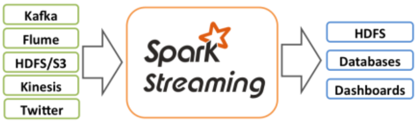
Big data: architectures and data analytics

Spark Streaming

What is Spark Streaming?

- Spark Streaming is a framework for large scale stream processing
  - Scales to 100s of nodes
  - Can achieve second scale latencies
  - Provides a simple **batch-like** API for implementing complex algorithm
  - Can absorb live data streams from Kafka, Flume, ZeroMQ, Twitter, …

What is Spark Streaming?



Motivation

- Many important applications must process large streams of live data and provide results in **near-real-time**
  - Social network trends
  - Website statistics
  - Intrusion detection systems
  - …

Requirements

- Scalable to large clusters
- Second-scale latencies
- Simple programming model
- Efficient fault-tolerance in stateful computations

Other Existing Streaming Systems

- Storm
  - Replays record if not processed by a node
  - Processes each record at least once
  - May update mutable state twice
  - Mutable state can be lost due to failure
- Storm Trident
  - Uses transactions to update state
  - Processes each record exactly once
  - Per state transaction updates slow

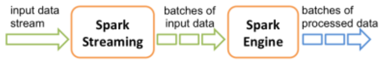
Spark Streaming

Discretized Stream Processing

- Spark streaming runs a streaming computation as a series of very small, deterministic batch jobs
- It splits each input stream in "portions" and processes one portion at a time (in the incoming order)
  - The same computation is applied on each portion of the stream
  - Each portion is called **batch**

Discretized Stream Processing

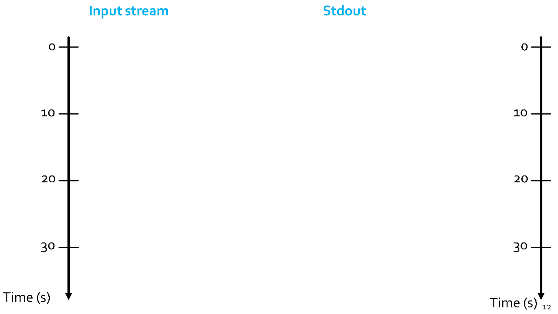
- Spark streaming
  - Splits the live stream into batches of X seconds
  - Treats each batch of data as RDDs and processes them using RDD operations
  - Finally, the processed results of the RDD operations are returned in batches



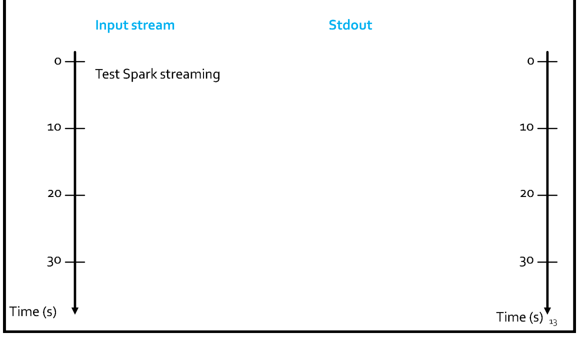
Word count – Spark Streaming version

- Problem specification
  - Input: a stream of sentences
  - Split the input stream in batches of 10 seconds each and print on the standard output, for each batch, the occurrences of each word appearing in the batch
    - i.e., execute the word count problem for each batch of 10 seconds

Word count – Spark Streaming version



Word count – Spark Streaming version

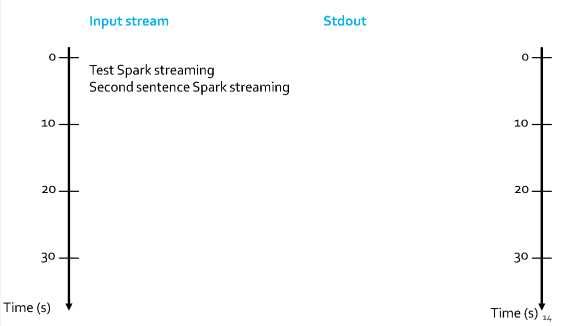


Input stream

Stdout

Test Spark streaming

Word count – Spark Streaming version

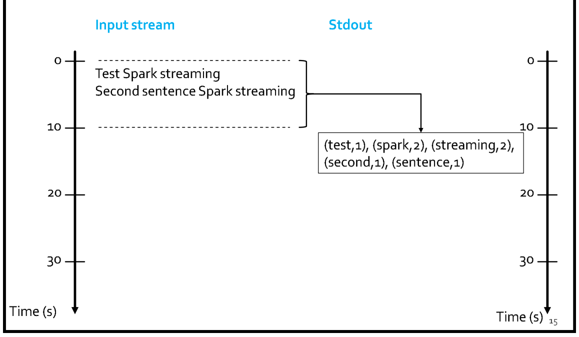


Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

Word count – Spark Streaming version



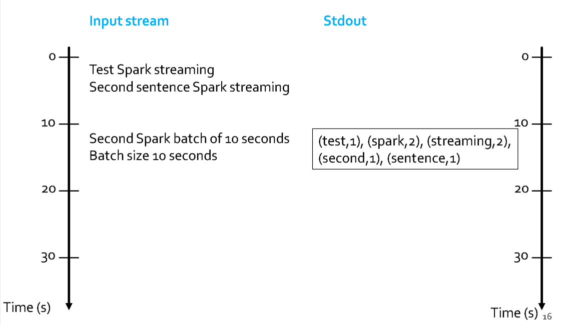
Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

(test,1), (spark,2), (streaming,2), (second,1), (sentence,1)

