2 x Intel(R) Xeon(R) CPU E5-2697 v2@ 2.70GHz
- **Core:** 20 / 24
- **Mem:** 80 / 128 GB
- **Disk:** 8 x HDD (1TB)
- **Network:** 10 Gbps

Architecture



Framework Configuration

Framework	Related Configuration
Apache Spark Streaming*	7 Executor 140 Parallelism
Aapche Flink*	7 TaskManager 140 Parallelism
Apache Storm*	28 Worker 140 KafkaSpout
Apache Gearpump*	28 Executors 140 KafkaSource

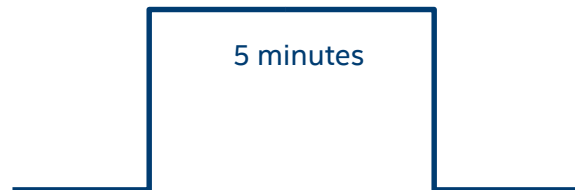
Raw Input Data

- Kafka Topic Partition: 140
- Size Per Message (configurable): 200 bytes
- Raw Input Message Example:

"0,227.209.164.46,nbizrgdziebsaecsecujfjcqtnpcnxxwiopmddorcxnlijdzgoi,1991-06-10,0.115967035,Mozilla/5.0 (iPhone; U; CPU like Mac OS X) AppleWebKit/420.1 (KHTML like Gecko) Version/3.0 Mobile/4A93Safari/419.3,YEM,YEM-AR,snowdrops,1"

- Strong Type: class UserVisit (ip, sessionId, browser)

- Keep feeding data at specific rate for 5 minutes



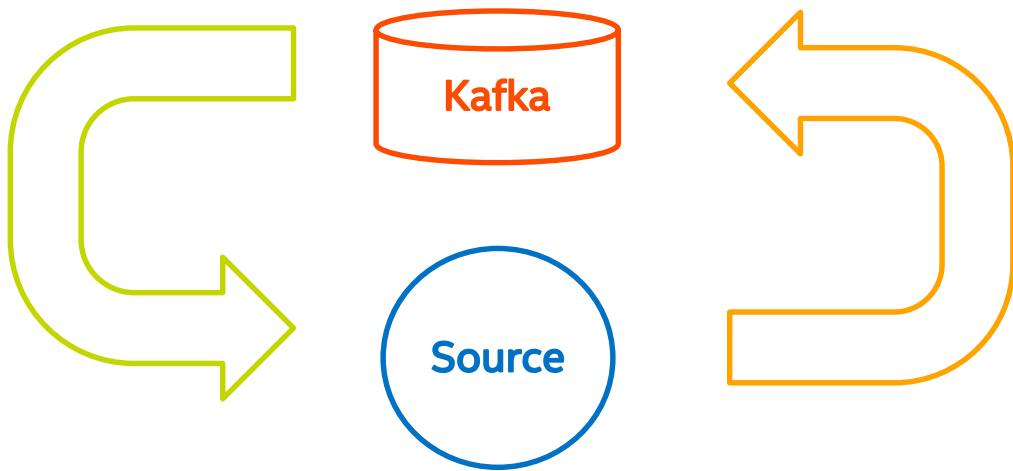
Data Input Rate

Throughput	Message/Second	Kafka Producer Num
40KB/s	0.2K	1
400KB/s	2K	1
4MB/s	20K	1
40MB/s	200K	1
80MB/s	400K	1
400MB/s	2M	10
600MB/s	3M	15
800MB/s	4M	20

