# Streaming Report

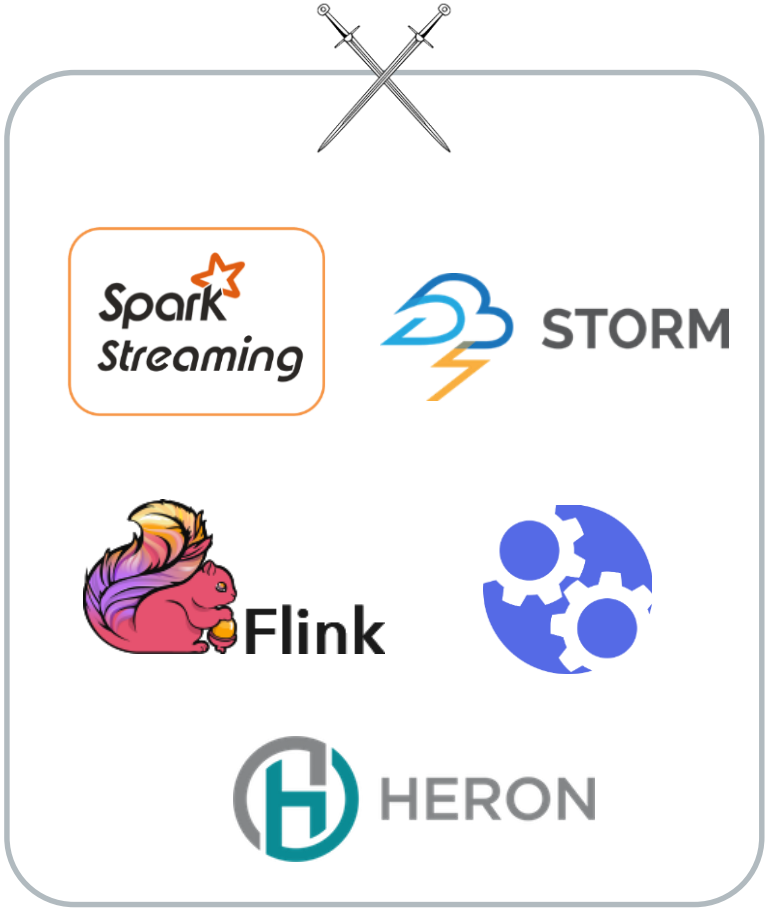
## Functional Comparison and Performance Evaluation

Mao Wei
Wang, Huafeng
Zhang, Tianlun

# Overview

- Streaming Core
- MISC
- Performance Benchmark

**Choose your weapon !**

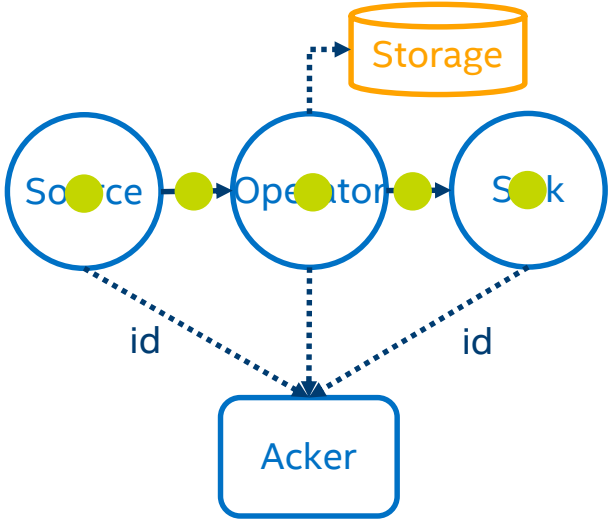


# Execution Model + Fault Tolerance Mechanism

## Continuous Streaming

### Ack per Record

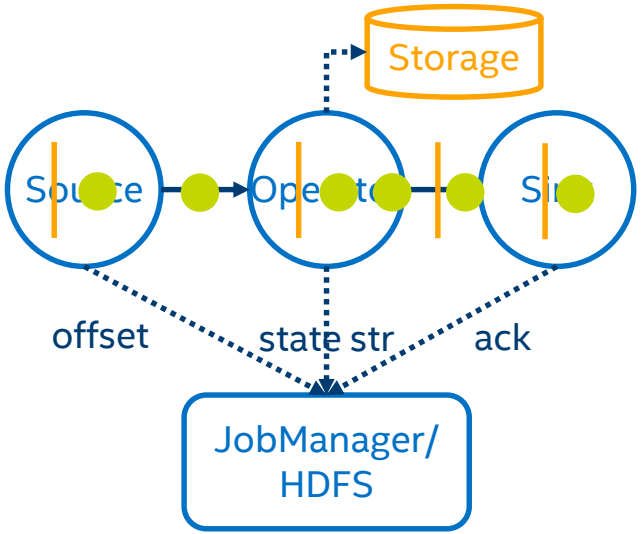
Storm | Heron




## Continuous Streaming

### Checkpoint "per Batch"

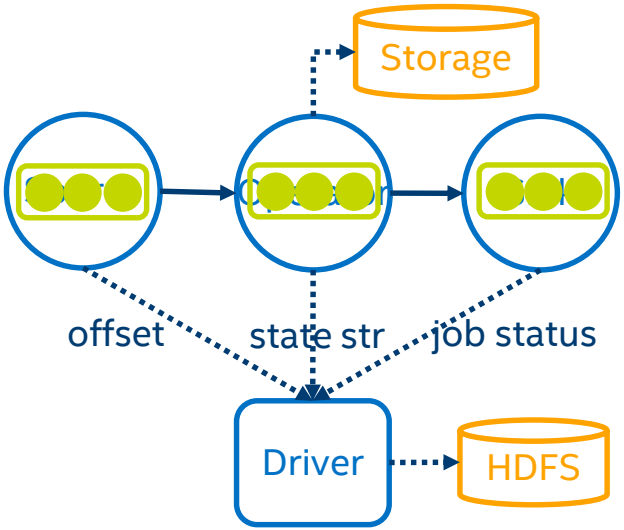
Flink | Gearpump




## Micro-Batch

### Checkpoint per Batch

Spark Streaming | Storm Trident




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

Continuous Streaming

Ack per Record

Storm

Heron

Continuous Streaming

Checkpoint “per Batch”

Flink

Gearpump

Micro-Batch

Checkpoint per Batch

Spark Streaming

Storm Trident

Low Latency

High Latency

High Overhead

Low Throughput

Low Overhead

High Throughput

# Delivery Guarantee

Storm | Heron | Flink | Gearpump | Spark Streaming | 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