Word count – Spark Streaming version



Input stream

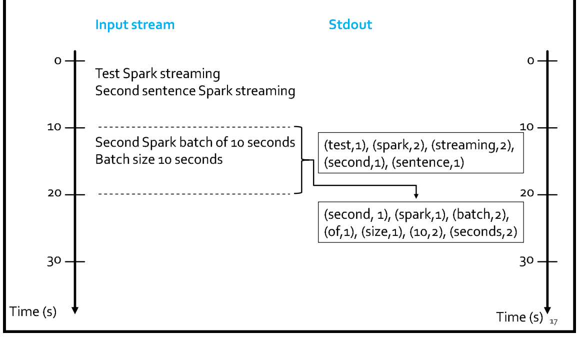
Stdout

Test Spark streaming
Second sentence Spark streaming

Second Spark batch of 10 seconds
Batch size 10 seconds

(test,1), (spark,2), (streaming,2), (second,1), (sentence,1)

Word count – Spark Streaming version



Input stream

Stdout

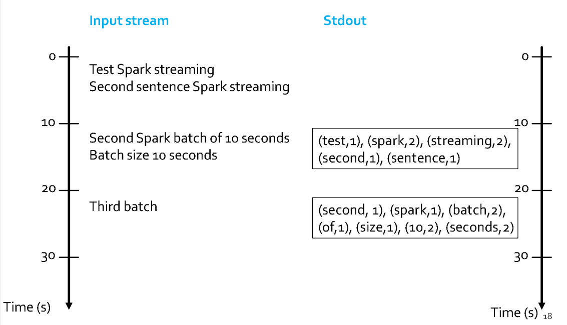
Test Spark streaming
Second sentence Spark streaming

Second Spark batch of 10 seconds
Batch size 10 seconds

(test,1), (spark,2), (streaming,2), (second,1), (sentence,1)

(second, 1), (spark,1), (batch,2), (of,1), (size,1), (10,2), (seconds,2)

Word count – Spark Streaming version



Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

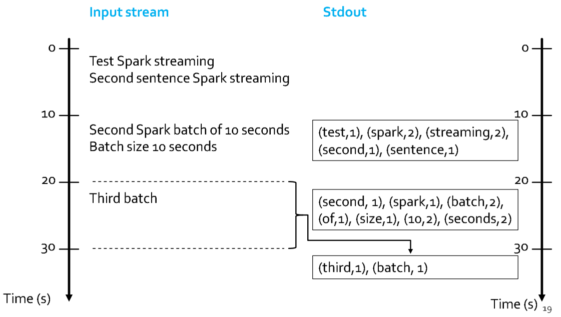
Second Spark batch of 10 seconds
Batch size 10 seconds

Third batch

(test,1), (spark,2), (streaming,2), (second,1), (sentence,1)

(second, 1), (spark,1), (batch,2), (of,1), (size,1), (10,2), (seconds,2)

Word count – Spark Streaming version



Test Spark streaming
Second sentence Spark streaming

Second Spark batch of 10 seconds
Batch size 10 seconds

Third batch

(test,1), (spark,2), (streaming,2), (second,1), (sentence,1)

(second, 1), (spark,1), (batch,2), (of,1), (size,1), (10,2), (seconds,2)

(third,1), (batch, 1)

Key concepts

- **DStream**
  - Sequence of RDDs representing a discretized version of the input stream of data
    - Twitter, HDFS, Kafka, Flume, ZeroMQ, Akka Actor, TCP sockets
  - One RDD for each batch of the input stream
- **PairDStream**
  - Sequence of PairRDDs representing a stream of pairs

Key concepts

- **Transformations**
  - Modify data from one DStream to another
  - Standard RDD operations
    - map, countByValue, reduce, join, …
  - Window and Stateful operations
    - window, countByValueAndWindow, …
- **Output Operations (actions)**
  - Send data to external entity
    - saveAsHadoopFiles, saveAsTextFile, …

Fault-tolerance

- DStreams remember the sequence of operations that created them from the original fault-tolerant input data
- Batches of input data are replicated in memory of multiple worker nodes, therefore fault-tolerant
- Data lost due to worker failure, can be recomputed from input data

Basic Structure of a Spark Streaming Program (1)

- Define a Spark Streaming Context object
  - Define the size of the batches (in seconds) associated with the Streaming context
- Specify the input stream and define a DStream based on it
- Specify the operations to execute for each batch of data
  - Use transformations and actions similar to the ones available for "standard" RDDs

Basic Structure of a Spark Streaming Program (2)

- Invoke the start method
  - To start processing the input stream
- Wait until the application is killed or the timeout specified in the application expires
  - If the timeout is not set and the application is not killed **the application will run forever**

Spark Streaming Context

- The Spark Streaming Context is defined by using the **JavaStreamingContext(SparkConf sparkC, Duration batchDuration)** constructor of **JavaStreamingContext**
- The **batchDuration** parameter specifies the "size" of the batches
- Example

```
JavaStreamingContext jssc =
new JavaStreamingContext(conf,Durations.seconds(10));
```

  - The input streams associated with this context will be split in batches of 10 seconds

Input Streams

- The input Streams can be generate from different sources
  - TCP socket, Kafka, Flume, Kinesis, Twitter
  - Also an HDFS folder can be used as "input stream"

Input Streams: TPC socket

- A DStream can be associated with the content emitted by a TCP socket
- **socketTextStream(String hostname, int port_number)** is used to create a DStream based on the textual content emitted by a TPC socket
- Example

```
JavaReceiverInputDStream<String> lines =
   jssc.socketTextStream("localhost", 9999);
```

  - "Store" the content emitted by localhost:9999 in the lines DStream

Input Streams: (HDFS) folder

- A DStream can be associated with the content of an input (HDFS) folder
  - Every time a new file is inserted in the folder, the content of the file is "stored" in the associated DStream and processed
- **textFileStream(String folder)** is used to create a DStream based on the content of the input folder

