In [1]:

```
import warnings
warnings.filterwarnings("ignore")
import pandas as pd
import sqlite3
import csv
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from wordcloud import WordCloud
import re
import os
from sqlalchemy import create_engine # database connection
import datetime as dt
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.stem.snowball import SnowballStemmer
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.multiclass import OneVsRestClassifier
from sklearn.linear_model import SGDClassifier
from sklearn import metrics
from sklearn.metrics import f1_score,precision_score,recall_score
from sklearn import svm
from sklearn.linear_model import LogisticRegression
from skmultilearn.adapt import mlknn
from skmultilearn.problem_transform import ClassifierChain
from skmultilearn.problem_transform import BinaryRelevance
from skmultilearn.problem_transform import LabelPowerset
from sklearn.naive_bayes import GaussianNB
from datetime import datetime
```

Stack Overflow: Tag Prediction

1. Business Problem

1.1 Description

Description

Stack Overflow is the largest, most trusted online community for developers to learn, share their programming knowledge, and build their careers.

Stack Overflow is something which every programmer use one way or another. Each month, over 50 million developers come to Stack Overflow to learn, share their knowledge, and build their careers. It features questions and answers on a wide range of topics in computer programming. The website serves as a platform for users to ask and answer questions, and, through membership and active participation, to vote questions and answers up or down and edit questions and answers in a fashion similar to a wiki or Digg. As of April 2014 Stack Overflow has over 4,000,000 registered users, and it exceeded 10,000,000 questions in late August 2015. Based on the type of tags assigned to questions, the top eight most discussed topics on the site are: Java, JavaScript, C#, PHP, Android, jQuery, Python and HTML.

Problem Statemtent

Suggest the tags based on the content that was there in the question posted on Stackoverflow.

Source: https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/

1.2 Source / useful links

Data Source : https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data
Youtube : https://youtu.be/nNDqbUhtIRg
Research paper : https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/tagging-1.pdf
Research paper : https://dl.acm.org/citation.cfm?id=2660970&dl=ACM&coll=DL

1.3 Real World / Business Objectives and Constraints

1. Predict as many tags as possible with high precision and recall.
2. Incorrect tags could impact customer experience on StackOverflow.
3. No strict latency constraints.

2. Machine Learning problem

2.1 Data

2.1.1 Data Overview

Refer: https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data
All of the data is in 2 files: Train and Test.

```
Train.csv contains 4 columns: Id,Title,Body,Tags.

Test.csv contains the same columns but without the Tags, which you are to predict.

Size of Train.csv - 6.75GB
```

Size of Test.csv - 2GB

Number of rows in Train.csv = 6034195

The questions are randomized and contains a mix of verbose text sites as well as sites related to math and programming. The number of questions from each site may vary, and no filtering has been performed on the questions (such as closed questions).

Data Field Explaination

Dataset contains 6,034,195 rows. The columns in the table are:

Id - Unique identifier for each question

Title - The question's title

Body - The body of the question

Tags - The tags associated with the question in a space-seperated format (all lowercase, should not contain tabs '\t' or ampersands '&')

2.1.2 Example Data point

Title: Implementing Boundary Value Analysis of Software Testing in a C++ program?
Body :

```
       #include<
       iostream>\n
       #include<
       stdlib.h>\n\n
       using namespace std;\n\n
       int main()\n
       {\n
                int n,a[n],x,c,u[n],m[n],e[n][4];\n

                cout<<"Enter the number of variables";\n
       cin>>n;\n\n
                cout<<"Enter the Lower, and Upper Limits
of the variables";\n
                for(int y=1; y<n+1; y++)\n
                {\n
                   cin>>m[y];\n
                   cin>>u[y];\n
                }\n
                for(x=1; x<n+1; x++)\n
                {\n
                   a[x] = (m[x] + u[x])/2;\n
                }\n
                c=(n*4)-4;\n
                for(int a1=1; a1<n+1; a1++)\n
                {\n\n
                   e[a1][0] = m[a1];\n
                   e[a1][1] = m[a1]+1;\n
                   e[a1][2] = u[a1]-1;\n
                   e[a1][3] = u[a1];\n
                }\n
                for(int i=1; i<n+1; i++)\n
                {\n
```

```
                       for(int l=1; l<=i; l++)\n
                       {\n
                           if(l!=1)\n
                           {\n
                               cout<<a[l]<<"\\t";\n

                           }\n
                       }\n
                       for(int j=0; j<4; j++)\n
                       {\n
                           cout<<e[i][j];\n
                           for(int k=0; k<n-(i+1); k++)\n

                           {\n
                               cout<<a[k]<<"\\t";\n

                           }\n
                           cout<<"\\n";\n
                       }\n
                    }    \n\n
                    system("PAUSE");\n
                    return 0;    \n
           }\n


\n\n


The answer should come in the form of a table like
\n\n



           1            50              50\n
           2            50              50\n
           99           50              50\n
           100          50              50\n
           50           1               50\n
           50           2               50\n
           50           99              50\n
           50           100             50\n
           50           50              1\n
           50           50              2\n
           50           50              99\n
           50           50              100\n


\n\n


if the no of inputs is 3 and their ranges are\n
        1,100\n
        1,100\n
        1,100\n
        (could be varied too)
\n\n


The output is not coming,can anyone correct the code or tell me
 what\'s wrong?
\n'
Tags : 'c++ c'
```

2.2 Mapping the real-world problem to a Machine Learning Problem

2.2.1 Type of Machine Learning Problem

It is a multi-label classification problem
Multi-label Classification: Multilabel classification assigns to each sample a set of target labels. This can be thought as predicting properties of a data-point that are not mutually exclusive, such as topics that are relevant for a document. A question on Stackoverflow might be about any of C, Pointers, FileIO and/or memory-management at the same time or none of these.
__Credit__: http://scikit-learn.org/stable/modules/multiclass.html

2.2.2 Performance metric

Micro-Averaged F1-Score (Mean F Score) : The F1 score can be interpreted as a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst score at 0. The relative contribution of precision and recall to the F1 score are equal. The formula for the F1 score is:

$$F1 = 2 * (\mathit{precision} * \mathit{recall}) / (\mathit{precision} + \mathit{recall})$$

In the multi-class and multi-label case, this is the weighted average of the F1 score of each class.

'Micro f1 score':
Calculate metrics globally by counting the total true positives, false negatives and false positives. This is a better metric when we have class imbalance.

'Macro f1 score':
Calculate metrics for each label, and find their unweighted mean. This does not take label imbalance into account.

https://www.kaggle.com/wiki/MeanFScore
http://scikit-learn.org/stable/modules/generated/sklearn.metrics.f1_score.html

Hamming loss : The Hamming loss is the fraction of labels that are incorrectly predicted.
https://www.kaggle.com/wiki/HammingLoss

3. Exploratory Data Analysis

3.1 Data Loading and Cleaning

3.1.1 Using Pandas with SQLite to Load the data

In [2]:

```
#Creating db file from csv
#Learn SQL: https://www.w3schools.com/sql/default.asp
if not os.path.isfile('train.db'):
    start = datetime.now()
    disk_engine = create_engine('sqlite:///train.db')
    start = dt.datetime.now()
    chunksize = 180000
    j = 0
    index_start = 1
    for df in pd.read_csv('Train.csv', names=['Id', 'Title', 'Body', 'Tags'], chunksize=chunksize, iterator=True, encoding='utf-8', ):
        df.index += index_start
        j+=1
        print('{} rows'.format(j*chunksize))
        df.to_sql('data', disk_engine, if_exists='append')
        index_start = df.index[-1] + 1
    print("Time taken to run this cell :", datetime.now() - start)
```

3.1.2 Counting the number of rows

In [3]:

```
if os.path.isfile('train.db'):
    start = datetime.now()
    con = sqlite3.connect('train.db')
    num_rows = pd.read_sql_query("""SELECT count(*) FROM data""", con)
    #Always remember to close the database
    print("Number of rows in the database :","\n",num_rows['count(*)'].
values[0])
    con.close()
    print("Time taken to count the number of rows :", datetime.now() -
start)
else:
    print("Please download the train.db file from drive or run the abov
e cell to genarate train.db file")
```

```
Number of rows in the database :
 6034196
Time taken to count the number of rows : 0:00:00.337998
```

3.1.3 Checking for duplicates

In [4]:

```
#Learn SQl: https://www.w3schools.com/sql/default.asp
if os.path.isfile('train.db'):
    start = datetime.now()
    con = sqlite3.connect('train.db')
    df_no_dup = pd.read_sql_query('SELECT Title, Body, Tags, COUNT(*) a
s cnt_dup FROM data WHERE Tags IS NOT NULL \
                                  GROUP BY Title, Body, Tags LIMIT 5000
00', con)
    con.close()
    print("Time taken to run this cell :", datetime.now() - start)
else:
    print("Please download the train.db file from drive or run the firs
t to genarate train.db file")
```

```
Time taken to run this cell : 0:01:17.795018
```

In [5]:

```
df_no_dup.head()
# we can observe that there are duplicates
```

Out[5]:

Title	Body	Tags	cnt_dup

	Title	Body	Tags	cnt_dup
0	Implementing Boundary Value Analysis of S...	<pre><code>#include&lt;iostream&gt;\n#include&...	c++ c	1
1	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding	1
2	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding columns	1
3	java.lang.NoClassDefFoundError: javax/serv...	<p>I followed the guide in <a href="http://sta...	jsp jstl	1
4	java.sql.SQLException:[Microsoft][ODBC Dri...	<p>I use the following code</p>\n\n<pre><code>...	java jdbc	2

In [6]:

```
print("number of duplicate questions :", num_rows['count(*)'].values[0]
- df_no_dup.shape[0], "(",(1-((df_no_dup.shape[0])/(num_rows['count(*)'
].values[0])))*100,"% )")
```

```
number of duplicate questions : 5534196 ( 91.71389195843159 % )
```

In [7]:

```
# number of times each question appeared in our database
df_no_dup.cnt_dup.value_counts()
```

Out[7]:

```
1    315993
2    150976
3     33020
4         9
6         1
5         1
Name: cnt_dup, dtype: int64
```

In [8]:

```
start = datetime.now()
df_no_dup["tag_count"] = df_no_dup["Tags"].apply(lambda text: len(text.
split(" ")))
```

```
# adding a new feature number of tags per question
print("Time taken to run this cell :", datetime.now() - start)
df_no_dup.head()
```

```
Time taken to run this cell : 0:00:00.376469
```

Out[8]:

	Title	Body	Tags	cnt_dup	tag
0	Implementing Boundary Value Analysis of S...	<pre><code>#include&lt;iostream&gt;\n#include&...	c++ c	1	
1	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding	1	
2	Dynamic Datagrid Binding in Silverlight?	<p>I should do binding for datagrid dynamicall...	c# silverlight data-binding columns	1	
3	java.lang.NoClassDefFoundError: javax/serv...	<p>I followed the guide in <a href="http://sta...	jsp jstl	1	
4	java.sql.SQLException:[Microsoft][ODBC Dri...	<p>I use the following code</p>\n\n<pre><code>...	java jdbc	2	

In [9]:

```
# distribution of number of tags per question
df_no_dup.tag_count.value_counts()
```

Out[9]:

```
3    144976
2    128685
4     99996
1     63344
5     62999
Name: tag_count, dtype: int64
```

In [10]:

```
#Creating a new database with no duplicates
if not os.path.isfile('train_no_dup.db'):
    disk_dup = create_engine("sqlite:///train_no_dup.db")
    no_dup = pd.DataFrame(df_no_dup, columns=['Title', 'Body', 'Tags'])
    no_dup.to_sql('no_dup_train',disk_dup)
```

In [11]:

```
#This method seems more appropriate to work with this much data.
#creating the connection with database file.
if os.path.isfile('train_no_dup.db'):
    start = datetime.now()
    con = sqlite3.connect('train_no_dup.db')
    tag_data = pd.read_sql_query("""SELECT Tags FROM no_dup_train WHERE
 Tags IS NOT NULL""", con)
    #Always remember to close the database
    con.close()

    # Let's now drop unwanted column.
    tag_data.drop(tag_data.index[0], inplace=True)
    #Printing first 5 columns from our data frame
    tag_data.head()
    print("Time taken to run this cell :", datetime.now() - start)
else:
    print("Please download the train.db file from drive or run the abov
e cells to genarate train.db file")
```

```
Time taken to run this cell : 0:00:20.241672
```

