SPARK SUMMIT 2017

Building Structured Streaming Connector for Continuous Applications

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Who Are We?

- Nan Zhu
  - Software Engineer@Azure HDInsight. Work on Spark Streaming/Structured Streaming service in Azure. Committee Member of XGBoost@DMLC and Apache MxNet (incubator). Spark Contributor.
- Arijit Tarafdar
  - Software Engineer@Azure HDInsight. Work on Spark/Spark Streaming on Azure. Previously worked with other distributed platforms like DryadLinq and MPI. Also worked on graph coloring algorithms which was contributed to ADOL-C (https://projects.coin-or.org/ADOL-C).

Agenda

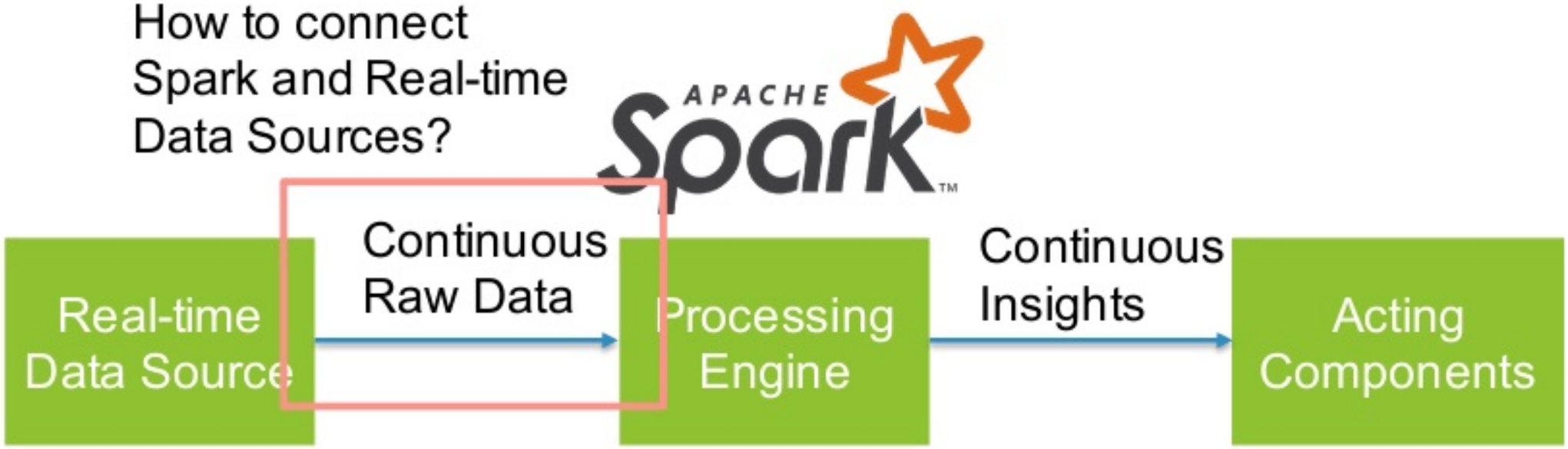
- What is/Why Continuous Application?
  - What are the challenges when we already have Spark in hand?
- Introduction of Azure Event Hubs and Structured Streaming
- Key Design Considerations in Building Structured Streaming Connector
- Test Structured Streaming Connector
- Summary

Continuous Application Architecture and Role of Spark Connectors (1)

- Not only size of data is increasing, but also the velocity of data
  - Sensors, IoT devices, social networks and online transactions are all generating data that needs to be monitored constantly and acted upon quickly.

Continuous Application Architecture and Role of Spark Connectors (2)

How to connect Spark and Real-time Data Sources?



Sensors, IoT Devices, Log Collectors, etc.

Spark Streaming, Structured Streaming

Block the fraud transactions, broadcast alerts, etc.

Building a Connector for *Real-time Data Source* and *Structured Streaming*

taking ***Azure Event Hubs*** as an example
(Comparing with Kafka Connector)