Input Streams: (HDFS) folder

- Example

```
JavaDStream<String> lines =
   jssc.textFileStream(inputFolder);
```

  - "Store" the content of the files inserted in the input folder in the lines Dstream
  - Every time new files are inserted in the folder their content is "stored" in the current "batch" of the stream

Input Streams: other sources

- Usually DStream objects are defined on top of streams emitted by specific applications that emit real-time streaming data
  - E.g., Apache Kafka, Apache Flume, Kinesis, Twitter
- You can also write your own applications for generating streams of data
  - However, Kafka, Flume and similar tools are usually a more reliable and effective solutions for generating streaming data

Transformations

- Analogously to standard RDDs, also DStream are characterized by a set of transformations
  - When applied to DStream objects, transformations return a new DStream Object
  - The transformation is applied on one batch (RDD) of the input DStream at a time and returns a batch (RDD) of the new DStream
    - i.e., each batch (RDD) of the input DStream is associated with exactly one batch (RDD) of the returned DStream
- Many of the available transformations are the same transformations available for standard RDDs

Basic Transformations on DStreams

- map(func)
  - Returns a new DStream by passing each element of the source DStream through a function func
- flatMap(func)
  - Each input item can be mapped to 0 or more output items. Returns a new DStream
- filter(func)
  - Returns a new DStream by selecting only the records of the source DStream on which func returns true

Basic Transformations on DStreams

- reduce(func)
  - Returns a new DStream of single-element RDDs by aggregating the elements in each RDD of the source DStream using a function func. The function should be associative so that it can be computed in parallel
- reduceByKey(func)
  - When called on a PairDStream of (K, V) pairs, returns a new PairDStream of (K, V) pairs where the values for each key are aggregated using the given reduce function
- countByValue()
  - When called on a DStream of elements of type K, returns a new PairDStream of (K, Long) pairs where the value of each key is its frequency in each batch of the source DStream

Basic Transformations on DStreams

- count()
  - Returns a new DStream of single-element RDDs by counting the number of elements in each batch (RDD) of the source Dstream
    - i.e., it counts the number of elements in each input batch (RDD)
- union(otherStream)
  - Returns a new DStream that contains the union of the elements in the source DStream and otherDStream.
- join(otherStream)
  - When called on two PairDStreams of (K, V) and (K, W) pairs, return a new PairDStream of (K, (V, W)) pairs with all pairs of elements for each key.

Basic Transformations on DStreams

- cogroup(otherStream)
  - When called on a PairDStream of (K, V) and (K, W) pairs, return a new DStream of (K, Seq[V], Seq[W]) tuples

Advanced transformation on DStreams

- transform(func)
  - It is a specific transformation of DStreams
  - It returns a new DStream by applying an RDD-to-RDD function to every RDD of the source Dstream
    - This can be used to do arbitrary RDD operations on the DStream
- For example, the functionality of joining every batch in a data stream with another dataset (a standard RDD) is not directly exposed in the DStream API
  - However, you can use transform to do that

Advanced transformation on DStreams

- transformToPair(func)
  - It is a specific transformation of PairDStreams
  - It returns a new PairDStream by applying a PairRDD-to-RPairDD function to every PairRDD of the source PairDStream
  - It must be used instead of transform when working with PairDStreams/PairRDDs

Basic Output Operations (actions) on DStreams

- print()
  - Prints the first 10 elements of every batch of data in a DStream on the driver node running the streaming application
    - Useful for development and debugging

Basic Output Operations (actions) on DStreams

- saveAsTextFiles(prefix, [suffix])
  - Saves the content of the DStream on which it is invoked as text files
    - One folder for each batch
    - The folder name at each batch interval is generated based on prefix, time of the batch (and suffix): "prefix-TIME_IN_MS[.suffix]"
  - It is not directly available for JavaDStream objects
    - A Scala DStream object must be created from a JavaDStream by invoking the dstream() method.
    - saveAsTextFiles can be invoked on the returned Scala Dstream
  - Example
    - Counts.dstream().saveAsTextFiles(outputPathPrefix, "");

Start and run the computation

- The start() method of the JavaSparkStreamingContext class is used to start the application on the input stream(s)
- The awaitTerminationOrTimeout(long millisecons) method is used to specify how long the application will run
- The awaitTerminationOrTimeout() method is used to run the application forever
  - Until the application is explicitly killed

Example: Word count – Spark Streaming version

- Problem specification
  - Input: a stream of sentences retrieved from localhost:9999
  - Split the input stream in batches of 10 seconds each and print on the standard output, for each batch, the occurrences of each word appearing in the batch
    - i.e., execute the word count problem for each batch of 10 seconds
  - Store the results also in an HDFS folder

Example: Word count – Spark Streaming version

```
package it.polito.bigdata.spark.StreamingWordCount;

import .....

public class SparkDriver {

    public static void main(String[] args) {

        String outputPathPrefix;

        outputPathPrefix=args[0];

        // Create a configuration object and set the name of the application
        SparkConf conf=new SparkConf().setAppName("Spark Streaming word count");

        // Create a Spark Streaming Context object
        JavaStreamingContext jssc = new JavaStreamingContext(conf, Durations.seconds(10));


        // Create a (Receiver) DStream that will connect to localhost:9999
        JavaReceiverInputDStream<String> lines = jssc.socketTextStream("localhost", 9999);
```

