STACKOVERFLOW QUESTION
TAGGING

In [41]:

```python
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 sklearn.model_selection import GridSearchCV
from sklearn.model_selection import cross_val_score
import numpy as np
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
import pickle
from sklearn.externals import joblib
```

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 (https://www.kaggle.com/c/facebook-recruiting-iii-keyword-extraction/data)
Youtube : https://youtu.be/nNDqbUhtIRg (https://youtu.be/nNDqbUhtIRg)
Research paper : https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/tagging-1.pdf (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 (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 (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         ci
n>>n;\n\n
                 cout<<"Enter the Lower, and Upper Limits of the var
iables";\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

           <p>The answer should come in the form of a table like</p>\n\n
           <pre><code>
           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
           </code></pre>\n\n
           <p>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)</p>\n\n
           <p>The output is not coming,can anyone correct the code or tell
        me what\'s wrong?</p>\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 * (precision * recall) / (precision + 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 (https://www.kaggle.com/wiki/MeanFScore)
http://scikit-learn.org/stable/modules/generated/sklearn.metrics.f1_score.html (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 (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 [0]:

```
#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'], chunk
        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 [0]:

```
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 above cell to ge
```

```
Number of rows in the database :
 6034196
Time taken to count the number of rows : 0:01:15.750352
```

3.1.3 Checking for duplicates

In [0]:

```
#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(*) as cnt_dup FR
    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 first to genarat
```

```
Time taken to run this cell : 0:04:33.560122
```

In [0]:

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

Out[6]:

	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 [0]:

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

```
number of duplicate questions : 1827881 ( 30.2920389063 % )
```

In [0]:

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

Out[8]:

```
1    2656284
2    1272336
3     277575
4         90
5         25
6          5
Name: cnt_dup, dtype: int64
```

In [0]:

```
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 : 0:00:03.169523
```

Out[9]:

	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 [0]:

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

Out[10]:

```
3    1206157
2    1111706
4     814996
1     568298
5     505158
Name: tag_count, dtype: int64
```

In [0]:

```
#Creating a new database with no duplicates
if not os.path.isfile(path+'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 [10]:

```
#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""", 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 above cells to g
```

```
Time taken to run this cell : 0:01:46.493856
```

3.2 Analysis of Tags

3.2.1 Total number of unique tags

In [0]:

```
# 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())
# 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 [12]:

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

```
Number of data points : 4206314
Number of unique tags : 42048
```

In [13]:

```
#'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 : ['.a', '.app', '.asp.net-mvc', '.aspxaut
h', '.bash-profile', '.class-file', '.cs-file', '.doc', '.drv', '.ds-
store']
```

3.2.3 Number of times a tag appeared

In [0]:

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

In [17]:

```
#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[17]:

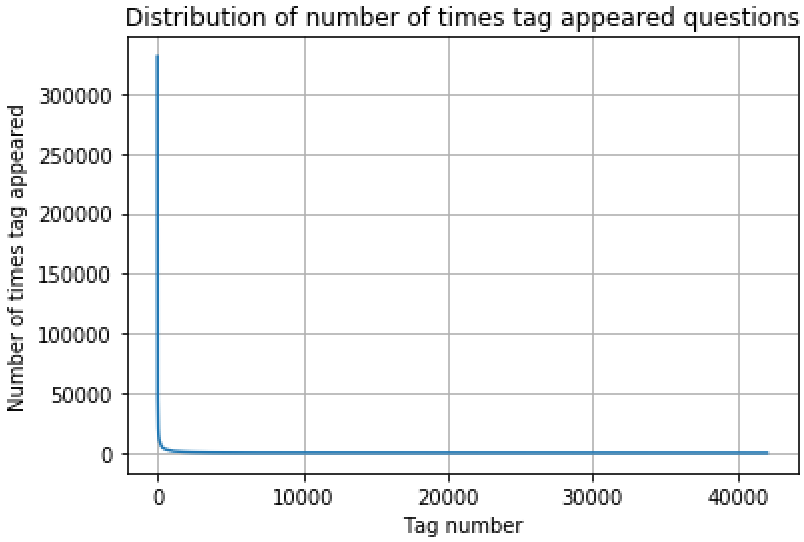
	Tags	Counts
0	.a	18
1	.app	37
2	.asp.net-mvc	1
3	.aspxauth	21
4	.bash-profile	138

In [0]:

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

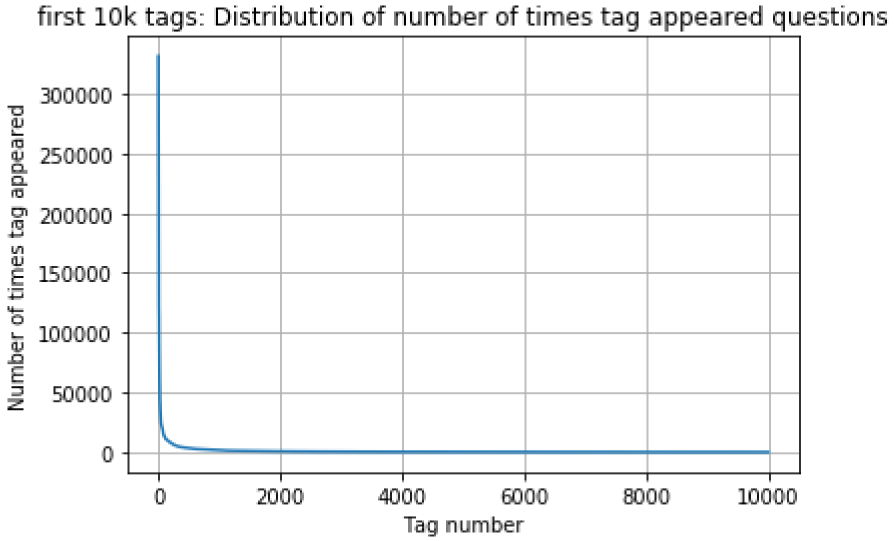
In [19]:

```
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 [20]:

```
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])
```

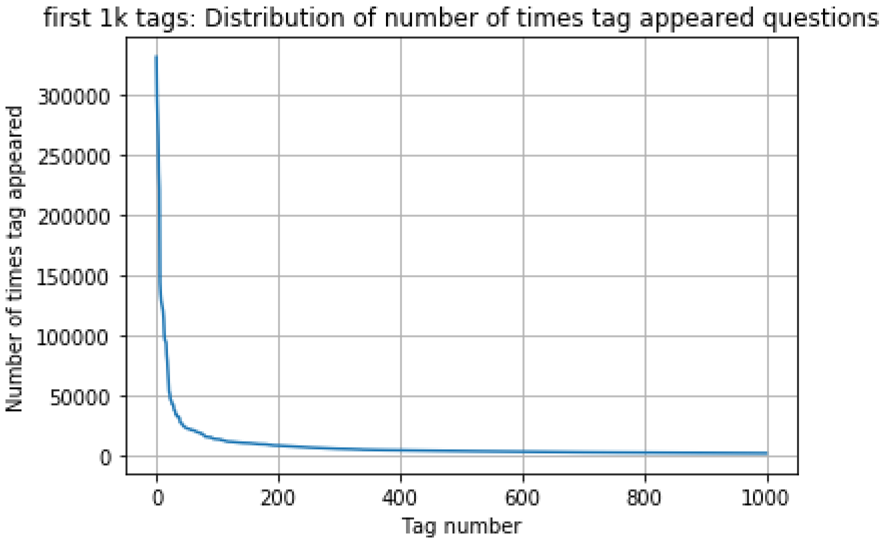


```
400 [331505  44829  22429  17728  13364  11162  10029   9148   8054
7151
   6466   5865   5370   4983   4526   4281   4144   3929   3750   359
3
   3453   3299   3123   2989   2891   2738   2647   2527   2431   233
1
   2259   2186   2097   2020   1959   1900   1828   1770   1723   167
3
   1631   1574   1532   1479   1448   1406   1365   1328   1300   126
6
   1245   1222   1197   1181   1158   1139   1121   1101   1076   105
6
   1038   1023   1006    983    966    952    938    926    911    89
1
    882    869    856    841    830    816    804    789    779    77
0
    752    743    733    725    712    702    688    678    671    65
8
    650    643    634    627    616    607    598    589    583    57
7
    568    559    552    545    540    533    526    518    512    50
6
    500    495    490    485    480    477    469    465    457    45
0
    447    442    437    432    426    422    418    413    408    40
3
```

```
      398    393    388    385    381    378    374    370    367     36
  5
      361    357    354    350    347    344    342    339    336     33
  2
      330    326    323    319    315    312    309    307    304     30
  1
      299    296    293    291    289    286    284    281    278     27
  6
      275    272    270    268    265    262    260    258    256     25
  4
      252    250    249    247    245    243    241    239    238     23
  6
      234    233    232    230    228    226    224    222    220     21
  9
      217    215    214    212    210    209    207    205    204     20
  3
      201    200    199    198    196    194    193    192    191     18
  9
      188    186    185    183    182    181    180    179    178     17
  7
      175    174    172    171    170    169    168    167    166     16
  5
      164    162    161    160    159    158    157    156    156     15
  5
      154    153    152    151    150    149    149    148    147     14
  6
      145    144    143    142    142    141    140    139    138     13
  7
      137    136    135    134    134    133    132    131    130     13
  0
      129    128    128    127    126    126    125    124    124     12
  3
      123    122    122    121    120    120    119    118    118     11
  7
      117    116    116    115    115    114    113    113    112     11
  1
      111    110    109    109    108    108    107    106    106     10
  6
      105    105    104    104    103    103    102    102    101     10
  1
      100    100     99     99     98     98     97     97     96      9
  6
       95     95     94     94     93     93     93     92     92      9
  1
       91     90     90     89     89     88     88     87     87      8
  6
       86     86     85     85     84     84     83     83     83      8
  2
       82     82     81     81     80     80     80     79     79      7
  8
       78     78     78     77     77     76     76     76     75      7
  5
       75     74     74     74     73     73     73     73     72      7
  2]
```

In [21]:

```
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])
```

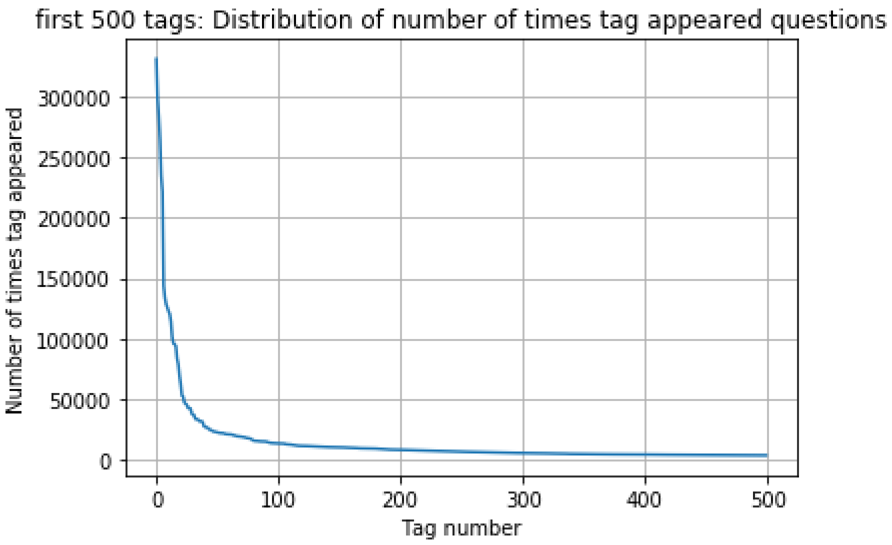