3.2 Analysis of Tags

3.2.1 Total number of unique tags

In [12]:

```
# Importing & Initializing the "CountVectorizer" object, which
#is scikit-learn's bag of words tool.

#by default 'split()' will tokenize each tag using space.
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(),max_featur
es=20000,ngram_range=(1,2))
# fit_transform() does two functions: First, it fits the model
# and learns the vocabulary; second, it transforms our training data
# into feature vectors. The input to fit_transform should be a list of
 strings.
tag_dtm = vectorizer.fit_transform(tag_data['Tags'])
```

In [13]:

```
print("Number of data points :", tag_dtm.shape[0])
print("Number of unique tags :", tag_dtm.shape[1])
```

```
Number of data points : 4206307
Number of unique tags : 20000
```

In [14]:

```
#'get_feature_name()' gives us the vocabulary.
tags = vectorizer.get_feature_names()
#Lets look at the tags we have.
print("Some of the tags we have :", tags[:10])
```

```
Some of the tags we have : ['.bash-profile', '.each', '.htaccess', '.ht
access apache2', '.htaccess cakephp', '.htaccess codeigniter', '.htacce
ss magento', '.htaccess mod-rewrite', '.htaccess redirect', '.htaccess
rewrite']
```

3.2.3 Number of times a tag appeared

In [15]:

```
# https://stackoverflow.com/questions/15115765/how-to-access-sparse-mat
rix-elements
#Lets now store the document term matrix in a dictionary.
freqs = tag_dtm.sum(axis=0).A1
result = dict(zip(tags, freqs))
```

In [16]:

```
#Saving this dictionary to csv files.
if not os.path.isfile('tag_counts_dict_dtm.csv'):
    with open('tag_counts_dict_dtm.csv', 'w') as csv_file:
        writer = csv.writer(csv_file)
        for key, value in result.items():
            writer.writerow([key, value])
tag_df = pd.read_csv("tag_counts_dict_dtm.csv", names=['Tags', 'Counts'
])
tag_df.head()
```

Out[16]:

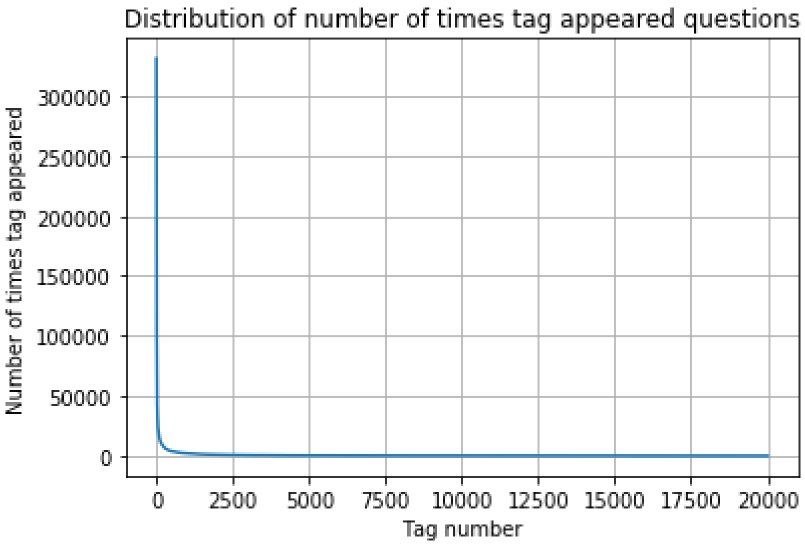
	Tags	Counts
0	storyboard	1939
1	html5 html5-video	273
2	html-tag	79
3	php opencart	128
4	android css	266

In [17]:

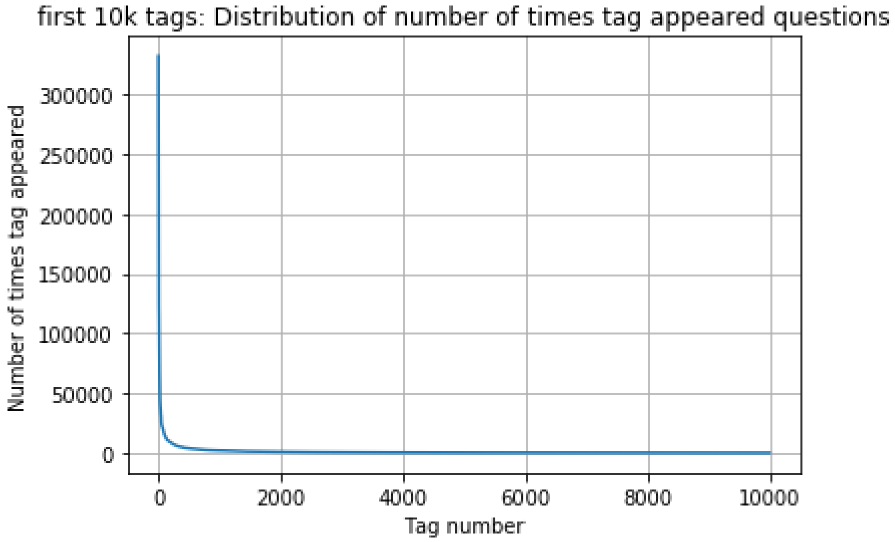
```
tag_df_sorted = tag_df.sort_values(['Counts'], ascending=False)
tag_counts = tag_df_sorted['Counts'].values
```

In [18]:

```
plt.plot(tag_counts)
plt.title("Distribution of number of times tag appeared questions")
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
```



In [19]:
```
plt.plot(tag_counts[0:10000])
plt.title('first 10k tags: Distribution of number of times tag appeared
 questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:10000:25]), tag_counts[0:10000:25])
```

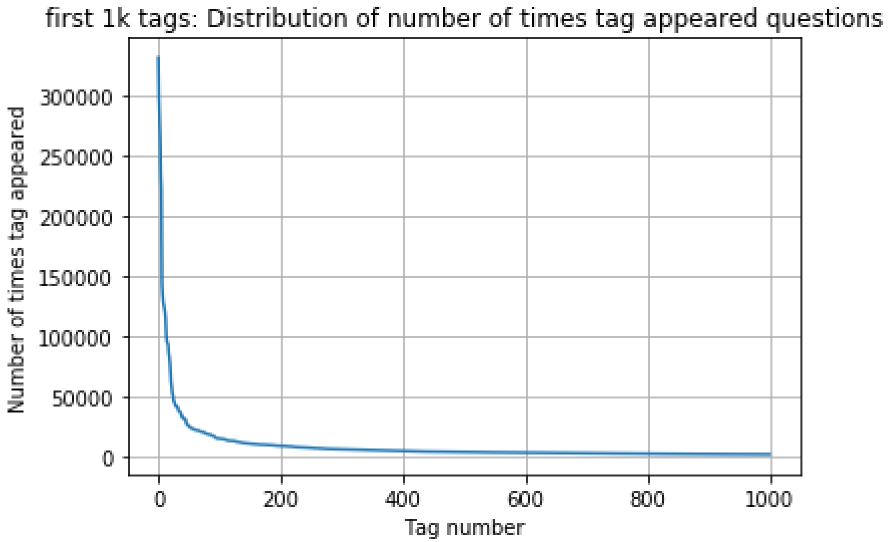


```
400 [331505   46769   25375   20180   15380   13157   11023   10029    9159    8
197
   7528    6704    6207    5817    5421    5128    4890    4526    4314    4201
   4050    3874    3728    3609    3483    3375    3235    3091    2986    2900
   2756    2698    2617    2531    2449    2399    2331    2266    2211    2162
   2107    2061    2013    1965    1929    1876    1839    1804    1757    1723
   1695    1662    1631    1601    1555    1525    1491    1464    1444    1419
   1390    1363    1339    1317    1300    1279    1255    1240    1225    1210
   1191    1178    1163    1153    1137    1121    1109    1090    1077    1065
   1051    1038    1029    1016    1005     985     974     962     951     941
    928     918     908     894     886     878     871     862     847     839
    832     822     814     806     798     788     781     776     768     759
    747     742     735     731     725     717     711     702     694     689
    685     680     673     666     659     654     649     644     638     633
```

```
        629      623      617      613      607      603      597      590      585      582
        578      573      568      562      558      553      549      544      541      538
        532      528      524      521      516      513      510      506      503      499
        495      492      489      485      482      479      475      473      468      466
        462      459      456      453      449      447      444      442      439      437
        433      431      429      426      424      422      419      416      414      412
        409      406      403      401      399      396      393      390      388      387
        385      383      380      378      375      374      372      370      369      366
        365      363      361      359      356      354      352      351      349      348
        346      344      342      341      340      338      336      335      333      331
        330      328      326      324      323      321      319      318      316      314
        313      311      310      308      307      306      304      303      301      300
        299      298      296      295      294      293      292      291      289      288
        286      285      284      283      282      280      279      278      277      276
        275      273      272      271      270      269      268      267      265      264
        263      262      260      259      259      258      257      256      255      253
        252      251      251      250      249      248      248      247      246      245
        244      243      242      241      240      239      238      238      237      236
        234      234      233      232      231      231      230      229      228      227
        227      226      225      224      223      222      221      220      220      219
        218      217      217      216      215      214      214      213      213      212
        211      210      209      209      208      207      206      206      205      205
        204      203      202      201      201      200      199      199      198      197
        197      196      196      195      194      194      193      193      192      192
        191      190      190      189      188      188      188      187      186      186
        185      184      184      183      183      182      182      181      180      180
        179      179      178      178      177      177      176      176      175      175]
```

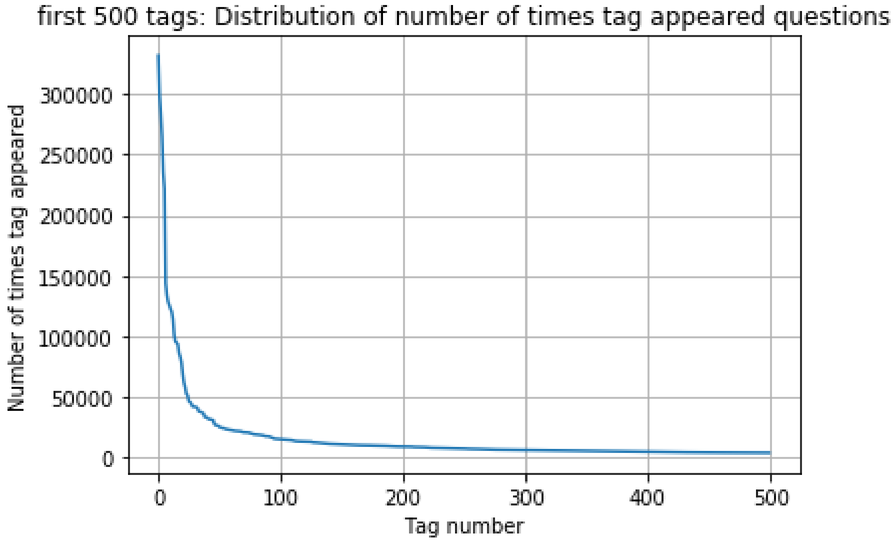
In [20]:

```
plt.plot(tag_counts[0:1000])
plt.title('first 1k tags: Distribution of number of times tag appeared
 questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:1000:5]), tag_counts[0:1000:5])
```



```
200 [331505 221533 122769  95160  69168  46769  42006  37868  33373  31
069
  25375  23585  22747  21942  21006  20180  19161  18432  17640  15671
  15380  15087  14108  13532  13364  13157  12407  11897  11454  11208
  11023  10741  10525  10288  10205  10029   9981   9787   9523   9265
   9159   9079   8833   8698   8545   8197   8065   7933   7828   7684
   7528   7265   7115   7044   6856   6704   6628   6513   6447   6291
   6207   6139   6039   5971   5866   5817   5757   5669   5574   5498
   5421   5399   5360   5283   5209   5128   5083   5020   4988   4939
   4890   4785   4663   4593   4548   4526   4501   4447   4392   4335
   4314   4289   4273   4241   4233   4201   4184   4157   4142   4088
   4050   4003   3971   3947   3919   3874   3849   3822   3799   3757
   3728   3703   3685   3660   3636   3609   3583   3563   3521   3509
   3483   3468   3447   3422   3402   3375   3333   3309   3293   3272
   3235   3198   3174   3148   3108   3091   3073   3050   3032   3008
   2986   2983   2953   2935   2920   2900   2878   2843   2819   2784
   2756   2749   2733   2724   2716   2698   2679   2667   2652   2627
   2617   2604   2598   2586   2548   2531   2520   2502   2489   2470
   2449   2441   2431   2416   2408   2399   2387   2371   2363   2346
   2331   2312   2301   2295   2284   2266   2259   2248   2242   2222
   2211   2206   2197   2186   2174   2162   2146   2138   2127   2117]
```