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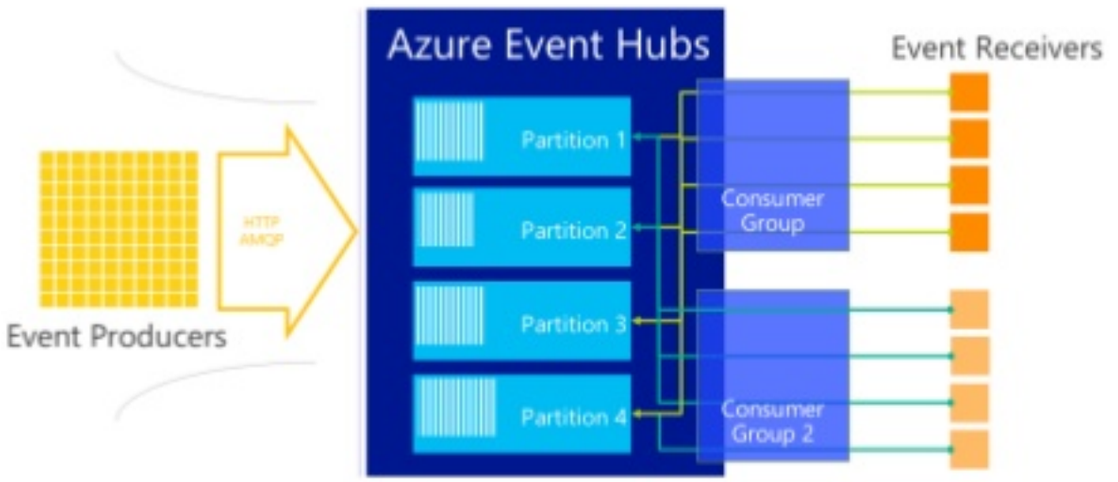
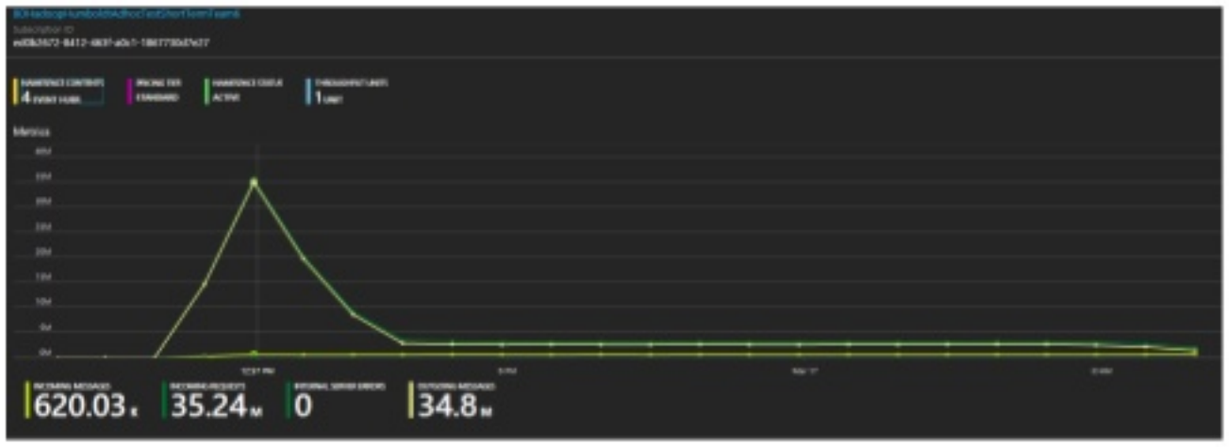
What is Azure Event Hubs?

Event Hubs conceptual architecture



Platform as a Service



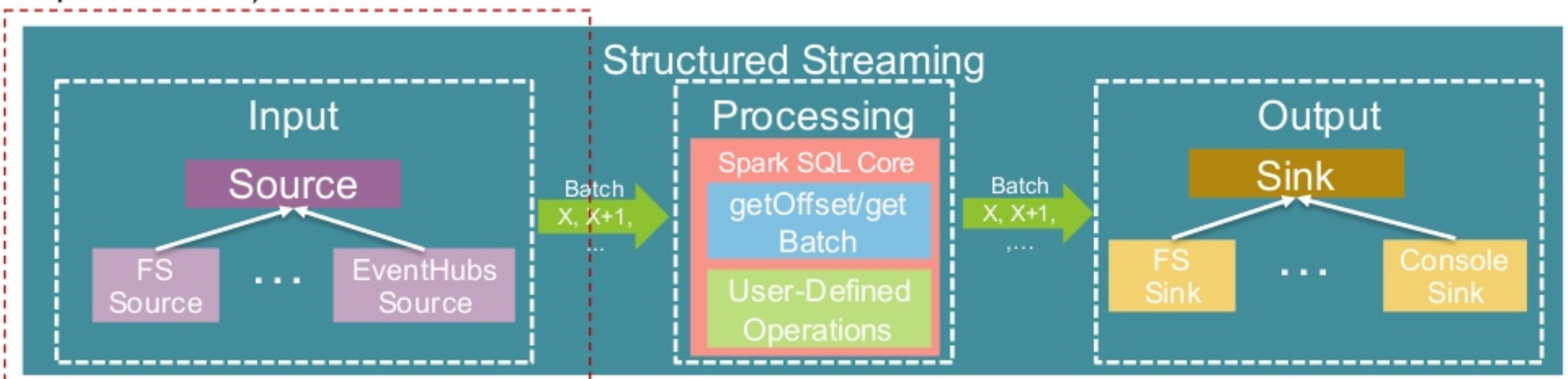
What is Structured Streaming?

- A relatively new component in Spark
  - Introduced in Spark 2.0
  - Keep evolving from Spark 2.0 – 2.2
- Streaming Analytic Engine for Structured Data
  - Sharing the same set of APIs with Spark SQL Batching Engine
  - Running computation over continuously arriving data and keep updating results

Abstraction in Structured Streaming

(Spark 2.1 Implementation)

Still follow Micro-Batch streaming model



Describe Data Source:

1. getOffset: offset of the last message to be processed in next batch
2. getBatch: build DataFrame for the next batch

Define Data Transforming Task with Spark SQL APIs (Structured Streaming Internal)

Describe Data Sink

1. addBatch: evaluate DataFrame and save data to target system

Implementation of a “Source”

	Description	Implementation
getOffset()	Return the last offset of next batch	***EndOffsetOfLastBatch*** “+” RateControlFunc(…)
getBatch(startOffset, endOffset)	Build DataFrame for next Batch	SS internal pases in startOffset and endOffset (results of getOffset)

1. How to represent ***Offset***
2. How to define ***Rate*** (To avoid tracking size of each message, rate is usually defined as # of messages)

Implementation of a “Source”