```
200 [331505 221533 122769  95160  62023  44829  37170  31897  26925
24537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  1370
3
  13364  13157  12407  11658  11228  11162  10863  10600  10350  1022
4
  10029   9884   9719   9411   9252   9148   9040   8617   8361   816
3
   8054   7867   7702   7564   7274   7151   7052   6847   6656   655
3
   6466   6291   6183   6093   5971   5865   5760   5577   5490   541
1
   5370   5283   5207   5107   5066   4983   4891   4785   4658   454
9
   4526   4487   4429   4335   4310   4281   4239   4228   4195   415
9
   4144   4088   4050   4002   3957   3929   3874   3849   3818   379
7
   3750   3703   3685   3658   3615   3593   3564   3521   3505   348
3
   3453   3427   3396   3363   3326   3299   3272   3232   3196   316
8
   3123   3094   3073   3050   3012   2989   2984   2953   2934   290
3
   2891   2844   2819   2784   2754   2738   2726   2708   2681   266
9
   2647   2621   2604   2594   2556   2527   2510   2482   2460   244
4
```

```
   2431   2409   2395   2380   2363   2331   2312   2297   2290   228
1
   2259   2246   2222   2211   2198   2186   2162   2142   2132   210
7
   2097   2078   2057   2045   2036   2020   2011   1994   1971   196
5
   1959   1952   1940   1932   1912   1900   1879   1865   1855   184
1
   1828   1821   1813   1801   1782   1770   1760   1747   1741   173
4
   1723   1707   1697   1688   1683   1673   1665   1656   1646   163
9]
```

In [22]:

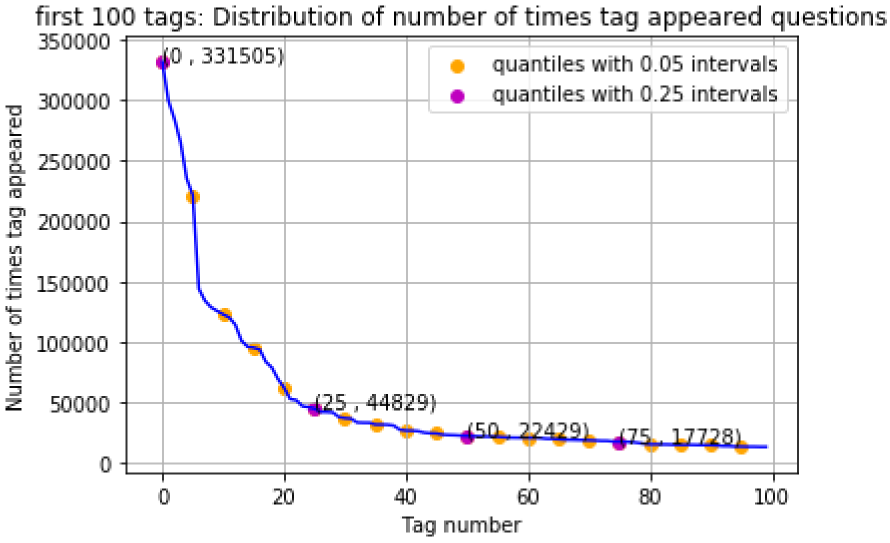
```
plt.plot(tag_counts[0:500])
plt.title('first 500 tags: Distribution of number of times tag appeared questions')
plt.grid()
plt.xlabel("Tag number")
plt.ylabel("Number of times tag appeared")
plt.show()
print(len(tag_counts[0:500:5]), tag_counts[0:500:5])
```



```
100 [331505 221533 122769  95160  62023  44829  37170  31897  26925
24537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  1370
3
  13364  13157  12407  11658  11228  11162  10863  10600  10350  1022
4
  10029   9884   9719   9411   9252   9148   9040   8617   8361   816
3
   8054   7867   7702   7564   7274   7151   7052   6847   6656   655
3
   6466   6291   6183   6093   5971   5865   5760   5577   5490   541
1
   5370   5283   5207   5107   5066   4983   4891   4785   4658   454
9
   4526   4487   4429   4335   4310   4281   4239   4228   4195   415
9
   4144   4088   4050   4002   3957   3929   3874   3849   3818   379
7
   3750   3703   3685   3658   3615   3593   3564   3521   3505   348
3]
```

In [23]:

```
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="quant
# quantiles with 0.25 difference
plt.scatter(x=list(range(0,100,25)), y=tag_counts[0:100:25], c='m', label = "quanti

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  62023  44829  37170  31897  26925  2
4537
  22429  21820  20957  19758  18905  17728  15533  15097  14884  1370
3]
```

In [24]:

```
# 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)))
```

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

Observations:

1. There are total 153 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 probelm.

3.2.4 Tags Per Question

In [25]:

```
#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]] a
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 4206314 datapoints.
[3, 4, 2, 2, 3]
```

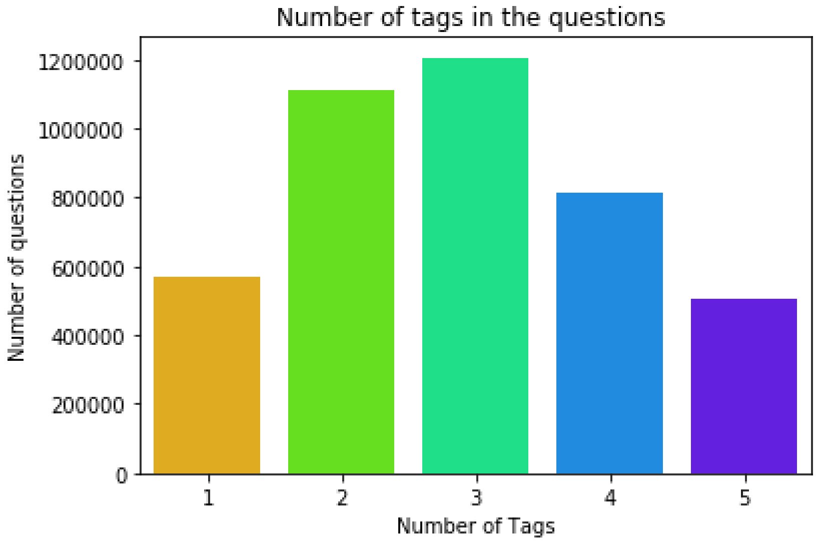
In [26]:

```
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_
```

```
Maximum number of tags per question: 5
Minimum number of tags per question: 1
Avg. number of tags per question: 2.899440
```

In [27]:

```
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:

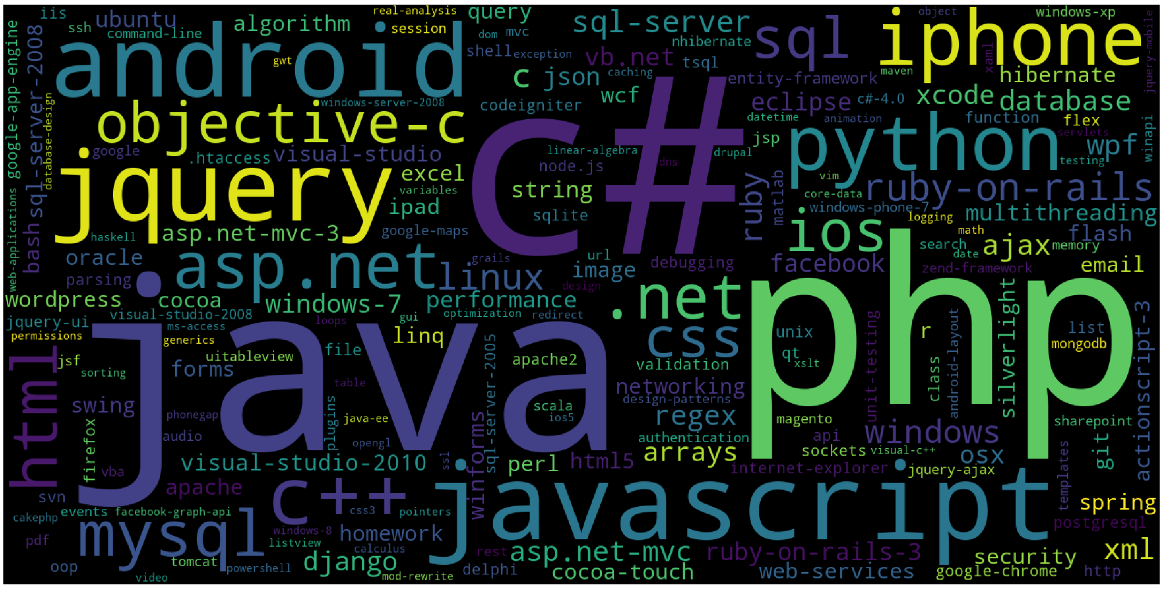
1. Maximum number of tags per question: 5
2. Minimum number of tags per question: 1

3. Avg. number of tags per question: 2.899
4. Most of the questions are having 2 or 3 tags

3.2.5 Most Frequent Tags

In [28]:

```
# 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)
```



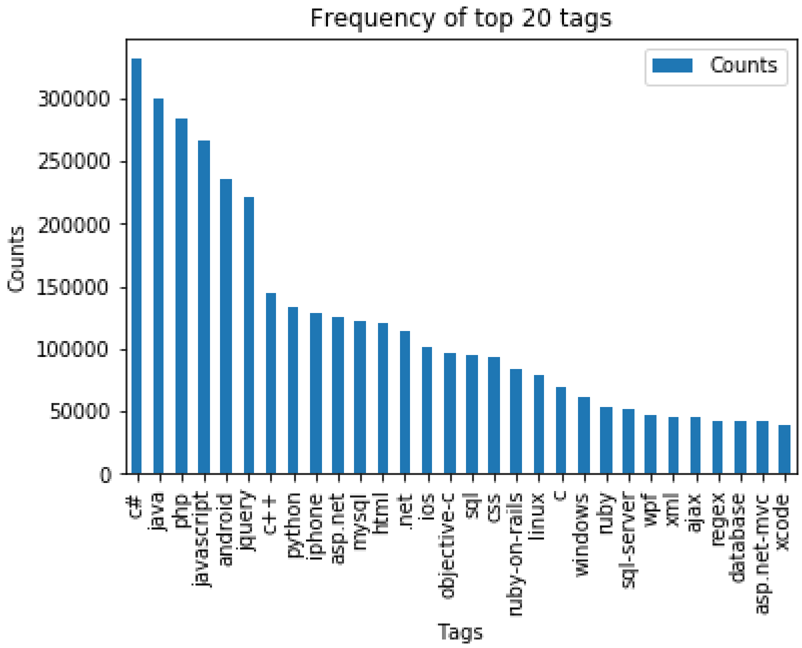
```
Time taken to run this cell : 0:00:04.645941
```