Storm | Heron

## Yes*

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

Flink | Gearpump

## Yes

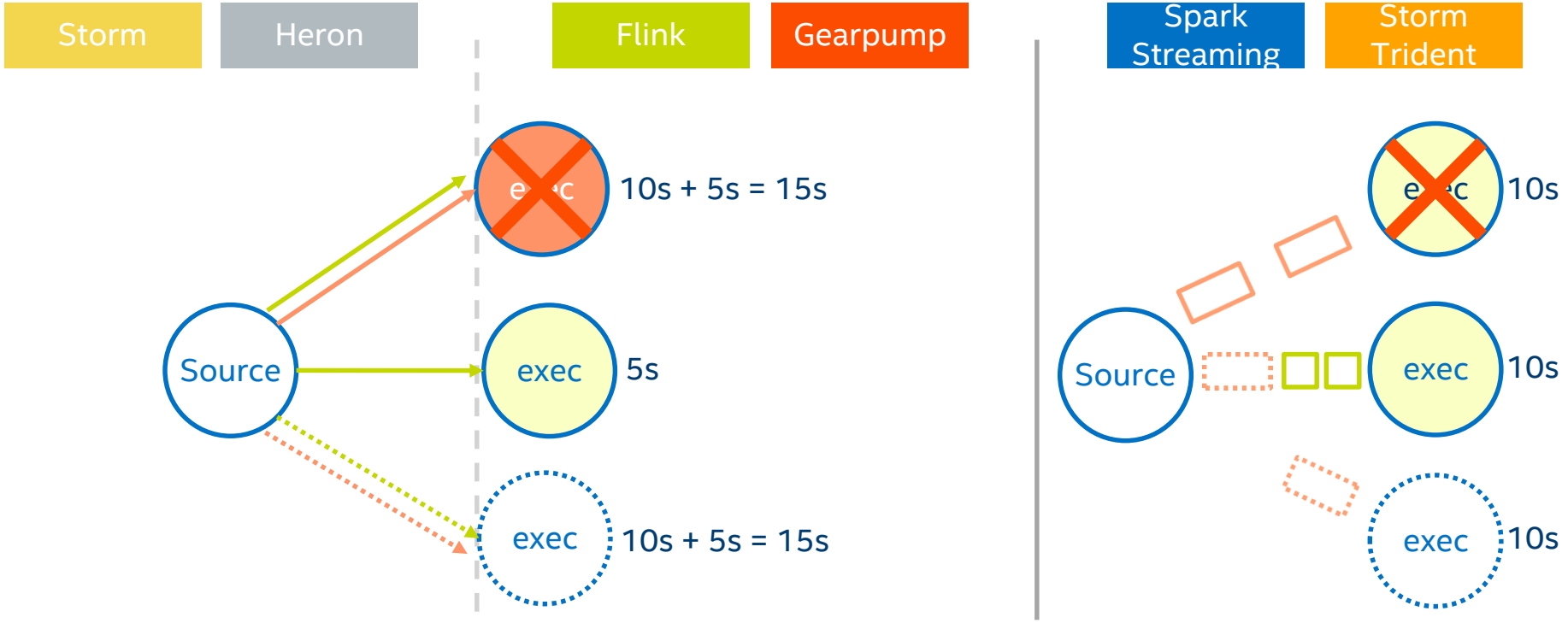
- Flink Java API:
  - ✓ ValueState
  - ✓ ListState
  - ✓ ReduceState
- Flink Scala API:
  - ✓ mapWithState
- Gearpump
  - ✓ persistState

Spark Streaming | Storm Trident

## Yes

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

# Dynamic Load Balance & Recovery Speed

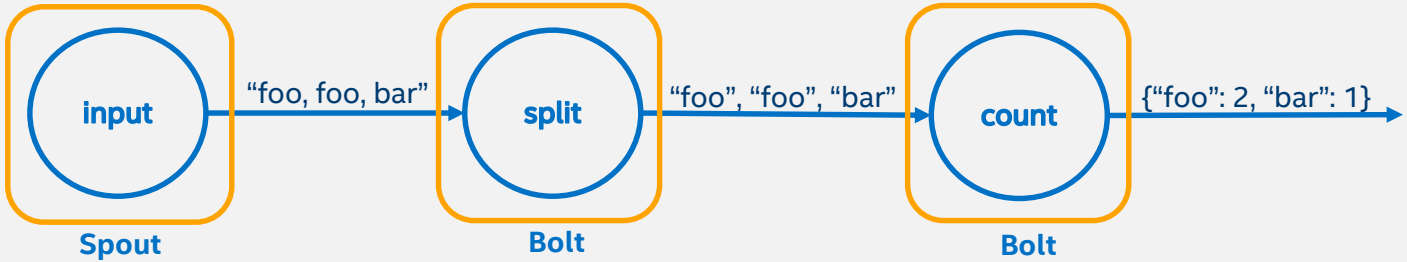


# API

# 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"));
```

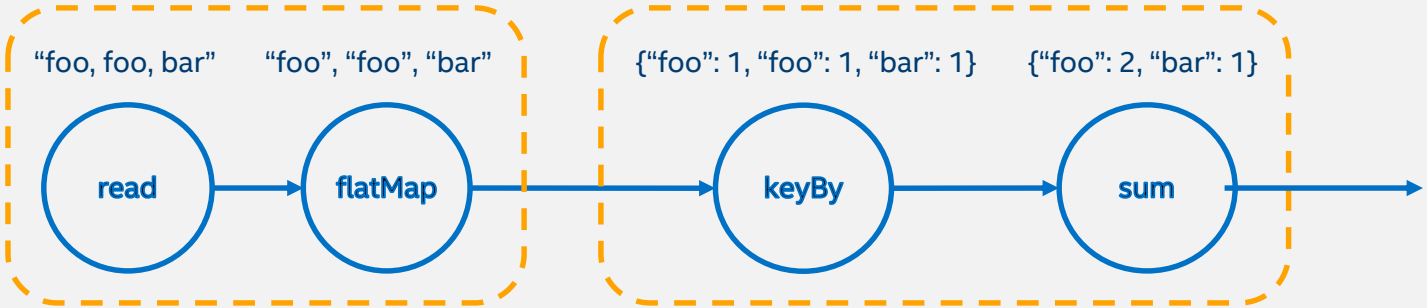


# Declarative

Spark Streaming
Storm Trident
Flink
Gearpump

- Higher order function as operators (map, 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

Spark Streaming | Storm | Heron*

## Python

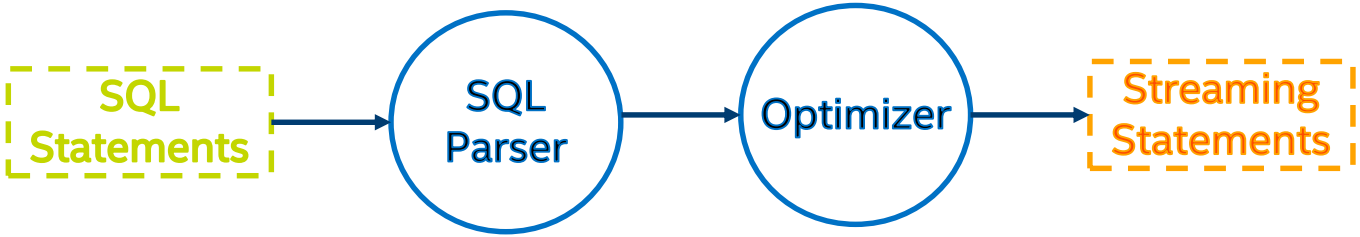
```
lines = ssc.textFileStream(params.get("input"))
words = lines.flatMap(lambda line: line.split(“,"))
pairs = words.map(lambda word: (word, 1))
counts = pairs.reduceByKey(lambda x, y: x + y)
counts.saveAsTextFiles(params.get("output"))
```

Structured Streaming* | 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

Spark Streaming

Flink

```
InputDStream.transform((rdd: RDD[Order], time: Time) =>
{
   import sqlContext.implicits._
   rdd.toDF.registAsTempTable
   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*

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**

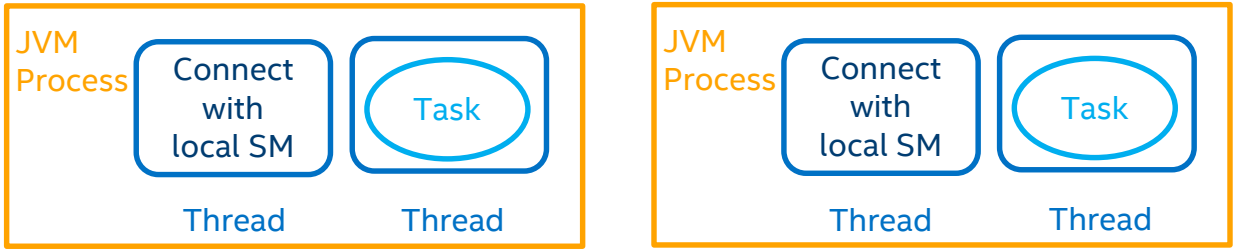
# Summary

| | Compositional | Declarative | Python/R | SQL |
|---|---|---|---|---|
| Spark Streaming | X | √ | √ | √ |
| Storm | √ | X | √ | NOT support aggregation, windowing and joining |
| Storm Trident | X | √ | X | |
| Gearpump | √ | √ | X | X |
| Flink | X | √ | X | Support select, from, where, union |
| Heron | √ | X | √* | X |

