# Spark ML Framework to build a classifier to predict Ad install probablity

## Setting Python Virtual Enviornment

In [1]:
```
!python3 -m venv virtual_env
!source virtual_env/bin/activate
```

# APACHE SPARK

**Using (pyspark) to load training data because in real time production environment, the gaming industry is expected to have TERABYTES of user behavioural so it make sense to load the data using Spark due to following reasons:**

**1) In-memory computation**

**2) Parallel processing**

### Importing pyspark libraries, constant module and enable logging

In [2]:
```
from collections import defaultdict
from pyspark.sql import SparkSession
from pyspark import SparkConf,SparkContext
from pyspark.sql import SQLContext,functions as F
from pyspark.sql.types import *
import logging
import seaborn as sns
import pandas as pd
pd.set_option('display.max_rows', 500)
pd.set_option('display.max_columns', 500)
pd.set_option('display.width', 1000)
```

### Define Constants fo Spark Session

In [5]:
```
P_APP_NAME="SPARK_ML_CLASSIFIER"
P_MASTER="local[2]"
P_DRIVER_MEMORY="10g"
P_EXECUTOR_MEMORY="5g"
P_EXECUTOR_CORES=2
P_EXECUTOR_INSTANCE=1
P_PIVOT_MAX_VALUES=100000
P_EXECUTOR_HEARTBEATS="7200s"
P_BROADCAST_TIMEOUT=36000
```

In [6]:
```
def set_spark_session():

    try:

        my_spark = SparkSession \
              .builder \
             .appName(P_APP_NAME) \
             .config('spark.driver.memory', P_DRIVER_MEMORY) \
             .config('spark.executor.memory', P_EXECUTOR_MEMORY) \
             .config('spark.executor.instances', P_EXECUTOR_INSTANCE) \
             .config("spark.executor.cores",P_EXECUTOR_CORES) \
             .config("spark.sql.pivotMaxValues", P_PIVOT_MAX_VALUES) \
             .config("spark.sql.inMemoryColumnarStorage.compressed",True) \
             .config("spark.sql.broadcastTimeout",P_BROADCAST_TIMEOUT) \
             .getOrCreate()

    except Exception as e:
        logging.exception("EXCEPTION -  Setting SparkSession"+str(e))
        raise e



    # Set SQL Context
    sqlContext=SQLContext(my_spark)


    return sqlContext,my_spark
```

In [7]:
```
sqlContext, my_spark = set_spark_session()
```

## Lets load the training data by specifying the SCHEMA

In [8]:
```
schema=StructType(  (
                StructField('unique_id',StringType(),True),
                StructField('timestamp',DateType(),True),
                StructField('advertisement_id',StringType(),True),
                StructField('device_os',StringType(),True),
                StructField('software_ver',StringType(),True),
                StructField('Game_Id',IntegerType(),True),
                StructField('location',StringType(),True),
                StructField('ad_start_Count',IntegerType(),True),
                StructField('ad_view_Count',IntegerType(),True),
                StructField('ad_click_Count',IntegerType(),True),
                StructField('ad_install_Count',IntegerType(),True),
                StructField('dummy1',StringType(),True),
                StructField('dummy2',StringType(),True),
                StructField('dummy3',StringType(),True),
                StructField('dummy4',StringType(),True),
                StructField('device',StringType(),True),
                StructField('install_label',IntegerType(),True)

               )

            )
```

In [9]:
```
df_train_spark2 = my_spark.read.format("csv")\
                              .option("delimiter", ";")\
                              .option("header", "true")\
                              .schema(schema)\
                              .load("training_data.csv")
```

In [10]:
```
df_train_spark2.printSchema()
```

```
root
 |-- unique_id: string (nullable = true)
 |-- timestamp: date (nullable = true)
 |-- advertisement_id: string (nullable = true)
 |-- device_os: string (nullable = true)
 |-- software_ver: string (nullable = true)
 |-- Game_Id: integer (nullable = true)
 |-- location: string (nullable = true)
 |-- ad_start_Count: integer (nullable = true)
 |-- ad_view_Count: integer (nullable = true)
 |-- ad_click_Count: integer (nullable = true)
 |-- ad_install_Count: integer (nullable = true)
 |-- dummy1: string (nullable = true)
 |-- dummy2: string (nullable = true)
 |-- dummy3: string (nullable = true)
 |-- dummy4: string (nullable = true)
 |-- device: string (nullable = true)
 |-- install_label: integer (nullable = true)
```