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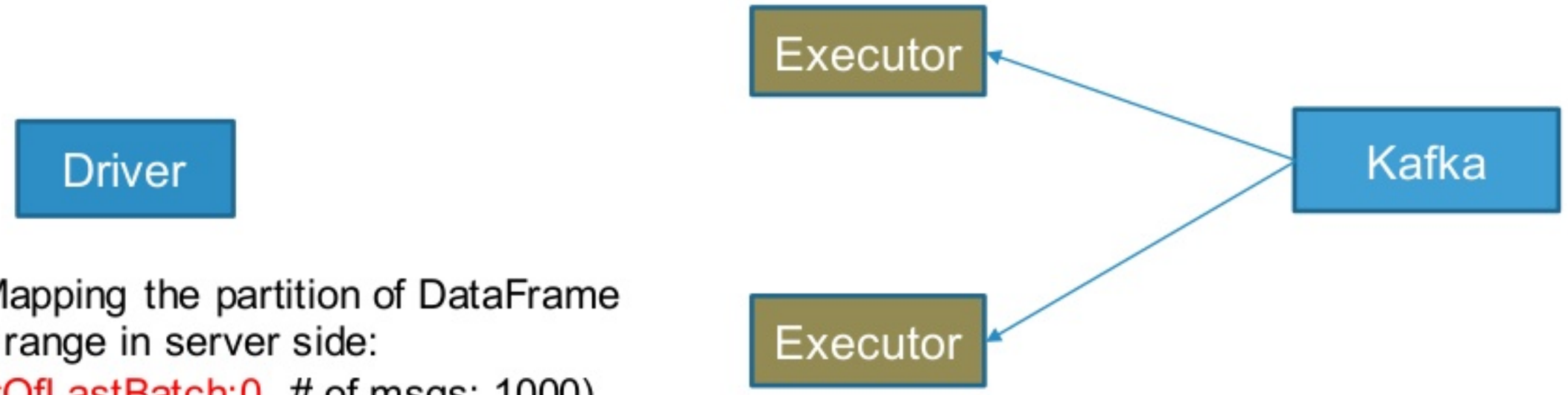
1. **How to represent *Offset***
2. How to define ***Rate*** (To avoid tracking size of each message, rate is usually defined as # of messages)

Various Forms of Message Offset

- Consecutive Numbers
  - 0, 1, 2, 3, …
  - Examples: Kafka, MQTT
  - Server-side index mapping an integer to the actual offset of the message in disk space
- Real offset
  - 0, sizeOf(msg0), sizeOf(msg0 + msg1), ...
  - Examples: Azure Event Hubs
  - No server-side index, passing offset as part of message to user

How it brings difference? - Kafka



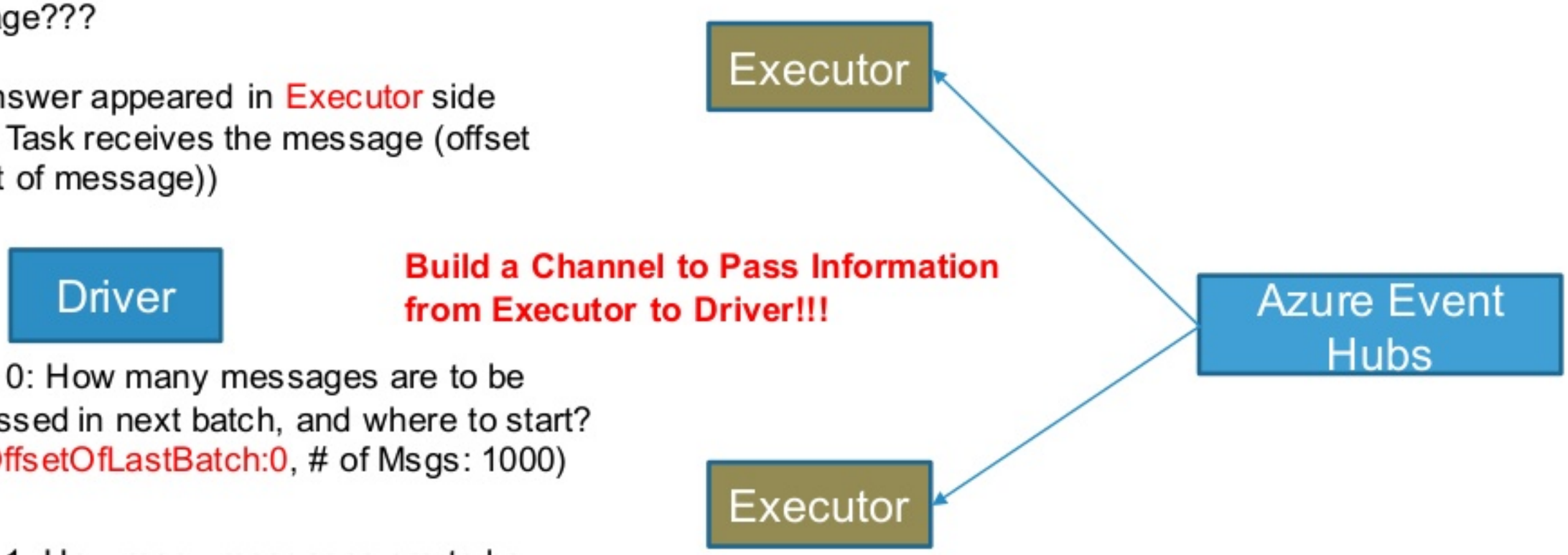
Batch 0: Mapping the partition of DataFrame to a offset range in server side:
(endOffsetOfLastBatch:0, # of msgs: 1000)

Batch 1: How many messages are to be processed in next batch, and where to start?
(endOffsetOfLastBatch: 999, # of msgs: 1000)

How it brings difference? - Event Hubs

What's the offset of 1000th message???

