Lab 5. Building Spark Streaming Applications with Kafka

In this lab, we will cover Apache Spark, which is distributed in memory processing engines and then we will walk through Spark Streaming concepts and how we can integrate Apache Kafka with Spark.

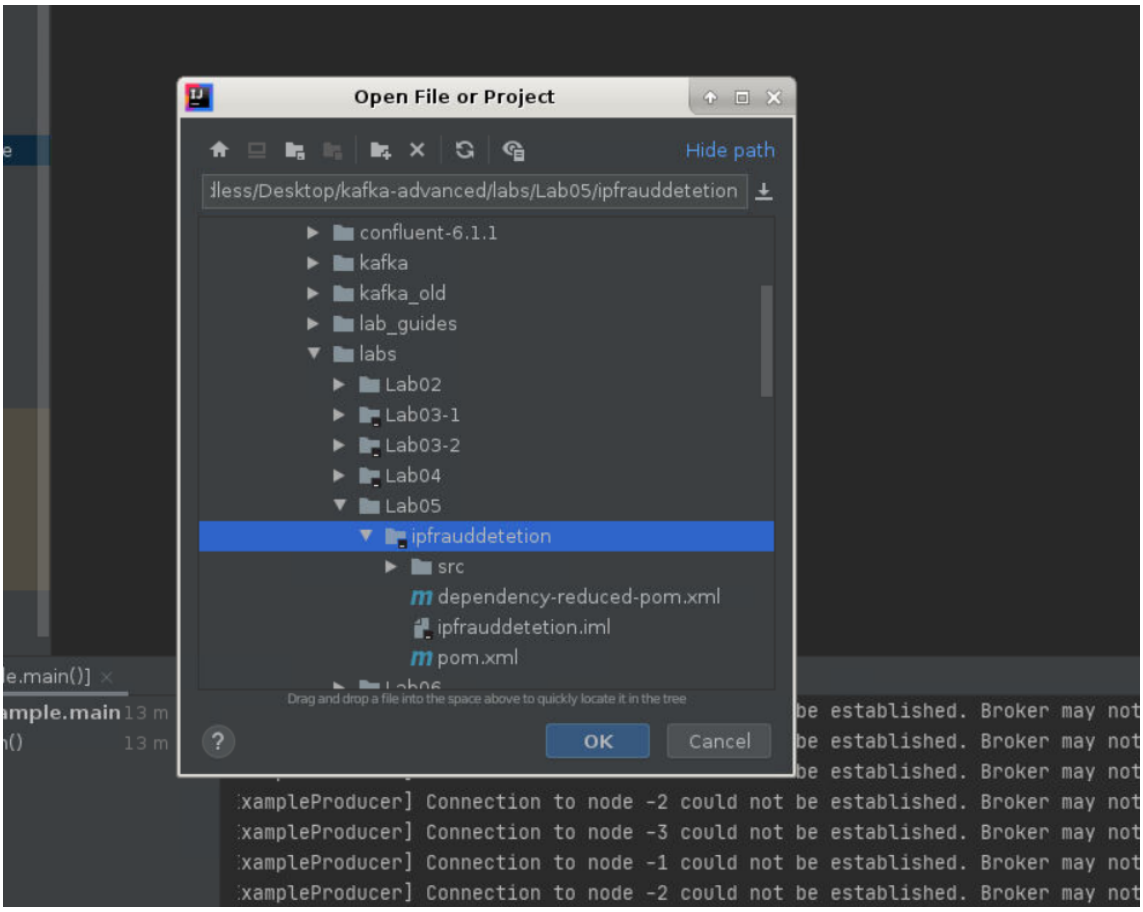
In short, we will cover the following topics:

- Introduction to Spark
- Direct approach (Spark-Kafka integration)
- Use case (Log processing)

Lab Solution

Complete solution for this lab is available in the following directory:

`~/kafka-advanced/labs/Lab05/ipfrauddetetion`



Spark Streaming

We have two approaches to integrate Kafka with Spark and we will go into detail on each:

- Receiver-based approach
- Direct approach

The receiver-based approach is the older way of doing integration. Direct API integration provides lots of advantages over the receiver-based approach.

Apache Spark Installation

Make sure you have compatible java installed on your machine. You can verify it by typing command:

```
java -version
```

Apache spark setup has been downloaded already on the following path and added to $PATH variable:

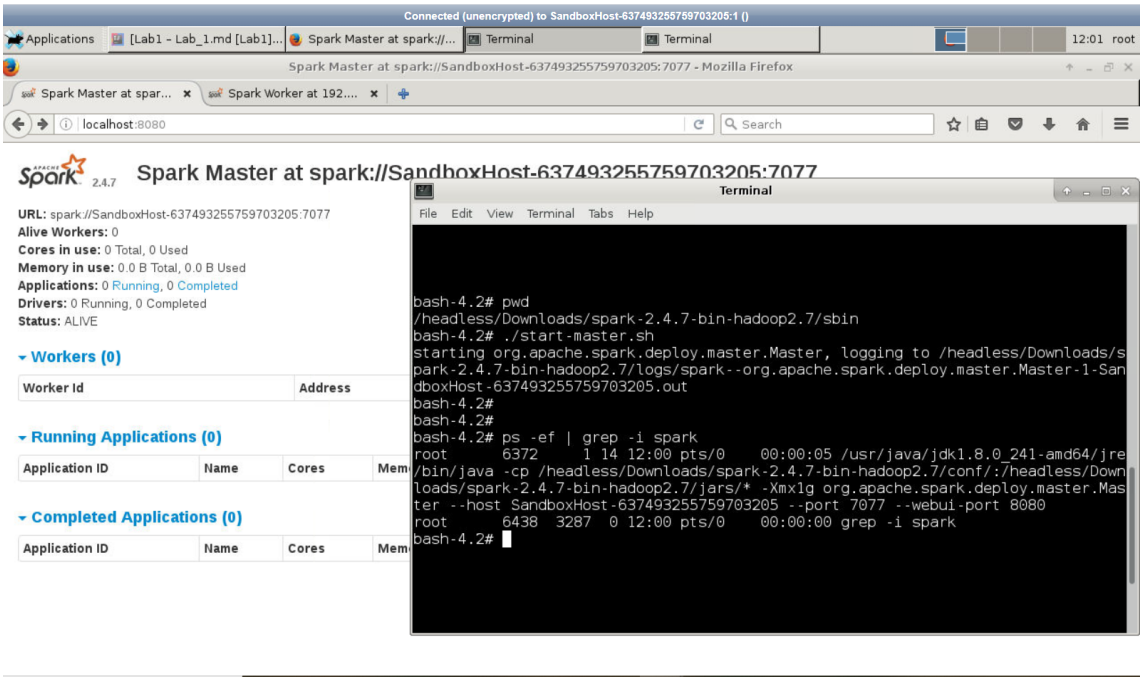
```
/headless/Downloads/spark-2.4.7-bin-hadoop2.7/
```