In [33]:
```
df_train_spark2.show(5, False)
```

```
+------------------------+----------+------------------------+---------+-
-----------+-------+--------+--------------+-------------+--------------+
----------------+---------+-------------+
|unique_id               |timestamp |advertisement_id        |device_os|s
oftware_ver|Game_Id|location|ad_start_Count|ad_view_Count|ad_click_Count|
ad_install_Count|device   |install_label|
+------------------------+----------+------------------------+---------+-
-----------+-------+--------+--------------+-------------+--------------+
----------------+---------+-------------+
|5c36658fb58fad351175f0b6|2019-01-09|59687f0d896a6b0e5ce6ea15|ios      |1
1.4.1      |1373094|US      |25            |24           |0             |
2               |iPhone8,2|0            |
|5c38d5ab1c16172870186b5a|2019-01-11|59687f0d896a6b0e5ce6ea15|ios      |1
2.1        |2739989|US      |10            |9            |2             |
0               |iPhone9,1|0            |
|5c38815de8f4e50e256e4f9c|2019-01-11|59687f0d896a6b0e5ce6ea15|ios      |1
2.1.2      |1373094|US      |27            |26           |0             |
0               |iPhone7,1|0            |
|5c409ace532d5806d2c6a5e6|2019-01-17|59687f0d896a6b0e5ce6ea15|ios      |1
2.1.2      |1217749|US      |15            |14           |2             |
0               |iPhone7,2|0            |
|5c3904b92d798c41e7f3088a|2019-01-11|59687f0d896a6b0e5ce6ea15|ios      |1
2.0.1      |1373094|US      |20            |18           |0             |
0               |iPhone8,1|0            |
+------------------------+----------+------------------------+---------+-
-----------+-------+--------+--------------+-------------+--------------+
----------------+---------+-------------+
only showing top 5 rows
```

In [11]:
```
df_train_spark2.select('unique_id','timestamp','software_ver','location','a
                      ,'device_os','device').distinct().show(10, truncate=Fa
```

```
+------------------------+----------+------------+--------+--------------
+---------+--------------------+
|unique_id               |timestamp |software_ver|location|ad_start_Count
|device_os|device              |
+------------------------+----------+------------+--------+--------------
+---------+--------------------+
|5c3e9dc10b2823fecd5d1990|2019-01-16|8.0.0       |US      |42
|android  |samsung SM-G955U    |
|5c40a0f69af55309a8258d51|2019-01-17|8.0.0       |US      |27
|android  |samsung SM-N950U    |
|5c350b7e0ff83a4f5ca78aef|2019-01-08|8.0.0       |US      |153
|android  |samsung SM-G930V    |
|5c3505ec33e3b14ba2061820|2019-01-08|7.0         |US      |33
|android  |samsung SM-G920V    |
|5c3cd64d0dc75c23b5fcebeb|2019-01-14|8.1.0       |GB      |273
|android  |HUAWEI CLT-L29      |
|5c44d09ab59f8ca275b7a1ea|2019-01-20|8.0.0       |GB      |72
|android  |samsung SM-J600FN   |
|5c341b80f2c54b4c7635fcf3|2019-01-08|8.0.0       |US      |76
|android  |samsung SM-G955U    |
|5c375e4596053725f3aa53c2|2019-01-10|7.0         |RU      |7
|android  |HUAWEI HUAWEI CAN-L11|
|5c349428a3b7900dbb93a997|2019-01-08|6.0.1       |RU      |5
|android  |Xiaomi Redmi 3S     |
|5c454e07c5a284df7710f240|2019-01-21|6.0.1       |RU      |22
|android  |Xiaomi Redmi 3S     |
+------------------------+----------+------------+--------+--------------
+---------+--------------------+
only showing top 10 rows
```

### Set Spark SQL Context to run SQL Queries

In [12]:
```
sqlContext=SQLContext(my_spark)
```

### Create a temp table to run SQL queries

In [13]:
```
df_train_spark2.createOrReplaceTempView("df_train_table")
```

### Vaow! Thats a Huge Imbalanced Data Set

In [14]:
```
sqlContext.sql('''
select install_label, count(1) as cnt from df_train_table group by 1
''').show(10, False)
```