The answer appeared in Executor side (when Task receives the message (offset as part of message))



Batch 0: How many messages are to be processed in next batch, and where to start? (endOffsetOfLastBatch:0, # of Msgs: 1000)

Batch 1: How many messages are to be processed in next batch, and where to start? (endOffsetOfLastBatch:?, endOffset: 1000)

Difference of KafkaSource and EventHubsSource

kafka

Azure Event Hubs

getOffset	**EndOffsetOfLastBatch (known before the batch is finished)**	**Collect the ending offsets of last batch from executors** & Calculate targetOffset of next Batch
getBatch(startOffset, endOffset)	StartOffset: **EndOffsetOfLastBatch (passed-in value from SS internal)**	StartOffset: **the collected values**

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More details about two-layered index to work with OffsetSeqLog in SS for offine discussion or QA

How it brings difference? - Event Hubs

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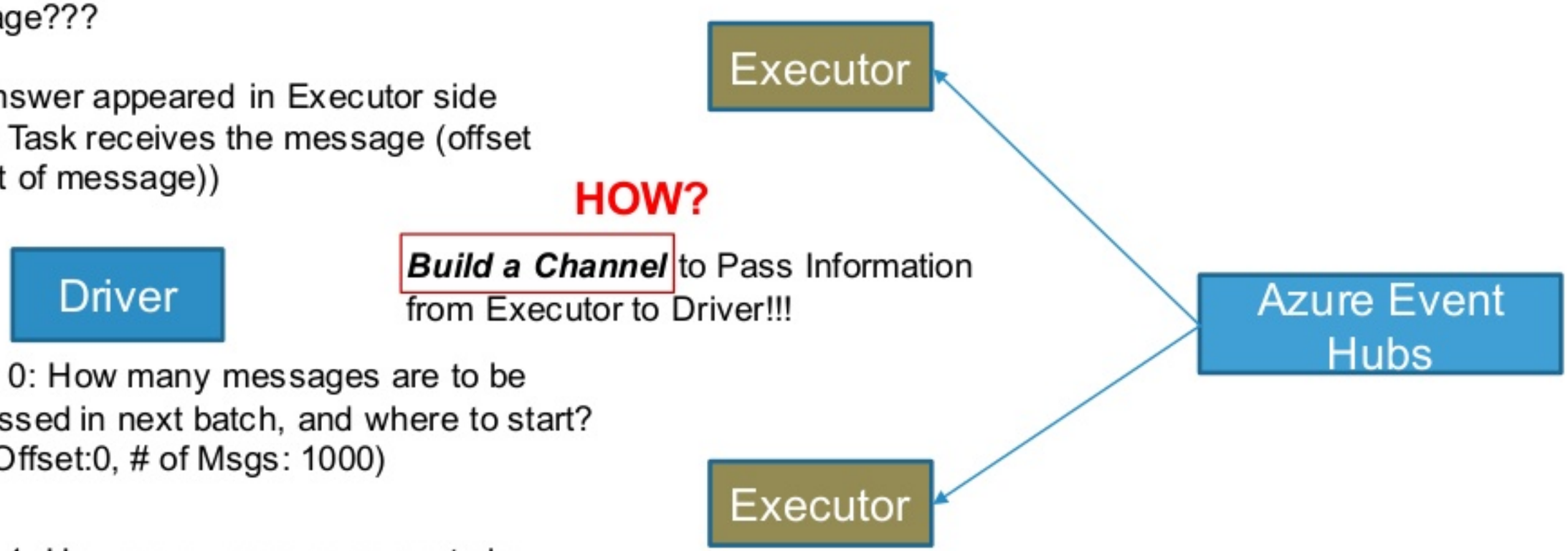
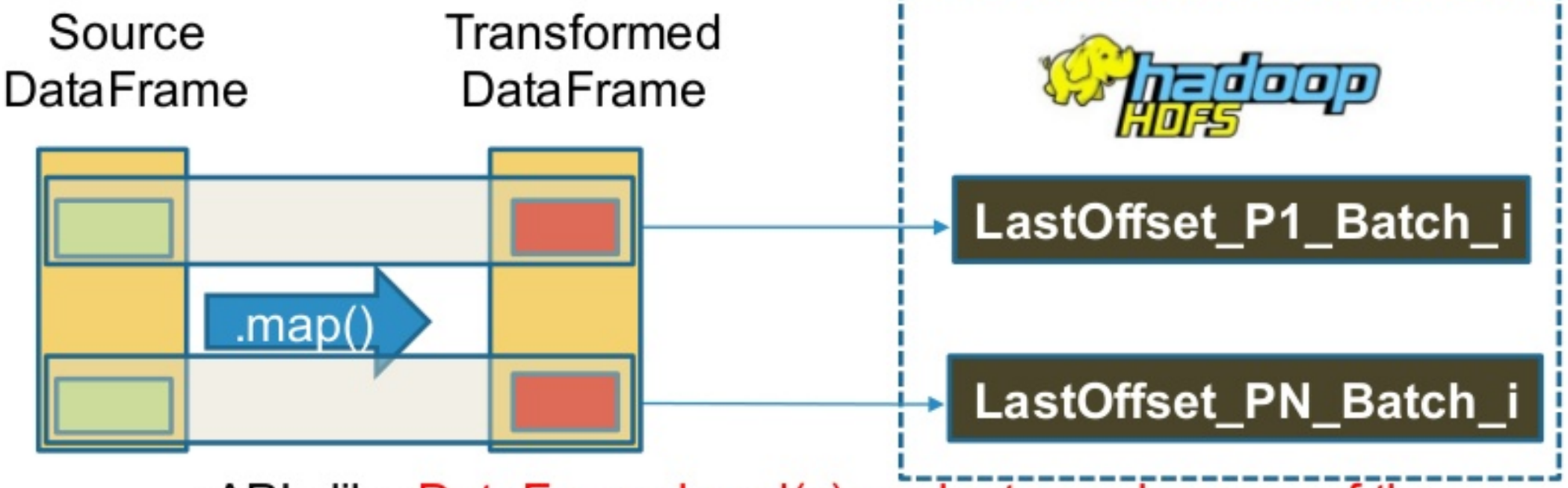


Batch 0: How many messages are to be processed in next batch, and where to start? (startOffset:0, # of Msgs: 1000)