Start Master

```
cd /headless/Downloads/spark-2.4.7-bin-hadoop2.7/

./sbin/start-master.sh
```

Inspect the response:

```
starting org.apache.spark.deploy.master.Master, logging to /headless/Downloads/spark-2.4.7-bin-hadoop2.7/logs/spark--org.apache.spark.deploy.master.Master-1-SandboxHost-637493255759703205.out
```



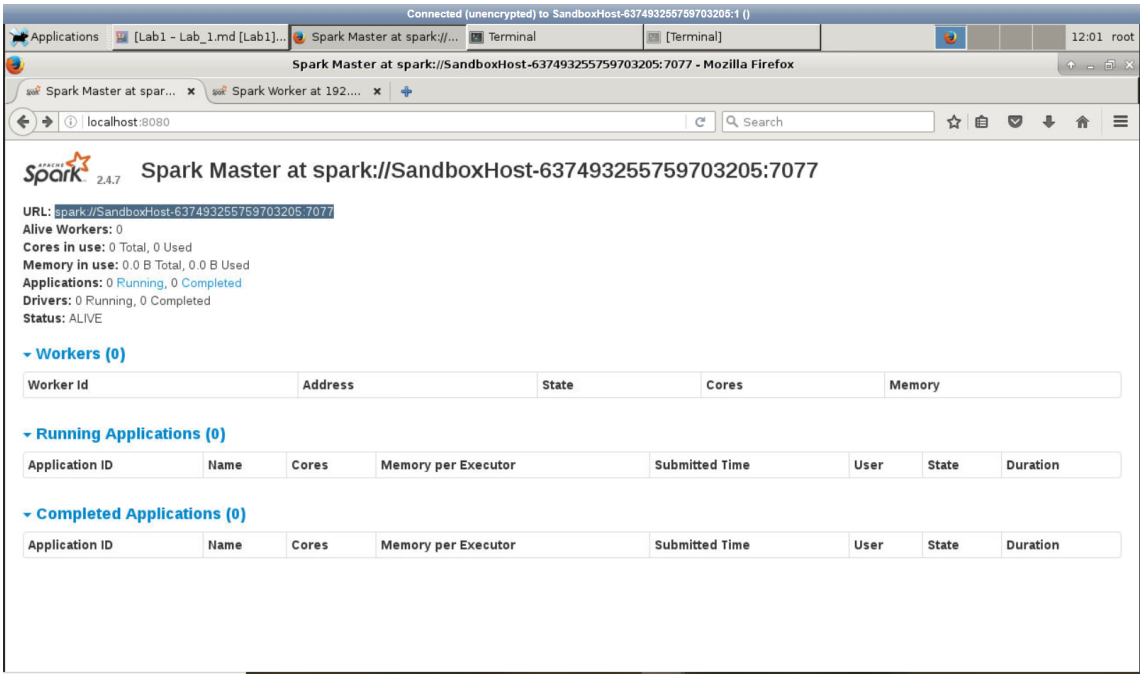
Once started, the master will print out a spark://HOST:PORT URL for itself, which you can use to connect workers to it, or pass as the “master” argument to SparkContext. You can also find this URL on the master’s web UI, which is http://localhost:8080 by default.

Similarly, you can start one or more workers and connect them to the master via:

Start Worker

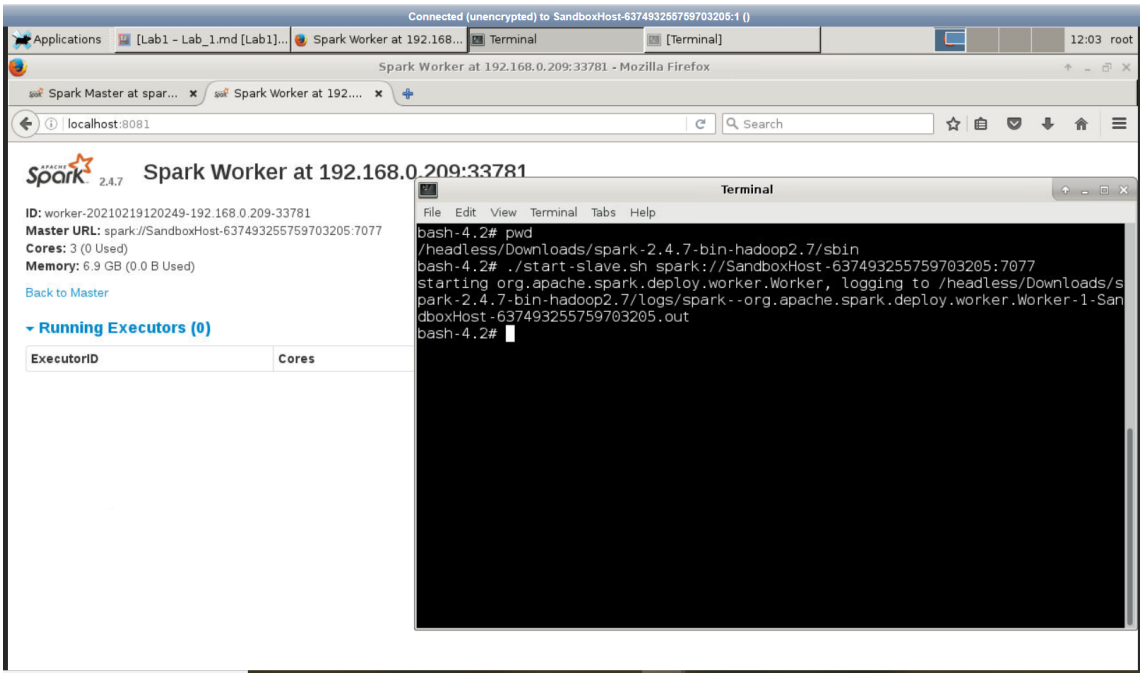
Start Worker and register the worker with master