# Runtime Model

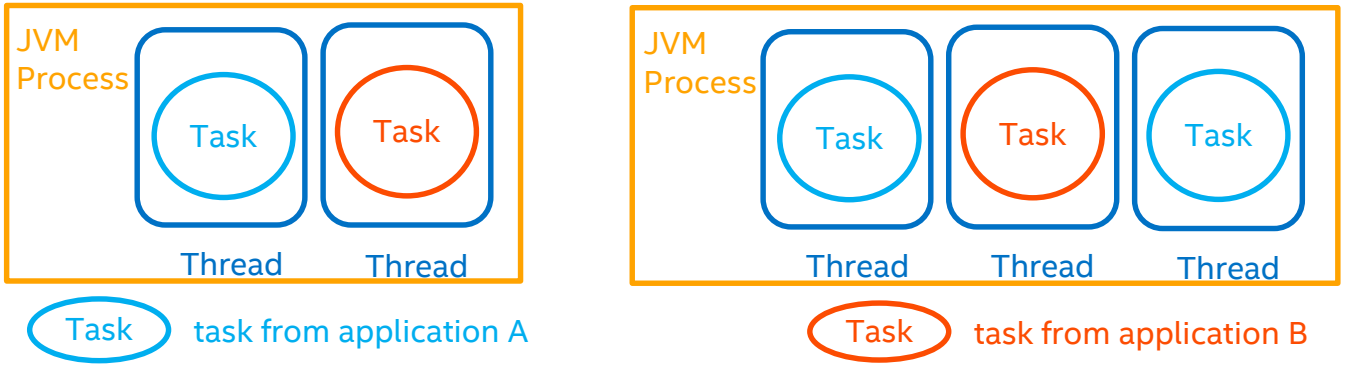
- Single Task on Single Process

Heron



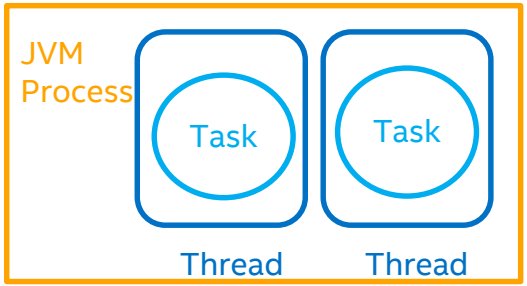

- Multi Tasks of Multi Applications on Single Process

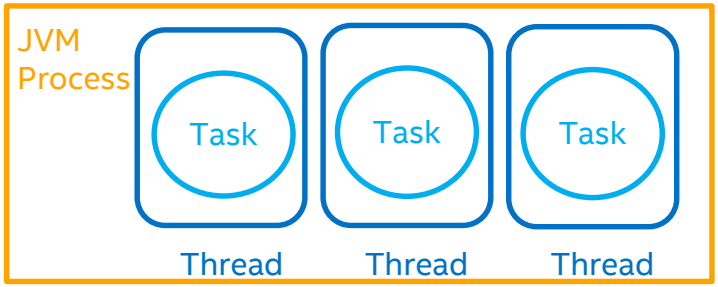
Flink



- Multi Tasks of Single application on Single Process
  - Single task on single thread

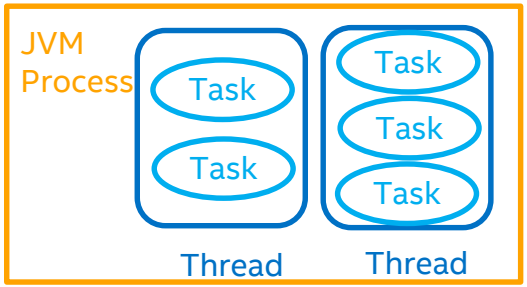
Spark Streaming

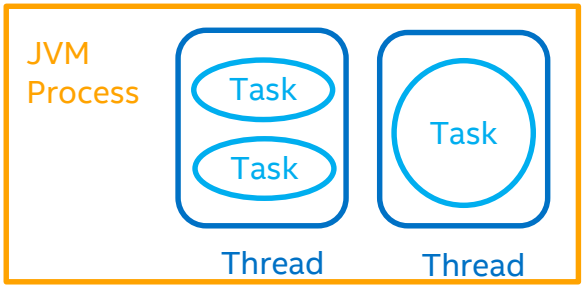



  - Multi tasks on single thread

Gearpump | Storm | Storm Trident



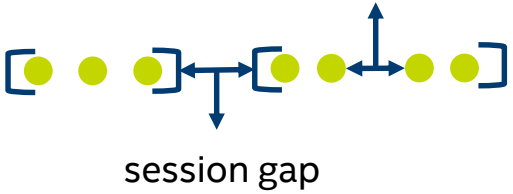



# MISC

- 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 |
|---|---|---|---|
| Spark Streaming | √ | X | X* |
| Storm | √ | √ | X |
| Storm Trident | √ | √ | X |
| Gearpump | √* | X | X |
| Flink | √ | √ | √ |
| Heron | X | X | X |

# Out-of-order Processing

| | Processing Time | Event Time | Watermark |
|---|---|---|---|
| Spark Streaming | √ | √* | X* |
| Storm | √ | √ | √ |
| Storm Trident | √ | X | X |
| Gearpump | √ | √ | √ |
| Flink | √ | √ | √ |
| Heron | √ | X | X |

# Memory Management

| | JVM Manage | Self Manage on-heap | Self Manage off-heap |
|---|---|---|---|
| Spark Streaming | √ | √* | √* |
| Flink | √ | √ | √ |
| Storm | √ | X | X |
| Gearpump | √ | X | X |
| Heron | √ | X | X |

# Resource Management

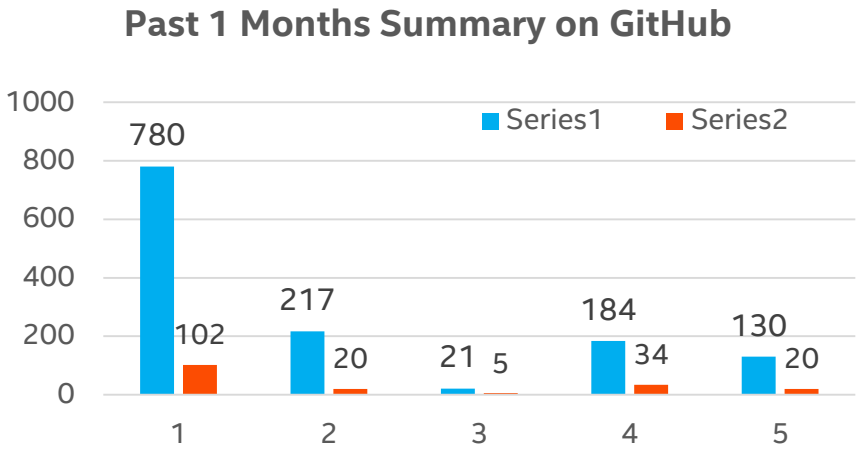
| | Standalone | YARN | Mesos |
|---|---|---|---|
| Spark Streaming | √ | √ | √ |
| Storm | √ | √ | √ |
| Storm Trident | √ | √ | √ |
| Gearpump | √ | √ | X |
| Flink | √ | √ | X |
| Heron | √ | √ | √ |