Batch 1: How many messages are to be processed in next batch, and where to start? (startOffset:?, endOffset: 1000)

HDFS-Based Channel

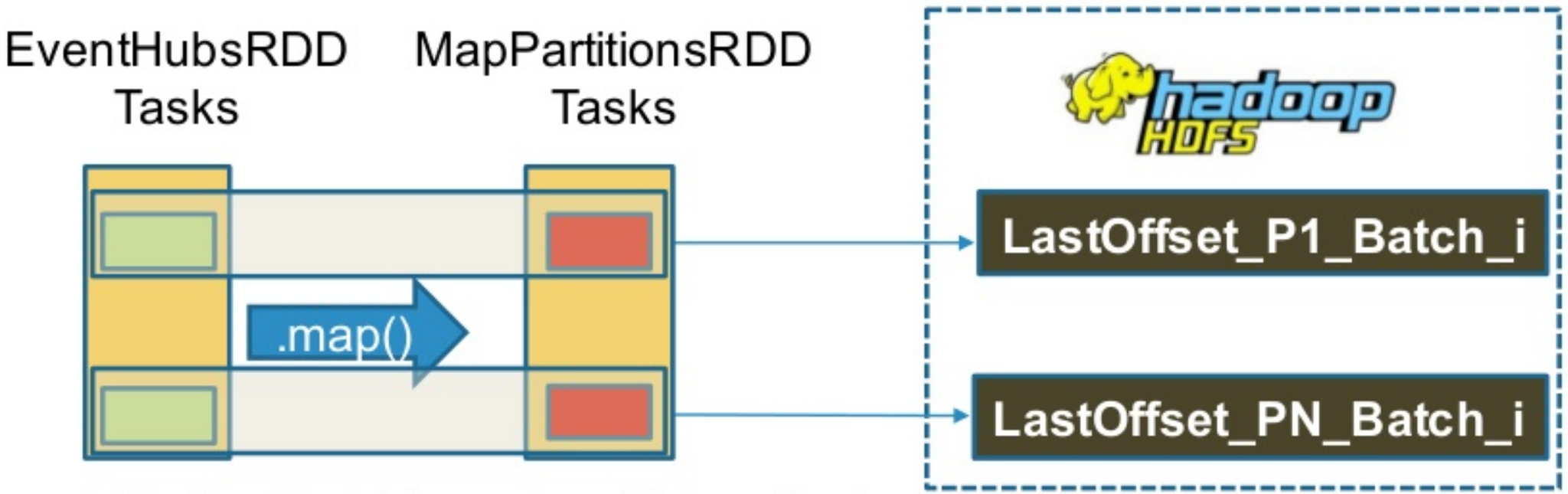
What's the next step??? Simply let Driver-side logic read the files? No!!!



- APIs like DataFrame.head(x) evaluates only some of the partitions…Batch 0 generate 3 files, and Batch 1 generates 5 files…
- You have to merge the latest files with the historical results and commit and then direct the driver-side logic to read

HDFS-Based Channel

- Ensure that all streams' offset are committed transactionally
- Discard the partially merged/committed results to rerun the batch



- APIs like DataFrame.head(x) evaluates only some of the partitions…Batch 0 generate 3 files, and Batch 1 generates 5 files…
- You have to merge the latest files with the historical results and ***commit***...

Takeaways (1)

- Data Source is not only designed for structured streaming
- Accommodate Connector Implementation with Data Source Design
- ***Message Addressing*** (Offset) in data source side is the ***Key Design Factor*** to be considered
  - Requirement of Additional Information Sharing Channel between Executors and Driver
    - Design to ensure the correctness of the channel

Structured Streaming Unit Testing Framework

- "Action" based structured streaming test flow – StartStream, AddData, CheckAnswer, AdvanceClock, StopStream, etc.
  - Kafka source unit tests use Kafka micro-service.
  - Unit test framework not usable as is.