Open `http://localhost:8080/` in browser and copy the master url

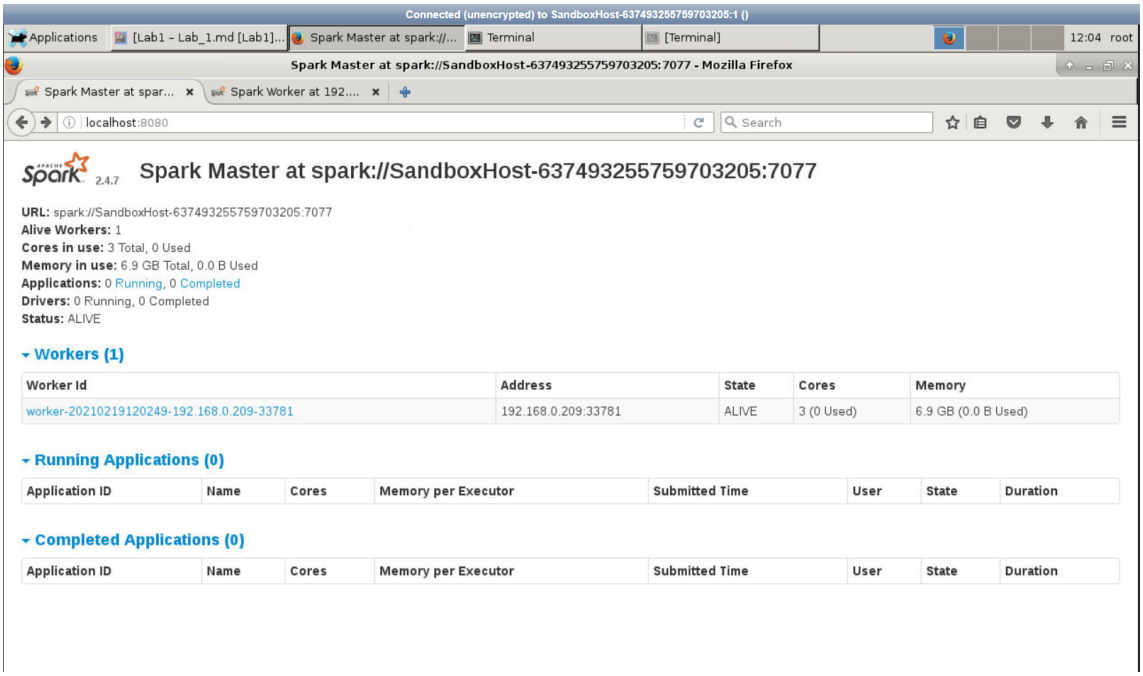


now start the worker and register it with master using following command (Update spark://hostname:7077 with the master hostname first):

`./sbin/start-slave.sh spark://hostname:7077`



Worker webUI: `http://localhost:8081`



Once you have started a worker, look at the master's web UI (http://localhost:8080 by default). You should see the new node listed there, along with its number of CPUs and memory (minus one gigabyte left for the OS).

Note: `spark-shell` and `spark-submit` have been added to `PATH` already and also present in following directory:

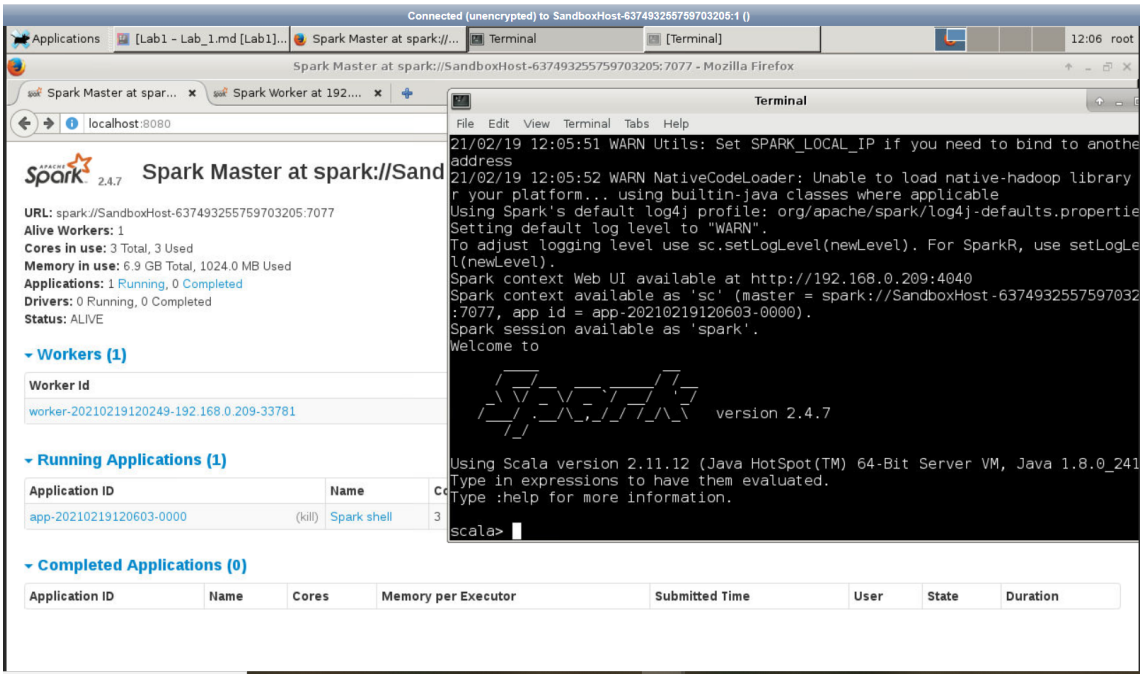
```
/headless/Downloads/spark-2.4.7-bin-hadoop2.7/
```