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 [29]:

```
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()
```



In [32]:

```
tag_df_sorted['Tags']
```

Out[32]:

```
4337             c#
18069          java
27249           php
18157    javascript
1234        android
            ...
29936     rbindlist
29934          rbga
29930          rbar
2925        azureus
42047       zzt-oop
Name: Tags, Length: 42048, dtype: object
```

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 1M 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 [7]:

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

In [8]:

```
#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
create_database_table("Processed.db", sql_create_table)
```

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

In [39]:

```
# 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 ORDER BY RANDOM(

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)
```

```
Time taken to run this cell : 0:23:09.457459
```

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

In [0]:

```
#http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an-sqlite-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], 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.DOTAL
    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 exceptt for the let
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words an

    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,wor
    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_
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_p
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/ques

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

```
number of questions completed= 100000
number of questions completed= 200000
number of questions completed= 300000
number of questions completed= 400000
number of questions completed= 500000
number of questions completed= 600000
number of questions completed= 700000
number of questions completed= 800000
number of questions completed= 900000
Avg. length of questions(Title+Body) before processing: 1169
Avg. length of questions(Title+Body) after processing: 327
Percent of questions containing code: 57
Time taken to run this cell : 0:47:05.946582
```

In [0]:

```
# 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 [0]:

```
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
=====================================================================
===============================
('ef code first defin one mani relationship differ key troubl defin o
ne zero mani relationship entiti ef object model look like use fluent
api object composit pk defin batch id batch detail id use fluent api
object composit pk defin batch detail id compani id map exist databas
tpt basic idea submittedtransact zero mani submittedsplittransact ass
oci navig realli need one way submittedtransact submittedsplittransac
t need dbcontext class onmodelcr overrid map class lazi load occur su
bmittedtransact submittedsplittransact help would much appreci edit t
aken advic made follow chang dbcontext class ad follow onmodelcr over
rid must miss someth get follow except thrown submittedtransact key b
atch id batch detail id zero one mani submittedsplittransact key batc
h detail id compani id rather assum convent creat relationship two ob
ject configur requir sinc obvious wrong',)
---------------------------------------------------------------------
-------------------------------
('explan new statement review section c code came accross statement b
lock come accross new oper use way someon explain new call way',)
---------------------------------------------------------------------
-------------------------------
('error function notat function solv logic riddl iloczyni list struct
ur list possibl candid solut list possibl coordin matrix wan na choos
one candid compar possibl candid element equal wan na delet coordin c
all function skasuj look like ni knowledg haskel cant see what wron
g',)
---------------------------------------------------------------------
-------------------------------
('step plan move one isp anoth one work busi plan switch isp realli s
oon need chang lot inform dns wan wan wifi question guy help mayb peo
pl plan correct chang current isp new one first dns know receiv new i
p isp major chang need take consider exchang server owa vpn two site
link wireless connect km away citrix server vmware exchang domain con
trol link place import server crucial step inform need know avoid dow
ntim busi regard ndavid',)
---------------------------------------------------------------------
-------------------------------
('use ef migrat creat databas googl migrat tutori af first run applic
creat databas ef enabl migrat way creat databas migrat rune applic tr
i',)
---------------------------------------------------------------------
-------------------------------
('magento unit test problem magento site recent look way check integr
magento site given point unit test jump one method would assum would
big job write whole lot test check everyth site work anyon involv uni
t test magento advis follow possibl test whole site custom modul nis
exampl test would amaz given site heavili link databas would nbe poss
ibl fulli test site without disturb databas better way automaticlli c
heck integr magento site say integr realli mean fault site ship payme
nt etc work correct',)
----------------------------------------------------------------------
-------------------------------
('find network devic without bonjour write mac applic need discov mac
pcs iphon ipad connect wifi network bonjour seem reason choic turn pr
oblem mani type router mine exampl work block bonjour servic need fin
d ip devic tri connect applic specif port determin process run best a
pproach accomplish task without violat app store sandbox',)
----------------------------------------------------------------------
-------------------------------
('send multipl row mysql databas want send user mysql databas column
user skill time nnow want abl add one row user differ time etc would
code send databas nthen use help schema',)
----------------------------------------------------------------------
-------------------------------
('insert data mysql php powerpoint event powerpoint present run conti
nu way updat slide present automat data mysql databas websit',)
----------------------------------------------------------------------
-------------------------------
```

In [9]:

```python
#Taking 1 Million 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 Questio
conn_r.commit()
conn_r.close()
```

In [10]:

```python
preprocessed_data.head()
```

Out[10]:

	question	tags
0	chang cpu soni vaio pcg grx tri everywher find...	cpu motherboard sony-vaio replacement disassembly
1	display size grayscal qimag qt abl display ima...	c++ qt qt4
2	datagrid selecteditem set back null eventtocom...	mvvm silverlight-4.0
3	filter string collect base listview item resol...	c# winforms string listview collections
4	disabl home button without use type keyguard c...	android android-layout android-manifest androi...