Example: Word count – Spark Streaming version

```
// Apply the "standard" trasformations to perform the word count task
// However, the "returned" RDDs are DStream/PairDStream RDDs
JavaDStream<String> words = lines.flatMap(new Split());

JavaPairDStream<String, Integer> wordsOnes = words.mapToPair(new WordOne());

JavaPairDStream<String, Integer> wordsCounts = wordsOnes.reduceByKey(new Sum());

// Print on the stdout 10 pairs of the wordsCounts PairDStream
wordsCounts.print();
```

Example: Word count – Spark Streaming version

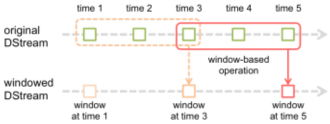
```
        // Store the result in the output folders with prefix outputPathPrefix
        wordsCounts.dstream().saveAsTextFiles(outputPathPrefix, "");

        // Start the computation
        jssc.start();

        // Await until termination or timeout
        jssc.awaitTerminationOrTimeout(120000);

        jssc.close();
    }
}
```

Window operation

- Spark Streaming also provides windowed computations
  - It allows you to apply transformations over a sliding window of data
    - Each window contains a set of batches of the input stream
    - Windows can be overlapped
      - i.e., the same batch can be included in many consecutive windows

Window operation

- Graphical example



- Every time the window slides over a source DStream, the source RDDs that fall within the window are combined and operated upon to produce the RDDs of the windowed DStream

Window operation

- In the example, the operation
  - is applied over the last 3 time units of data (i.e., the last 3 batches of the input DStream)
    - Each window contains the data of 3 batches
  - and slides by 2 time units

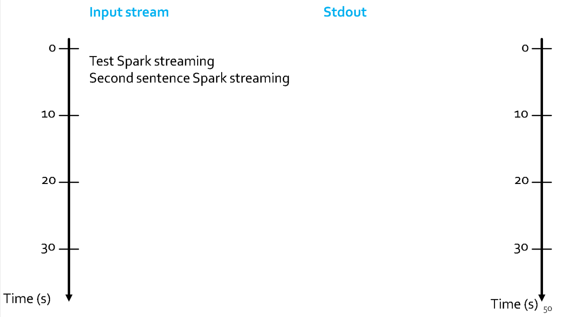
Window operation: parameters

- Any window operation needs to specify two parameters:
  - Window length
    - The duration of the window (3 in the example)
  - Sliding interval
    - The interval at which the window operation is performed (2 in the example)
- These two parameters must be multiples of the batch interval of the source DStream

Word count and Window

- Problem specification
  - Input: a stream of sentences
  - Split the input stream in batches of 10 seconds
  - Define widows with the following characteristics
    - Window length: 20 seconds (i.e., 2 batches)
    - Sliding interval: 10 seconds (i.e., 1 batch)
  - Print on the standard output, for each window, the occurrences of each word appearing in the window
    - i.e., execute the word count problem for each window

Word count and Window

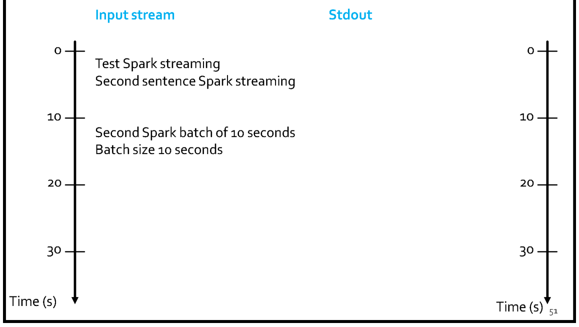


Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

Word count and Window



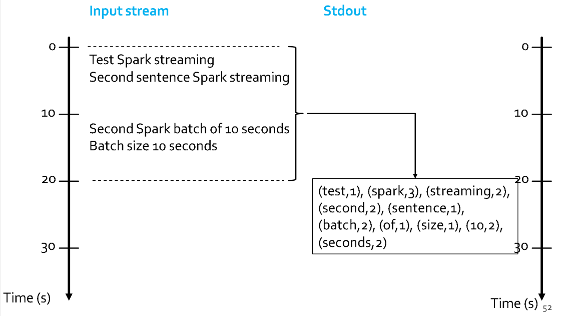
Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

Second Spark batch of 10 seconds
Batch size 10 seconds

Word count and Window



Input stream

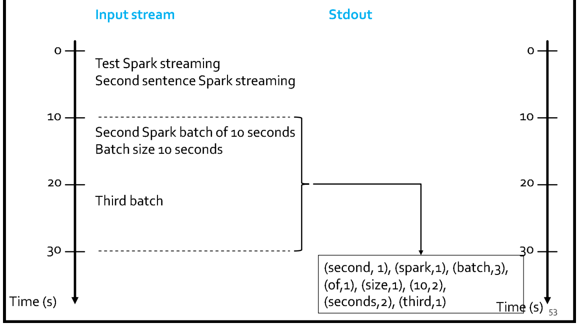
Stdout

Test Spark streaming
Second sentence Spark streaming

Second Spark batch of 10 seconds
Batch size 10 seconds

(test,1), (spark,3), (streaming,2), (second,2), (sentence,1), (batch,2), (of,1), (size,1), (10,2), (seconds,2)

Word count and Window



Input stream

Stdout

Test Spark streaming
Second sentence Spark streaming

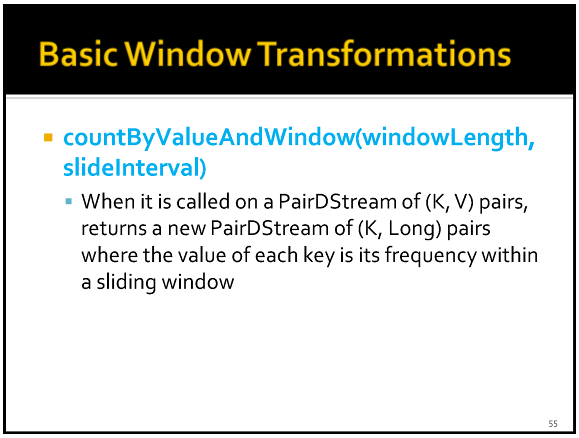
Second Spark batch of 10 seconds
Batch size 10 seconds