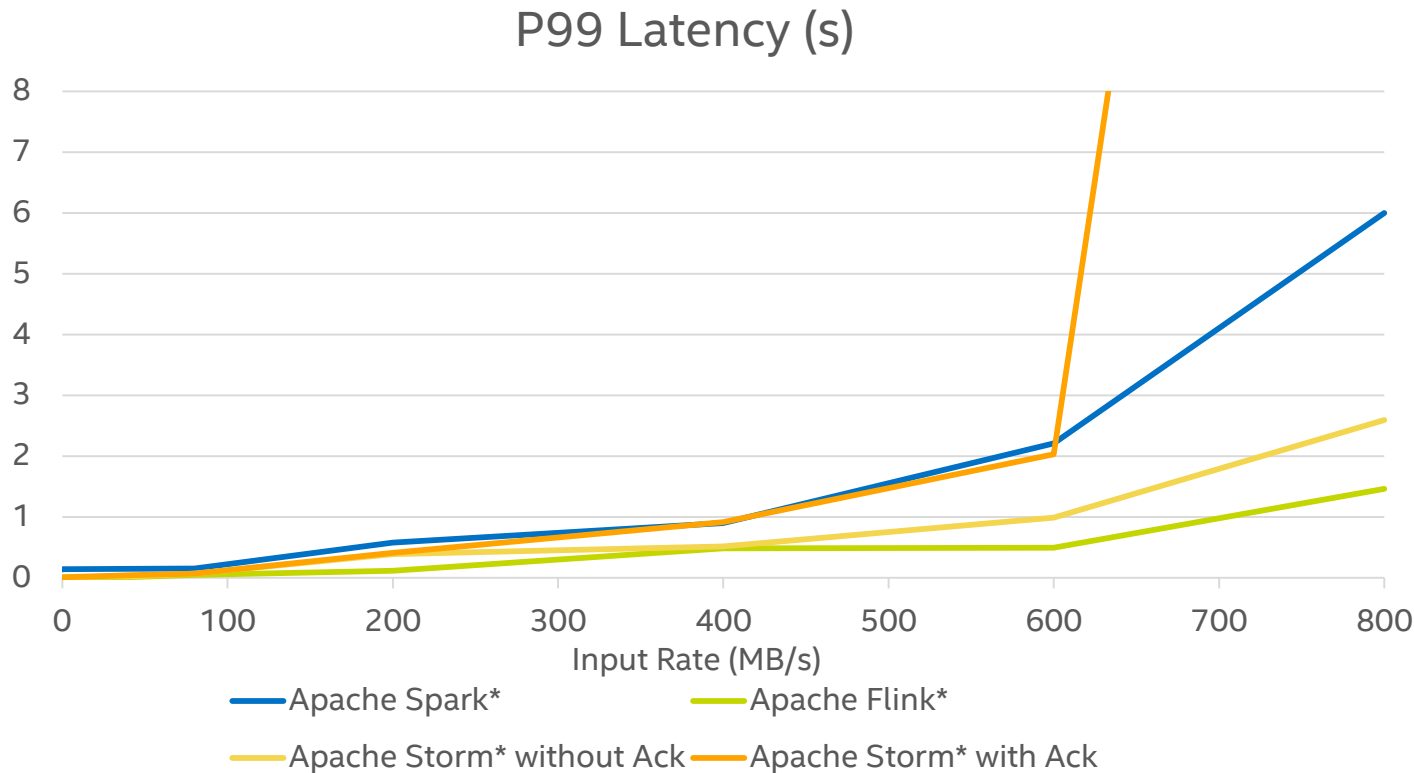
Let's start with the simplest case

Test Case: Identity

The application reads input data from Kafka and then writes result to Kafka immediately, there is no complex business logic involved.



Result



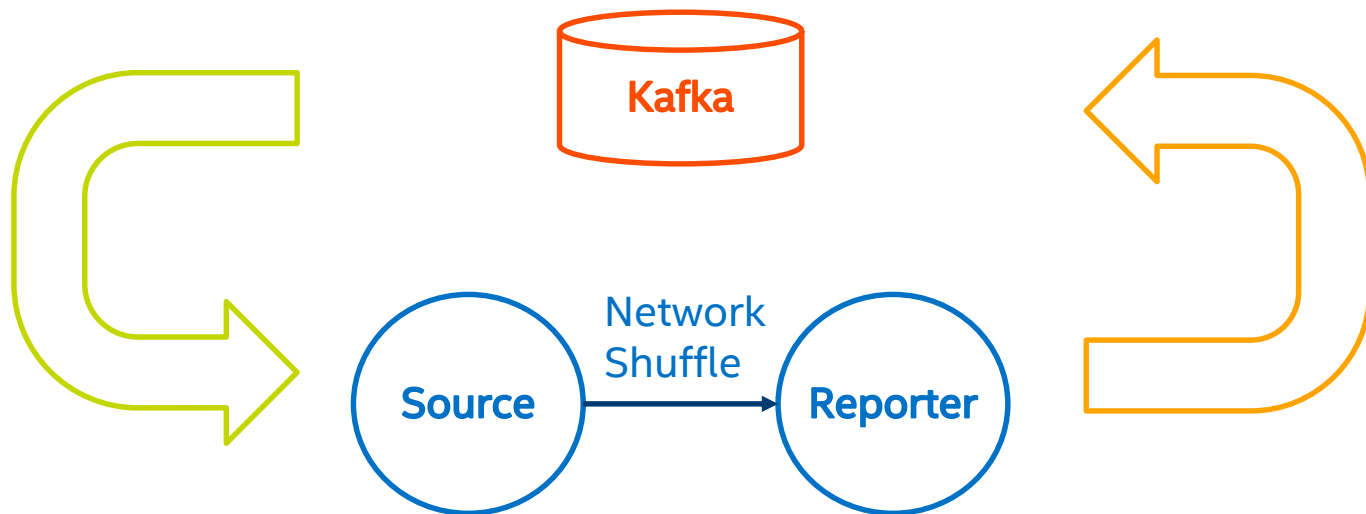
*Other names and brands may be claimed as the property of others.