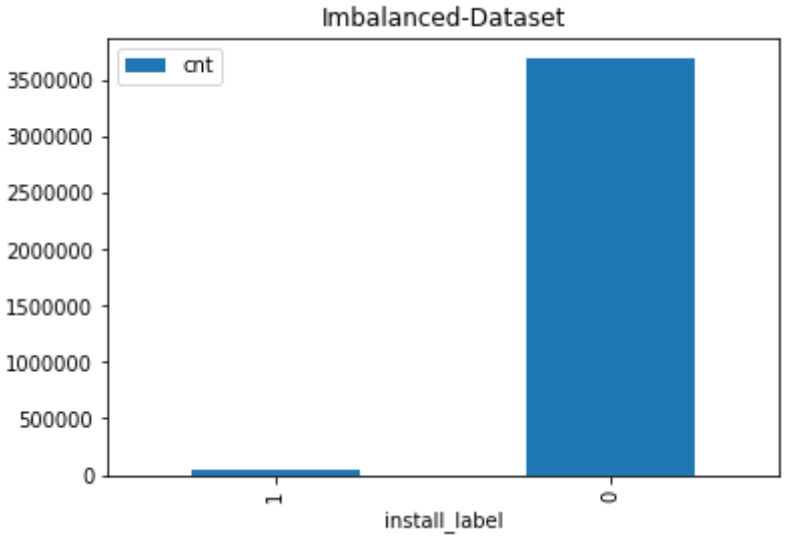
```
+-------------+-------+
|install_label|cnt    |
+-------------+-------+
|1            |44744  |
|0            |3694193|
+-------------+-------+
```

In [15]:
```
stats=sqlContext.sql('''
select install_label, count(1) as cnt from df_train_table group by 1
''')
```

In [16]:
```
stats.show()
```

```
+-------------+-------+
|install_label|    cnt|
+-------------+-------+
|            1|  44744|
|            0|3694193|
+-------------+-------+
```

In [17]:
```
stats.toPandas().plot(kind='bar', title='Imbalanced-Dataset',x='install_lab
```



In [18]:
```
sqlContext.sql('''
    select advertisement_id, install_label, count(1) as cnt
    from df_train_table
    where 1=1
    group by 1,2
    order by 3 desc
''').show(10, False)
```

```
+------------------------+-------------+-----+
|advertisement_id        |install_label|cnt  |
+------------------------+-------------+-----+
|5c3bfb0b36c2c6cc18710e7b|0            |41482|
|5c385d02ee4549000d8b9ddd|0            |36345|
|5c0f2ff2f4ee9d00225714c2|0            |32688|
|5afbea849f23a400284f2619|0            |30184|
|5c26db700f371292325680ec|0            |28402|
|5bd2b810eb4bb3b817722baa|0            |26347|
|5af41f3346d16a019f9d327d|0            |24042|
|5c333b4d1d94abf8a325e55a|0            |23469|
|5ba35fbb478f4102c28b1811|0            |22620|
|5bd2ccefc9c2110ad461c1b3|0            |22267|
+------------------------+-------------+-----+
only showing top 10 rows
```

In [19]:
```
sqlContext.sql('''
    select count( distinct location)
    from df_train_table
   ''').show(100, False)
```

```
+------------------------+
|count(DISTINCT location)|
+------------------------+
|221                     |
+------------------------+
```

In [20]:
```
sqlContext.sql('''
    select location, install_label, count(1) as cnt
    from df_train_table
    where 1=1
    group by 1,2
    order by 3 desc
''').show(10, False)
```

```
+--------+-------------+------+
|location|install_label|cnt   |
+--------+-------------+------+
|US      |0            |571342|
|RU      |0            |284031|
|IN      |0            |263013|
|BR      |0            |197981|
|DE      |0            |146836|
|GB      |0            |125766|
|FR      |0            |123234|
|TR      |0            |121841|
|CN      |0            |116602|
|ID      |0            |114815|
+--------+-------------+------+
only showing top 10 rows
```

In [21]:
```
sqlContext.sql('''
    select device_os, install_label, count(1) as cnt
    from df_train_table
    where device_os is not null
    group by 1,2
    order by 3 desc
''').show(100, False)
```

```
+---------+-------------+-------+
|device_os|install_label|cnt    |
+---------+-------------+-------+
|android  |0            |2696965|
|ios      |0            |997228 |
|android  |1            |32079  |
|ios      |1            |12665  |
+---------+-------------+-------+
```