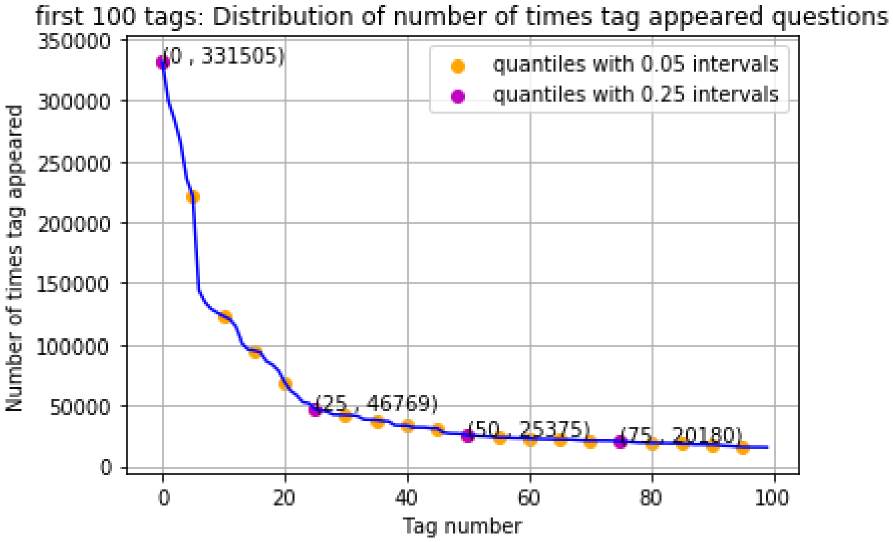
```
In [21]: plt.plot(tag_counts[0:500])
         plt.title('first 500 tags: Distribution of number of times tag appeared
          questions')
         plt.grid()
         plt.xlabel("Tag number")
         plt.ylabel("Number of times tag appeared")
         plt.show()
         print(len(tag_counts[0:500:5]), tag_counts[0:500:5])
```



```
100 [331505 221533 122769  95160  69168  46769  42006  37868  33373  31
069
  25375  23585  22747  21942  21006  20180  19161  18432  17640  15671
  15380  15087  14108  13532  13364  13157  12407  11897  11454  11208
  11023  10741  10525  10288  10205  10029   9981   9787   9523   9265
   9159   9079   8833   8698   8545   8197   8065   7933   7828   7684
   7528   7265   7115   7044   6856   6704   6628   6513   6447   6291
   6207   6139   6039   5971   5866   5817   5757   5669   5574   5498
   5421   5399   5360   5283   5209   5128   5083   5020   4988   4939
   4890   4785   4663   4593   4548   4526   4501   4447   4392   4335
   4314   4289   4273   4241   4233   4201   4184   4157   4142   4088]
```

In [22]:

```
plt.plot(tag_counts[0:100], c='b')
plt.scatter(x=list(range(0,100,5)), y=tag_counts[0:100:5], c='orange',
label="quantiles with 0.05 intervals")
# quantiles with 0.25 difference
plt.scatter(x=list(range(0,100,25)), y=tag_counts[0:100:25], c='m', lab
el = "quantiles with 0.25 intervals")

for x,y in zip(list(range(0,100,25)), tag_counts[0:100:25]):
    plt.annotate(s="({} , {})".format(x,y), xy=(x,y), xytext=(x-0.05, y
+500))

plt.title('first 100 tags: Distribution of number of times tag appeared
 questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.legend()
plt.show()
print(len(tag_counts[0:100:5]), tag_counts[0:100:5])
```



```
20 [331505 221533 122769  95160  69168  46769  42006  37868  33373  310
69
  25375  23585  22747  21942  21006  20180  19161  18432  17640  15671]
```

In [23]:

```
# Store tags greater than 10K in one list
lst_tags_gt_10k = tag_df[tag_df.Counts>10000].Tags
#Print the length of the list
print ('{} Tags are used more than 10000 times'.format(len(lst_tags_gt_
10k)))
# Store tags greater than 100K in one list
lst_tags_gt_100k = tag_df[tag_df.Counts>100000].Tags
#Print the length of the list.
print ('{} Tags are used more than 100000 times'.format(len(lst_tags_gt
_100k)))
```

```
178 Tags are used more than 10000 times
14 Tags are used more than 100000 times
```

Observations:

1. There are total 178 tags which are used more than 10000 times.
2. 14 tags are used more than 100000 times.
3. Most frequent tag (i.e. c#) is used 331505 times.
4. Since some tags occur much more frequenctly than others, Micro-averaged F1-score is the appropriate metric for this problem.

3.2.4 Tags Per Question

In [24]:

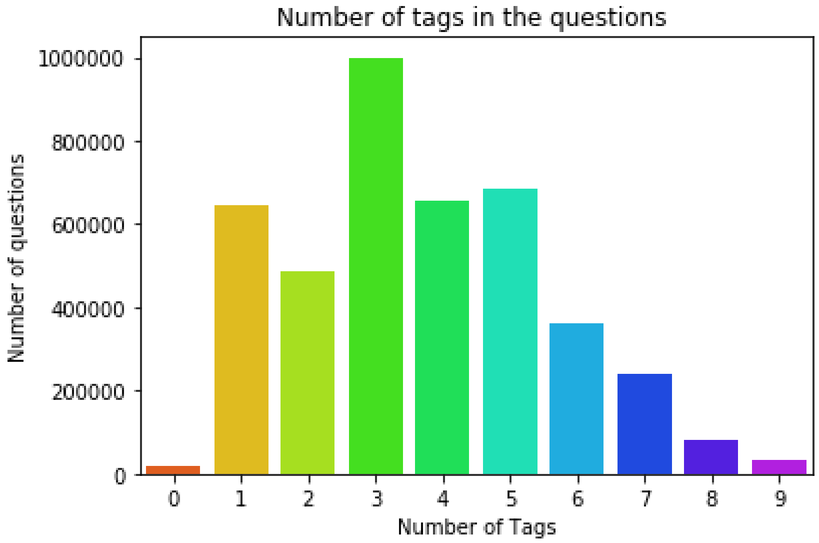
```
#Storing the count of tag in each question in list 'tag_count'
tag_quest_count = tag_dtm.sum(axis=1).tolist()
#Converting list of lists into single list, we will get [[3], [4], [2],
 [2], [3]] and we are converting this to [3, 4, 2, 2, 3]
tag_quest_count=[int(j) for i in tag_quest_count for j in i]
print ('We have total {} datapoints.'.format(len(tag_quest_count)))

print(tag_quest_count[:5])
```

```
We have total 4206307 datapoints.
[5, 6, 3, 3, 4]
```

```
In [25]: print( "Maximum number of tags per question: %d"%max(tag_quest_count))
         print( "Minimum number of tags per question: %d"%min(tag_quest_count))
         print( "Avg. number of tags per question: %f"% ((sum(tag_quest_count)*
         1.0)/len(tag_quest_count)))
```

```
Maximum number of tags per question: 9
Minimum number of tags per question: 0
Avg. number of tags per question: 3.669640
```

```
In [26]: sns.countplot(tag_quest_count, palette='gist_rainbow')
         plt.title("Number of tags in the questions ")
         plt.xlabel("Number of Tags")
         plt.ylabel("Number of questions")
         plt.show()
```



Observations:

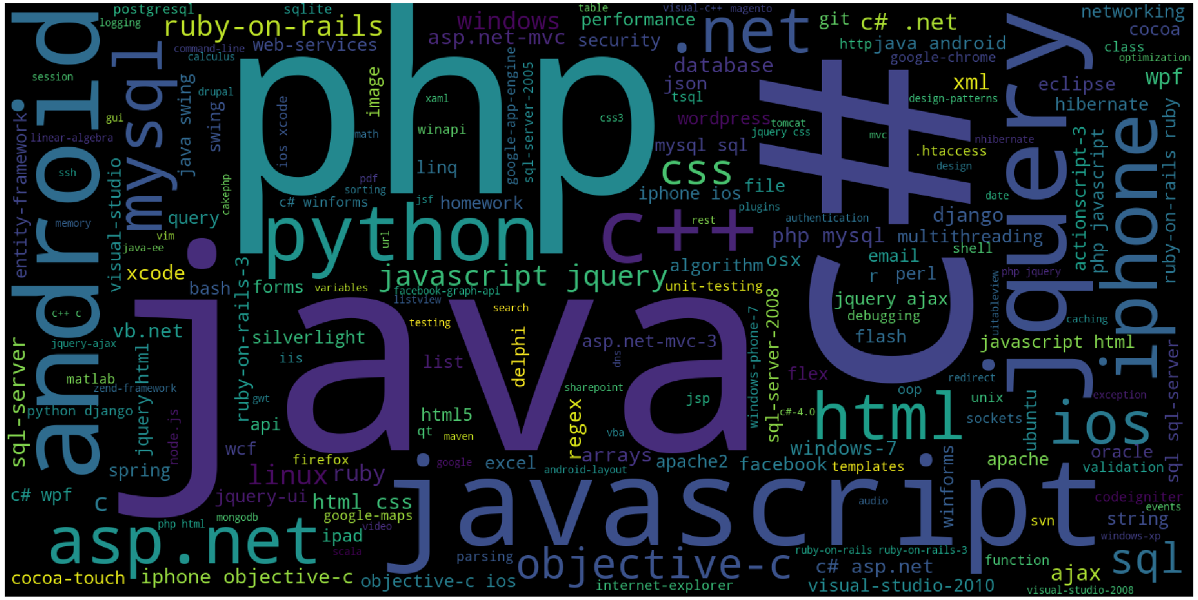
1. Maximum number of tags per question: 9
2. Minimum number of tags per question: 0
3. Avg. number of tags per question: 3.669

4. Most of the questions are having 3 or 5 tags.

3.2.5 Most Frequent Tags

In [27]:

```
# Ploting word cloud
start = datetime.now()

# Lets first convert the 'result' dictionary to 'list of tuples'
tup = dict(result.items())
#Initializing WordCloud using frequencies of tags.
wordcloud = WordCloud(    background_color='black',
                          width=1600,
                          height=800,
                    ).generate_from_frequencies(tup)

fig = plt.figure(figsize=(30,20))
plt.imshow(wordcloud)
plt.axis('off')
plt.tight_layout(pad=0)
fig.savefig("tag.png")
plt.show()
print("Time taken to run this cell :", datetime.now() - start)
```



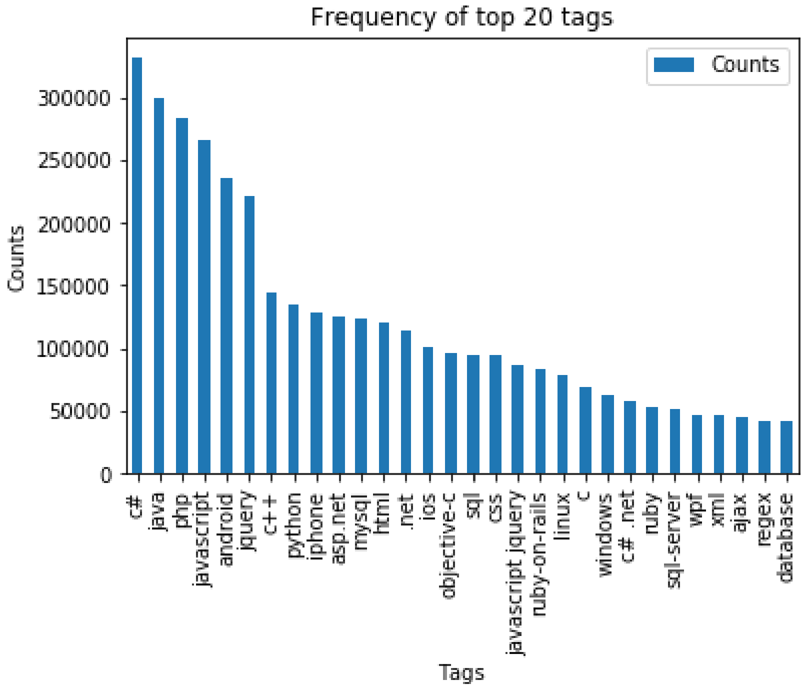
```
Time taken to run this cell : 0:00:05.020815
```

Observations:
A look at the word cloud shows that "c#", "java", "php", "asp.net", "javascript", "c++" are some of the most frequent tags.

3.2.6 The top 20 tags

In [28]:

```
i=np.arange(30)
tag_df_sorted.head(30).plot(kind='bar')
plt.title('Frequency of top 20 tags')
plt.xticks(i, tag_df_sorted['Tags'])
plt.xlabel('Tags')
plt.ylabel('Counts')
plt.show()
```



Observations:

1. Majority of the most frequent tags are programming language.
2. C# is the top most frequent programming language.
3. Android, IOS, Linux and windows are among the top most frequent operating systems.