For more complete information about performance and benchmark results, visit www.intel.com/benchmarks.

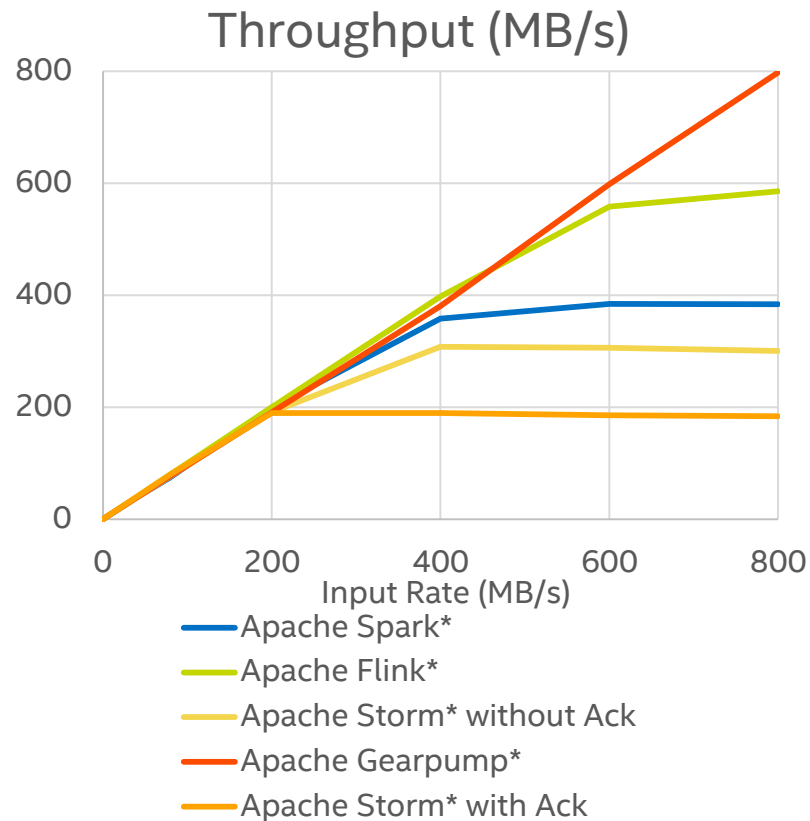
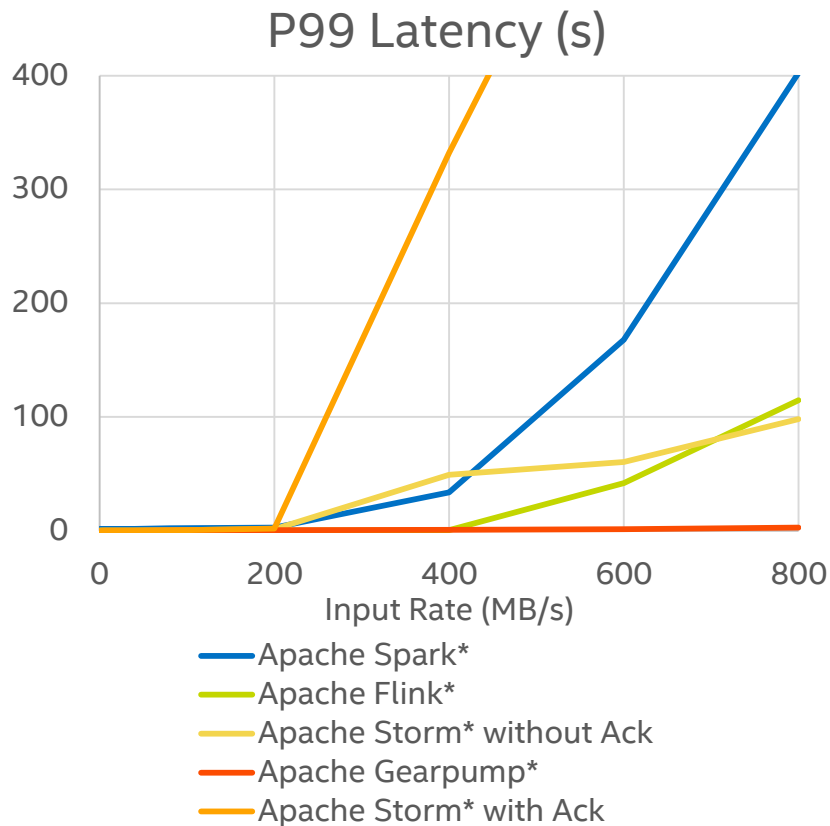
Q: What if source data are skew or even packed?