In [22]:
```
columns_to_be_dropped=['dummy1','dummy2','dummy3','dummy4']
df_train_spark2=df_train_spark2.drop(*columns_to_be_dropped)
```

In [23]:
```
df_train_spark2.printSchema()
```

```
root
 |-- unique_id: string (nullable = true)
 |-- timestamp: date (nullable = true)
 |-- advertisement_id: string (nullable = true)
 |-- device_os: string (nullable = true)
 |-- software_ver: string (nullable = true)
 |-- Game_Id: integer (nullable = true)
 |-- location: string (nullable = true)
 |-- ad_start_Count: integer (nullable = true)
 |-- ad_view_Count: integer (nullable = true)
 |-- ad_click_Count: integer (nullable = true)
 |-- ad_install_Count: integer (nullable = true)
 |-- device: string (nullable = true)
 |-- install_label: integer (nullable = true)
```

In [24]:
```
from pyspark.ml import Pipeline
from pyspark.ml.classification import RandomForestClassifier
from pyspark.ml.feature import IndexToString, StringIndexer, VectorIndexer
from pyspark.ml.evaluation import MulticlassClassificationEvaluator

from pyspark.ml.linalg import Vectors

from pyspark.ml.feature import StringIndexer
from pyspark.ml.feature import OneHotEncoder
from pyspark.ml.feature import VectorAssembler
from pyspark.ml.feature import StandardScaler
from pyspark.ml.feature import MinMaxScaler
from pyspark.ml.feature import OneHotEncoderEstimator
```

In [25]:
```
#There are better way to perform oversampling (e.g. SMOTE Synthetic Minorit
#However, I am using under-sampling to keep the solution simple

df_binary_zero = df_train_spark2[df_train_spark2['install_label'] == 0]
df_binary_one = df_train_spark2[df_train_spark2['install_label'] == 1]

df_binary_zero_under = df_binary_zero.rdd.takeSample(withReplacement=False,
                                                     num=df_binary_one.coun
                                                     )

df_binary_zero_under1 = my_spark.createDataFrame(df_binary_zero_under)

spark_df = df_binary_one.union(df_binary_zero_under1)
```

In [26]:
```
spark_df.groupBy('install_label').count().show()
```

```
+-------------+-----+
|install_label|count|
+-------------+-----+
|            0|44744|
|            1|44744|
+-------------+-----+
```

In [27]:
```
spark_df.printSchema()
```

```
root
 |-- unique_id: string (nullable = true)
 |-- timestamp: date (nullable = true)
 |-- advertisement_id: string (nullable = true)
 |-- device_os: string (nullable = true)
 |-- software_ver: string (nullable = true)
 |-- Game_Id: long (nullable = true)
 |-- location: string (nullable = true)
 |-- ad_start_Count: long (nullable = true)
 |-- ad_view_Count: long (nullable = true)
 |-- ad_click_Count: long (nullable = true)
 |-- ad_install_Count: long (nullable = true)
 |-- device: string (nullable = true)
 |-- install_label: long (nullable = true)
```

In [28]:
```
spark_df.dtypes
```

Out[28]:
```
[('unique_id', 'string'),
 ('timestamp', 'date'),
 ('advertisement_id', 'string'),
 ('device_os', 'string'),
 ('software_ver', 'string'),
 ('Game_Id', 'bigint'),
 ('location', 'string'),
 ('ad_start_Count', 'bigint'),
 ('ad_view_Count', 'bigint'),
 ('ad_click_Count', 'bigint'),
 ('ad_install_Count', 'bigint'),
 ('device', 'string'),
 ('install_label', 'bigint')]
```

## Verify Categorical and Numeric Features before Feature Engineering

In [29]:
```
cat_cols = [i[0] for i in spark_df.dtypes if i[1].startswith('string')]
print(str(len(cat_cols)) + '  categorical features')

num_cols = [i[0] for i in spark_df.dtypes if i[1].startswith('int') | i[1].
print(str(len(num_cols)) + '  numerical features')

time_cols = [i[0] for i in spark_df.dtypes if i[1].startswith('date')]
print(str(len(time_cols)) + '  date features')
```

```
6  categorical features
5  numerical features
1  date features
```