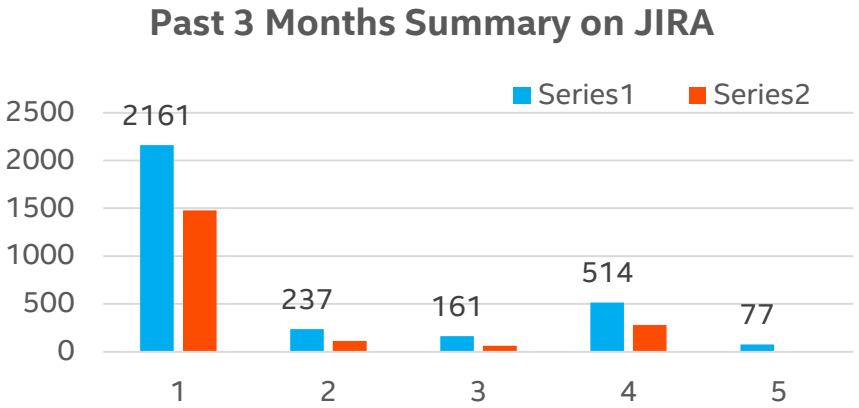
# Web UI

| | Submit Jobs | Cancel Jobs | Inspect Jobs | Show Statistics | Show Input Rate | Check Exceptions | Inspect Config | Alert |
|---|---|---|---|---|---|---|---|---|
| Spark Streaming | X | √ | √ | √ | √ | √ | √ | X |
| Storm | X | √ | √ | √ | √* | √ | √ | X |
| Gearpump | √ | √ | √ | √ | √* | √ | √ | X |
| Flink | √ | √ | √ | √ | X | √ | √ | X |
| Heron | X | X | √ | √ | √* | √ | √ | X |

# Community Maturity

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



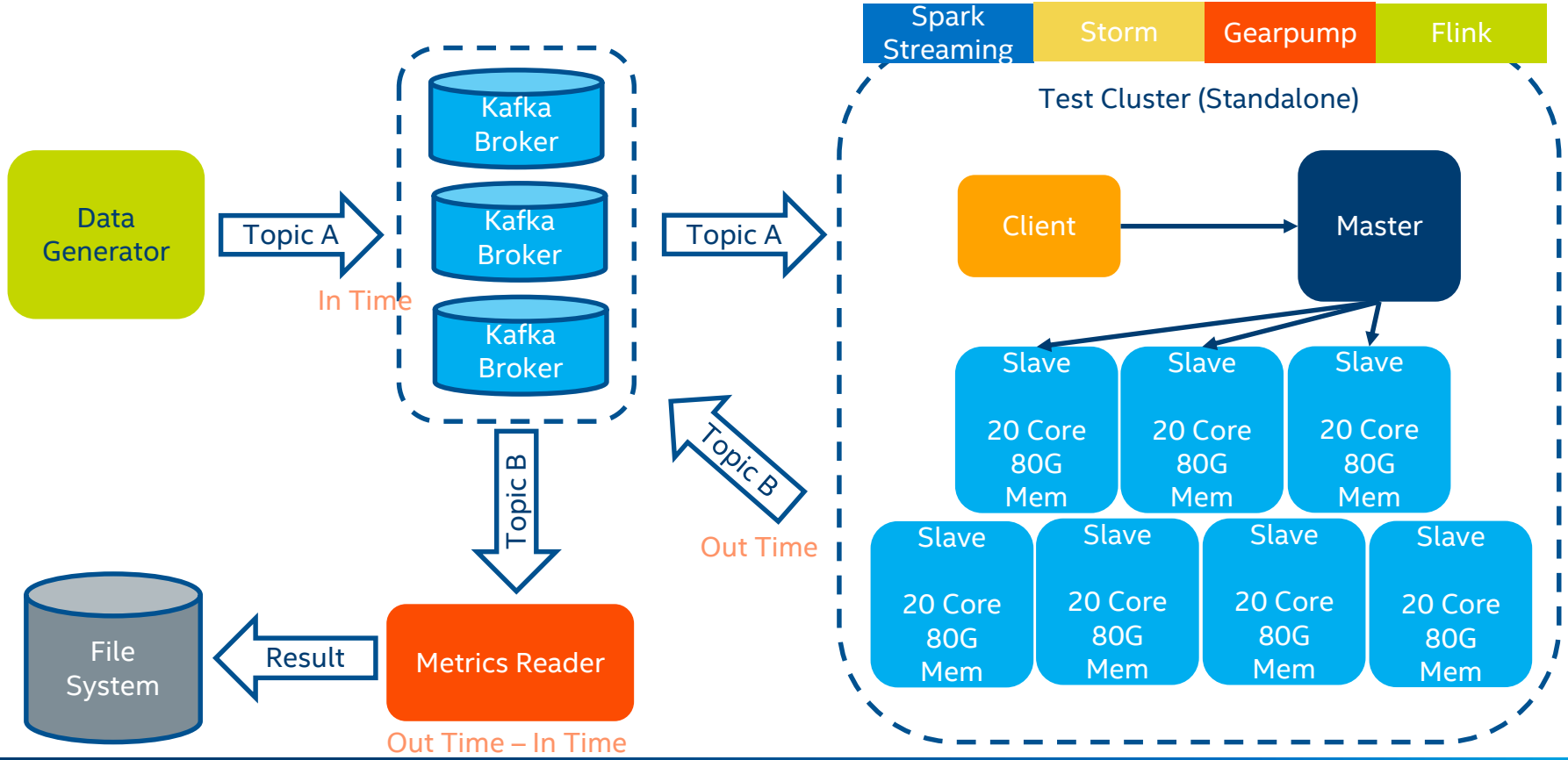
# Performance Benchmark

HiBench 6.0

# Test Philosophical

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

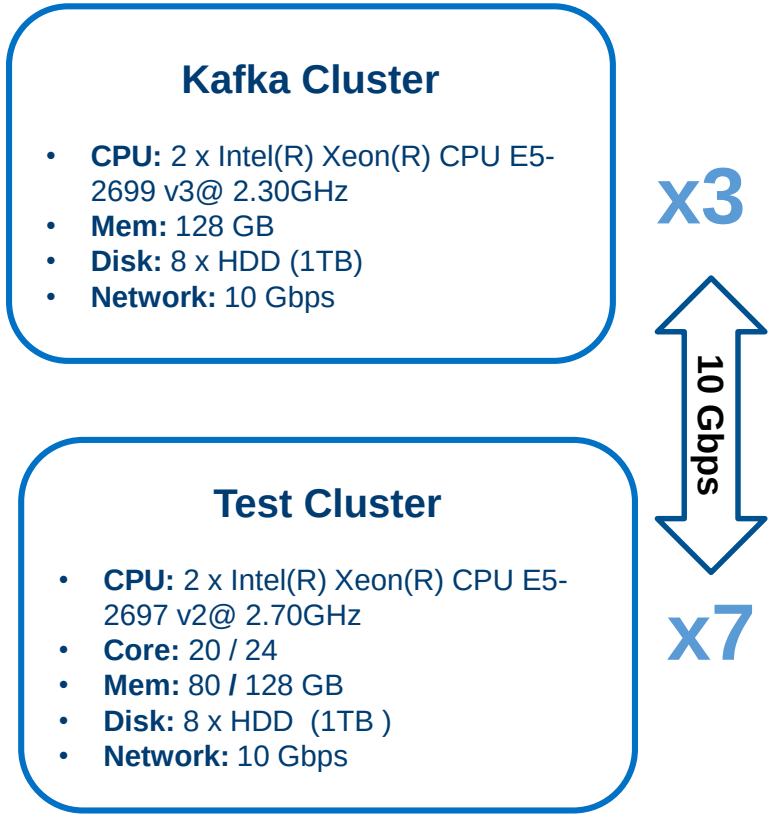
# Architecture



# The Setup

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

- Heron require specific Operation System (Ubuntu / CentOS / Mac OS )
- Structured Streaming doesn't support Kafka source yet (Spark 2. 0 )