Test Case: Repartition

Basically, this test case can stand for the efficiency of data shuffle.



Result



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Observation

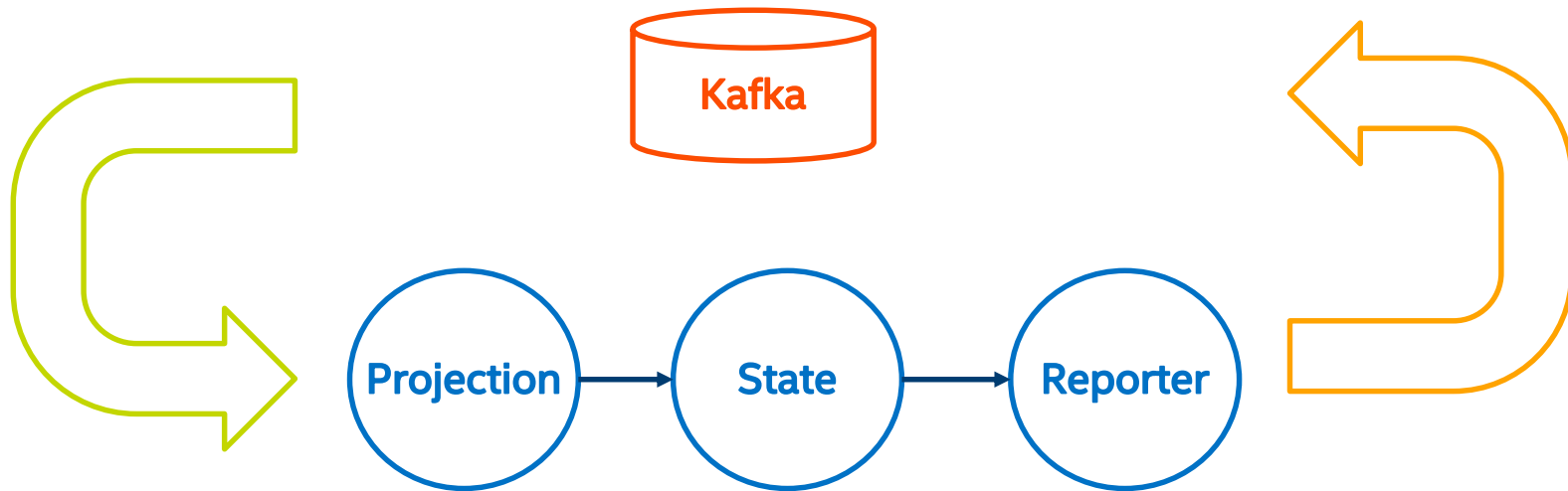
- Flink and Storm has close performance and are better choices to meet **sub-second SLA** requirement if no repartition happened.
- Spark Streaming need to schedule task with additional context. Under tiny batch interval case, the overhead could be dramatic worse compared to other frameworks.
- According to our test, minimum Batch Interval of Spark is about 80ms (140 tasks per batch), otherwise task schedule delay will keep increasing
- Repartition is heavy for every framework, but usually it's unavoidable.
- Latency of Gearpump is still quite low even under 800MB/s input throughput.

Q: What if I want to apply slightly complex logic which need to maintain entire state?