In [30]:
```
spark_df.createOrReplaceTempView("spark_df_table")
```

In [31]:
```
spark_df= sqlContext.sql('''
select tbl.*,
CAST (tbl.timestamp as String) timestamp_s
from spark_df_table tbl
''')
```

In [34]:
```
spark_df.printSchema()
```

```
root
 |-- unique_id: string (nullable = true)
 |-- timestamp: date (nullable = true)
 |-- advertisement_id: string (nullable = true)
 |-- device_os: string (nullable = true)
 |-- software_ver: string (nullable = true)
 |-- Game_Id: long (nullable = true)
 |-- location: string (nullable = true)
 |-- ad_start_Count: long (nullable = true)
 |-- ad_view_Count: long (nullable = true)
 |-- ad_click_Count: long (nullable = true)
 |-- ad_install_Count: long (nullable = true)
 |-- device: string (nullable = true)
 |-- install_label: long (nullable = true)
 |-- timestamp_s: string (nullable = true)
```

# Feature Engineering

# SPARK PIPELINE

**StringIndexer** - It encodes a string column of labels to a column of label indices

**OneHotEncoder** - It maps a categorical feature, represented as a label index, to a binary vector with at most a single one-value indicating the presence of a specific feature value from among the set of all feature values.

**VectorAssembler** - It is a transformer that combines a given list of columns into a single vector column. It is useful for combining raw features and features generated by different feature transformers into a single feature vector, in order to train ML models like logistic regression and decision trees

**StandardScaler**- It transforms a dataset of Vector rows, normalizing each feature to have unit standard deviation and/or zero mean. It takes parameters:

In [40]:
```
stringIndexer1 = StringIndexer(handleInvalid='keep', inputCol='advertisemen
stringIndexer2 = StringIndexer(handleInvalid='keep', inputCol='device_os',
stringIndexer3 = StringIndexer(handleInvalid='keep', inputCol='software_ver
stringIndexer4 = StringIndexer(handleInvalid='keep', inputCol='location', c
stringIndexer5 = StringIndexer(handleInvalid='keep', inputCol='device', out
stringIndexer6 = StringIndexer(handleInvalid='keep', inputCol='timestamp_s'

oneHotEncoder = OneHotEncoderEstimator(inputCols=
                                       ["advertisement_id_i",
                                       "device_os_i",
                                       "software_ver_i",
                                       "location_i",
                                       "device_i",
                                       "timestamp_i",
                                       ],
                                   outputCols=["advertisement_id_o",
                                       "device_os_o",
                                       "software_ver_o",
                                       "location_o",
                                       "device_o",
                                       "timestamp_o",
                                       ]
                                )

unscaled_features =["advertisement_id_o","device_os_o","software_ver_o","lo
                    ,"Game_Id","ad_start_Count","ad_view_Count","ad_click_Co


vectorAssembler = VectorAssembler(inputCols=unscaled_features, outputCol="v


standardScaler = StandardScaler(inputCol="vector_features", outputCol="scal
#standardScaler = MinMaxScaler(inputCol="unscaled_features", outputCol="sca




stages = [stringIndexer1,
          stringIndexer2,
          stringIndexer3,
          stringIndexer4,
          stringIndexer5,
          stringIndexer6,
          oneHotEncoder,
          vectorAssembler,
          standardScaler
          ]

pipeline = Pipeline(stages=stages)
model = pipeline.fit(spark_df)
pipeline_df = model.transform(spark_df)
```

In [41]:
```
pipeline_df = pipeline_df.withColumnRenamed("install_label", "label")
```

In [42]:
```
pipeline_df.dtypes
```

Out[42]:
```
[('unique_id', 'string'),
 ('timestamp', 'date'),
 ('advertisement_id', 'string'),
 ('device_os', 'string'),
 ('software_ver', 'string'),
 ('Game_Id', 'bigint'),
 ('location', 'string'),
 ('ad_start_Count', 'bigint'),
 ('ad_view_Count', 'bigint'),
 ('ad_click_Count', 'bigint'),
 ('ad_install_Count', 'bigint'),
 ('device', 'string'),
 ('label', 'bigint'),
 ('timestamp_s', 'string'),
 ('advertisement_id_i', 'double'),
 ('device_os_i', 'double'),
 ('software_ver_i', 'double'),
 ('location_i', 'double'),
 ('device_i', 'double'),
 ('timestamp_i', 'double'),
 ('timestamp_o', 'vector'),
 ('software_ver_o', 'vector'),
 ('advertisement_id_o', 'vector'),
 ('device_os_o', 'vector'),
 ('location_o', 'vector'),
 ('device_o', 'vector'),
 ('vector_features', 'vector'),
 ('scaled_features', 'vector')]
```