3.3 Cleaning and preprocessing of Questions

3.3.1 Preprocessing

1. Sample 0.5M data points
2. Separate out code-snippets from Body

3. Remove Spcial characters from Question title and description (not in code)
4. Remove stop words (Except 'C')
5. Remove HTML Tags
6. Convert all the characters into small letters
7. Use SnowballStemmer to stem the words

In [29]:

```
import nltk
nltk.download('stopwords')

def striphtml(data):
    cleanr = re.compile('<.*?>')
    cleantext = re.sub(cleanr, ' ', str(data))
    return cleantext
stop_words = set(stopwords.words('english'))
stemmer = SnowballStemmer("english")
```

```
[nltk_data] Downloading package stopwords to
[nltk_data]     /home/sujit_biswal624882/nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
```

In [30]:

```
#http://www.sqlitetutorial.net/sqlite-python/create-tables/
def create_connection(db_file):
    """ create a database connection to the SQLite database
        specified by db_file
    :param db_file: database file
    :return: Connection object or None
    """
    try:
        conn = sqlite3.connect(db_file)
        return conn
    except Error as e:
        print(e)

    return None

def create_table(conn, create_table_sql):
    """ create a table from the create_table_sql statement
    :param conn: Connection object
    :param create_table_sql: a CREATE TABLE statement
    :return:
    """
    try:
        c = conn.cursor()
        c.execute(create_table_sql)
    except Error as e:
        print(e)

def checkTableExists(dbcon):
    cursr = dbcon.cursor()
    str = "select name from sqlite_master where type='table'"
    table_names = cursr.execute(str)
    print("Tables in the databse:")
    tables =table_names.fetchall()
    print(tables[0][0])
    return(len(tables))

def create_database_table(database, query):
    conn = create_connection(database)
    if conn is not None:
        create_table(conn, query)
        checkTableExists(conn)
    else:
        print("Error! cannot create the database connection.")
    conn.close()

sql_create_table = """CREATE TABLE IF NOT EXISTS QuestionsProcessed (question text NOT NULL, code text, tags text, words_pre integer, words_post integer, is_code integer);"""
create_database_table("Processed.db", sql_create_table)
```

```
Tables in the databse:
QuestionsProcessed
```

In [31]:

```
# http://www.sqlitetutorial.net/sqlite-delete/
# https://stackoverflow.com/questions/2279706/select-random-row-from-a-sqlite-table
```

```
start = datetime.now()
read_db = 'train_no_dup.db'
write_db = 'Processed.db'
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT Title, Body, Tags From no_dup_train ORDE
R BY RANDOM() LIMIT 50000;")

if os.path.isfile(write_db):
    conn_w = create_connection(write_db)
    if conn_w is not None:
        tables = checkTableExists(conn_w)
        writer =conn_w.cursor()
        if tables != 0:
            writer.execute("DELETE FROM QuestionsProcessed WHERE 1")
            print("Cleared All the rows")
print("Time taken to run this cell :", datetime.now() - start)
```

```
Tables in the databse:
QuestionsProcessed
Cleared All the rows
Time taken to run this cell : 0:00:26.870566
```

we create a new data base to store the sampled and preprocessed questions

In [32]:

```
#### http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an
-sqlite-table/

import nltk
nltk.download('punkt')

start = datetime.now()
preprocessed_data_list=[]
reader.fetchone()
questions_with_code=0
len_pre=0
```

```
len_post=0
questions_proccesed = 0
for row in reader:

    is_code = 0

    title, question, tags = row[0], row[1], row[2]

    if '<code>' in question:
        questions_with_code+=1
        is_code = 1
    x = len(question)+len(title)
    len_pre+=x

    code = str(re.findall(r'<code>(.*?)</code>', question, flags=re.DOTALL))

    question=re.sub('<code>(.*?)</code>', '', question, flags=re.MULTILINE|re.DOTALL)
    question=striphtml(question.encode('utf-8'))

    title=title.encode('utf-8')

    question=str(title)+" "+str(question)
    question=re.sub(r'[^A-Za-z]+',' ',question)
    words=word_tokenize(str(question.lower()))

    #Removing all single letter and and stopwords from question except for the letter 'c'
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words and (len(j)!=1 or j=='c'))

    len_post+=len(question)
    tup = (question,code,tags,x,len(question),is_code)
    questions_proccesed += 1
    writer.execute("insert into QuestionsProcessed(question,code,tags,words_pre,words_post,is_code) values (?,?,?,?,?,?)",tup)
    if (questions_proccesed%100000==0):
        print("number of questions completed=",questions_proccesed)
```

```
no_dup_avg_len_pre=(len_pre*1.0)/questions_proccesed
no_dup_avg_len_post=(len_post*1.0)/questions_proccesed

print( "Avg. length of questions(Title+Body) before processing: %d"%no_dup_avg_len_pre)
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_post)
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/questions_proccesed))

print("Time taken to run this cell :", datetime.now() - start)
```

```
[nltk_data] Downloading package punkt to
[nltk_data]     /home/sujit_biswal624882/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
```

```
Avg. length of questions(Title+Body) before processing: 1171
Avg. length of questions(Title+Body) after processing: 325
Percent of questions containing code: 57
Time taken to run this cell : 0:01:14.824407
```

In [33]:

```
# dont forget to close the connections, or else you will end up with locks
conn_r.commit()
conn_w.commit()
conn_r.close()
conn_w.close()
```

In [34]:

```
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT question From QuestionsProcessed LIMIT 10")
        print("Questions after preprocessed")
        print('='*100)
        reader.fetchone()
        for row in reader:
            print(row)
            print('-'*100)
conn_r.commit()
conn_r.close()
```

```
Questions after preprocessed
==========================================================================
==============================
('self sign certif work behind apach revers proxi want use apach revers
proxi collect app server plan se ca sign ssl certif apach instanc want
use self sign certif app server instanc apach app sever connect also en
crypt dont want instal ca sign ssl certif app server instanc dont apach
allow configur self sign certif app server instanc',)
--------------------------------------------------------------------------
------------------------------
('python return max number array error python script connect websit via
ftp list current version number program locat websit creat array hold v
ersion number till script would pick largest number array tell exampl a
rray would usual look like use return largest valu array unfortun recei
v largest number fact latest version number nthe thing could think cut
list array receiv past back get full version number sinc websit contain
mani version know effici help would great appreci',)
--------------------------------------------------------------------------
------------------------------
('auto start applic user login mac java program creat bundl jar file cr
eat packag want auto start applic user login time rather manual set log
in item go user account system pref went link make app open login use l
aunchservic lssharedfilelist link code packag maker add xcode code post
instal script',)
--------------------------------------------------------------------------
------------------------------
('xcode ctrl drag edit code snippet xcode ctrl drag ib implement get th
ing like great howev chang code snippet action ni want brace line aka l
ook like',)
--------------------------------------------------------------------------
------------------------------
('close select dropdown list programat javascript jqueri dropdown initi
one singl valu user click singl element remov new element ad say load a
jax call issu server return new valu ad control problem control remain
open updat would like close exampl http jsfiddl net vtortola cgubk exam
pl ajax get data probabl someth wrong call jsfiddl api show select rema
in open updat want know close dropdown list programat focus anoth input
cheer',)
-----------------------------------------------------------------------
-----------------------------
('mutual friend request return wrong mutual friend app show user mutual
facebook friend show friend mutual friend well get show mutual friend w
ant see friend mutual friend random peopl',)
-----------------------------------------------------------------------
-----------------------------
('integr jetbrain teamciti atlassian stash stash come new rest api allo
w tell stash build relat specif changeset let stash know build teamcit
i',)
-----------------------------------------------------------------------
-----------------------------
('use urllib submit soap request soap request known work use tool like
say soapui tri get work use urllib tri far work abl find spec document
post soap server urllib necessari requir',)
-----------------------------------------------------------------------
-----------------------------
('compil linq queri built sql function queri execut c take way much tim
e use sqlcommand command new sqlcommand queri connect sqldataread reade
r command executeread read data take minut execut c much quicker ssms s
ee googl search someth compiledqueri confus whether still use built sql
function year month day getdat anyon show exampl creat call compil quer
i use built function grate thank advanc',)
-----------------------------------------------------------------------
-----------------------------
```

In [35]:

```
#Taking 50K entries to a dataframe.
write_db = 'Processed.db'
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        preprocessed_data = pd.read_sql_query("""SELECT question, Tags
 FROM QuestionsProcessed WHERE TAGS IS NOT NULL""", conn_r)
conn_r.commit()
conn_r.close()
```

In [36]:

```
preprocessed_data.head()
```

Out[36]:

	question	tags
0	carri exist wp user new buddypress instal made...	buddypress
1	self sign certif work behind apach revers prox...	apache ssl
2	python return max number array error python sc...	python arrays numbers max
3	auto start applic user login mac java program ...	packagemaker autostart
4	xcode ctrl drag edit code snippet xcode ctrl d...	xcode4

In [37]:

```
print("number of data points in sample :", preprocessed_data.shape[0])
print("number of dimensions :", preprocessed_data.shape[1])
```

```
number of data points in sample : 49999
number of dimensions : 2
```

4. Machine Learning Models

4.1 Converting tags for multilabel problems

X	y1	y2	y3	y4
x1	0	1	1	0
x1	1	0	0	0
x1	0	1	0	0

In [38]:

```
# binary='true' will give a binary vectorizer
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(), binary='true',max_features=20000,ngram_range=(1,2))
multilabel_y = vectorizer.fit_transform(preprocessed_data['tags'])
```

We will sample the number of tags instead considering all of them (due to limitation of computing power)

In [39]:

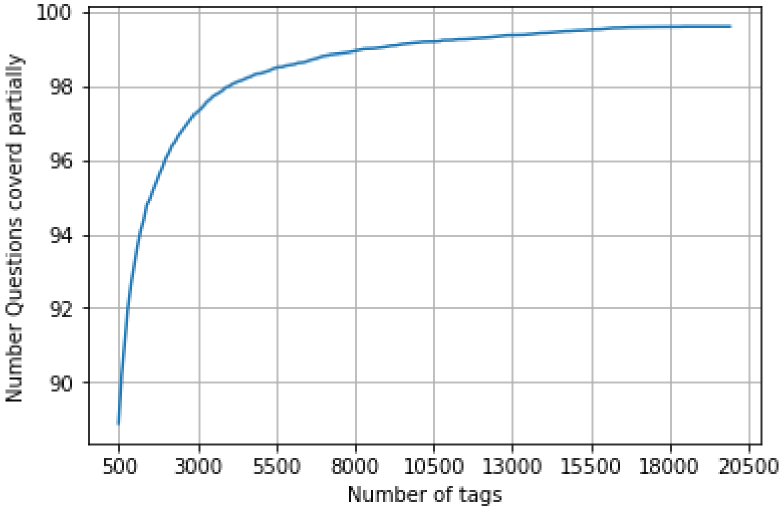
```
def tags_to_choose(n):
    t = multilabel_y.sum(axis=0).tolist()[0]
    sorted_tags_i = sorted(range(len(t)), key=lambda i: t[i], reverse=T
rue)
    multilabel_yn=multilabel_y[:,sorted_tags_i[:n]]
    return multilabel_yn

def questions_explained_fn(n):
    multilabel_yn = tags_to_choose(n)
    x= multilabel_yn.sum(axis=1)
    return (np.count_nonzero(x==0))
```

In [40]:

```
questions_explained = []
total_tags=multilabel_y.shape[1]
total_qs=preprocessed_data.shape[0]
for i in range(500, total_tags, 100):
    questions_explained.append(np.round(((total_qs-questions_explained_
fn(i))/total_qs)*100,3))
```

In [41]:

```
fig, ax = plt.subplots()
ax.plot(questions_explained)
xlabel = list(500+np.array(range(-50,450,50))*50)
ax.set_xticklabels(xlabel)
plt.xlabel("Number of tags")
plt.ylabel("Number Questions coverd partially")
plt.grid()
plt.show()
# you can choose any number of tags based on your computing power, mini
mun is 50(it covers 90% of the tags)
print("with ",5500,"tags we are covering ",questions_explained[50],"% o
f questions")
```



```
with  5500 tags we are covering  98.496 % of questions
```

In [42]:

```
multilabel_yx = tags_to_choose(5500)
print("number of questions that are not covered :", questions_explained
_fn(5500),"out of ", total_qs)
```

```
number of questions that are not covered : 752 out of  49999
```

In [43]:

```
print("Number of tags in sample :", multilabel_y.shape[1])
print("number of tags taken :", multilabel_yx.shape[1],"(",(multilabel_
yx.shape[1]/multilabel_y.shape[1])*100,"%)")
```

```
Number of tags in sample : 20000
number of tags taken : 5500 ( 27.500000000000004 %)
```