Test Case: Stateful WordCount

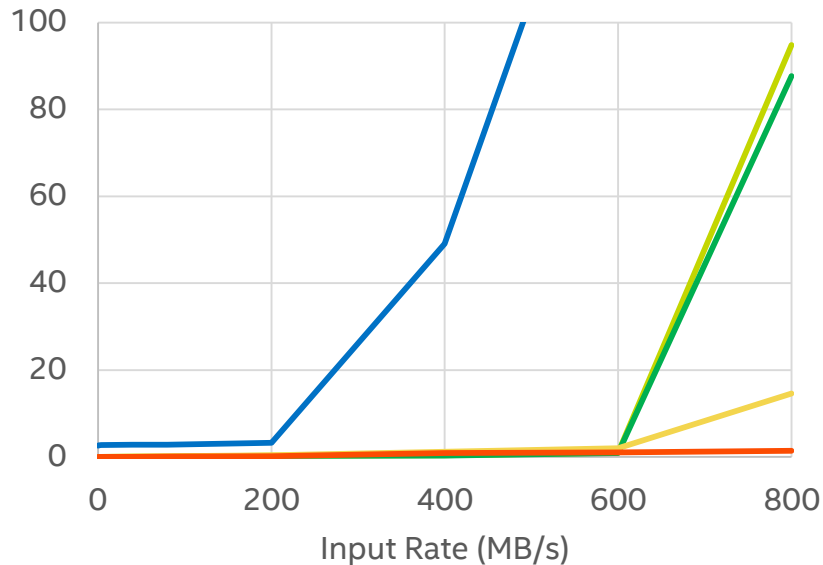
Native state operator is supported by all frameworks we evaluated

Stateful operator performance + Checkpoint/Acker cost



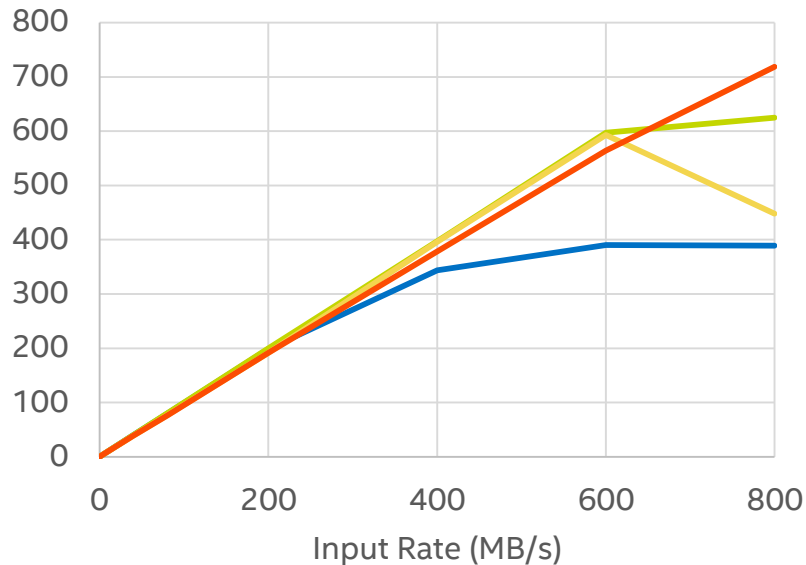
Result

P99 Latency (s)



— Apache Spark*
— Apache Flink*
— Apache Flink* without CP
— Apache Storm*
— Apache Gearpump*

Throughput (MB/s)