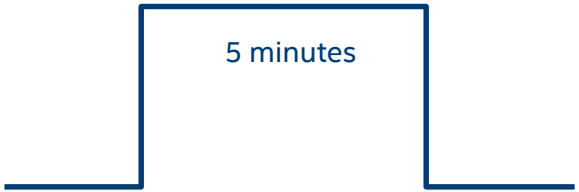
# Raw Input Data

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

"0,227.209.164.46,nbizrgdziebsaecsecujfjcqtvnpcnxxwiopmddorcxnlijdizgoi,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



# Framework Configuration

| Framework | Related Configuration |
| --- | --- |
| Spark Streaming | 7 Executor<br>140 Parallelism |
| Flink | 7 TaskManager<br>140 Parallelism |
| Storm | 28 Worker<br>140 KafkaSpout |
| Gearpump | 28 Executors<br>140 KafkaSource |

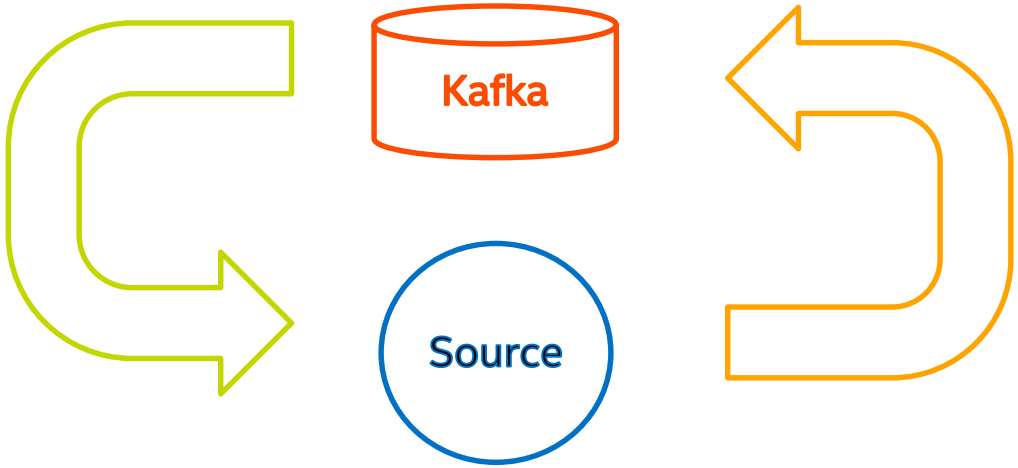
# Data Input Rate

| 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 |

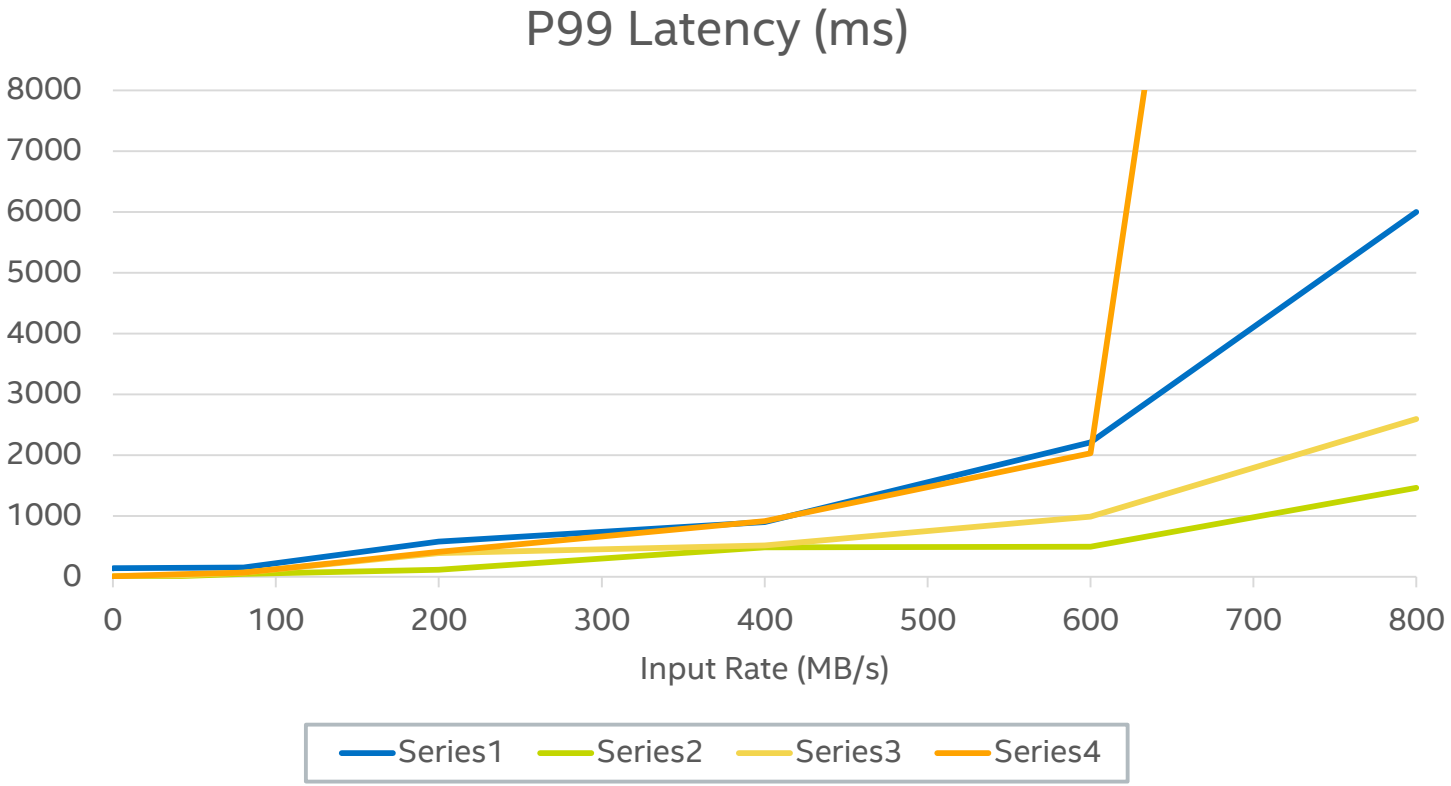
# Let’s start with the simplest case

# Test Case: Identity

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



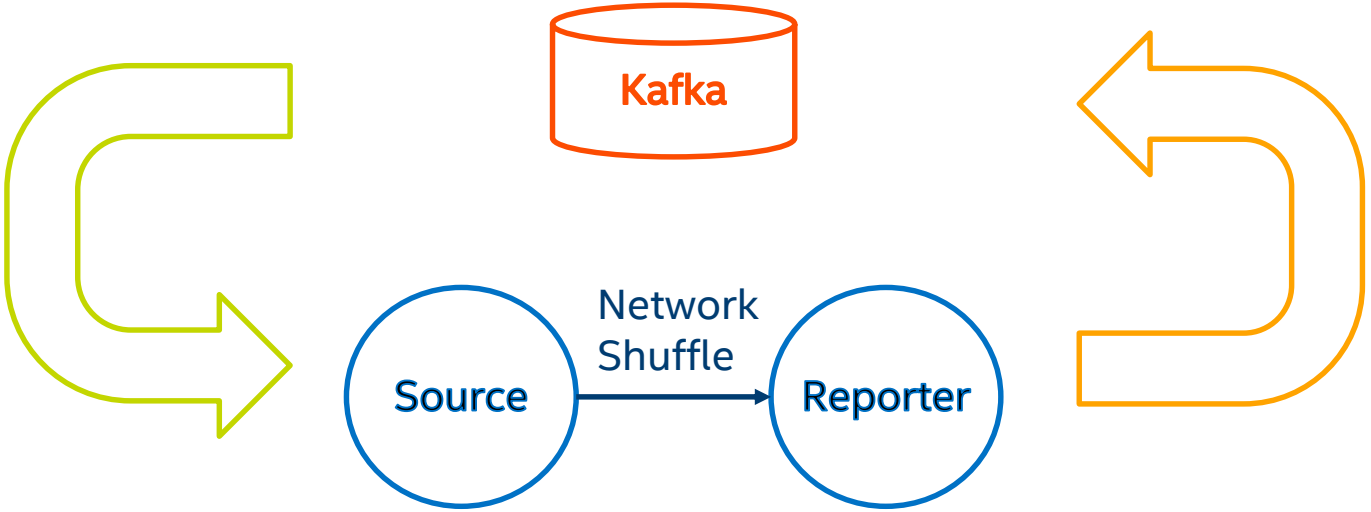
# Result


P99 Latency (ms)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
Input Rate (MB/s)
Series1