Spark Shell

Your cluster on single node is ready now, you can test it using running command **spark-shell**

```
[user@hostname ~]$ spark-shell --master spark://hostname:7077
```

Reload the master webui. You will get one running application:



You can exit the spark shell using typing `:q` then enter

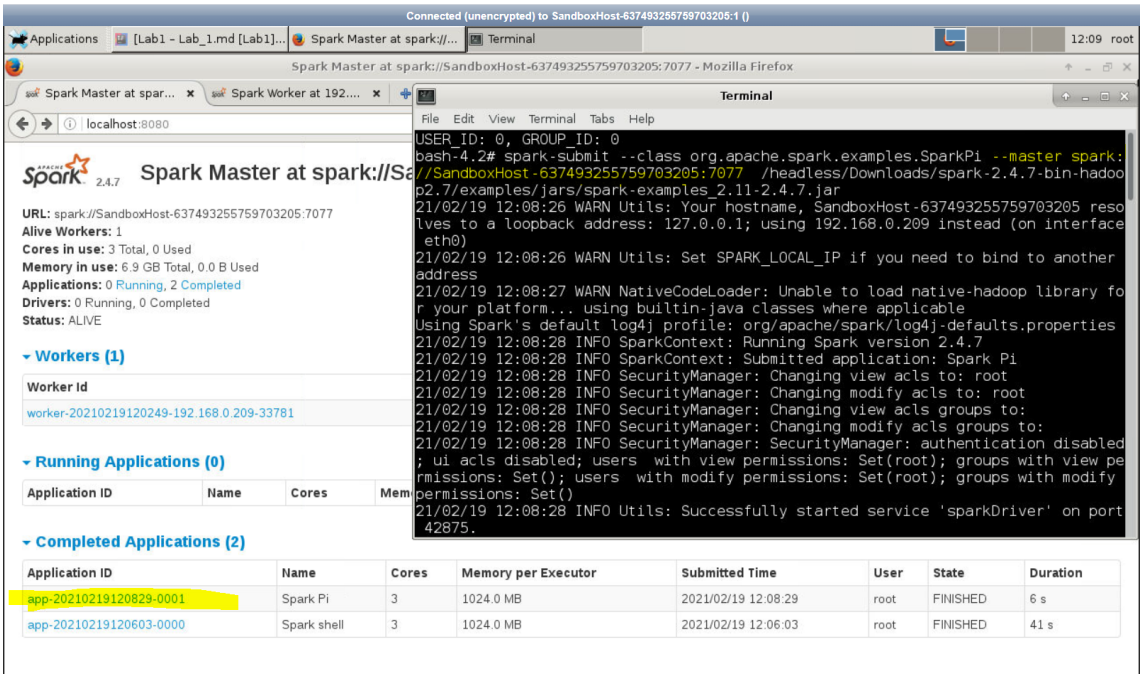
Spark Submit

Now, submit example application using spark-submit. Replace spark://hostname:7077 with hostname of master node first.

```
spark-submit --class org.apache.spark.examples.SparkPi --master spark://hostname:7077
/headless/Downloads/spark-2.4.7-bin-hadoop2.7/examples/jars/spark-examples_2.11-
2.4.7.jar
```

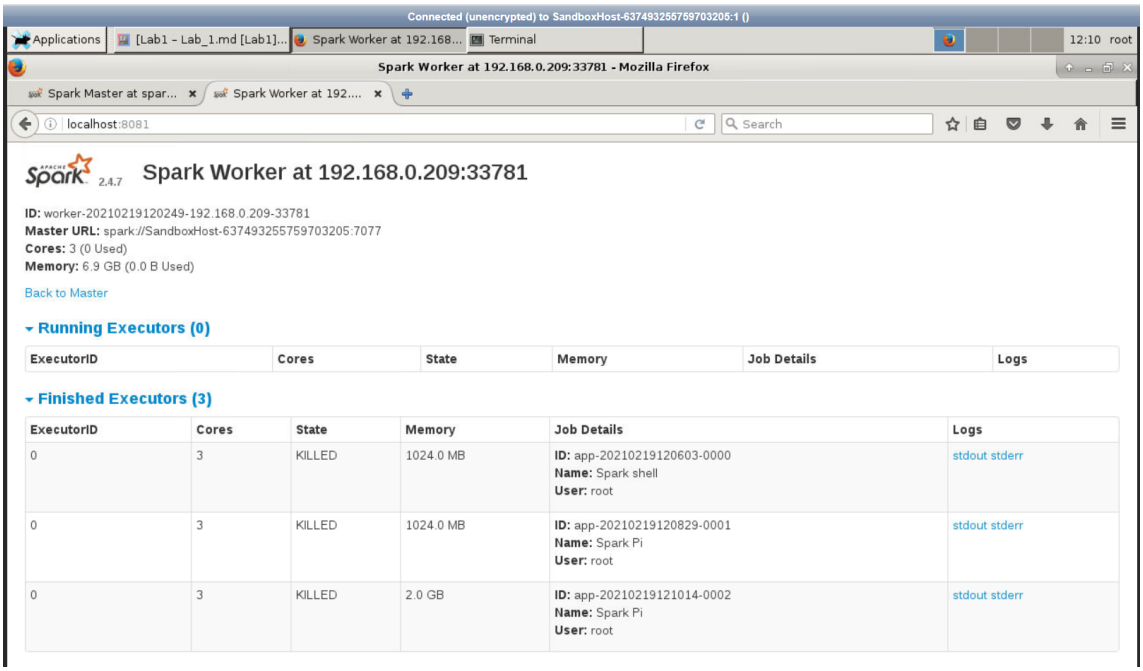
If this example execute successfully, your spark installation is fine. You can see the results in console log:

```
2019-09-12 13:53:27 INFO DAGScheduler:54 - Job 0 finished: reduce at SparkPi.scala:38,
took 0.615754 sPi is roughly 3.1416557082785412 2019-09-12 13:53:27 INFO
AbstractConnector:318 - Stopped Spark@6914bc2c{HTTP/1.1,[http/1.1]}{0.0.0.0:4040}
```



Task

1. Run above spark-submit command but assign '2g' memory. You will get output after running spark-submit command as shown in the screenshot below:



Hint: Add following parameter while running spark-submit `--executor-memory 2g` .