— Apache Spark*
— Apache Flink*
— Apache Storm*
— Gearpump*

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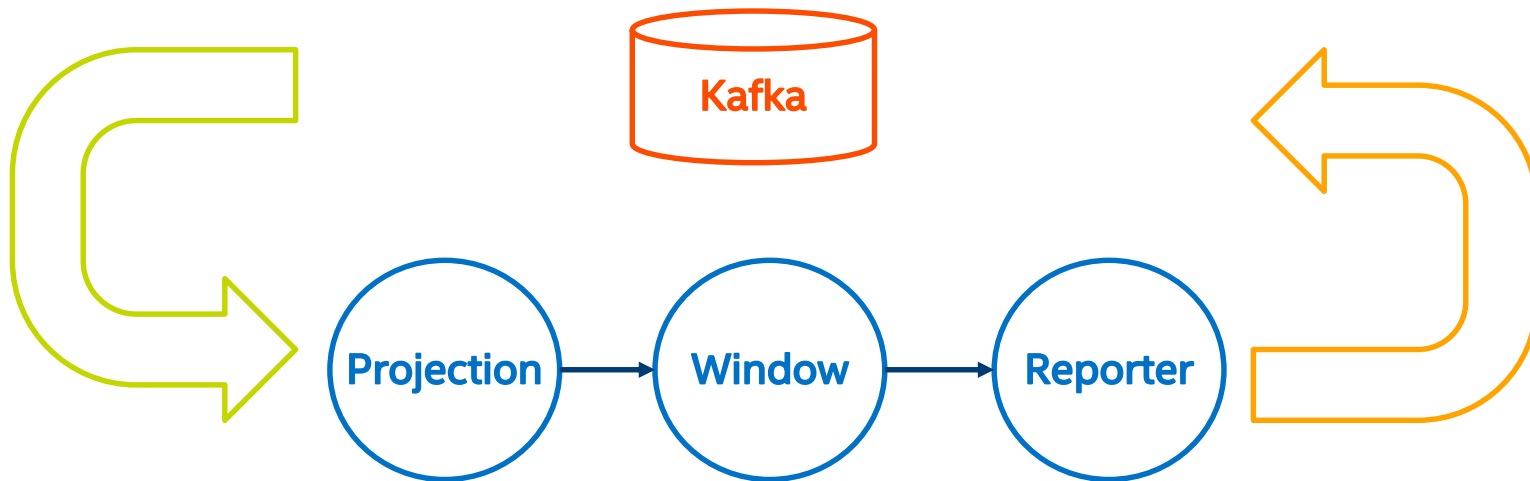
Observation

- Exactly-once semantics usually require state management and checkpoint. But better guarantees come at high cost.
- There is no obvious performance difference in Flink when switching fault tolerance on or off.
- Checkpoint mechanisms and storages play a critical role here.

Q: How about Window Operation?