Third batch

(second, 1), (spark,1), (batch,3), (of,1), (size,1), (10,2), (seconds,2), (third,1)

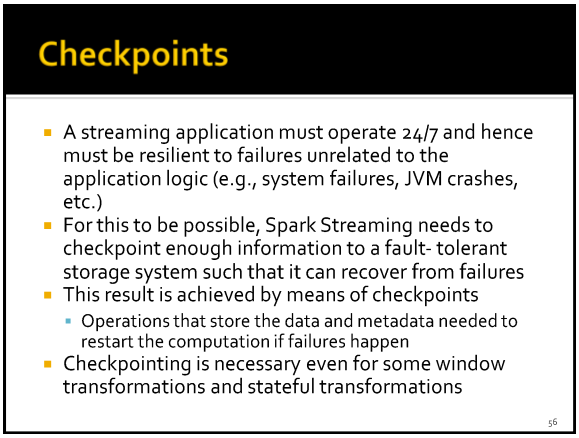
Basic Window Transformations

- window(windowLength, slideInterval)
  - Returns a new DStream which is computed based on windowed batches of the source DStream.
- countByWindow(windowLength, slideInterval)
  - Returns a new single-element stream containing the number of elements of each window
    - The returned object is a JavaDStream<Long>. However, it contains only one value for each window (the number of elements of the last analyzed window)
- reduceByWindow(func, windowLength, slideInterval)
  - Returns a new single-element stream, created by aggregating elements in the stream over a sliding interval using func. The function should be associative so that it can be computed correctly in parallel



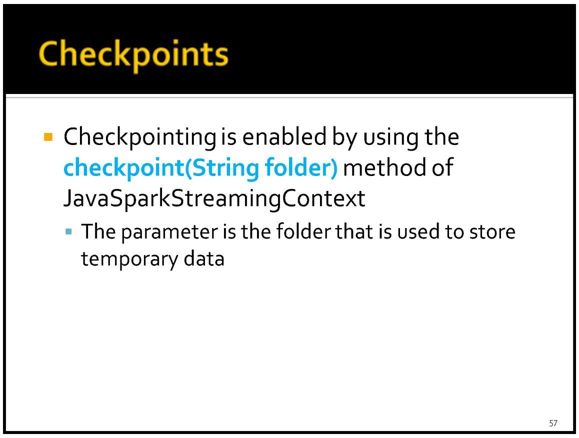
Basic Window Transformations

- **countByValueAndWindow(windowLength, slideInterval)**
  - When it is called on a PairDStream of (K, V) pairs, returns a new PairDStream of (K, Long) pairs where the value of each key is its frequency within a sliding window



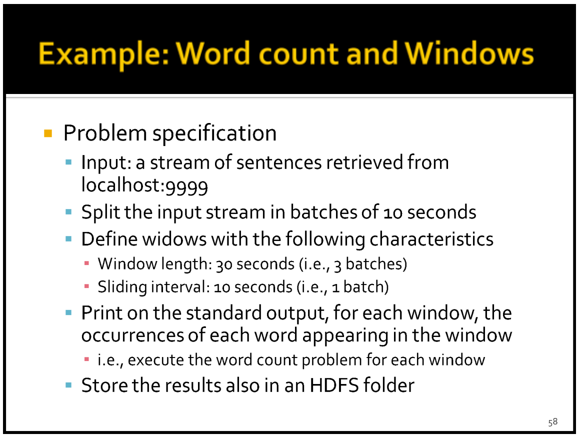
Checkpoints

- A streaming application must operate 24/7 and hence must be resilient to failures unrelated to the application logic (e.g., system failures, JVM crashes, etc.)
- For this to be possible, Spark Streaming needs to checkpoint enough information to a fault- tolerant storage system such that it can recover from failures
- This result is achieved by means of checkpoints
  - Operations that store the data and metadata needed to restart the computation if failures happen
- Checkpointing is necessary even for some window transformations and stateful transformations



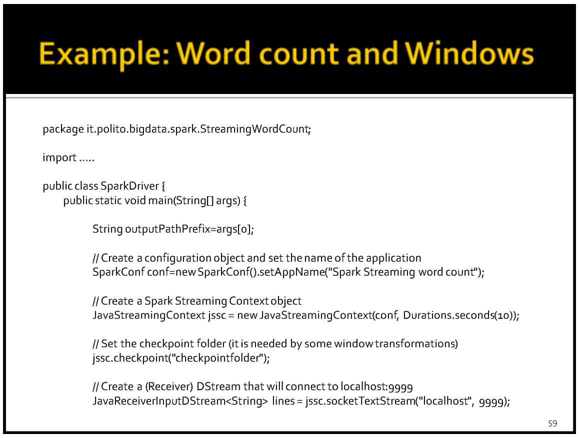
Checkpoints

- Checkpointing is enabled by using the **checkpoint(String folder)** method of JavaSparkStreamingContext
  - The parameter is the folder that is used to store temporary data