### Train Test Split

In [43]:
```
(trainingData, testData) = pipeline_df.randomSplit([0.7, 0.3])
```

In [44]:
```
trainingData.groupBy('label').count().show()
```

```
+-----+-----+
|label|count|
+-----+-----+
|    0|31294|
|    1|31347|
+-----+-----+
```

In [45]:
```
testData.groupBy('label').count().show()
```

```
+-----+-----+
|label|count|
+-----+-----+
|    0|13450|
|    1|13397|
+-----+-----+
```

## Train a Spark ML RandomForest model

In [46]:
```
rf = RandomForestClassifier(labelCol="label", featuresCol="scaled_features"
```

## Hyper-Parameter Tuning & Cross Validation

In [47]:
```
from pyspark.ml.tuning import CrossValidator, ParamGridBuilder
from sklearn.metrics import roc_curve, auc
from pyspark.ml.evaluation import BinaryClassificationEvaluator

# Hyper-Parameter Tuning
paramGrid_rf = ParamGridBuilder() \
    .addGrid(rf.numTrees, [40, 60, 80, 100]) \
    .build()

# Cross Validation
crossval_rf = CrossValidator(estimator=rf,
                             estimatorParamMaps=paramGrid_rf,
                             evaluator=BinaryClassificationEvaluator(),
                             numFolds=3)
```

## Fit model to data train

In [48]:
```
model=crossval_rf.fit(trainingData)
```

## Make predictions.

In [51]:
```
predictions = model.transform(testData)
```

In [52]:
```
predictions.summary
```

Out[52]:
```
<bound method DataFrame.summary of DataFrame[unique_id: string, timestam
p: date, advertisement_id: string, device_os: string, software_ver: strin
g, Game_Id: bigint, location: string, ad_start_Count: bigint, ad_view_Cou
nt: bigint, ad_click_Count: bigint, ad_install_Count: bigint, device: str
ing, label: bigint, timestamp_s: string, advertisement_id_i: double, devi
ce_os_i: double, software_ver_i: double, location_i: double, device_i: do
uble, timestamp_i: double, timestamp_o: vector, software_ver_o: vector, a
dvertisement_id_o: vector, device_os_o: vector, location_o: vector, devic
e_o: vector, vector_features: vector, scaled_features: vector, rawPredict
ion: vector, probability: vector, prediction: double]>
```

In [54]:
```
# Select example rows to display.
predictions.select("unique_id","probability","prediction","label").show(20,
```

```
+------------------------+----------------------------------------+------
----+-----+
|unique_id               |probability                             |predic
tion|label|
+------------------------+----------------------------------------+------
----+-----+
|5c33eba781a8c737c2ec42de|[0.49086168693113674,0.5091383130688633]|1.0
|1    |
|5c33ebf3c4e4943aa8d34284|[0.49091789641817646,0.5090821035818236]|1.0
|1    |
|5c33edf170df593bb1449cdc|[0.47250782851328116,0.5274921714867189]|1.0
|1    |
|5c33efc439eec03b7c79a024|[0.48925811886795517,0.5107418811320449]|1.0
|1    |
|5c33f14221dfc23be5d89ddb|[0.4699375032656l995,0.5300624967343801]|1.0
|1    |
|5c33f16784ee253d24c108a6|[0.5034721368858157,0.49652786311418423]|0.0
|1    |
|5c33f2c87cd9e33d59178db2|[0.4864659990220912,0.5135340009779088] |1.0
|1    |
|5c33f985ab1b4d3f367114d7|[0.48925811886795517,0.5107418811320449]|1.0
|1    |
|5c33fbf3001c943fd5fa87da|[0.49227419772595127,0.5077258022740487]|1.0
|1    |
|5c3401b382b0ca43c413a8b5|[0.4915733341965586,0.5084266658034414] |1.0
|1    |
|5c3402fe1b46b642bb7915f2|[0.47148950332940637,0.5285104966705937]|1.0
|1    |
|5c3403bf37e56442bb7d2153|[0.4715972808158412,0.5284027191841589] |1.0
|1    |
|5c3405992805dd4537973df3|[0.5029289295747852,0.4970710704252149] |0.0
|1    |
|5c34119e03891d48f1621f3c|[0.4885507588088194,0.5114492411911806] |1.0
|1    |
|5c34160a1686004b389c8898|[0.49086168693113674,0.5091383130688633]|1.0
|1    |
|5c342207cf05034ebd56ad9e|[0.4913428786546833,0.5086571213453167] |1.0
|1    |
|5c342676db3e6052424d7391|[0.47230892808126307,0.527691071918737] |1.0
|1    |
|5c34270ea875c952771660db|[0.4686930962772564,0.5313069037227437] |1.0
|1    |
|5c342a84e1d701534bc34fab|[0.48509983518928357,0.5149001648107165]|1.0
|1    |
|5c34324025c6e057a4d384bc|[0.48913894456851514,0.5108610554314849]|1.0
|1    |
+------------------------+----------------------------------------+------
----+-----+
only showing top 20 rows
```