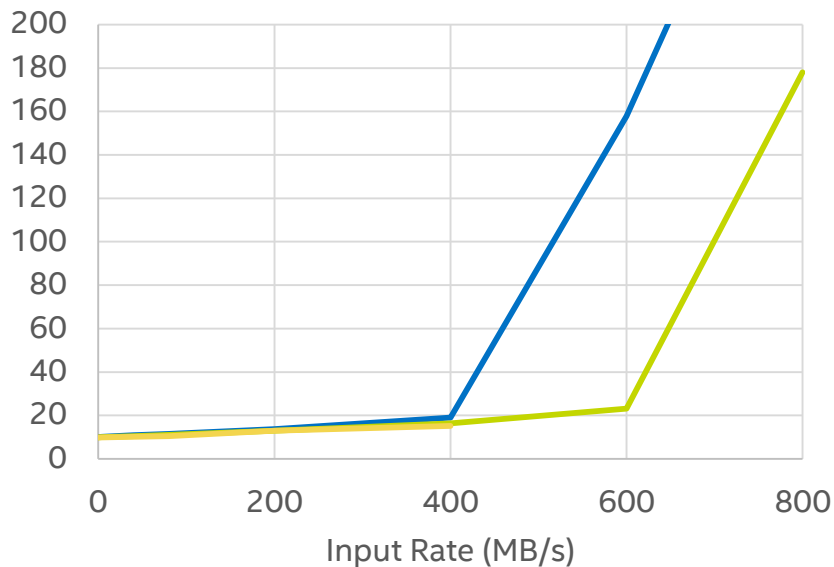
Test Case: Window Based Aggregation

This test case manages a 10-seconds sliding window



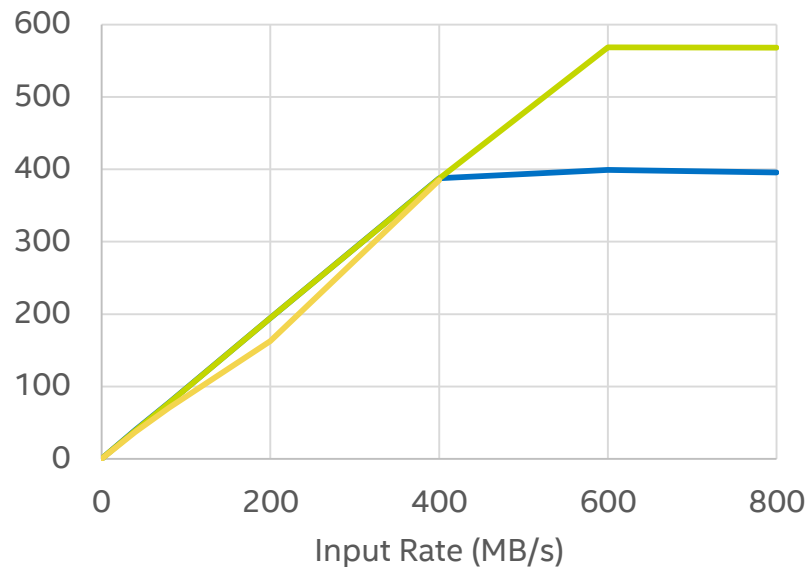
Result

P99 Latency (s)



— Apache Spark* — Apache Flink* — Storm*

Throughput (MB/s)



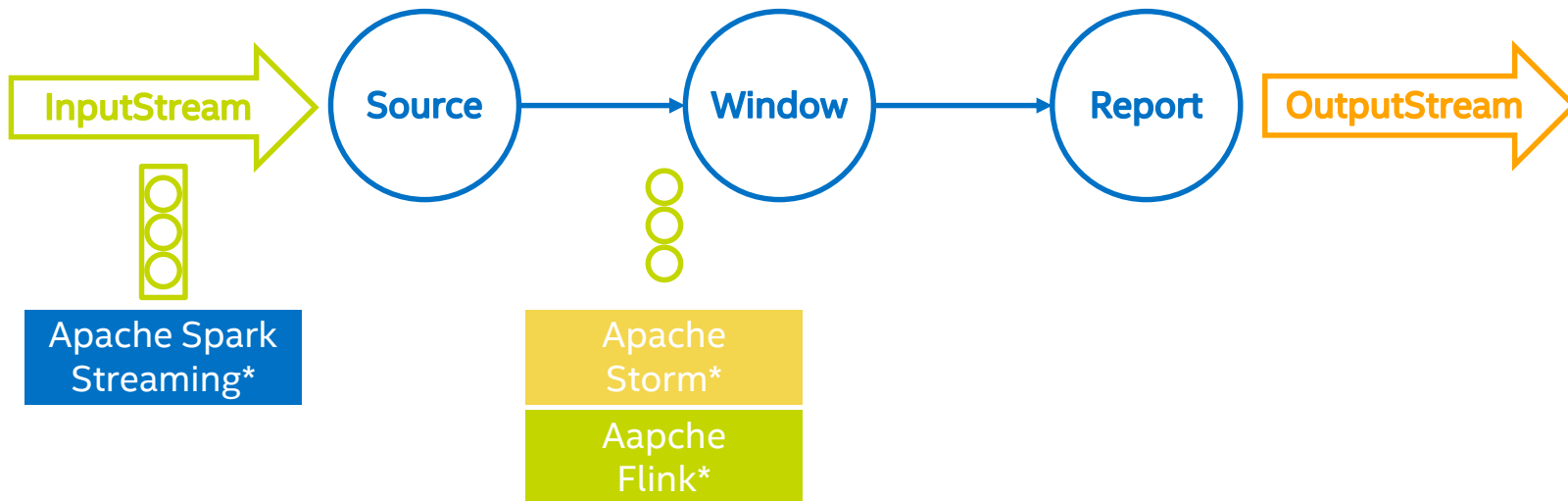
— Apache Spark* — Apache Flink* — Storm*

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Observation

The native streaming execution model helps here



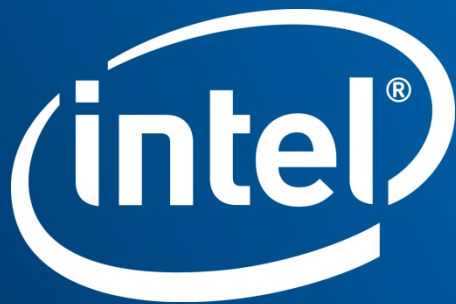
So which streaming framework should I use?

Do your own benchmark

HiBench : a cross platforms micro-benchmark suite for big data
(<https://github.com/intel-hadoop/HiBench>)

Open Source since 2012

Better streaming benchmark supporting will be included in next release
[HiBench 6.0]



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