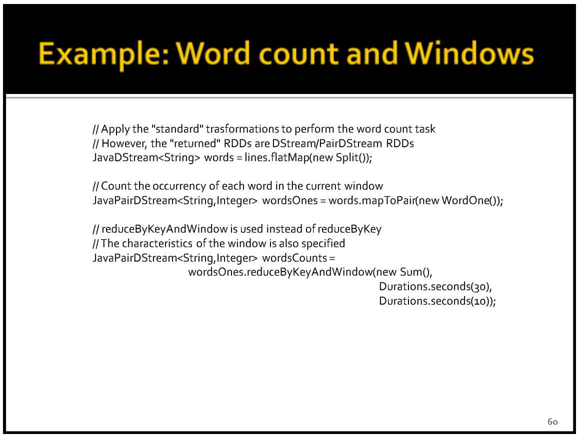
Example: Word count and Windows

- Problem specification
  - Input: a stream of sentences retrieved from localhost:9999
  - Split the input stream in batches of 10 seconds
  - Define widows with the following characteristics
    - Window length: 30 seconds (i.e., 3 batches)
    - Sliding interval: 10 seconds (i.e., 1 batch)
  - Print on the standard output, for each window, the occurrences of each word appearing in the window
    - i.e., execute the word count problem for each window
  - Store the results also in an HDFS folder



Example: Word count and Windows

```
package it.polito.bigdata.spark.StreamingWordCount;

import .....

public class SparkDriver {
    public static void main(String[] args) {

         String outputPathPrefix=args[0];

         // Create a configuration object and set the name of the application
         SparkConf conf=new SparkConf().setAppName("Spark Streaming word count");

         // Create a Spark Streaming Context object
         JavaStreamingContext jssc = new JavaStreamingContext(conf, Durations.seconds(10));

         // Set the checkpoint folder (it is needed by some window transformations)
         jssc.checkpoint("checkpointfolder");

         // Create a (Receiver) DStream that will connect to localhost:9999
         JavaReceiverInputDStream<String>  lines = jssc.socketTextStream("localhost", 9999);
```



Example: Word count and Windows

```
// Apply the "standard" trasformations to perform the word count task
// However, the "returned" RDDs are DStream/PairDStream RDDs
JavaDStream<String>  words = lines.flatMap(new Split());

// Count the occurrency of each word in the current window
JavaPairDStream<String,Integer>  wordsOnes = words.mapToPair(new WordOne());

// reduceByKeyAndWindow is used instead of reduceByKey
// The characteristics of the window is also specified
JavaPairDStream<String,Integer>  wordsCounts =
                  wordsOnes.reduceByKeyAndWindow(new Sum(),
                                                      Durations.seconds(30),
                                                      Durations.seconds(10));
```

Example: Word count and Windows

```
        // Print the num. of occurrencies of each word of the current window (only 10 of them)
        wordsCounts.print();

        // Store the output of the computation in the folders with prefix outputPathPrefix
        wordsCounts.dstream().saveAsTextFiles(outputPathPrefix,"");


        // Start the computation
        jssc.start();

        jssc.awaitTerminationOrTimeout(120000);

        jssc.close();

    }
}
```

UpdateStateByKey Transformation

- The updateStateByKey transformation allows maintaining arbitrary state while continuously updating it with new information
    - It is based on two steps
        - Define the state
            - The state can be an arbitrary data type
        - Define the state update function
            - Specify with a function how to update the state using the previous state and the new values from an input stream

UpdateStateByKey Transformation

- In every batch, Spark will apply the state update function for all existing keys, regardless of whether they have new data in a batch or not
    - If the update function returns None then the key-value pair will be eliminated
- The function is used to update the value associated with a key by combining the former value and the new values associated with the key
    - The call method of the "function" is invoked on the list of values associated with on one key at a time and return the new aggregated value for the considered key

Word count example (Stateful version)

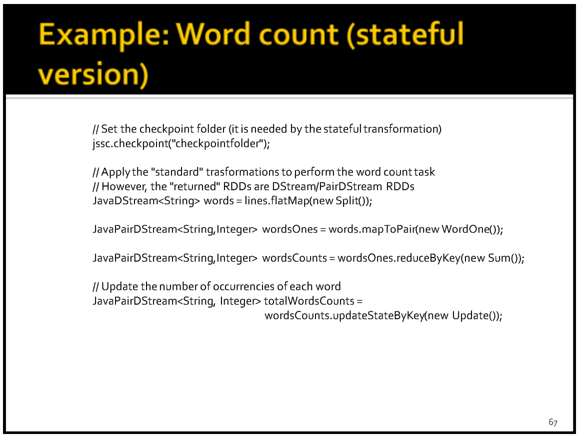
- By using the UpdateStateByKey, the application can continuously update the number of occurrences of each word
    - The number of occurrences stored in the PairDStream returned by this transformation is computed over the union of all the batches (for the first one to current one)
        - For efficiency reasons, the new value is computed by combining the last value with the values of the current batch

Example: Word count (stateful version)

- Problem specification
    - Input: a stream of sentences retrieved from localhost:9999
    - Split the input stream in batches of 10 seconds
    - Print on the standard output, every 10 seconds, the occurrences of each word appearing in the stream (from time 0 to the current time)
        - i.e., execute the word count problem from the beginning of the stream to current time
    - Store the results also in an HDFS folder