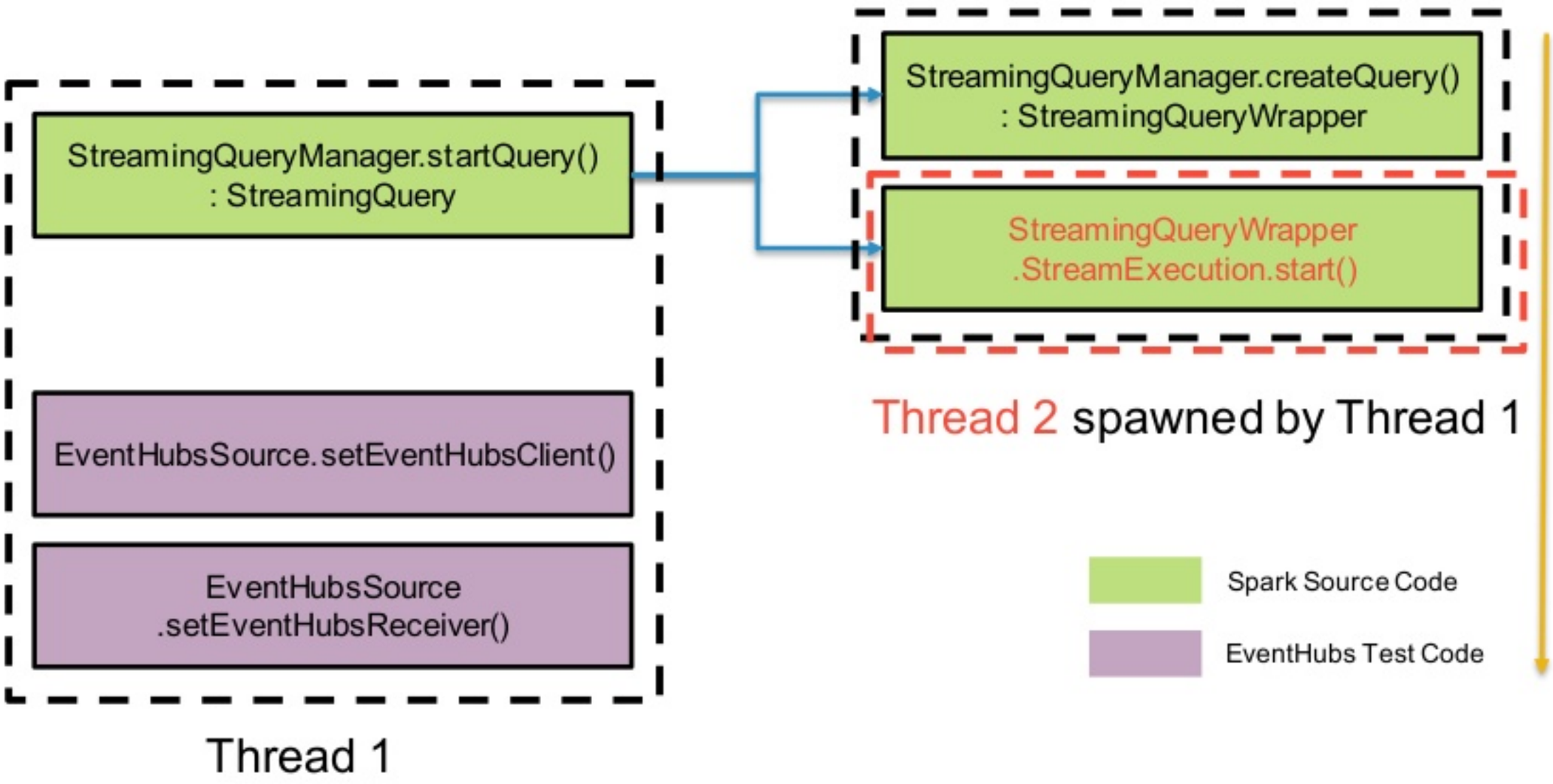
Unit Testing Event Hubs Source

- No Kafka type micro-service available for Event Hubs.
- Two simulated clients – Event Hubs AMQP and Event Hubs REST clients.
- Replace both clients before first call to the Event Hubs source.

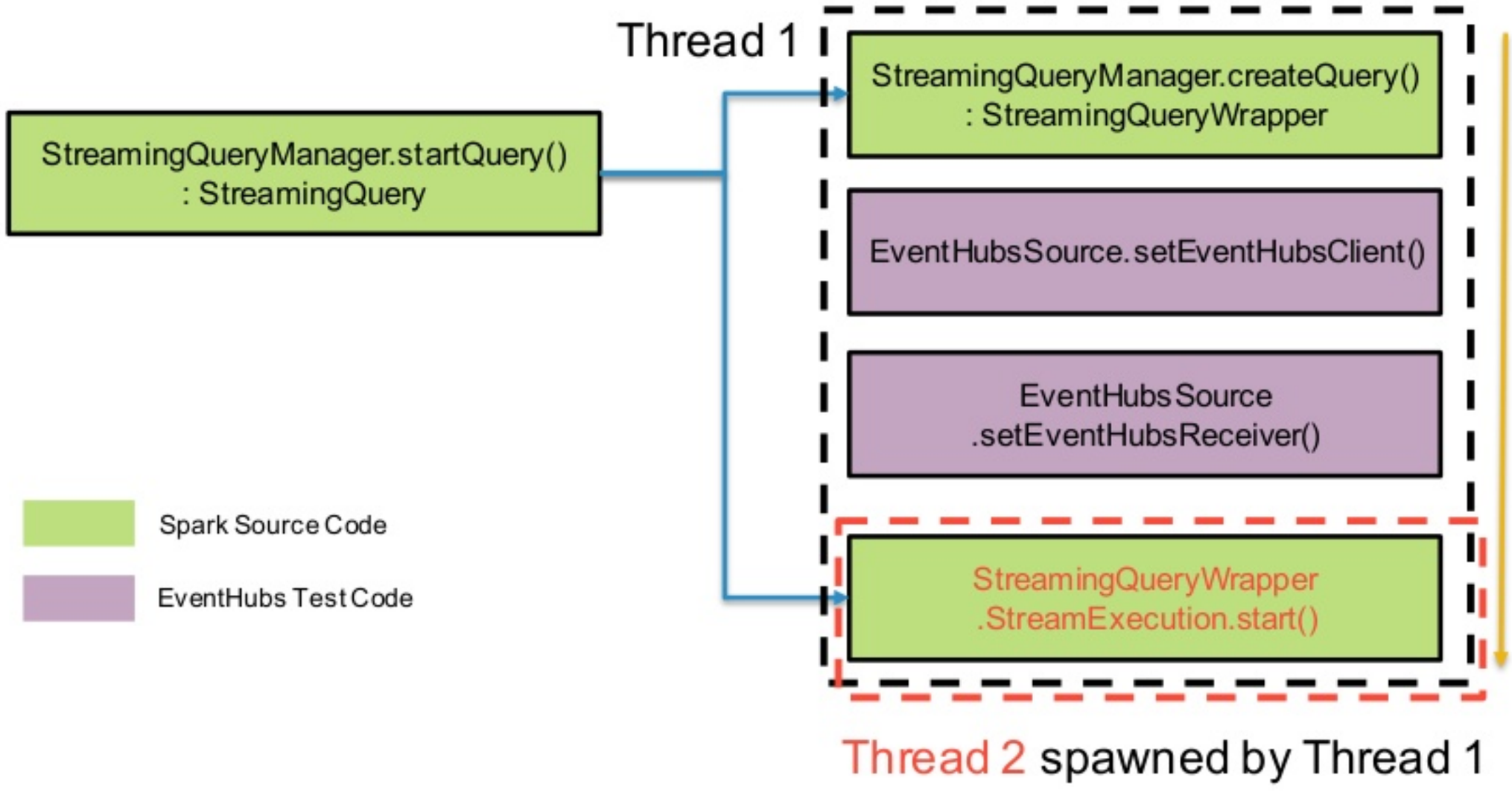
Issues With Unit Test Framework

- No separation between test setup and test execution.
- Unreliable update of the Event Hubs clients before asynchronous call to StreamingQueryManager.startQuery().
- Task serialization issue with AddData as part of StreamTest.