Create Kafka Topic

Now, we need to create `test1` in Kafka. To do so, execute the following command:

```
cd ~/kafka-advanced

kafka/bin/kafka-topics.sh --create --zookeeper localhost:2181 --replication-factor 1 --partitions 1 --topic test1
```

Direct approach

In receiver-based approach, there are issues of data loss, costing less throughput using write-ahead logs and difficulty in achieving exactly one semantic of data processing. To overcome all these problems, Spark introduced the direct stream approach of integrating Spark with Kafka.

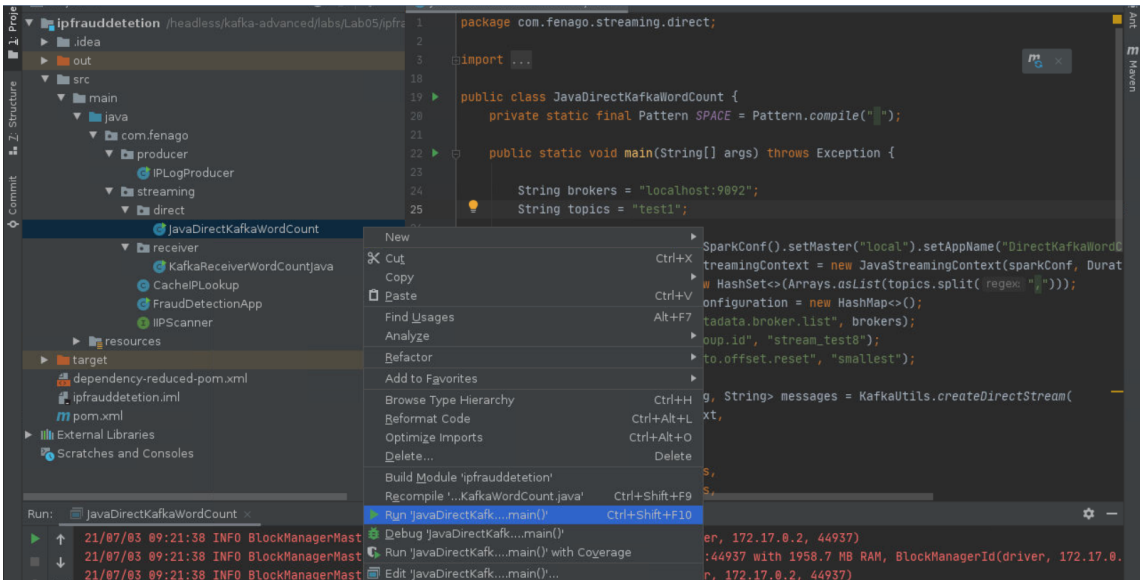
Java example for direct approach

Again, let us take a Java example:

```
import java.util.HashMap;
import java.util.HashSet;
import java.util.Arrays;
import java.util.Map;
import java.util.Set;
import java.util.regex.Pattern;

import scala.Tuple2;

import kafka.serializer.StringDecoder;

import org.apache.Spark.SparkConf;
import org.apache.Spark.streaming.api.java.*;
import org.apache.Spark.streaming.kafka.KafkaUtils;
import org.apache.Spark.streaming.Durations;

public class JavaDirectKafkaWordCount {
    private static final Pattern SPACE = Pattern.compile(" ");

    public static void main(String[] args) throws Exception {

        String brokers = "localhost:9092";
        String topics = "test1";

        SparkConf SparkConf = new
SparkConf().setAppName("DirectKafkaWordCount").setMaster("local[2]");
        JavaStreamingContext javaStreamingContext = new
JavaStreamingContext(SparkConf, Durations.seconds(2));

        Set<String> topicsSet = new HashSet<>(Arrays.asList(topics.split(",")));
        Map<String, String> kafkaConfiguration = new HashMap<>();
        kafkaConfiguration.put("metadata.broker.list", brokers);

        JavaPairInputDStream<String, String> messages = KafkaUtils.createDirectStream(
                javaStreamingContext,
                String.class,
                String.class,
                StringDecoder.class,
```

```
                StringDecoder.class,
                kafkaConfiguration,
                topicsSet
        );

        JavaDStream<String> lines = messages.map(Tuple2::_2);

        JavaDStream<String> words = lines.flatMap(x ->
Arrays.asList(SPACE.split(x)).iterator());

        JavaPairDStream<String, Integer> wordCounts = words.mapToPair(s -> new
Tuple2<>(s, 1))
                .reduceByKey((i1, i2) -> i1 + i2);

        wordCounts.print();

        javaStreamingContext.start();
        javaStreamingContext.awaitTermination();
    }
}
```

Run the example as shown below:



Use case log processing - fraud IP detection

This section will cover a small use case which uses Kafka and Spark Streaming to detect a fraud IP, and the number of times the IP tried to hit the server. We will cover the use case in the following:

- **Producer**: We will use Kafka Producer API, which will read a log file and publish records to Kafka topic. However, in a real case, we may use Flume or producer application, which directly takes a log record on a real-time basis and publish to Kafka topic.
- **Fraud IPs list**: We will maintain a list of predefined fraud IP range which can be used to identify fraud IPs. For this application we are using in memory IP list which can be replaced by fast key based lookup, such as HBase.

- **Spark Streaming**: Spark Streaming application will read records from Kafka topic and will detect IPs and domains which are suspicious.