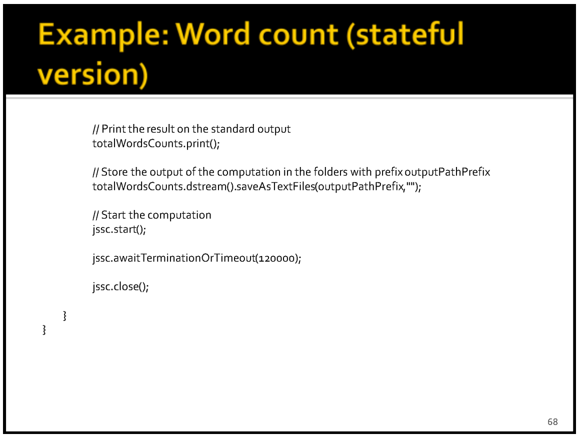
Example: Word count (stateful version)

```
package it.polito.bigdata.spark.StreamingWordCount;

import .....

public class SparkDriver {
    public static void main(String[] args) {

        String outputPathPrefix=args[0];

        // Create a configuration object and set the name of the application
        SparkConf conf=new SparkConf().setAppName("Spark Streaming word count");

        // Create a Spark Streaming Context object
        JavaStreamingContext jssc = new JavaStreamingContext(conf, Durations.seconds(10));


        // Create a (Receiver) DStream that will connect to localhost:9999
        JavaReceiverInputDStream<String> lines = jssc.socketTextStream("localhost", 9999);
```



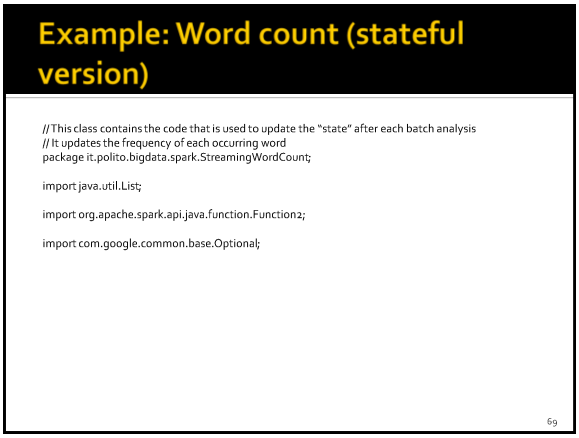
Example: Word count (stateful version)

```
// Set the checkpoint folder (it is needed by the stateful transformation)
jssc.checkpoint("checkpointfolder");

// Apply the "standard" trasformations to perform the word count task
// However, the "returned" RDDs are DStream/PairDStream RDDs
JavaDStream<String> words = lines.flatMap(new Split());

JavaPairDStream<String,Integer> wordsOnes = words.mapToPair(new WordOne());

JavaPairDStream<String,Integer> wordsCounts = wordsOnes.reduceByKey(new Sum());

// Update the number of occurrencies of each word
JavaPairDStream<String, Integer> totalWordsCounts =
                                  wordsCounts.updateStateByKey(new Update());
```



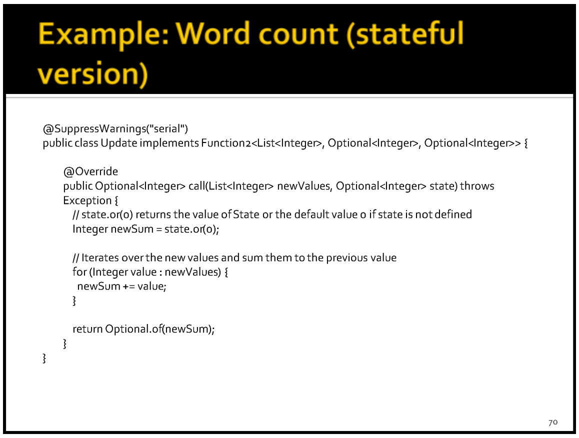
Example: Word count (stateful version)

```
        // Print the result on the standard output
        totalWordsCounts.print();

        // Store the output of the computation in the folders with prefix outputPathPrefix
        totalWordsCounts.dstream().saveAsTextFiles(outputPathPrefix,"");

        // Start the computation
        jssc.start();

        jssc.awaitTerminationOrTimeout(120000);

        jssc.close();

    }
}
```



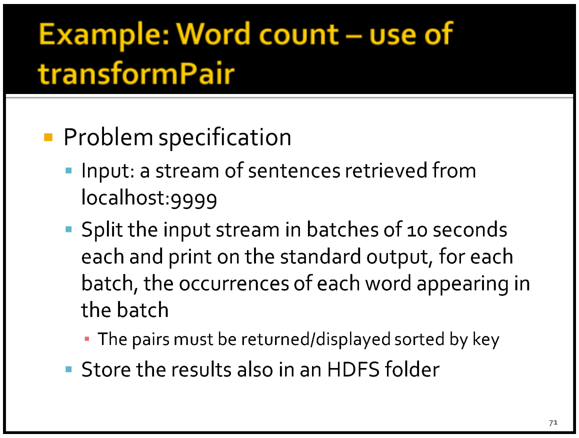
Example: Word count (stateful version)

```
// This class contains the code that is used to update the "state" after each batch analysis
// It updates the frequency of each occurring word
package it.polito.bigdata.spark.StreamingWordCount;

import java.util.List;

import org.apache.spark.api.java.function.Function2;

import com.google.common.base.Optional;
```



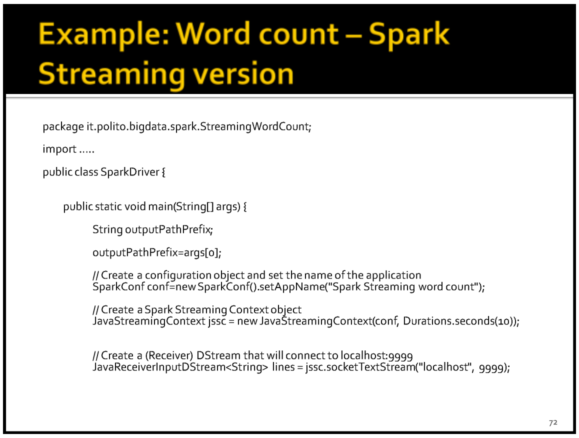
Example: Word count (stateful version)

```
@SuppressWarnings("serial")
public class Update implements Function2<List<Integer>, Optional<Integer>, Optional<Integer>> {

    @Override
    public Optional<Integer> call(List<Integer> newValues, Optional<Integer> state) throws
    Exception {
      // state.or(0) returns the value of State or the default value 0 if state is not defined
      Integer newSum = state.or(0);

      // Iterates over the new values and sum them to the previous value
      for (Integer value : newValues) {
        newSum += value;
      }

      return Optional.of(newSum);
    }
}
```