What Is The Asynchrony Problem?



One Way To Solve Asynchrony Problem



Solving Asynchrony in Client Substitutions (1)

- **Invoke createQuery**

```
val createQueryMethod =
sparkSession.streams.getClass.getDeclaredMethods.filter(m =>
              m.getName == "createQuery").head
createQueryMethod.setAccessible(true)
currentStream = createQueryMethod.invoke(…)
```

- **Set as active query**

```
val activeQueriesField =
sparkSession.streams.getClass.getDeclaredFields.filter(f => f.getName ==
"org$apache$spark$sql$streaming$StreamingQueryManager$$activeQueries").head
activeQueriesField.setAccessible(true)

val activeQueries = activeQueriesField.get(sparkSession.streams).
asInstanceOf[mutable.HashMap[UUID, StreamingQuery]]

activeQueries += currentStream.id -> currentStream
```

Solve Asynchrony in Client Substitutions (2)

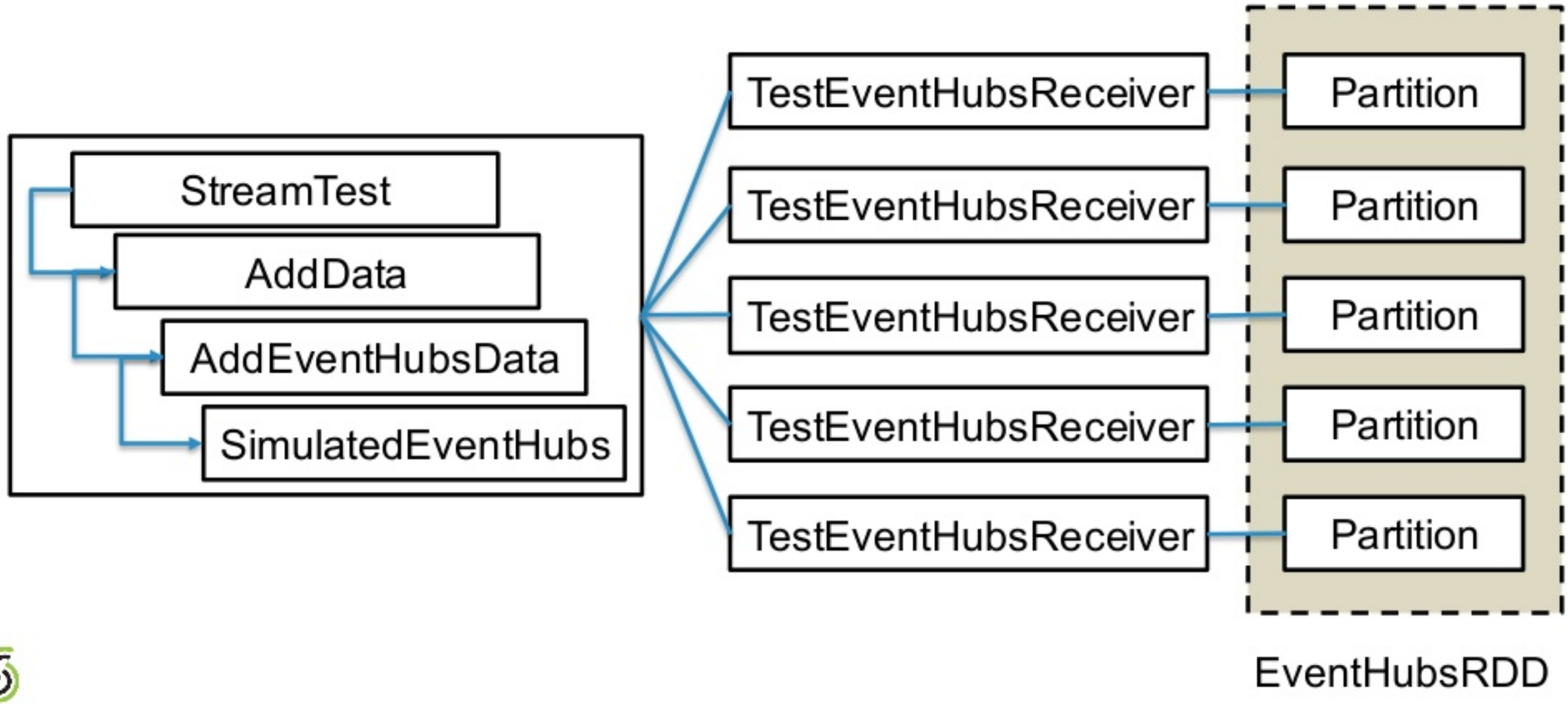
- **Substitute Event Hubs clients in source**

```
val eventHubsSource = sources.head
eventHubsSource.setEventHubClient(…)
eventHubsSource.setEventHubsReceiver(…)
```