## Model Performance Measures

Accuracy - Model performance
Confusion Matrix:: a table showing correct predictions and types of incorrect predictions.

Precision:: the number of true positives divided by all positive predictions. Precision is also called Positive Predictive Value. It is a measure of a classifier's exactness. Low precision indicates a high number of false positives.

Recall:: the number of true positives divided by the number of positive values in the test data. Recall is also called Sensitivity or the True Positive Rate. It is a measure of a classifier's completeness. Low recall indicates a high number of false negatives.

F1:: Score: the weighted average of precision and recall.

In [55]:
```
#Evaluate model by calculating accuracy and area under curve (AUC)
rf_hyper_eval = BinaryClassificationEvaluator(rawPredictionCol="probability
rf_hyper_AUC  = rf_hyper_eval.evaluate(predictions)
#rf_hyper_ACC  = rf_hyper_eval.evaluate(predictions, {rf_hyper_eval.metricN

print("Performance Measure")
#print("Accuracy = %0.2f" % rf_hyper_ACC)
print("AUC = %.2f" % rf_hyper_AUC)
```

```
Performance Measure
AUC = 0.92
```

In [56]:
```
cm_rf_result_hyper = predictions.crosstab("prediction", "label")
cm_rf_result_hyper = cm_rf_result_hyper.toPandas()
cm_rf_result_hyper
```

Out[56]:

| prediction_label | 0 | 1 |
|---|---|---|
| 0 1.0 | 1551 | 11452 |
| 1 0.0 | 11899 | 1945 |

In [57]:
```
predictions.select('prediction','label').distinct().show()
```

```
+----------+-----+
|prediction|label|
+----------+-----+
|       1.0|    1|
|       0.0|    1|
|       1.0|    0|
|       0.0|    0|
+----------+-----+
```

In [58]:
```
#calculate accuracy, sensitivity, specificity and precision
TP = cm_rf_result_hyper["1"][0]
FP = cm_rf_result_hyper["0"][0]
TN = cm_rf_result_hyper["0"][1]
FN = cm_rf_result_hyper["1"][1]


Accuracy = (TP+TN)/(TP+FP+TN+FN)
Sensitivity = TP/(TP+FN)
Specificity = TN/(TN+FP)
Precision = TP/(TP+FP)

print ("Accuracy = %0.2f" %Accuracy )
print ("Sensitivity/Recall = %0.2f" %Sensitivity )
print ("Specificity = %0.2f" %Specificity )
print ("Precision = %0.2f" %Precision )
```

```
Accuracy = 0.87
Sensitivity/Recall = 0.85
Specificity = 0.88
Precision = 0.88
```

In [59]:
```
from pyspark.ml.evaluation import RegressionEvaluator
evaluator = RegressionEvaluator(labelCol="label", predictionCol="prediction

rmse = evaluator.evaluate(predictions)
print("Root Mean Squared Error (RMSE) on test data = %g" % rmse)
```

```
Root Mean Squared Error (RMSE) on test data = 0.360859
```

In [60]:
```
sqlContext.clearCache()
```

# THANK YOU