Series2
Series3
Series4

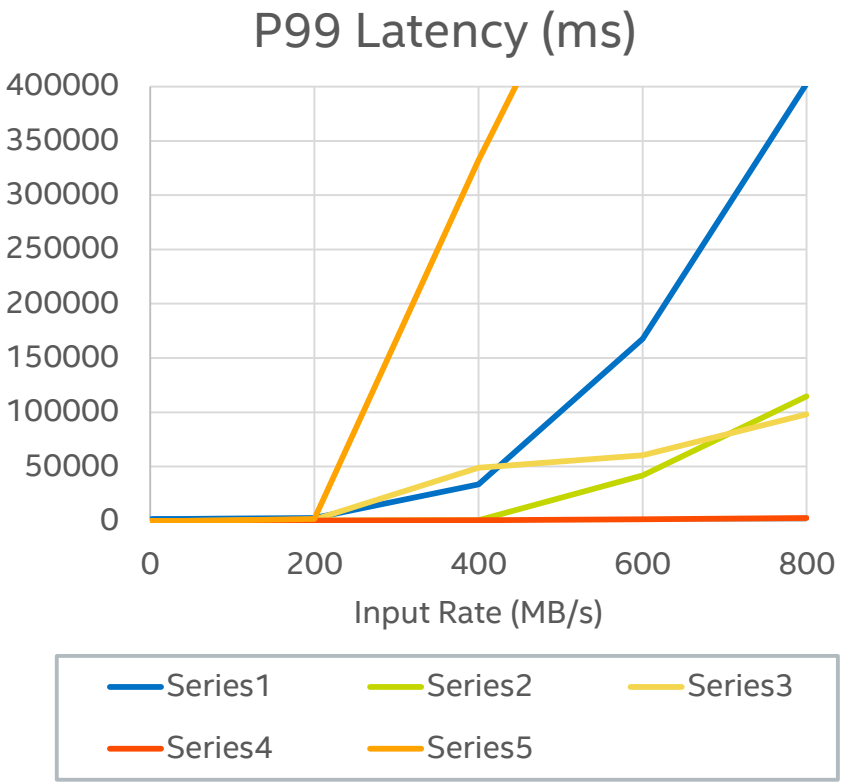
# Q: What if source data are skew or even packed?

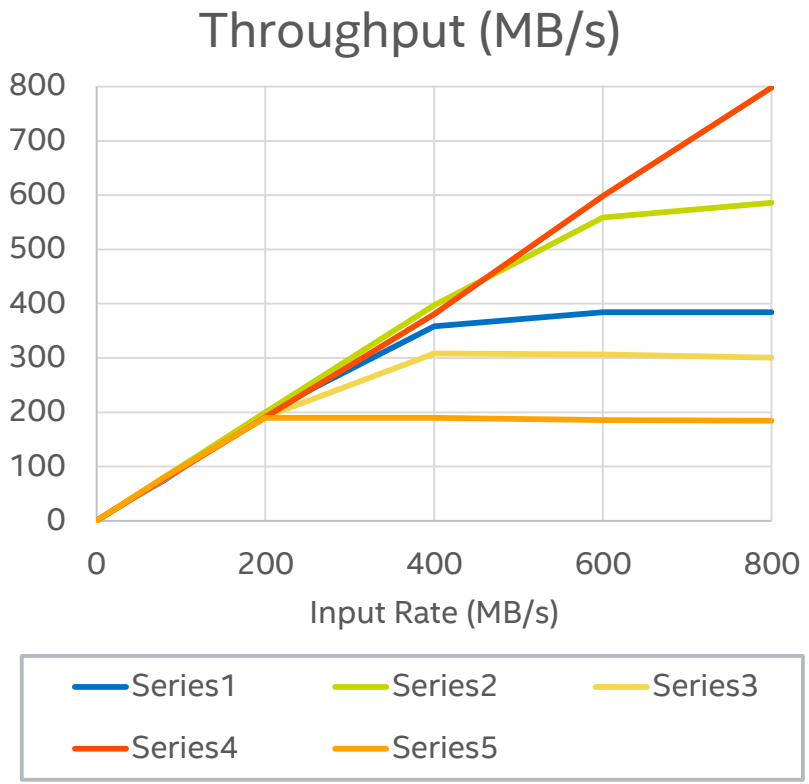
# Test Case: Repartition

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



# Result


P99 Latency (ms)
400000
350000
300000
250000
200000
150000
100000
50000
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3
Series4
Series5


Throughput (MB/s)
800
700
600
500
400
300
200
100
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3
Series4
Series5

# Observation

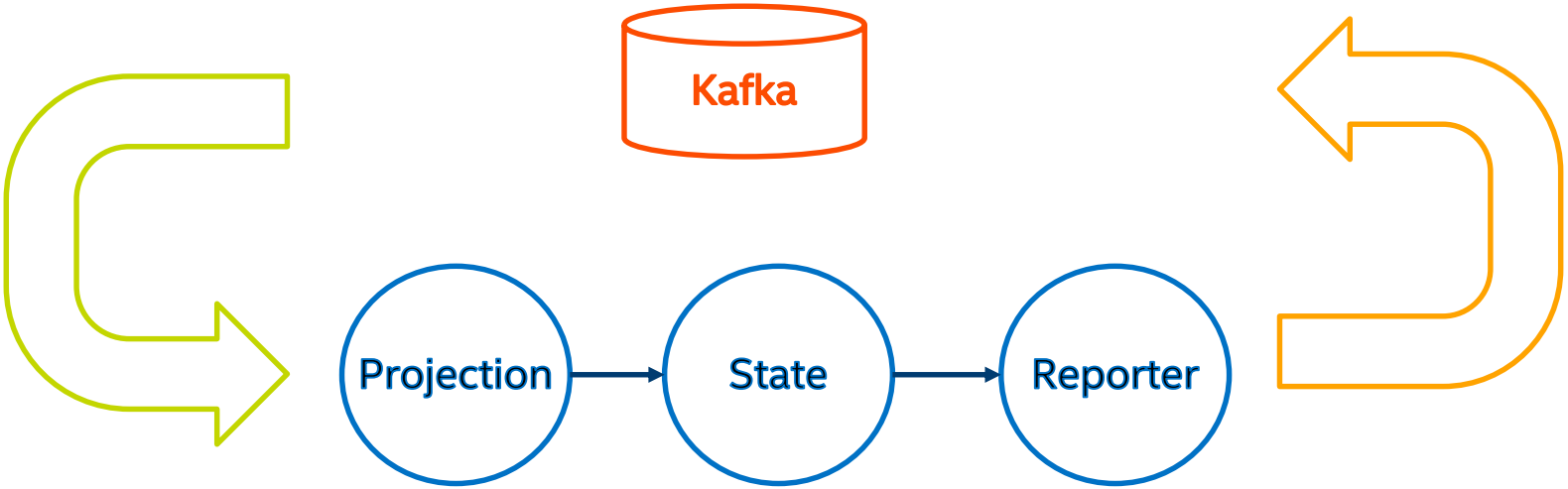
- Flink and Storm has close performance and are better choices to meet **sub-second SLA** requirement if no repartition happened.
- Spark Streaming need to schedule task with additional context. Under tiny batch interval case, the overhead could be dramatic worse compared to other frameworks.
- According 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?