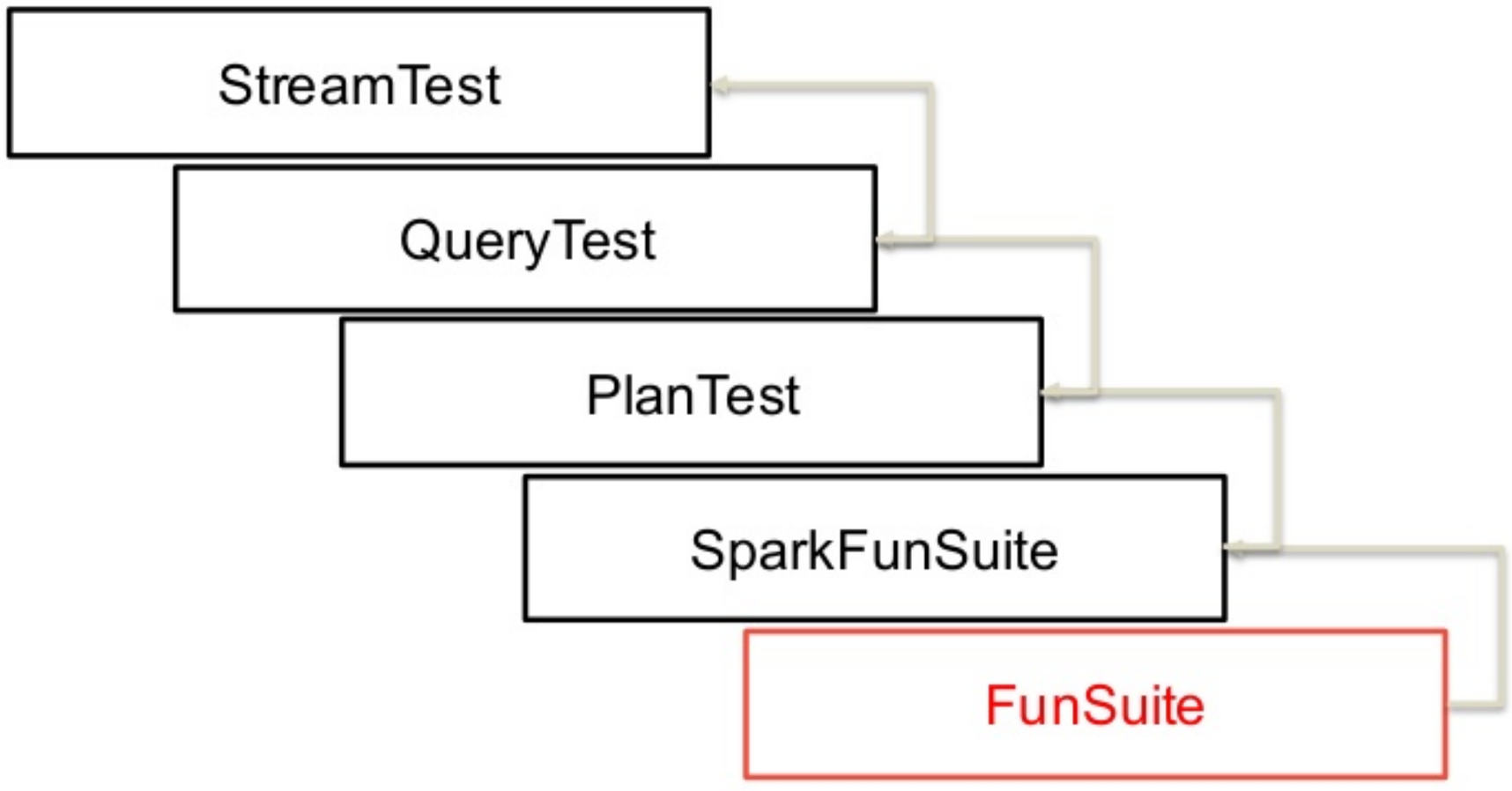
- **Start StreamExecution**

```
currentStream.start()
```

What Is The Task Serialization Issue?



What Is StreamTest Inheritance Model?



Solving Task Serialization Issue

- **Separate StreamTest into two traits:**

  – **EventHubsStreamTest**

```
trait EventHubsStreamTest extends QueryTest with BeforeAndAfter with
SharedSQLContext with Timeouts with Serializable { }
```

  – **EventHubsAddData**

```
trait EventHubsAddData extends StreamAction with Serializable {}
```

After All These Changes…

```
testStream(sourceQuery)(
      StartStream(…),
      CheckAnswer(…),
      AddEventHubsData(…),
      AdvanceManualClock(…),
      CheckAnswer(…),
      StopStream,
      StartStream(…),
      CheckAnswer(…),
      AddEventHubsData(…),
      AdvanceManualClock(…),
      AdvanceManualClock(…),
      CheckAnswer(…))
```

Summary/Takeaway(2)

- We have a production grade Spark Streaming connector for Structured Streaming for the widely used Event Hubs as streaming source on Azure (https://github.com/hdinsight/spark-eventhubs)

- Design, implementation and testing of Structured Streaming Connectors
  - Accommodate Connector Implementation with Data Source Design (message addressing)
  - Unit Test with Simulated Service
  - Asynchrony – the biggest enemy to a easy test
    - Clear Boundary between test setup and test execution

Contributing Back To Community

- Failed Recovery from checkpoint caused by the multi-threads issue in Spark Streaming scheduler https://issues.apache.org/jira/browse/SPARK-19280

  One Realistic Example of its Impact: You are potentially getting wrong data when you use Kafka and reduceByWindow and recover from a failure

- Data loss caused by improper post-batch-completed processing https://issues.apache.org/jira/browse/SPARK-18905
- Inconsistent Behavior of Spark Streaming Checkpoint https://issues.apache.org/jira/browse/SPARK-19233

Thank You!!!

https://github.com/hdinsight/spark-eventhubs

https://azure.microsoft.com/en-us/services/hdinsight/