We consider top 15% tags which covers 99% of the questions

4.2 Split the data into test and train (80:20)

In [44]:

```
total_size=preprocessed_data.shape[0]
train_size=int(0.80*total_size)

x_train=preprocessed_data.head(train_size)
x_test=preprocessed_data.tail(total_size - train_size)

y_train = multilabel_yx[0:train_size,:]
y_test = multilabel_yx[train_size:total_size,:]
```

In [45]:

```
print("Number of data points in train data :", y_train.shape)
print("Number of data points in test data :", y_test.shape)
```

```
Number of data points in train data : (39999, 5500)
Number of data points in test data : (10000, 5500)
```

4.3 Featurizing data

In [46]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=200000, smoot
h_idf=True, norm="l2", \
                             tokenizer = lambda x: x.split(), sublinear
_tf=False, ngram_range=(1,2))
x_train_multilabel = vectorizer.fit_transform(x_train['question'])
x_test_multilabel = vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 0:00:11.048061
```

In [47]:

```
print("Dimensions of train data X:",x_train_multilabel.shape, "Y :",y_t
rain.shape)
print("Dimensions of test data X:",x_test_multilabel.shape,"Y:",y_test.
shape)
```

```
Dimensions of train data X: (39999, 94094) Y : (39999, 5500)
Dimensions of test data X: (10000, 94094) Y: (10000, 5500)
```

In [48]:

```
# https://www.analyticsvidhya.com/blog/2017/08/introduction-to-multi-la
```

```
bel-classification/
#https://stats.stackexchange.com/questions/117796/scikit-multi-label-cl
assification
# classifier = LabelPowerset(GaussianNB())
"""
from skmultilearn.adapt import MLkNN
classifier = MLkNN(k=21)

# train
classifier.fit(x_train_multilabel, y_train)

# predict
predictions = classifier.predict(x_test_multilabel)
print(accuracy_score(y_test,predictions))
print(metrics.f1_score(y_test, predictions, average = 'macro'))
print(metrics.f1_score(y_test, predictions, average = 'micro'))
print(metrics.hamming_loss(y_test,predictions))

"""
# we are getting memory error because the multilearn package
# is trying to convert the data into dense matrix
# ---------------------------------------------------------------------
------
#MemoryError                              Traceback (most recent call
 last)
#<ipython-input-170-f0e7c7f3e0be> in <module>()
#----> classifier.fit(x_train_multilabel, y_train)
```

Out[48]:

```
"\nfrom skmultilearn.adapt import MLkNN\nclassifier = MLkNN(k=21)\n\n#
train\nclassifier.fit(x_train_multilabel, y_train)\n\n# predict\npredic
tions = classifier.predict(x_test_multilabel)\nprint(accuracy_score(y_t
est,predictions))\nprint(metrics.f1_score(y_test, predictions, average
= 'macro'))\nprint(metrics.f1_score(y_test, predictions, average = 'mic
ro'))\nprint(metrics.hamming_loss(y_test,predictions))\n\n"
```

4.4 Applying Logistic Regression with OneVsRest Classifier

In [49]:
```
# this will be taking so much time try not to run it, download the lr_with_equal_weight.pkl file and use to predict
# This takes about 6-7 hours to run.
start = datetime.now()
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='l1'), n_jobs=1)
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict(x_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test,predictions))
print("Macro F1 score :",metrics.f1_score(y_test, predictions, average = 'macro'))
print("Micro F1 score :",metrics.f1_score(y_test, predictions, average = 'micro'))
print("Hamming Loss :",metrics.hamming_loss(y_test,predictions))

report = metrics.classification_report(y_test, predictions,output_dict=True)
ovr_classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 5500 in Total
print("Precision recall report :\n")
print(ovr_classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.0713
Macro F1 score : 0.06971582995764285
Micro F1 score : 0.32809117080250294
Hamming Loss : 0.0005134727272727272

Precision recall report :

      f1-score  precision    recall  support
0     0.324421   0.549849  0.230088    791.0
1     0.552147   0.773956  0.429155    734.0
10    0.709163   0.847619  0.609589    292.0
100   0.468750   0.681818  0.357143     42.0
```

```
1000  0.000000   0.000000  0.000000      2.0
1001  0.000000   0.000000  0.000000      3.0
1002  0.000000   0.000000  0.000000      2.0
1003  0.000000   0.000000  0.000000      4.0
1004  0.000000   0.000000  0.000000     10.0
1005  0.000000   0.000000  0.000000      5.0

Time taken to run this cell : 0:28:27.868461
```

In [50]:

```
#joblib_in = open("lr_with_equal_weight.pkl","rb")
#classifier = joblib.load(joblib_in)
```

4.5 Modeling with less data points (50K data points) and more weight to title and 500 tags only.

In [51]:

```
sql_create_table = """CREATE TABLE IF NOT EXISTS QuestionsProcessed (qu
estion text NOT NULL, code text, tags text, words_pre integer, words_po
st integer, is_code integer);"""
create_database_table("Titlemoreweight.db", sql_create_table)
```

```
Tables in the databse:
QuestionsProcessed
```

In [52]:

```
# http://www.sqlitetutorial.net/sqlite-delete/
# https://stackoverflow.com/questions/2279706/select-random-row-from-a-
sqlite-table

read_db = 'train_no_dup.db'
write_db = 'Titlemoreweight.db'
train_datasize = 40000
if os.path.isfile(read_db):
    conn_r = create_connection(read_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        # for selecting first 50K rows
        reader.execute("SELECT Title, Body, Tags From no_dup_train LIMI
T 50001;")
```

```
        # for selecting random points
        #reader.execute("SELECT Title, Body, Tags From no_dup_train ORD
ER BY RANDOM() LIMIT 500001;")

if os.path.isfile(write_db):
    conn_w = create_connection(write_db)
    if conn_w is not None:
        tables = checkTableExists(conn_w)
        writer =conn_w.cursor()
        if tables != 0:
            writer.execute("DELETE FROM QuestionsProcessed WHERE 1")
            print("Cleared All the rows")
```

```
Tables in the databse:
QuestionsProcessed
Cleared All the rows
```

4.5.1 Preprocessing of questions

1. Separate Code from Body
2. Remove Spcial characters from Question title and description (not in code)
3. **Give more weightage to title : Add title three times to the question**
4. Remove stop words (Except 'C')
5. Remove HTML Tags
6. Convert all the characters into small letters
7. Use SnowballStemmer to stem the words

In [53]:

```
#http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an-sql
ite-table/
start = datetime.now()
preprocessed_data_list=[]
reader.fetchone()
questions_with_code=0
len_pre=0
len_post=0
```

```
questions_proccesed = 0
for row in reader:

    is_code = 0

    title, question, tags = row[0], row[1], str(row[2])

    if '<code>' in question:
        questions_with_code+=1
        is_code = 1
    x = len(question)+len(title)
    len_pre+=x

    code = str(re.findall(r'<code>(.*?)</code>', question, flags=re.DOTALL))

    question=re.sub('<code>(.*?)</code>', '', question, flags=re.MULTILINE|re.DOTALL)
    question=striphtml(question.encode('utf-8'))

    title=title.encode('utf-8')

    # adding title three time to the data to increase its weight
    # add tags string to the training data

    question=str(title)+" "+str(title)+" "+str(title)+" "+question

#     if questions_proccesed<=train_datasize:
#         question=str(title)+" "+str(title)+" "+str(title)+" "+question+" "+str(tags)
#     else:
#         question=str(title)+" "+str(title)+" "+str(title)+" "+question

    question=re.sub(r'[^A-Za-z0-9#+.\-]+',' ',question)
    words=word_tokenize(str(question.lower()))

    #Removing all single letter and and stopwords from question exceptt for the letter 'c'
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words and (len(j)!=1 or j=='c'))

    len_post+=len(question)
    tup = (question,code,tags,x,len(question),is_code)
    questions_proccesed += 1
    writer.execute("insert into QuestionsProcessed(question,code,tags,words_pre,words_post,is_code) values (?,?,?,?,?,?)",tup)
    if (questions_proccesed%100000==0):
        print("number of questions completed=",questions_proccesed)

no_dup_avg_len_pre=(len_pre*1.0)/questions_proccesed
no_dup_avg_len_post=(len_post*1.0)/questions_proccesed

print( "Avg. length of questions(Title+Body) before processing: %d"%no_dup_avg_len_pre)
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_post)
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/questions_proccesed))

print("Time taken to run this cell :", datetime.now() - start)
```

```
Avg. length of questions(Title+Body) before processing: 1224
Avg. length of questions(Title+Body) after processing: 437
Percent of questions containing code: 56
Time taken to run this cell : 0:01:56.713871
```

In [54]:

```
# never forget to close the conections or else we will end up with database locks
conn_r.commit()
conn_w.commit()
conn_r.close()
conn_w.close()
```

Sample quesitons after preprocessing of data

In [55]:

```
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        reader =conn_r.cursor()
        reader.execute("SELECT question From QuestionsProcessed LIMIT 1
0")
        print("Questions after preprocessed")
        print('='*100)
        reader.fetchone()
        for row in reader:
            print(row)
            print('-'*100)
conn_r.commit()
conn_r.close()
```

```
Questions after preprocessed
=======================================================================
=============================
('dynam datagrid bind silverlight dynam datagrid bind silverlight dynam
datagrid bind silverlight bind datagrid dynam code wrote code debug cod
e block seem bind correct grid come column form come grid column althou
gh necessari bind nthank repli advance..',)
-----------------------------------------------------------------------
-----------------------------
('java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryval
id java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryva
lid java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryv
alid follow guid link instal jstl got follow error tri launch jsp page
java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryvalid
taglib declar instal jstl 1.1 tomcat webapp tri project work also tri v
ersion 1.2 jstl still messag caus solv',)
-----------------------------------------------------------------------
-----------------------------
('java.sql.sqlexcept microsoft odbc driver manag invalid descriptor ind
ex java.sql.sqlexcept microsoft odbc driver manag invalid descriptor in
dex java.sql.sqlexcept microsoft odbc driver manag invalid descriptor i
ndex use follow code display caus solv',)
-----------------------------------------------------------------------
-----------------------------
('better way updat feed fb php sdk better way updat feed fb php sdk bet
ter way updat feed fb php sdk novic facebook api read mani tutori still
```

```
confused.i find post feed api method like correct second way use curl s
ometh like way better',)
-----------------------------------------------------------------------
-----------------------------
('btnadd click event open two window record ad btnadd click event open
two window record ad btnadd click event open two window record ad open
window search.aspx use code hav add button search.aspx nwhen insert rec
ord btnadd click event open anoth window nafter insert record close win
dow',)
-----------------------------------------------------------------------
-----------------------------
('sql inject issu prevent correct form submiss php sql inject issu prev
ent correct form submiss php sql inject issu prevent correct form submi
ss php check everyth think make sure input field safe type sql inject g
ood news safe bad news one tag mess form submiss place even touch life
figur exact html use templat file forgiv okay entir php script get exec
ut see data post none forum field post problem use someth titl field no
ne data get post current use print post see submit noth work flawless s
tatement though also mention script work flawless local machin use host
come across problem state list input test mess',)
-----------------------------------------------------------------------
-----------------------------
('countabl subaddit lebesgu measur countabl subaddit lebesgu measur cou
ntabl subaddit lebesgu measur let lbrace rbrace sequenc set sigma -alge
bra mathcal want show left bigcup right leq sum left right countabl add
it measur defin set sigma algebra mathcal think use monoton properti so
mewher proof start appreci littl help nthank ad han answer make follow
addit construct given han answer clear bigcup bigcup cap emptyset neq l
eft bigcup right left bigcup right sum left right also construct subset
monoton left right leq left right final would sum leq sum result follo
w',)
-----------------------------------------------------------------------
-----------------------------
('hql equival sql queri hql equival sql queri hql equival sql queri hql
queri replac name class properti name error occur hql error',)
-----------------------------------------------------------------------
-----------------------------
('undefin symbol architectur i386 objc class skpsmtpmessag referenc err
or undefin symbol architectur i386 objc class skpsmtpmessag referenc er
ror undefin symbol architectur i386 objc class skpsmtpmessag referenc e
```

```
for underlin symbol architectur i386 objc class skpsmtpmessag referenc e

rror import framework send email applic background import framework i.e
skpsmtpmessag somebodi suggest get error collect2 ld return exit status
import framework correct sorc taken framework follow mfmailcomposeviewc
ontrol question lock field updat answer drag drop folder project click
copi nthat',)
------------------------------------------------------------------------
-----------------------------
```

Saving Preprocessed data to a Database

In [56]:

```
#Taking 50K entries to a dataframe.
write_db = 'Titlemoreweight.db'
if os.path.isfile(write_db):
    conn_r = create_connection(write_db)
    if conn_r is not None:
        preprocessed_data = pd.read_sql_query("""SELECT question, Tags
 FROM QuestionsProcessed""", conn_r)
conn_r.commit()
conn_r.close()
```

In [57]:

```
preprocessed_data.head()
```

Out[57]:

	question	tags
0	dynam datagrid bind silverlight dynam datagrid...	c# silverlight data-binding
1	dynam datagrid bind silverlight dynam datagrid...	c# silverlight data-binding columns
2	java.lang.noclassdeffounderror javax servlet j...	jsp jstl
3	java.sql.sqlexcept microsoft odbc driver manag...	java jdbc
4	better way updat feed fb php sdk better way up...	facebook api facebook-php-sdk

In [58]:

```
print("number of data points in sample :", preprocessed_data.shape[0])
print("number of dimensions :", preprocessed_data.shape[1])
```

```
number of data points in sample : 50000
number of dimensions : 2
```

Converting string Tags to multilable output variables

In [59]:

```
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(), binary='true',max_features=20000,ngram_range=(1,2))
multilabel_y = vectorizer.fit_transform(preprocessed_data['tags'])
```

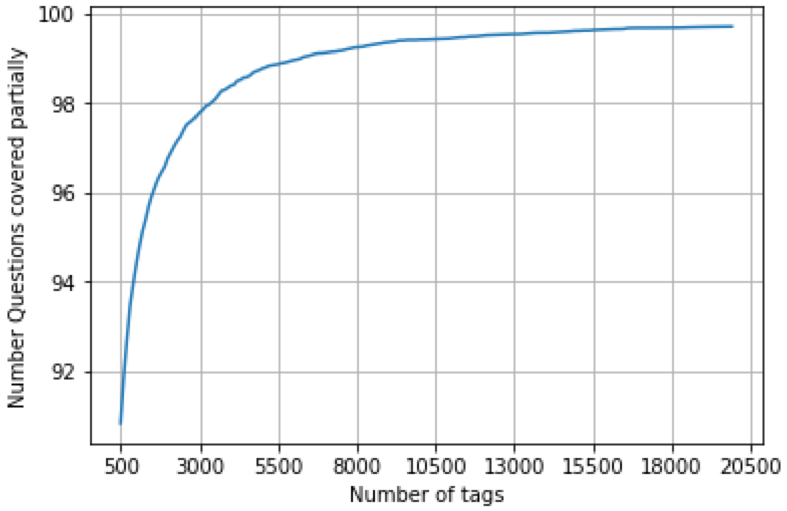
Selecting 500 Tags

In [60]:

```
questions_explained = []
total_tags=multilabel_y.shape[1]
total_qs=preprocessed_data.shape[0]
for i in range(500, total_tags, 100):
    questions_explained.append(np.round(((total_qs-questions_explained_fn(i))/total_qs)*100,3))
```

In [61]:

```
fig, ax = plt.subplots()
ax.plot(questions_explained)
xlabel = list(500+np.array(range(-50,450,50))*50)
ax.set_xticklabels(xlabel)
plt.xlabel("Number of tags")
plt.ylabel("Number Questions covered partially")
plt.grid()
plt.show()

# you can choose any number of tags based on your computing power, minimun is 500(it covers 90% of the tags)
print("with ",5500,"tags we are covering ",questions_explained[50],"% of questions")
print("with ",500,"tags we are covering ",questions_explained[0],"% of questions")
```



```
with  5500 tags we are covering  98.88 % of questions
with  500 tags we are covering  90.818 % of questions
```

In [62]:

```
# we will be taking 500 tags
multilabel_yx = tags_to_choose(500)
print("number of questions that are not covered :", questions_explained
_fn(500),"out of ", total_qs)
```

```
number of questions that are not covered : 4591 out of  50000
```

In [63]:

```
x_train=preprocessed_data.head(train_datasize)
x_test=preprocessed_data.tail(preprocessed_data.shape[0] - 40000)

y_train = multilabel_yx[0:train_datasize,:]
y_test = multilabel_yx[train_datasize:preprocessed_data.shape[0],:]
```

In [64]:

```
print("Number of data points in train data :", y_train.shape)
print("Number of data points in test data :", y_test.shape)
```

```
Number of data points in train data : (40000, 500)
Number of data points in test data : (10000, 500)
```

In [65]:

```
print(preprocessed_data.shape[0])
```

```
50000
```

Application of TFIDF :-

4.5.2 Featurizing Data with TFIDF Vectorizer

In [66]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=20000, smooth_idf=True, norm="l2", \
                             tokenizer = lambda x: x.split(), sublinear_tf=False, ngram_range=(1,2))
x_train_multilabel = vectorizer.fit_transform(x_train['question'])
x_test_multilabel = vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 0:00:12.606605
```

In [67]:

```
print("Dimensions of train data X:",x_train_multilabel.shape, "Y :",y_train.shape)
print("Dimensions of test data X:",x_test_multilabel.shape,"Y:",y_test.shape)
```

```
Dimensions of train data X: (40000, 20000) Y : (40000, 500)
Dimensions of test data X: (10000, 20000) Y: (10000, 500)
```

4.5.3 (TFIDF) Applying Logistic Regression :- OneVsRest Classifier + SGDClassifier (loss='log')

In [68]:

```
start = datetime.now()
```

```
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.0000
1, penalty='l1'), n_jobs=-1)
classifier.fit(x_train_multilabel, y_train)
predictions = classifier.predict (x_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming Loss ",metrics.hamming_loss(y_test,predictions))

precision = precision_score(y_test, predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1 = f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision, recall, f1))

precision = precision_score(y_test, predictions, average='macro')
recall = recall_score(y_test, predictions, average='macro')
f1 = f1_score(y_test, predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision, recall, f1))
print (" ")

report = metrics.classification_report(y_test, predictions,output_dict=
True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.207
Hamming Loss  0.0033218
Micro-average quality numbers
```

```
Precision: 0.6645, Recall: 0.2679, F1-measure: 0.3819

Macro-average quality numbers
Precision: 0.4635, Recall: 0.2007, F1-measure: 0.2610


Precision recall report :

     f1-score  precision    recall  support
0    0.318937   0.623377  0.214286    224.0
1    0.305419   0.642487  0.200323    619.0
10   0.366947   0.623810  0.259921    504.0
100  0.521739   0.750000  0.400000     30.0
101  0.378788   0.714286  0.257732     97.0
102  0.192308   0.312500  0.138889     36.0
103  0.196078   0.333333  0.138889     36.0
104  0.312500   0.500000  0.227273     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.045455   0.111111  0.028571     35.0

Time taken to run this cell : 0:00:24.330834
```

In [69]:

```
#joblib.dump(classifier, 'lr_with_more_title_weight.pkl')
```

4.5.4 (TFIDF) Applying Logistic Regression :- OneVsRest Classifier + Logistic Regression

In [70]:

```
start = datetime.now()
classifier_2 = OneVsRestClassifier(LogisticRegression(penalty='l2'), n_
jobs=-1)
classifier_2.fit(x_train_multilabel, y_train)
predictions_2 = classifier_2.predict(x_test_multilabel)
print("Accuracy :",metrics.accuracy_score(y_test, predictions_2))
print("Hamming Loss ",metrics.hamming_loss(y_test,predictions_2))

precision = precision_score(y_test, predictions_2, average='micro')
recall = recall_score(y_test, predictions_2, average='micro')
f1 = f1_score(y_test, predictions_2, average='micro')
```

```
print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1))

precision = precision_score(y_test, predictions_2, average='macro')
recall = recall_score(y_test, predictions_2, average='macro')
f1 = f1_score(y_test, predictions_2, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, recall, f1))

report = metrics.classification_report(y_test, predictions_2,output_dict=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.1596
Hamming Loss  0.0034734
Micro-average quality numbers
Precision: 0.7952, Recall: 0.1253, F1-measure: 0.2165
Macro-average quality numbers
Precision: 0.2431, Recall: 0.0495, F1-measure: 0.0762

Precision recall report :

     f1-score  precision    recall  support
0    0.325260   0.723077  0.209821    224.0
1    0.220708   0.704348  0.130856    619.0
10   0.257329   0.718182  0.156746    504.0
100  0.235294   1.000000  0.133333     30.0
101  0.150943   0.888889  0.082474     97.0
```

```
102  0.097561   0.400000  0.055556     36.0
103  0.142857   0.500000  0.083333     36.0
104  0.160000   0.666667  0.090909     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.054054   0.500000  0.028571     35.0

Time taken to run this cell : 0:00:41.021962
```

4.5.5 (TFIDF) Hyperparameter Tuning on "Logistic Regression :- OneVsRest Classifier + SGDClassifier(loss='log')"

In [87]:

```
x_cv_multilabel = x_train_multilabel[32000:40000]

start_time = datetime.now()
warnings.filterwarnings('ignore')
params = {"estimator__alpha":C_hyperparam}
#Carrying out 5-fold Cross Validation.

logistic = OneVsRestClassifier(SGDClassifier(loss='log',penalty='l1'),
n_jobs=-1)
TFIDF_model1 = GridSearchCV(logistic,params,scoring='f1_micro', cv=5,n_
jobs=1,verbose=1)
TFIDF_model1.fit(x_train_multilabel,y_train)

print("Time Required to Carry out Hyperparameter Tuning :- ", datetime.
now()-start_time)
print("Best Values Obtained :-", TFIDF_model1.best_estimator_)
print("Best Cross Validation Score :-", TFIDF_model1.best_score_)
```

```
Fitting 5 folds for each of 7 candidates, totalling 35 fits
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent
workers.
[Parallel(n_jobs=1)]: Done  35 out of  35 | elapsed: 12.3min finished
```

```
Time Required to Carry out Hyperparameter Tuning :-  0:12:44.195745
Best Values Obtained :- OneVsRestClassifier(estimator=SGDClassifier(alp
ha=1e-06, average=False,
                                            class_weight=None
                                            class_weight=None,
                                            early_stopping=False, epsil
on=0.1,

                                            eta0=0.0, fit_intercept=Tru
e,

                                            l1_ratio=0.15,
                                            learning_rate='optimal', lo
ss='log',

                                            max_iter=1000, n_iter_no_ch
ange=5,

                                            n_jobs=None, penalty='l1',
                                            power_t=0.5, random_state=N
one,

                                            shuffle=True, tol=0.001,
                                            validation_fraction=0.1, ve
rbose=0,

                                            warm_start=False),
                    n_jobs=-1)
Best Cross Validation Score :- 0.40200532332152966
```

4.5.6 Applying Optimized Logistic Regression :- "SGDClassifier(loss='log') + OneVsRest Classifier" on Test Dataset

In [88]:

```
classifier = OneVsRestClassifier(estimator=SGDClassifier(alpha=10**(-6
), average=False,class_weight=None,
             early_stopping=False, epsilon=0.1,eta0=0.0, fit_intercept=
True,l1_ratio=0.15,learning_rate='optimal',
             loss='log',max_iter=1000, n_iter_no_change=5,n_jobs=None,
penalty='l1',power_t=0.5, random_state=None,
             shuffle=True, tol=0.001,validation_fraction=0.1, verbose=0
,warm_start=False),n_jobs=-1)
```

In [89]:

```
start = datetime.now()

classifier.fit(x_train_multilabel, y_train)
predictions =classifier.predict(x_test_multilabel)
```

```
print("Accuracy :",metrics.accuracy_score(y_test, predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions))

precision = precision_score(y_test,predictions, average='micro')
recall = recall_score(y_test, predictions, average='micro')
f1= f1_score(y_test, predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision,recall,f1))

precision  = precision_score(y_test,predictions, average='macro')
recall = recall_score(y_test,predictions, average='macro')
f1 = f1_score(y_test,predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision, recall, f1))

report = metrics.classification_report(y_test, predictions,output_dict=
True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.1815
Hamming loss  0.0036454
Micro-average quality numbers
Precision: 0.5426, Recall: 0.3070, F1-measure: 0.3921
Macro-average quality numbers
Precision: 0.4277, Recall: 0.2226, F1-measure: 0.2742

Precision recall report :
     f1-score  precision    recall  support
0    0.278481   0.264000  0.294643    224.0

1    0.357333   0.397233  0.324717    619.0
10   0.368742   0.479365  0.299603    504.0
100  0.521739   0.750000  0.400000     30.0
101  0.342857   0.558140  0.247423     97.0
102  0.222222   0.333333  0.166667     36.0
103  0.192308   0.312500  0.138889     36.0
104  0.352941   0.500000  0.272727     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.090909   0.222222  0.057143     35.0

Time taken to run this cell : 0:00:29.102101
```