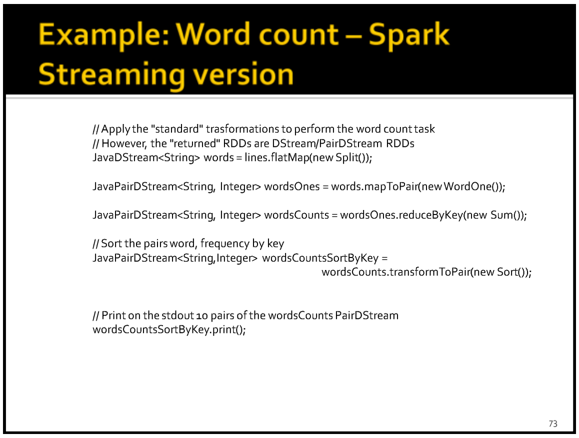
Example: Word count – use of transformPair

- Problem specification
  - Input: a stream of sentences retrieved from localhost:9999
  - Split the input stream in batches of 10 seconds each and print on the standard output, for each batch, the occurrences of each word appearing in the batch
    - The pairs must be returned/displayed sorted by key
  - Store the results also in an HDFS folder



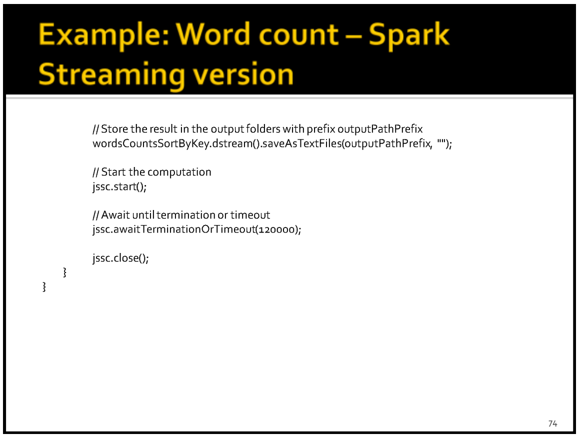
Example: Word count – Spark Streaming version

```
package it.polito.bigdata.spark.StreamingWordCount;

import .....

public class SparkDriver {


    public static void main(String[] args) {

        String outputPathPrefix;

        outputPathPrefix=args[0];

        // Create a configuration object and set the name of the application
        SparkConf conf=new SparkConf().setAppName("Spark Streaming word count");

        // Create a Spark Streaming Context object
        JavaStreamingContext jssc = new JavaStreamingContext(conf, Durations.seconds(10));


        // Create a (Receiver) DStream that will connect to localhost:9999
        JavaReceiverInputDStream<String> lines = jssc.socketTextStream("localhost", 9999);
```



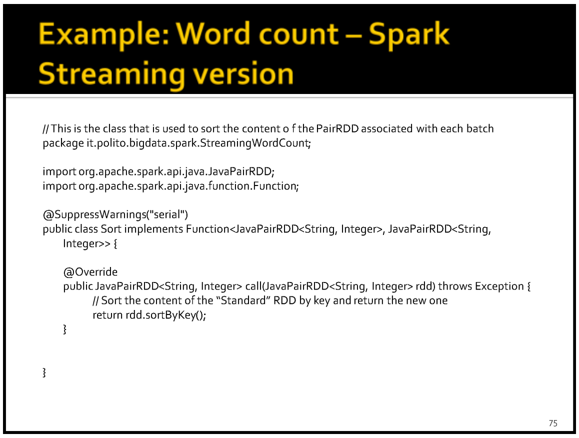
Example: Word count – Spark Streaming version

```
// Apply the "standard" trasformations to perform the word count task
// However, the "returned" RDDs are DStream/PairDStream RDDs
JavaDStream<String> words = lines.flatMap(new Split());

JavaPairDStream<String, Integer> wordsOnes = words.mapToPair(new WordOne());

JavaPairDStream<String, Integer> wordsCounts = wordsOnes.reduceByKey(new Sum());

// Sort the pairs word, frequency by key
JavaPairDStream<String,Integer> wordsCountsSortByKey =
                                        wordsCounts.transformToPair(new Sort());


// Print on the stdout 10 pairs of the wordsCounts PairDStream
wordsCountsSortByKey.print();
```



Example: Word count – Spark Streaming version

```
            // Store the result in the output folders with prefix outputPathPrefix
            wordsCountsSortByKey.dstream().saveAsTextFiles(outputPathPrefix, "");

            // Start the computation
            jssc.start();

            // Await until termination or timeout
            jssc.awaitTerminationOrTimeout(120000);

            jssc.close();
    }
}
```



Example: Word count – Spark Streaming version

```
// This is the class that is used to sort the content o f the PairRDD associated with each batch
package it.polito.bigdata.spark.StreamingWordCount;

import org.apache.spark.api.java.JavaPairRDD;
import org.apache.spark.api.java.function.Function;

@SuppressWarnings("serial")
public class Sort implements Function<JavaPairRDD<String, Integer>, JavaPairRDD<String,
    Integer>> {

    @Override
    public JavaPairRDD<String, Integer> call(JavaPairRDD<String, Integer> rdd) throws Exception {
        // Sort the content of the "Standard" RDD by key and return the new one
        return rdd.sortByKey();
    }


}
```