Maven

[**Maven**] is a build and project management tool and we will be building this project using Maven. I recommend using Eclipse or IntelliJ for creating projects. Add the following dependencies and plugins to your `pom.xml`:

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://Maven.apache.org/POM/4.0.0"
         xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://Maven.apache.org/POM/4.0.0
http://Maven.apache.org/xsd/Maven-4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>

    <groupId>com.fenago</groupId>
    <artifactId>ip-fraud-detetion</artifactId>
    <version>1.0-SNAPSHOT</version>
    <packaging>jar</packaging>

    <name>kafka-producer</name>

    <properties>
        <project.build.sourceEncoding>UTF-8</project.build.sourceEncoding>
    </properties>


    <dependencies>
        <!-- https://mvnrepository.com/artifact/org.apache.Spark/Spark-streaming-
kafka_2.10 -->
        <dependency>
            <groupId>org.apache.Spark</groupId>
            <artifactId>Spark-streaming-kafka_2.10</artifactId>
            <version>1.6.3</version>
        </dependency>


        <!-- https://mvnrepository.com/artifact/org.apache.hadoop/hadoop-common -->
        <dependency>
            <groupId>org.apache.hadoop</groupId>
            <artifactId>hadoop-common</artifactId>
            <version>2.7.2</version>
        </dependency>

        <!-- https://mvnrepository.com/artifact/org.apache.Spark/Spark-core_2.10 -->
        <dependency>
            <groupId>org.apache.Spark</groupId>
            <artifactId>Spark-core_2.10</artifactId>
            <version>2.0.0</version>
            <scope>provided</scope>

        </dependency>
        <!-- https://mvnrepository.com/artifact/org.apache.Spark/Spark-streaming_2.10
```

```
-->
        <dependency>
            <groupId>org.apache.Spark</groupId>
            <artifactId>Spark-streaming_2.10</artifactId>
            <version>2.0.0</version>
            <scope>provided</scope>

        </dependency>


        <dependency>
            <groupId>org.apache.kafka</groupId>
            <artifactId>kafka_2.11</artifactId>
            <version>0.10.0.0</version>
        </dependency>
    </dependencies>

    <build>
        <plugins>
            <plugin>
                <groupId>org.apache.Maven.plugins</groupId>
                <artifactId>Maven-shade-plugin</artifactId>
                <version>2.4.2</version>
                <executions>
                    <execution>
                        <phase>package</phase>
                        <goals>
                            <goal>shade</goal>
                        </goals>
                        <configuration>
                            <filters>
                                <filter>
                                    <artifact>junit:junit</artifact>
                                    <includes>
                                        <include>junit/framework/**</include>
                                        <include>org/junit/**</include>
                                    </includes>
                                    <excludes>
                                        <exclude>org/junit/experimental/**</exclude>
                                        <exclude>org/junit/runners/**</exclude>
                                    </excludes>
                                </filter>
                                <filter>
                                    <artifact>*:*</artifact>
                                    <excludes>
                                        <exclude>META-INF/*.SF</exclude>
                                        <exclude>META-INF/*.DSA</exclude>
                                        <exclude>META-INF/*.RSA</exclude>
                                    </excludes>
                                </filter>
                            </filters>
                            <transformers>
```

```
                                <transformer

implementation="org.apache.Maven.plugins.shade.resource.ServicesResourceTransformer"/>

                                <transformer

implementation="org.apache.Maven.plugins.shade.resource.ManifestResourceTransformer">

<mainClass>com.fenago.streaming.FraudDetectionApp</mainClass>
                                </transformer>
                            </transformers>
                        </configuration>
                    </execution>
                </executions>
            </plugin>
            <plugin>
                <groupId>org.codehaus.mojo</groupId>
                <artifactId>exec-Maven-plugin</artifactId>
                <version>1.2.1</version>
                <executions>
                    <execution>
                        <goals>
                            <goal>exec</goal>
                        </goals>
                    </execution>
                </executions>
                <configuration>
                    <includeProjectDependencies>true</includeProjectDependencies>
                    <includePluginDependencies>false</includePluginDependencies>
                    <executable>java</executable>
                    <classpathScope>compile</classpathScope>
                    <mainClass>com.fenago.streaming.FraudDetectionApp</mainClass>
                </configuration>
            </plugin>


            <plugin>
                <groupId>org.apache.Maven.plugins</groupId>
                <artifactId>Maven-compiler-plugin</artifactId>
                <configuration>
                    <source>1.8</source>
                    <target>1.8</target>
                </configuration>
            </plugin>
        </plugins>
    </build>
</project>
```

Producer

You can use IntelliJ or Eclipse to build a producer application. This producer reads a log file taken from an Apache project which contains detailed records like:

```
64.242.88.10 - - [08/Mar/2004:07:54:30 -0800] "GET
/twiki/bin/edit/Main/Unknown_local_recipient_reject_code?
topicparent=Main.ConfigurationVariables HTTP/1.1" 401 12846
```

You can have just one record in the test file and the producer will produce records by generating random IPs and replace it with existing. So, we will have millions of distinct records with unique IP addresses.

Record columns are separated by space delimiters, which we change to commas in producer. The first column represents the IP address or the domain name which will be used to detect whether the request was from a fraud client. The following is the Java Kafka producer which remembers logs.

Property reader

We preferred to use a property file for some important values such as topic, Kafka broker URL, and so on. If you want to read more values from the property file, then feel free to change it in the code. `streaming.properties` file:

```
topic=ipTest2
broker.list=localhost:9092
appname=IpFraud
group.id=Stream
```

The following is an example of the property reader:

```
import java.io.FileNotFoundException;
import java.io.IOException;
import java.io.InputStream;
import java.util.Properties;

public class PropertyReader {

    private Properties prop = null;

    public PropertyReader() {

        InputStream is = null;
        try {
            this.prop = new Properties();
            is = this.getClass().getResourceAsStream("/streaming.properties");
            prop.load(is);
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }

    public String getPropertyValue(String key) {
        return this.prop.getProperty(key);
    }
}
```

Producer code

Do not run producer code yet, we will build and run Spark Streaming application first

A producer application is designed to be like a real-time log producer where the producer runs every three seconds and produces a new record with random IP addresses. You can add a few records in the `IP_LOG.log` file and then the producer will take care of producing millions of unique records from those three records.

We have also enabled auto creation of topics so you need not create topic before running your producer application. You can change the topic name in the `streaming.properties` file mentioned before:

```
import com.fenago.reader.PropertyReader;
import org.apache.kafka.clients.producer.KafkaProducer;
import org.apache.kafka.clients.producer.ProducerRecord;
import org.apache.kafka.clients.producer.RecordMetadata;

import java.io.BufferedReader;
import java.io.File;
import java.io.IOException;
import java.io.InputStreamReader;
import java.util.*;
import java.util.concurrent.Future;


public class IPLogProducer extends TimerTask {
    static String path = "";

    public BufferedReader readFile() {
        BufferedReader BufferedReader = new BufferedReader(new InputStreamReader(
                this.getClass().getResourceAsStream("/IP_LOG.log")));
        return BufferedReader;

    }

    public static void main(final String[] args) {
        Timer timer = new Timer();
        timer.schedule(new IPLogProducer(), 3000, 3000);
    }

    private String getNewRecordWithRandomIP(String line) {
        Random r = new Random();
        String ip = r.nextInt(256) + "." + r.nextInt(256) + "." + r.nextInt(256) + "."
+ r.nextInt(256);
        String[] columns = line.split(" ");
        columns[0] = ip;
        return Arrays.toString(columns);
    }

    @Override
    public void run() {
        PropertyReader propertyReader = new PropertyReader();

        Properties producerProps = new Properties();
        producerProps.put("bootstrap.servers",
propertyReader.getPropertyValue("broker.list"));
        producerProps.put("key.serializer",
```

```
"org.apache.kafka.common.serialization.StringSerializer");
        producerProps.put("value.serializer",
"org.apache.kafka.common.serialization.StringSerializer");
        producerProps.put("auto.create.topics.enable", "true");

        KafkaProducer<String, String> ipProducer = new KafkaProducer<String, String>
(producerProps);

        BufferedReader br = readFile();
        String oldLine = "";
        try {
            while ((oldLine = br.readLine()) != null) {
                String line = getNewRecordWithRandomIP(oldLine).replace("[",
"").replace("]", "");
                ProducerRecord ipData = new ProducerRecord<String, String>
(propertyReader.getPropertyValue("topic"), line);
                Future<RecordMetadata> recordMetadata = ipProducer.send(ipData);
            }
        } catch (IOException e) {
            e.printStackTrace();
        }
        ipProducer.close();
    }
}
```

Fraud IP lookup

The following classes will help us as a lookup service which will help us to identify if request is coming from a fraud IP. We have used interface before implementing the class so that we can add more NoSQL databases or any fast lookup service. You can implement this service and add a lookup service by using HBase or any other fast key lookup service. We are using in-memory lookup and just added the fraud IP range in the cache. Add the following code to your project:

```
public interface IIPScanner {

    boolean isFraudIP(String ipAddresses);

}
```

`CacheIPLookup` is the implementation for the `IIPSCanner` interface which does in memory lookup:

```
import java.io.Serializable;
import java.util.HashSet;
import java.util.Set;


public class CacheIPLookup implements IIPScanner, Serializable {

    private Set<String> fraudIPList = new HashSet<>();

    public CacheIPLookup() {
        fraudIPList.add("212");
        fraudIPList.add("163");
```

```
        fraudIPList.add("15");
        fraudIPList.add("224");
        fraudIPList.add("126");
        fraudIPList.add("92");
        fraudIPList.add("91");
        fraudIPList.add("10");
        fraudIPList.add("112");
        fraudIPList.add("194");
        fraudIPList.add("198");
        fraudIPList.add("11");
        fraudIPList.add("12");
        fraudIPList.add("13");
        fraudIPList.add("14");
        fraudIPList.add("15");
        fraudIPList.add("16");
    }


    @Override
    public boolean isFraudIP(String ipAddresses) {

        return fraudIPList.contains(ipAddresses);
    }
}
```

Streaming code

We haven't focused much on modularization in our code. The IP fraud detection application scans each record and filters those records which qualify as a the fraud record based on fraud IP lookup service. The lookup service can be changed to use any fast lookup database. We are using in memory lookup service for this application:

```
import com.fenago.reader.PropertyReader;
import org.apache.Spark.SparkConf;
import org.apache.Spark.api.java.function.Function;
import org.apache.Spark.streaming.api.java.JavaStreamingContext;
import java.util.Set;
import java.util.regex.Pattern;
import java.util.HashMap;
import java.util.HashSet;
import java.util.Arrays;
import java.util.Map;
import scala.Tuple2;
import kafka.serializer.StringDecoder;
import org.apache.Spark.streaming.api.java.*;
import org.apache.Spark.streaming.kafka.KafkaUtils;
import org.apache.Spark.streaming.Durations;

public class FraudDetectionApp {
    private static final Pattern SPACE = Pattern.compile(" ");

    private static void main(String[] args) throws Exception {
        PropertyReader propertyReader = new PropertyReader();
        CacheIPLookup cacheIPLookup = new CacheIPLookup();
```

```
        SparkConf SparkConf = new
SparkConf().setAppName("IP_FRAUD").setMaster("local[2]");
        JavaStreamingContext javaStreamingContext = new
JavaStreamingContext(SparkConf, Durations.seconds(3));

        Set<String> topicsSet = new HashSet<>
(Arrays.asList(propertyReader.getPropertyValue("topic").split(",")));
        Map<String, String> kafkaConfiguration = new HashMap<>();
        kafkaConfiguration.put("metadata.broker.list",
propertyReader.getPropertyValue("broker.list"));
        kafkaConfiguration.put("group.id",
propertyReader.getPropertyValue("group.id"));

        JavaPairInputDStream<String, String> messages = KafkaUtils.createDirectStream(
                javaStreamingContext,
                String.class,
                String.class,
                StringDecoder.class,
                StringDecoder.class,
                kafkaConfiguration,
                topicsSet
        );
        JavaDStream<String> ipRecords = messages.map(Tuple2::_2);