Application of BOW - Upto Bi-Grams :-

5.1 Featurizing data with BOW Vectorizer

In [73]:

```
start = datetime.now()
BOW_vectorizer = CountVectorizer(min_df=0.00009,max_features=20000,
                                 tokenizer = lambda x: x.split(), ngram
_range=(1,2))
x_bow_train_multilabel = BOW_vectorizer.fit_transform(x_train['questio
n'])
x_bow_test_multilabel = BOW_vectorizer.transform(x_test['question'])
print("Time taken to run this cell :", datetime.now() - start)
```

```
Time taken to run this cell : 0:00:13.971770
```

In [74]:

```
print("Dimensions of train data X:",x_bow_train_multilabel.shape, "Y :"
,y_train.shape)
print("Dimensions of test data X:",x_bow_test_multilabel.shape,"Y:",y_t
est.shape)
```

```
Dimensions of train data X: (40000, 20000) Y : (40000, 500)
Dimensions of test data X: (10000, 20000) Y: (10000, 500)
Dimensions of test data X: (10000, 10000) Y: (10000, 500)
```

5.2 (BOW) Applying Logistic Regression :- OneVsRest Classifier + SGDClassifier (loss='log')

In [75]:

```python
start = datetime.now()
classifier2 = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='l1'), n_jobs=1)
classifier2.fit(x_bow_train_multilabel, y_train)
predictions2 = classifier2.predict (x_bow_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, predictions2))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions2))

precision2 = precision_score(y_test, predictions2, average='micro')
recall2 = recall_score(y_test, predictions2, average='micro')
f1_2 = f1_score(y_test, predictions2, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision2, recall2, f1_2))

precision2 = precision_score(y_test, predictions2, average='macro')
recall2 = recall_score(y_test, predictions2, average='macro')
f1_2 = f1_score(y_test, predictions2, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision2, recall2, f1_2))

report = metrics.classification_report(y_test, predictions2, output_dict=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.0645
Hamming loss  0.0098328
Micro-average quality numbers
Precision: 0.1601, Recall: 0.3690, F1-measure: 0.2233
Macro-average quality numbers
Precision: 0.1102, Recall: 0.2771, F1-measure: 0.1435

Precision recall report :

     f1-score  precision    recall  support
0    0.198758   0.137694  0.357143    224.0
1    0.339324   0.305699  0.381260    619.0
10   0.347261   0.326353  0.371032    504.0
100  0.158273   0.100917  0.366667     30.0
101  0.372093   0.426667  0.329897     97.0
102  0.115226   0.067633  0.388889     36.0
103  0.136646   0.088000  0.305556     36.0
104  0.155340   0.098765  0.363636     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.065574   0.040541  0.171429     35.0

Time taken to run this cell : 0:17:20.428468
```

5.3 (BOW) Applying Logistic Regression :- OneVsRest Classifier + Logistic Regression

In [76]:

```
start = datetime.now()
classifier3 = OneVsRestClassifier(LogisticRegression(C=1.0,penalty='l2'
), n_jobs=1)
classifier3.fit(x_bow_train_multilabel, y_train)
predictions3 = classifier3.predict (x_bow_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, predictions3))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions3))
```

```
precision3 = precision_score(y_test, predictions3, average='micro')
recall3 = recall_score(y_test, predictions3, average='micro')
f1_3= f1_score(y_test, predictions3, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision3, recall3, f1_3))

precision3 = precision_score(y_test, predictions3, average='macro')
recall3 = recall_score(y_test, predictions3, average='macro')
f1_3 = f1_score(y_test, predictions3, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision3, recall3, f1_3))

report = metrics.classification_report(y_test, predictions3,output_dict
=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.1707
Hamming loss  0.0037462
Micro-average quality numbers
Precision: 0.5206, Recall: 0.2764, F1-measure: 0.3611
Macro-average quality numbers
Precision: 0.3819, Recall: 0.1916, F1-measure: 0.2401

Precision recall report :

     f1-score  precision    recall  support
0    0.289044   0.302439  0.276786    224.0
```

```
1    0.367424   0.443936  0.313409    619.0
10   0.344473   0.489051  0.265873    504.0

100  0.474576   0.482759  0.466667     30.0
101  0.302158   0.500000  0.216495     97.0
102  0.233333   0.291667  0.194444     36.0
103  0.218182   0.315789  0.166667     36.0
104  0.193548   0.333333  0.136364     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.000000   0.000000  0.000000     35.0

Time taken to run this cell : 0:29:07.881966
```

5.4 (BOW) Hyperparameter Tuning on "Logistic Regression :- OneVsRest Classifier + Logistic Regression"

In [77]:

```
C_hyperparam =[]
#initializing an empty list

for a in range(-6,7,2):
    C_hyperparam.append(10**a)

print(C_hyperparam)
```

```
[1e-06, 0.0001, 0.01, 1, 100, 10000, 1000000]
```

In [78]:

```
from sklearn.model_selection import GridSearchCV
from sklearn.preprocessing import StandardScaler

#performing scaling
Scaler1 = StandardScaler(with_mean=False)
X_Train_SCBOW = Scaler1.fit_transform(x_bow_train_multilabel)
X_Test_SCBOW = Scaler1.transform(x_bow_test_multilabel)
```

Basically to carry out the Hyperparameter Tuning with the CV Dataset, we first need to obtain the CV Data :- We will be carrying out Simple CV instead of GridSearchCV so as to minimise the Time Complexity for the same.

We will obtain the CV Dataset by splitting the Train Dataset :- x_bow_train_multilabel in the 80:20 ratio.

In [79]:

```
#Obtaining the CV Dataset from the Train Dataset :- X_CV
x_bow_cv_multilabel = x_bow_train_multilabel[32000:40000]
X_CV_SCBOW = Scaler1.transform(x_bow_cv_multilabel)

print(X_CV_SCBOW.shape)
```

```
(8000, 20000)
```

In [80]:

```
#Obtaining the CV Dataset from the Train Dataset :- Y_CV
y_cv = y_train[32000:40000]
print(y_cv.shape)
```

```
(8000, 500)
```

(BOW) Hyperparameter Tuning using GridSearch on Better Model :-

In [82]:

```
start_time = datetime.now()
warnings.filterwarnings('ignore')
params  = {"estimator__C":C_hyperparam}

#Carrying out 5-fold Cross Validation.

logistic = OneVsRestClassifier(LogisticRegression(penalty='l2'), n_jobs=1)
BOW_model1 = GridSearchCV(logistic,params,scoring='f1_micro', cv=5,n_jobs=1,verbose=1)
BOW_model1.fit(X_Train_SCBOW,y_train)

print("Time Required to Carry out Hyperparameter Tuning :- ", datetime.now()-start_time)
print("Best Values Obtained :-", BOW_model1.best_estimator_)
print("Best Cross Validation Score :-", BOW_model1.best_score_)
```

```
Fitting 5 folds for each of 7 candidates, totalling 35 fits
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent
workers.

[Parallel(n_jobs=1)]: Done  35 out of  35 | elapsed: 683.6min finished
```

```
Time Required to Carry out Hyperparameter Tuning :-  12:02:43.933640
Best Values Obtained :- OneVsRestClassifier(estimator=LogisticRegressio
n(C=100, class_weight=None,
                                                 dual=False, fit_interc
ept=True,
                                                 intercept_scaling=1,
                                                 l1_ratio=None, max_ite
r=100,
                                                 multi_class='auto',
                                                 n_jobs=None, penalty
='l2',
                                                 random_state=None,
                                                 solver='lbfgs', tol=0.
0001,
                                                 verbose=0, warm_start=
False),
                    n_jobs=1)
Best Cross Validation Score :- 0.307864297932658
```

5.5 Applying Optimized Logistic Regression :- "Logistic Regression + OneVsRest Classifier" on Test Dataset

In [81]:

```
BOW_classifier = OneVsRestClassifier(LogisticRegression(C=100, class_we
ight=None,
                 dual=False, fit_intercept=True,intercept_scaling=1,l1_
ratio=None, max_iter=100,multi_class='auto',
                 n_jobs=None, penalty='l2',random_state=None,solver='lb
fgs', tol=0.0001,verbose=0, warm_start=False), n_jobs=1)
```

In [82]:

```
start = datetime.now()
BOW_classifier = OneVsRestClassifier(LogisticRegression(C=100,penalty=
'l2'), n_jobs=1)
```

```
BOW_classifier.fit(x_bow_train_multilabel, y_train)
BOW_predictions = BOW_classifier.predict(x_bow_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, BOW_predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,BOW_predictions))

BOW_precision = precision_score(y_test, BOW_predictions, average='micro')
BOW_recall = recall_score(y_test, BOW_predictions, average='micro')
BOW_f1= f1_score(y_test, BOW_predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(BOW_precision, BOW_recall, BOW_f1))

BOW_precision  = precision_score(y_test,BOW_predictions, average='macro')
BOW_recall = recall_score(y_test,BOW_predictions, average='macro')
BOW_f1 = f1_score(y_test,BOW_predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(BOW_precision, BOW_recall, BOW_f1))

report = metrics.classification_report(y_test,BOW_predictions,output_dict=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.1498
Hamming loss  0.004091
Micro-average quality numbers
Precision: 0.4489, Recall: 0.2994, F1-measure: 0.3592
```

```
Macro-average quality numbers
Precision: 0.3543, Recall: 0.2098, F1-measure: 0.2482

Precision recall report :

     f1-score  precision    recall  support
0    0.240708   0.199413  0.303571    224.0
1    0.353511   0.353226  0.353796    619.0
10   0.357820   0.444118  0.299603    504.0
100  0.451613   0.437500  0.466667     30.0
101  0.315068   0.469388  0.237113     97.0
102  0.253968   0.296296  0.222222     36.0
103  0.245614   0.333333  0.194444     36.0
104  0.294118   0.416667  0.227273     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.000000   0.000000  0.000000     35.0

Time taken to run this cell : 0:33:49.036671
```

Application of Linear SVM :-

5.6 (BOW) Applying Linear SVM :- OneVsRest Classifier + SGDClassifier (loss='hinge')

In [83]:

```
start = datetime.now()
classifier4 = OneVsRestClassifier(SGDClassifier(loss='hinge', alpha=0.0
0001, penalty='l1'), n_jobs=1)
classifier4.fit(x_train_multilabel,y_train)
predictions4 = classifier4.predict (x_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, predictions4))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions4))

precision4 = precision_score(y_test, predictions4, average='micro')
recall4 = recall_score(y_test, predictions4, average='micro')
f1_4 = f1_score(y_test, predictions4, average='micro')
```

```python
print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision4, recall4, f1_4))

precision4 = precision_score(y_test, predictions4, average='macro')
recall4 = recall_score(y_test, predictions4, average='macro')
f1_4 = f1_score(y_test, predictions4, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision4, recall4, f1_4))

report = metrics.classification_report(y_test, predictions4,output_dict=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.2122
Hamming loss  0.0032816
Micro-average quality numbers
Precision: 0.6765, Recall: 0.2744, F1-measure: 0.3904
Macro-average quality numbers
Precision: 0.3895, Recall: 0.1989, F1-measure: 0.2441

Precision recall report :

     f1-score  precision    recall  support
0    0.321637   0.466102  0.245536    224.0
1    0.345652   0.528239  0.256866    619.0
10   0.323319   0.579487  0.224206    504.0
100  0.500000   0.666667  0.400000     30.0
101  0.358209   0.648649  0.247423     97.0
```

```
102  0.000000   0.000000  0.000000     36.0
103  0.054054   1.000000  0.027778     36.0
104  0.275862   0.571429  0.181818     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.000000   0.000000  0.000000     35.0

Time taken to run this cell : 0:01:56.350026
```