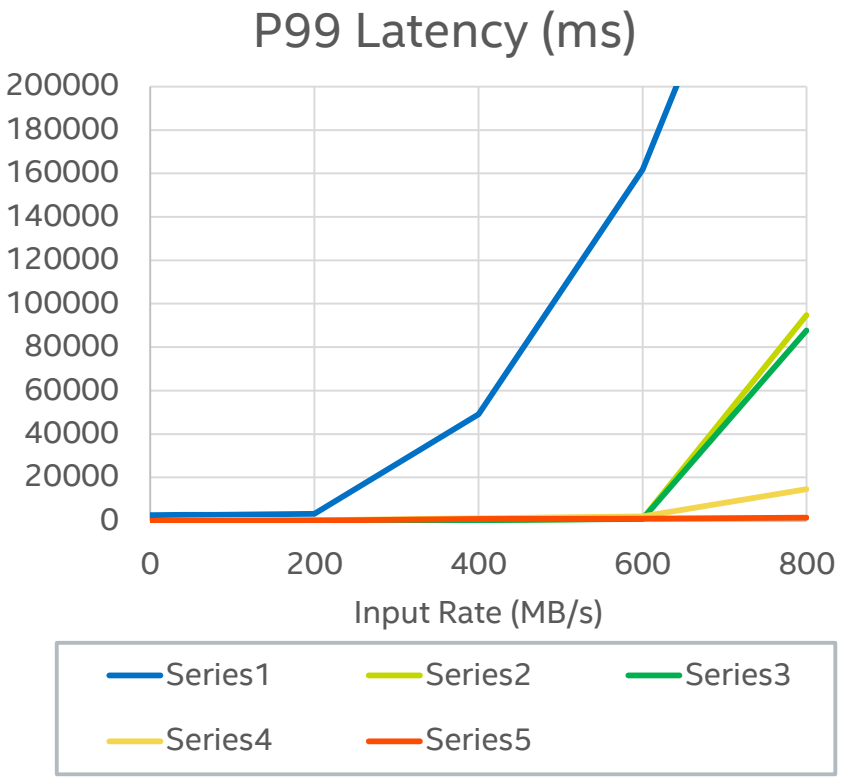
# Test Case: Stateful WordCount

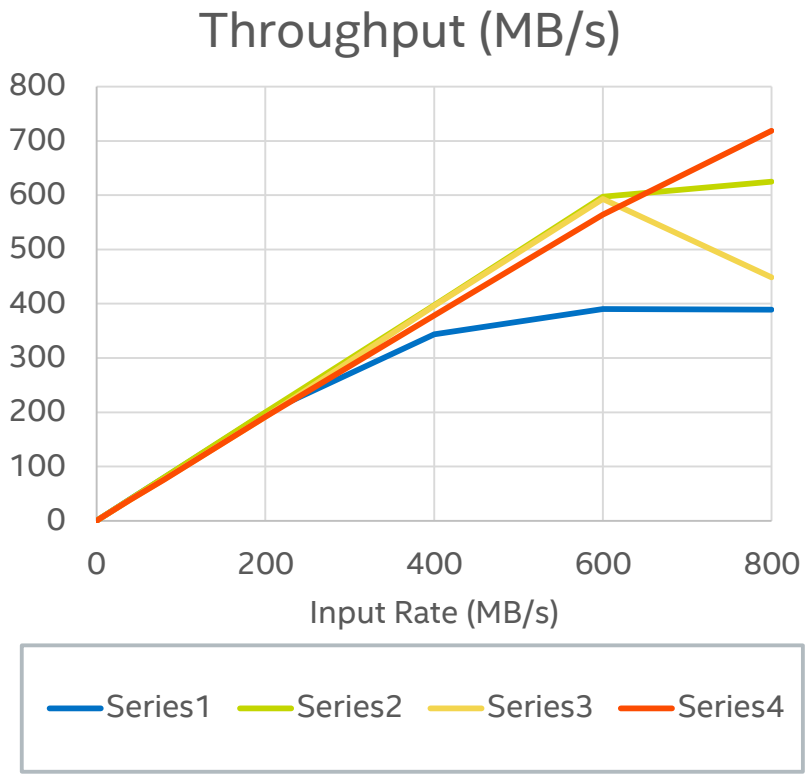
Native state operator is supported by all frameworks we evaluated

Stateful operator performance + Checkpoint/Acker cost



# Result


P99 Latency (ms)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3
Series4
Series5


Throughput (MB/s)
800
700
600
500
400
300
200
100
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3
Series4

# 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.

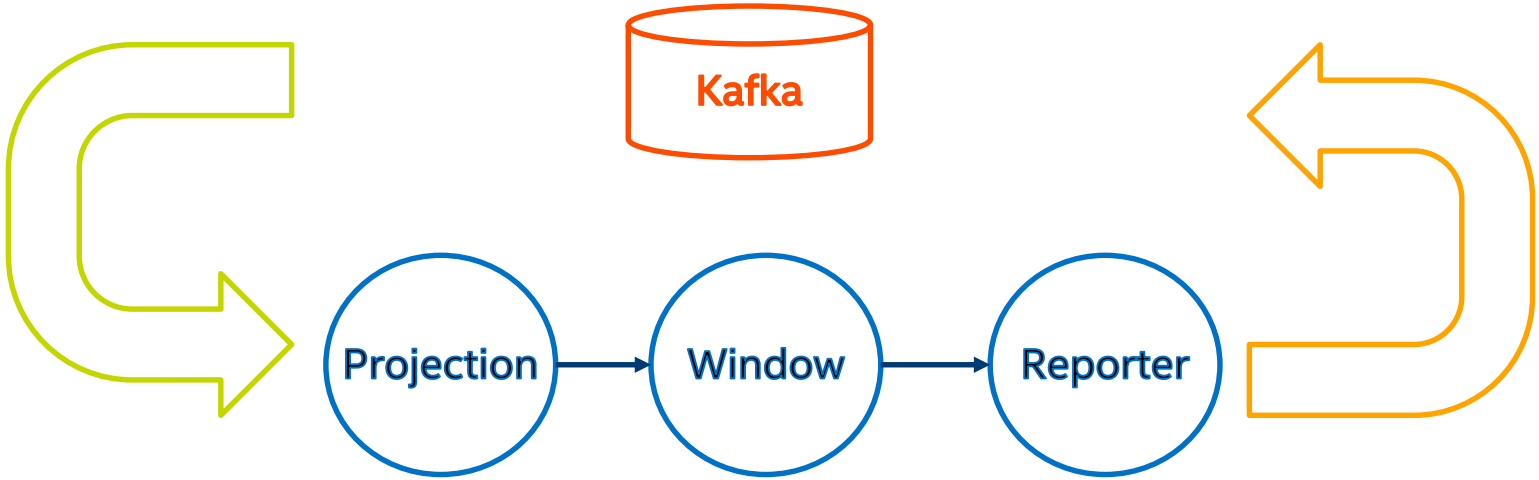
- Checkpoint mechanisms and storages play a critical role here.