        JavaDStream<String> fraudIPs = ipRecords.filter(new Function<String, Boolean>
() {
            @Override
            public Boolean call(String s) throws Exception {
                String IP = s.split(",")[0];
                String[] ranges = IP.split("\\.");
                String range = null;
                try {
                    range = ranges[0];
                } catch (ArrayIndexOutOfBoundsException ex) {

                }
                return cacheIPLookup.isFraudIP(range);

            }
        });

        DStream<String> fraudDstream = fraudIPs.dstream();
        fraudDstream.saveAsTextFiles("FraudRecord", "");

        javaStreamingContext.start();
        javaStreamingContext.awaitTermination();
    }
}
```

Create Kafka Topic

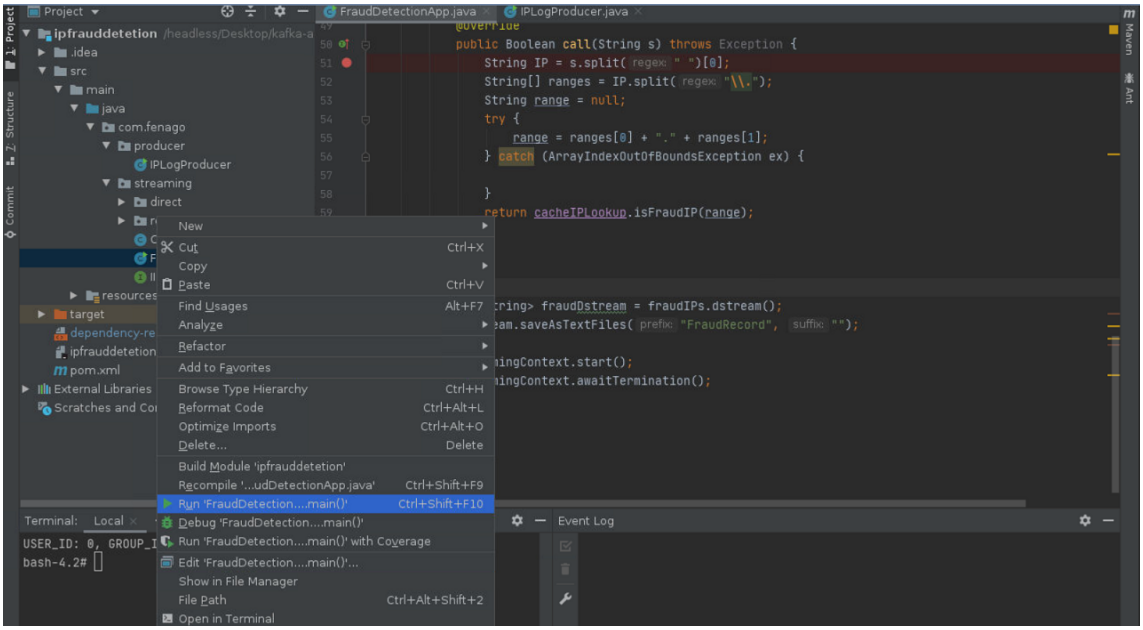
Now, we need to create `iplog` in Kafka. To do so, execute the following command:

```
cd ~/kafka-advanced

kafka/bin/kafka-topics.sh --create --zookeeper localhost:2181 --replication-factor 1 --partitions 1 --topic iplog
```

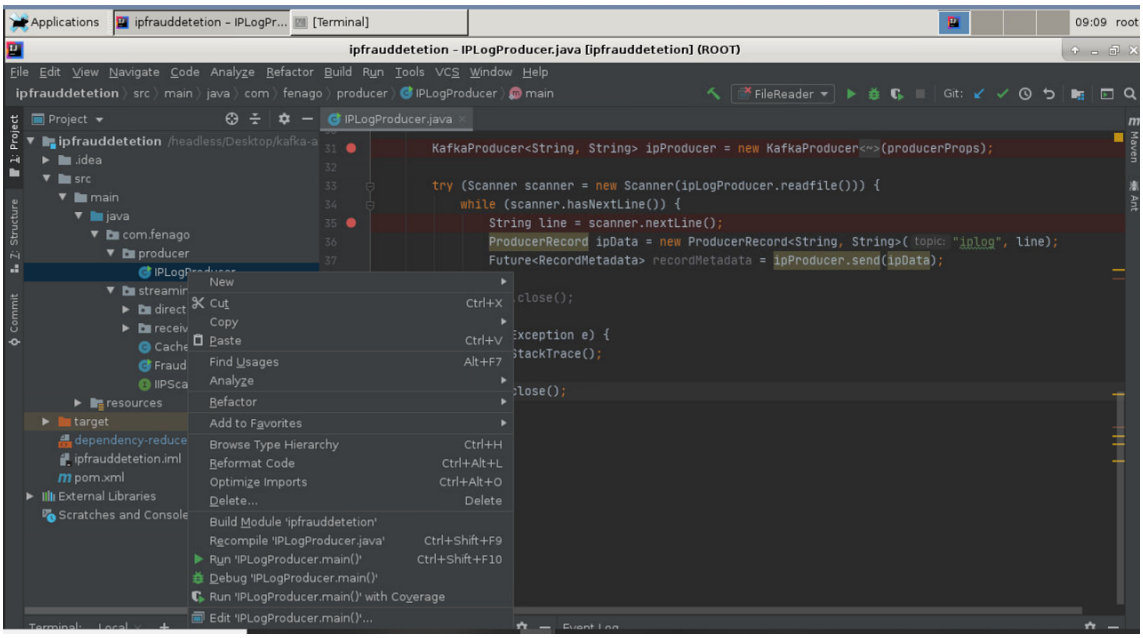
Run Spark Streaming Application

Once the Spark Streaming application starts, run Kafka producer and check the records.

Step 1: Run spark streaming code as shown below:



Step 2: Run producer code as shown below:



Summary

In this lab, we learned about Apache Spark. Our focus was on covering different ways we can integrate Kafka with Spark and their advantages and disadvantages. We also covered APIs for the receiver-based approach and direct approach. Finally, we covered a small use case about IP fraud detection through the log file and lookup service. You can now create your own Spark streaming application.