5.7 (BOW) Applying Linear SVM :- OneVsRest Classifier + Linear SVC

In [84]:

```
from sklearn.svm import LinearSVC

start = datetime.now()
classifier5 = OneVsRestClassifier(LinearSVC(loss='squared_hinge',C=1.0,
 penalty='l2'), n_jobs=1)
classifier5.fit(x_train_multilabel, y_train)
predictions5 = classifier5.predict(x_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, predictions5))
print("Hamming loss ",metrics.hamming_loss(y_test,predictions5))

precision5 = precision_score(y_test, predictions5, average='micro')
recall5 = recall_score(y_test, predictions5, average='micro')
f1_5 = f1_score(y_test, predictions5, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision5, recall5, f1_5))

precision5 = precision_score(y_test, predictions5, average='macro')
recall5 = recall_score(y_test, predictions5, average='macro')
f1_5 = f1_score(y_test, predictions5, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(pr
ecision5, recall5, f1_5))

report = metrics.classification_report(y_test, predictions5,output_dict
=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.2114
Hamming loss  0.0032714
Micro-average quality numbers
Precision: 0.7029, Recall: 0.2525, F1-measure: 0.3716
Macro-average quality numbers
Precision: 0.4377, Recall: 0.1723, F1-measure: 0.2292

Precision recall report :

     f1-score  precision    recall  support
0    0.364198   0.590000  0.263393    224.0
1    0.347144   0.565693  0.250404    619.0
10   0.356125   0.631313  0.248016    504.0
100  0.511628   0.846154  0.366667     30.0
101  0.343750   0.709677  0.226804     97.0
102  0.095238   0.333333  0.055556     36.0
103  0.097561   0.400000  0.055556     36.0
104  0.214286   0.500000  0.136364     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.000000   0.000000  0.000000     35.0

Time taken to run this cell : 0:01:17.783593
```

5.8 (BOW) Hyperparameter Tuning on "Linear SVM :- OneVsRest Classifier + Linear SVC"

In [96]:

```
from sklearn.model_selection import GridSearchCV
```

```
start_time = datetime.now()
warnings.filterwarnings('ignore')
params  = {"estimator__alpha":C_hyperparam}

#Carrying out 5-fold Cross Validation.

svm = OneVsRestClassifier(SGDClassifier(loss='hinge', penalty='l1'), n_
jobs=1)
svm_model1 = GridSearchCV(svm,params,scoring='f1_micro', cv=5,n_jobs=1,
verbose=1)
svm_model1.fit(x_train_multilabel,y_train)

print("Time Required to Carry out Hyperparameter Tuning :- ", datetime.
now()-start_time)
print("Best Values Obtained :-", svm_model1.best_estimator_)
print("Best Cross Validation Score :-", svm_model1.best_score_)
```

```
Fitting 5 folds for each of 7 candidates, totalling 35 fits
```

```
[Parallel(n_jobs=1)]: Using backend SequentialBackend with 1 concurrent
workers.
[Parallel(n_jobs=1)]: Done  35 out of  35 | elapsed: 59.0min finished
```

```
Time Required to Carry out Hyperparameter Tuning :-  1:01:42.124050
Best Values Obtained :- OneVsRestClassifier(estimator=SGDClassifier(alp
ha=1e-06, average=False,
                                            class_weight=None,
                                            early_stopping=False, epsil
on=0.1,
                                            eta0=0.0, fit_intercept=Tru
e,
                                            l1_ratio=0.15,
                                            learning_rate='optimal',
                                            loss='hinge', max_iter=100
0,
                                            n_iter_no_change=5, n_jobs=
None,
                                            penalty='l1', power_t=0.5,
                                            random_state=None, shuffle=
True
True,
                                             tol=0.001, validation_fract
ion=0.1,
                                             verbose=0, warm_start=Fals
e),
                    n_jobs=1)
Best Cross Validation Score :- 0.3914180794669484
```

5.9 Applying Optimized Linear SVM :- "OneVsRest Classifier + SGDClassifier" on Test Dataset

In [85]:

```python
from sklearn.svm import LinearSVC
SVM_classifier = OneVsRestClassifier(SGDClassifier(alpha=10**(-6), aver
age=False,
                 class_weight=None,early_stopping=False, epsilon=0.1,et
a0=0.0, fit_intercept=True,l1_ratio=0.15,
                 learning_rate='optimal',loss='hinge', max_iter=1000,n_
iter_no_change=5, n_jobs=None,penalty='l1',
                 power_t=0.5,random_state=None, shuffle=True,tol=0.001,
 validation_fraction=0.1,
                 verbose=0, warm_start=False))
```

In [86]:

```python
start = datetime.now()

SVM_classifier.fit(x_train_multilabel, y_train)
SVM_predictions = SVM_classifier.predict(x_test_multilabel)

print("Accuracy :",metrics.accuracy_score(y_test, SVM_predictions))
print("Hamming loss ",metrics.hamming_loss(y_test,SVM_predictions))

SVM_precision = precision_score(y_test, SVM_predictions, average='micr
o')
SVM_recall = recall_score(y_test, SVM_predictions, average='micro')
SVM_f1= f1_score(y_test, SVM_predictions, average='micro')

print("Micro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(SV
M_precision, SVM_recall, SVM_f1))

SVM_precision  = precision_score(y_test,SVM_predictions, average='macr
o')
SVM_recall = recall_score(y_test,SVM_predictions, average='macro')
SVM_f1 = f1_score(y_test,SVM_predictions, average='macro')

print("Macro-average quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(SV
M_precision, SVM_recall, SVM_f1))

report = metrics.classification_report(y_test, SVM_predictions,output_d
ict=True)
classification = pd.DataFrame(report).transpose()
print("  ")

#Printing only the Top 10 Rows out of 500 in Total
print("Precision recall report :\n")
print(classification.head(10))
print(" ")

print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.1495
Hamming loss  0.004062
Micro-average quality numbers
Precision: 0.4556, Recall: 0.3115, F1-measure: 0.3700
Macro-average quality numbers
Precision: 0.3453, Recall: 0.2310, F1-measure: 0.2618

Precision recall report :

     f1-score  precision    recall  support
0    0.225914   0.179894  0.303571    224.0
1    0.343928   0.347039  0.340872    619.0
10   0.350792   0.454259  0.285714    504.0
100  0.461538   0.545455  0.400000     30.0
101  0.326241   0.522727  0.237113     97.0
102  0.281250   0.321429  0.250000     36.0
103  0.107143   0.150000  0.083333     36.0
```

```
104  0.324324   0.400000  0.272727     22.0
105  0.000000   0.000000  0.000000      8.0
106  0.000000   0.000000  0.000000     35.0

Time taken to run this cell : 0:02:55.102056
```

6. Conclusions :-

- StackOverflow is a Website where Users can post Programming Questions for other users to answer the same. The Objective in the case of StackOverflow Tag Prediction is to predict tags for the Questions that are posted on StackOverflow. There are a bunch of different domains on StackOverflow and it is important that the questions are given labels in a way that maximises User Experience. Eg :- If the following question is asked :- "What is the Difference between Pointers and References in C++?". Now StackOverFlow should give Tags such as "C++", "Pointers" etc. This helps the whole community because the people who have followed these Topics and are Programmers themselves in these languages can help the other person out. It also reduces the case that a Question related to Python is sent to a C Programmer with no language on the intricacies of Python.

- Note that a Single Question over here could have Multiple Tags assigned to it. This means that it is not just a Multiclass Classification Problem but a Multilabel Classification Problem. Also following are the constraints that we are dealing with while trying to solve this problem :- Incorrect Tags could Impact the User Experience on StackOverFlow. There are no strict Latency Constraints.

Based on these 2 Conditions we can assume that we Require a Model with High Precision and Recall Values, and the metric that we tried to optimize was the Micro-F1 Score :- weighted average of F1 Score across all the Classes that we had. This is a very good metric, especially when we have Class Imbalance. (We saw this when we carried out EDA in the Beginning).

- We have a total of approximately 6M Questions. Each question over here has the following features - 'Title','Body','Tags'. However, in the interest of time and the Computational Limitations of my Laptop, I am loading only the Top 0.5M rows into a database, and I will sample only 50K Datapoints. {Only for 50K Datapoints, the Hyperparameter Tuning in the case of Logistic Regression Takes more than 12 Hours}.

- We carry out EDA to obtain information such as which are the most Frequent Tags appearing across the questions and find that "c#,java,php" are some of the most frequent Tags on the Platform and we had seen that there are a total of approx. 20K Unique Tags, out of which 98% variance is retained when we use 5500 Tags and 90% variance is retained when we have 500 Tags. Again, in the interest of Time and Low Computational Power available, we will only be taking 500 Tags for our analysis. After this stage preprocessing of questions is carried out where code snippets are separated and special characters are removed from both the Title as well as the Body.All the stopwords are removed followed by Stemming.

- We featurize our models with the help of BOW(1,2 grams) and TFIDF Vectorizers, and for this we will sample 50K Data Points with 3 times more weight added to the titles.{Because usually Titles have more keywords than the code or Body}. Note that we have used OneVSRestClassifier with both SGDClassifier Logistic Regression Computation as well as with Simple Logistic Regression Computation, because of the algorithmic differences in how these 2 Values are computed.
- Finally we can compare all of our models where we realize that the implementation of "Linear SVM with SGDClassifier (loss='hinge')" using TFIDF Vectorizer resulted in us having the best Micro F1-Score of 0.394 which is very close to our second best model with a Micro-F1 Score 0.393. {Logistic Regression:OVR + SGDClassifier- Tuned using TFIDF Vectorization}

  Please take a look at the Different Models that we tried to Train and the metric values that we achieved in relation to Accuracy,Precision,Recall,Hamming Loss, The Best Hyperparameter obtained after carrying out GridSearch for the values of lambda or alpha and the Micro F1-Scores thus obtained.

In [112]:

```python
from prettytable import PrettyTable

print("Values Obtained after working with 50K Datapoints :-")
print(" ")
```

```
x=PrettyTable()
x.field_names=["Model","Vectorizer","Param","Acc","Hamming","Pre","Re",
"Mic_F1"]

x.add_row(["Log Regression:OVR + SGDClassifier(loss='log')","TFIDF","a=
0.01","0.21","0.003","0.67","0.27","0.38"])
x.add_row(["Log Regression:OVR + LogisticRegression","TFIDF","-","0.16"
,"0.003","0.80","0.16","0.22"])
x.add_row(["Log Regression:OVR + SGDClassifier- Tuned","TFIDF","a=10^(-
6)","0.18","0.003","0.55","0.31","0.393"])
x.add_row (["Log Regression:OVR + SGDClassifier(loss='log')","BOW","a=
0.01","0.06","0.009","0.16","0.36","0.22"])
x.add_row (["Log Regression:OVR + LogisticRegression","BOW","C=1.0","0.
17","0.003","0.52","0.28","0.360"])
x.add_row (["Log Regression:OVR + LogisticRegression - Tuned","BOW","C=
100","0.14","0.004","0.45","0.30","0.361"])
x.add_row(["Linear SVM:OVR + SGDClassifier(loss='hinge')","TFIDF","a=0.
01","0.21","0.003","0.68","0.28","0.394"])
x.add_row(["Linear SVM:OVR + Linear SVC","TFIDF","C=1.0","0.21","0.003"
,"0.70","0.25","0.37"])
x.add_row(["Linear SVM:OVR + SGDClassifier-Tuned","TFIDF","a=10**(-6)",
"0.15","0.004","0.46","0.32","0.38"])
print(x)
```

```
Values Obtained after working with 50K Datapoints :-

+-----------------------------------------------------+------------+-------
-----+------+---------+------+------+--------+
|                        Model                        | Vectorizer |   Para
m    | Acc  | Hamming | Pre  |  Re  | Mic_F1 |
+-----------------------------------------------------+------------+-------
-----+------+---------+------+------+--------+
|  Log Regression:OVR + SGDClassifier(loss='log') |   TFIDF    |   a=0.
01   | 0.21 |  0.003  | 0.67 | 0.27 |  0.38  |
|     Log Regression:OVR + LogisticRegression     |   TFIDF    |     -
     | 0.16 |  0.003  | 0.80 | 0.16 |  0.22  |
|    Log Regression:OVR + SGDClassifier- Tuned    |   TFIDF    | a=10^
(-6)   | 0.18 |  0.003  | 0.55 | 0.31 | 0.393  |
|  Log Regression:OVR + SGDClassifier(loss='log') |    BOW     |   a=0.
```

```
01   | 0.06 |  0.009  | 0.16 | 0.36 |  0.22  |
|     Log Regression:OVR + LogisticRegression     |     BOW     |    C=1.
0    | 0.17 |  0.003  | 0.52 | 0.28 | 0.360  |
| Log Regression:OVR + LogisticRegression - Tuned |     BOW     |    C=10
0    | 0.14 |  0.004  | 0.45 | 0.30 | 0.361  |
|   Linear SVM:OVR + SGDClassifier(loss='hinge')  |    TFIDF    |    a=0.
01   | 0.21 |  0.003  | 0.68 | 0.28 | 0.394  |
|           Linear SVM:OVR + Linear SVC           |    TFIDF    |    C=1.
0    | 0.21 |  0.003  | 0.70 | 0.25 |  0.37  |
|       Linear SVM:OVR + SGDClassifier-Tuned      |    TFIDF    | a=10**
(-6) | 0.15 |  0.004  | 0.46 | 0.32 |  0.38  |
+-------------------------------------------------+------------+-------
-----+------+---------+------+------+--------+
```