# Q: How about Window Operation?

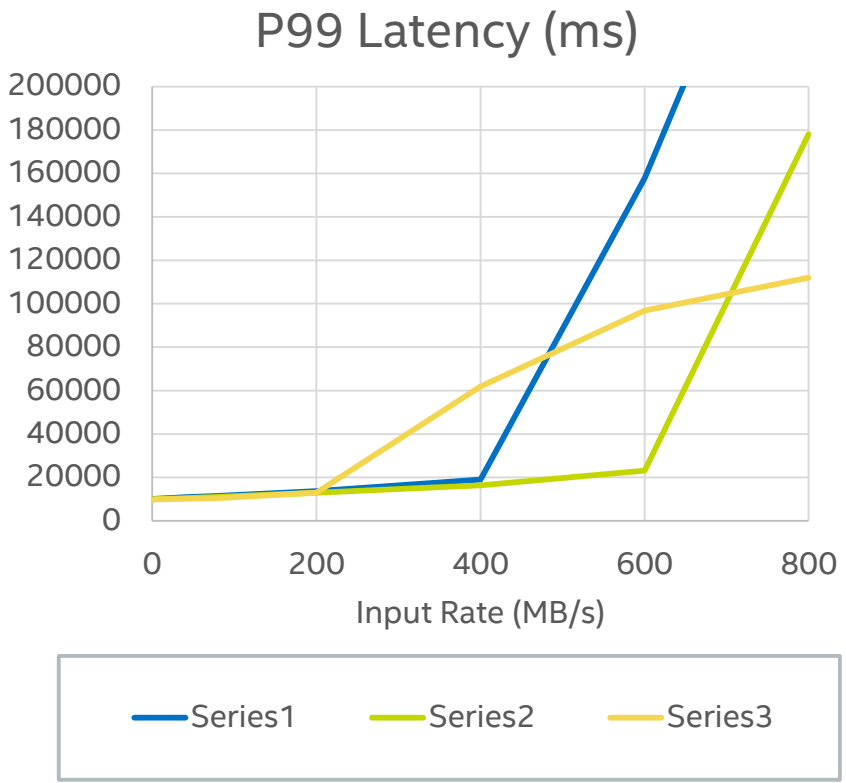
# Test Case: Window Based Aggregation

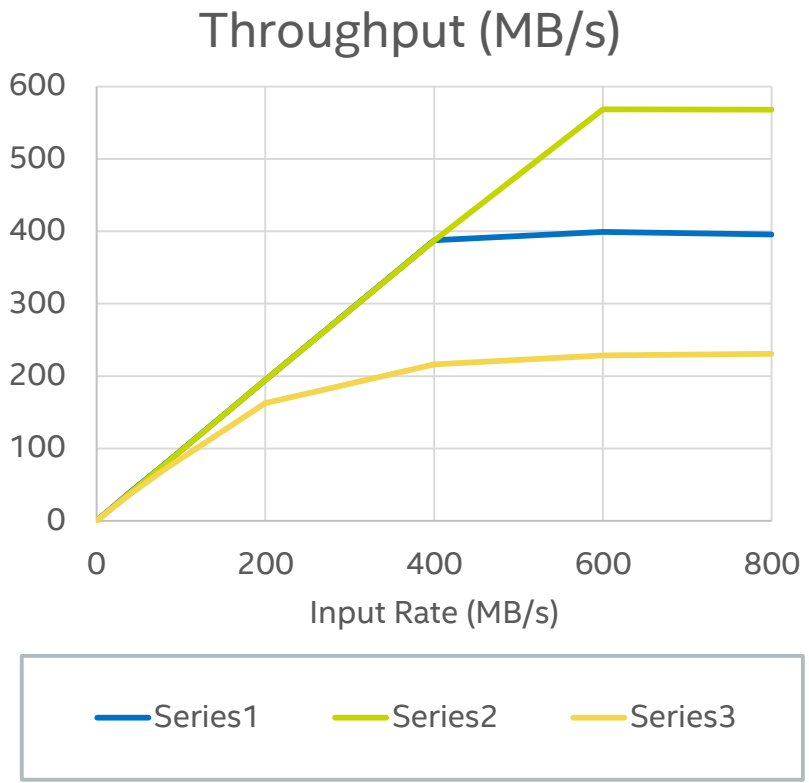
## This test case manages a 10-seconds sliding window.

*Latency = End2End – window.duration*



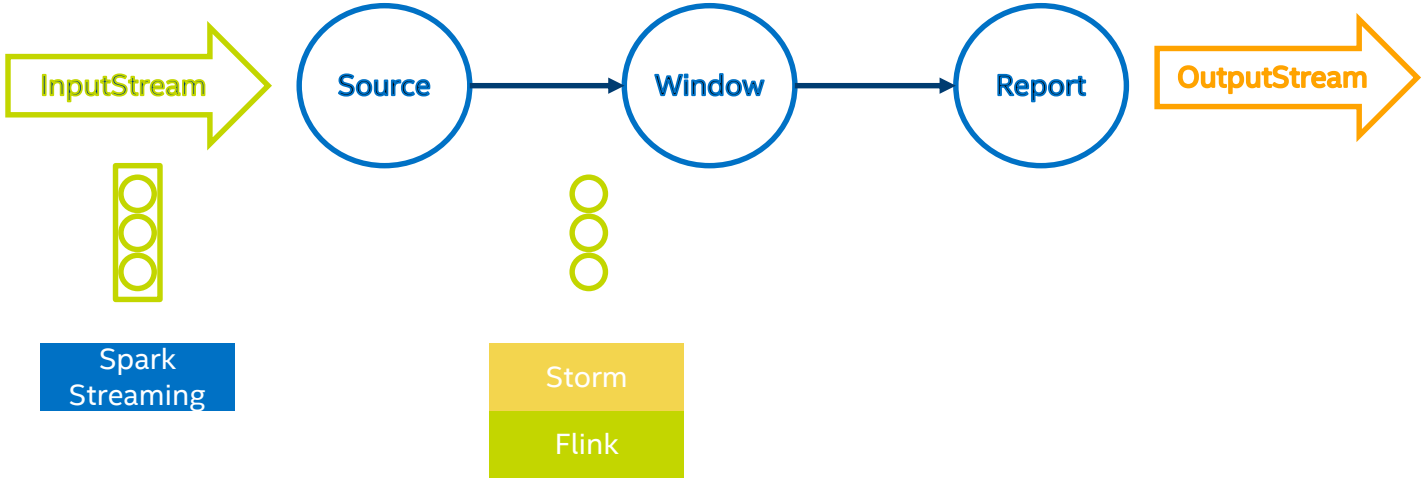
# Result


P99 Latency (ms)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3


Throughput (MB/s)
600
500
400
300
200
100
0
0
200
400
600
800
Input Rate (MB/s)
Series1
Series2
Series3

# Observation

## The native streaming execution model helps here



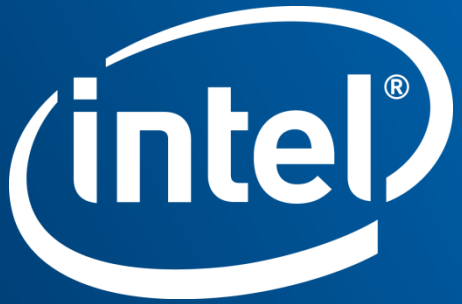
# So which streaming framework should I use?

# 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]


intel®

# Legal Disclaimer

No license (express or implied, by estoppel or otherwise) to any intellectual property rights is granted by this document.

Intel does not control or audit third-party benchmark data or the web sites referenced in this document. You should visit the referenced web site and confirm whether referenced data are accurate.

Intel and the Intel logo are trademarks of Intel Corporation in the U.S. and/or other countries.

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