In [11]:

```
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 : 999999
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 [15]:

```
# binary='true' will give a binary vectorizer
vectorizer = CountVectorizer(tokenizer = lambda x: x.split(), binary='true')
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 [16]:

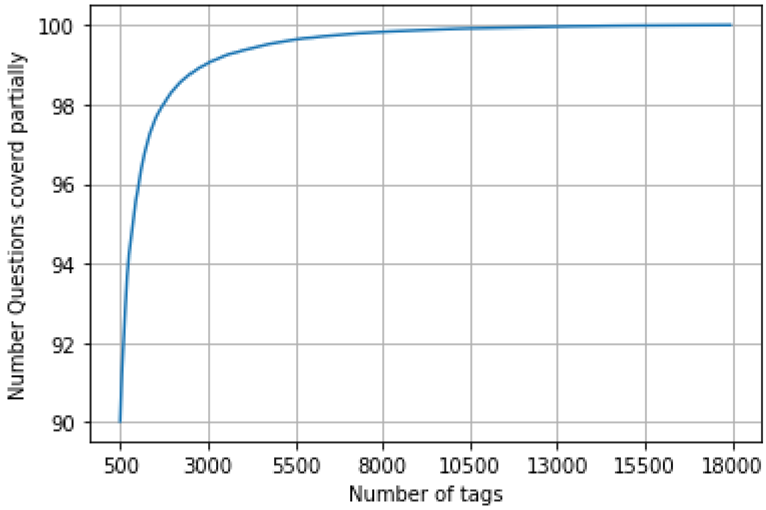
```
def tags_to_choose(n):
    t = multilabel_y.sum(axis=0).tolist()[0]
    sorted_tags_i = sorted(range(len(t)), key=lambda i: t[i], reverse=True)
    multilabel_yn=multilabel_y[:,sorted_tags_i[:n]]
    return multilabel_yn

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

In [17]:

```
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
```

In [18]:

```
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, minimun is 50(it
print("with ",5500,"tags we are covering ",questions_explained[50],"% of questions"
```



```
with  5500 tags we are covering  99.035 % of questions
```

In [19]:

```
multilabel_yx = tags_to_choose(5500)
print("number of questions that are not covered :", questions_explained_fn(5500),"o
```

```
number of questions that are not covered : 9645 out of  999999
```

In [20]:

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

```
Number of tags in sample : 35422
number of tags taken : 5500 ( 15.527073570097679 %)
```

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

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

In [21]:

```
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 [22]:

```
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 : (799999, 5500)
Number of data points in test data : (200000, 5500)
```

4.3 Featurizing data

In [0]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=200000, smooth_idf=True,
                             tokenizer = lambda x: x.split(), sublinear_tf=False, n
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 : 0:09:50.460431
```

In [0]:

```
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)
```

```
Diamensions of train data X: (799999, 88244) Y : (799999, 5500)
Diamensions of test data X: (200000, 88244) Y: (200000, 5500)
```

In [0]:

```
# https://www.analyticsvidhya.com/blog/2017/08/introduction-to-multi-label-classifi
#https://stats.stackexchange.com/questions/117796/scikit-multi-label-classificatior
# 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[92]:

```
"\nfrom skmultilearn.adapt import MLkNN\nclassifier = MLkNN(k=21)\n\n
# train\nclassifier.fit(x_train_multilabel, y_train)\n\n# predict\npr
edictions = classifier.predict(x_test_multilabel)\nprint(accuracy_sco
re(y_test,predictions))\nprint(metrics.f1_score(y_test, predictions,
average = 'macro'))\nprint(metrics.f1_score(y_test, predictions, aver
age = 'micro'))\nprint(metrics.hamming_loss(y_test,predictions))\n\n"
```

4.4 Applying Logistic Regression with OneVsRest Classifier

In [0]:

```
# this will be taking so much time try not to run it, download the lr_with_equal_we
# This takes about 6-7 hours to run.
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='
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 scoore :",metrics.f1_score(y_test, predictions, average = 'micro'))
print("hamming loss :",metrics.hamming_loss(y_test,predictions))
print("Precision recall report :\n",metrics.classification_report(y_test, predictio
```

```
accuracy : 0.081965
macro f1 score : 0.0963020140154
micro f1 scoore : 0.374270748817
hamming loss : 0.00041225090909090907
Precision recall report :
              precision    recall  f1-score   support

          0       0.62      0.23      0.33     15760
          1       0.79      0.43      0.56     14039
          2       0.82      0.55      0.66     13446
          3       0.76      0.42      0.54     12730
          4       0.94      0.76      0.84     11229
          5       0.85      0.64      0.73     10561
          6       0.70      0.30      0.42      6958
          7       0.87      0.61      0.72      6309
          8       0.70      0.40      0.50      6032
          9       0.78      0.43      0.55      6020
         10       0.86      0.62      0.72      5707
         11       0.52      0.17      0.25      5723
         12       0.55      0.10      0.16      5521
```

In [0]:

```
from sklearn.externals import joblib
joblib.dump(classifier, 'lr_with_equal_weight.pkl')
```

4.5 Modeling with less data points (0.5M data points) and more weight to title and 500 tags only.

In [ ]:

```
sql_create_table = """CREATE TABLE IF NOT EXISTS QuestionsProcessed (question text
create_database_table("Titlemoreweight.db", sql_create_table)
```

In [24]:

```
pwd
```

Out[24]:

```
'D:\\APPLIEDAI\\Ajay\\stackoverflow'
```

In [30]:

```python
# http://www.sqlitetutorial.net/sqlite-delete/
# https://stackoverflow.com/questions/2279706/select-random-row-from-a-sqlite-table
import os
read_db = 'train_no_dup.db'
write_db = 'Titlemoreweight.db'
train_datasize = 400000
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 0.5M rows
        reader.execute("SELECT Title, Body, Tags From no_dup_train LIMIT 500001;")
        # for selecting random points
        #reader.execute("SELECT Title, Body, Tags From no_dup_train ORDER BY RANDOM


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**

```
<li> Remove stop words (Except 'C') </li>
<li> Remove HTML Tags </li>
<li> Convert all the characters into small letters </li>
<li> Use SnowballStemmer to stem the words </li>
```

In [ ]:

```
#http://www.bernzilla.com/2008/05/13/selecting-a-random-row-from-an-sqlite-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.DOTAL
    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(ta
#     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 let
    question=' '.join(str(stemmer.stem(j)) for j in words if j not in stop_words an

    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,wor
    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_
print( "Avg. length of questions(Title+Body) after processing: %d"%no_dup_avg_len_p
print ("Percent of questions containing code: %d"%((questions_with_code*100.0)/ques

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

In [ ]:

```
# 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 [0]:

```
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
=====================================================================
===============================
('dynam datagrid bind silverlight dynam datagrid bind silverlight dyn
am datagrid bind silverlight bind datagrid dynam code wrote code debu
g code block seem bind correct grid come column form come grid column
although necessari bind nthank repli advance..',)
---------------------------------------------------------------------
-------------------------------
('java.lang.noclassdeffounderror javax servlet jsp tagext taglibraryv
alid java.lang.noclassdeffounderror javax servlet jsp tagext taglibra
ryvalid java.lang.noclassdeffounderror javax servlet jsp tagext tagli
braryvalid follow guid link instal jstl got follow error tri launch j
sp page java.lang.noclassdeffounderror javax servlet jsp tagext tagli
braryvalid taglib declar instal jstl 1.1 tomcat webapp tri project wo
rk also tri version 1.2 jstl still messag caus solv',)
---------------------------------------------------------------------
-------------------------------
('java.sql.sqlexcept microsoft odbc driver manag invalid descriptor i
ndex java.sql.sqlexcept microsoft odbc driver manag invalid descripto
r index java.sql.sqlexcept microsoft odbc driver manag invalid descri
ptor index use follow code display caus solv',)
---------------------------------------------------------------------
-------------------------------
('better way updat feed fb php sdk better way updat feed fb php sdk b
etter way updat feed fb php sdk novic facebook api read mani tutori s
till confused.i find post feed api method like correct second way use
curl someth like way better',)
---------------------------------------------------------------------
-------------------------------
('btnadd click event open two window record ad btnadd click event ope
n two window record ad btnadd click event open two window record ad o
pen window search.aspx use code hav add button search.aspx nwhen inse
rt record btnadd click event open anoth window nafter insert record c
lose window',)
---------------------------------------------------------------------
-------------------------------
('sql inject issu prevent correct form submiss php sql inject issu pr
event correct form submiss php sql inject issu prevent correct form s
ubmiss php check everyth think make sure input field safe type sql in
ject good news safe bad news one tag mess form submiss place even tou
ch life figur exact html use templat file forgiv okay entir php scrip
t get execut see data post none forum field post problem use someth t
itl field none data get post current use print post see submit noth w
ork flawless statement 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 c
ountabl subaddit lebesgu measur let lbrace rbrace sequenc set sigma -
algebra mathcal want show left bigcup right leq sum left right counta
bl addit measur defin set sigma algebra mathcal think use monoton pro
perti somewher proof start appreci littl help nthank ad han answer ma
ke follow addit construct given han answer clear bigcup bigcup cap em
ptyset neq left bigcup right left bigcup right sum left right also co
nstruct subset monoton left right leq left right final would sum leq 
sum result follow',)
---------------------------------------------------------------------
-------------------------------
('hql equival sql queri hql equival sql queri hql equival sql queri h
ql queri replac name class properti name error occur hql error',)
---------------------------------------------------------------------
-------------------------------
('undefin symbol architectur i386 objc class skpsmtpmessag referenc e
rror undefin symbol architectur i386 objc class skpsmtpmessag referen
c error undefin symbol architectur i386 objc class skpsmtpmessag refe
renc error import framework send email applic background import frame
work i.e skpsmtpmessag somebodi suggest get error collect2 ld return 
exit status import framework correct sorc taken framework follow mfma
ilcomposeviewcontrol question lock field updat answer drag drop folde
r project click copi nthat',)
---------------------------------------------------------------------
-------------------------------
```

__ Saving Preprocessed data to a Database __

In [37]:

```
#Taking 0.5 Million 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 Questio
conn_r.commit()
conn_r.close()
```

In [ ]:

```
# 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()
```

In [39]:

```
preprocessed_data.head()
```

Out[39]:

	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 [40]:

```
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 : 500000
number of dimensions : 2
```

Converting string Tags to multilable output variables

In [25]:

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

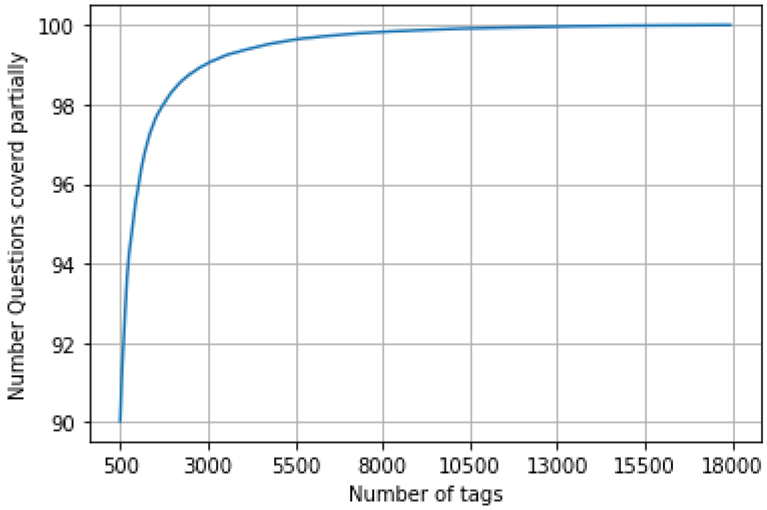
Selecting 500 Tags

In [26]:

```
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
```

In [27]:

```
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, minimun is 500(i
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  99.035 % of questions
with  500 tags we are covering  90.025 % of questions
```

In [28]:

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

```
number of questions that are not covered : 99745 out of  999999
```

In [30]:

```
train_datasize = 400000

x_train=preprocessed_data.head(train_datasize)
x_test=preprocessed_data.tail(preprocessed_data.shape[0] - 400000)

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

In [33]:

```
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 : (400000, 500)
Number of data points in test data : (599999, 500)
```

4.5.2 Featurizing data with TfIdf vectorizer

4.5.2 Featurizing data with TfIdf Vectorizer

In [52]:

```
start = datetime.now()
vectorizer = TfidfVectorizer(min_df=0.00009, max_features=200000, smooth_idf=True,
                             tokenizer = lambda x: x.split(), sublinear_tf=False, n
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 : 0:04:15.255264
```

In [53]:

```
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: (400000, 95585) Y : (400000, 500)
Dimensions of test data X: (100000, 95585) Y: (100000, 500)
```

4.5.3 Applying Logistic Regression with OneVsRest Classifier

In [54]:

```
start = datetime.now()
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='
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(precision, rec

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(precision, rec

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

```
Accuracy : 0.23703
Hamming loss  0.00278042
Micro-average quality numbers
Precision: 0.7216, Recall: 0.3259, F1-measure: 0.4490
Macro-average quality numbers
Precision: 0.5492, Recall: 0.2581, F1-measure: 0.3351
              precision    recall  f1-score   support

           0       0.95      0.64      0.77      5519
           1       0.69      0.26      0.38      8190
           2       0.81      0.38      0.51      6529
           3       0.81      0.43      0.56      3231
           4       0.80      0.41      0.54      6430
           5       0.82      0.34      0.48      2879
           6       0.88      0.49      0.63      5086
           7       0.88      0.54      0.67      4533
           8       0.62      0.13      0.21      3000
           9       0.81      0.52      0.63      2765
          10       0.59      0.16      0.26      3051
          11       0.70      0.33      0.45      3000
```

In [56]:

```
import joblib
```

In [57]:

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

Out[57]:

```
['lr_with_more_title_weight.pkl']
```

In [58]:

```
start = datetime.now()
classifier_2 = OneVsRestClassifier(LogisticRegression(penalty='l1'), 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, rec

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, rec

print (metrics.classification_report(y_test, predictions_2))
print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.25123
Hamming loss  0.00270306
Micro-average quality numbers
Precision: 0.7172, Recall: 0.3673, F1-measure: 0.4858
Macro-average quality numbers
Precision: 0.5568, Recall: 0.2950, F1-measure: 0.3709
              precision    recall  f1-score   support

           0       0.94      0.72      0.82      5519
           1       0.70      0.34      0.45      8190
           2       0.80      0.42      0.55      6529
           3       0.82      0.49      0.61      3231
           4       0.80      0.44      0.57      6430
           5       0.82      0.38      0.52      2879
           6       0.86      0.53      0.66      5086
           7       0.87      0.58      0.70      4533
           8       0.60      0.14      0.22      3000
           9       0.82      0.57      0.67      2765
          10       0.60      0.20      0.30      3051
          11       0.68      0.28      0.40      3000
```

5. Assignments

1. Use bag of words upto 4 grams and compute the micro f1 score with Logistic regression(OvR)
2. Perform hyperparam tuning on alpha (or lambda) for Logistic regression to improve the performance using GridSearch
3. Try OneVsRestClassifier with Linear-SVM (SGDClassifier with loss-hinge)

Featurizing data - BOW

In [23]:

```
def bow(train, ds, feature):
    vectorizer = CountVectorizer(ngram_range=(1, 4), max_features=200000, min_df=0.
                                 tokenizer = lambda x: x.split())
    vectorizer.fit(train[feature])
    feature_bow = vectorizer.transform(ds[feature].values)
    print("Shape of matrix after one hot encodig ",feature_bow.shape)
    return feature_bow
```

In [34]:

```
question_bow_x_train_ = bow(x_train, x_train, 'question')
question_bow_x_test_ = bow(x_train, x_test, 'question')
```

```
Shape of matrix after one hot encodig  (400000, 90506)
Shape of matrix after one hot encodig  (599999, 90506)
```

In [37]:

```
start = datetime.now()
classifier = OneVsRestClassifier(SGDClassifier(loss='log', alpha=0.00001, penalty='
classifier.fit(question_bow_x_train_, y_train)
predictions = classifier.predict (question_bow_x_test_)


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(precision, rec

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(precision, rec

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

```
Accuracy : 0.12518687531145886
Hamming loss  0.004409294015490026
Micro-average quality numbers
Precision: 0.4004, Recall: 0.4446, F1-measure: 0.4213
Macro-average quality numbers
Precision: 0.2921, Recall: 0.3726, F1-measure: 0.3251
              precision    recall  f1-score   support

           0       0.44      0.42      0.43     47524
           1       0.55      0.54      0.55     42561
           2       0.63      0.61      0.62     40426
           3       0.54      0.50      0.52     37964
           4       0.84      0.84      0.84     33571
           5       0.72      0.67      0.69     31779
           6       0.49      0.46      0.47     20526
           7       0.71      0.68      0.69     18810
           8       0.52      0.48      0.50     18365
           9       0.52      0.51      0.52     17933
          10       0.67      0.66      0.66     17263
```

OneVsRestClassifier with Logistic regression

(alpha tuning using Gridsearch)

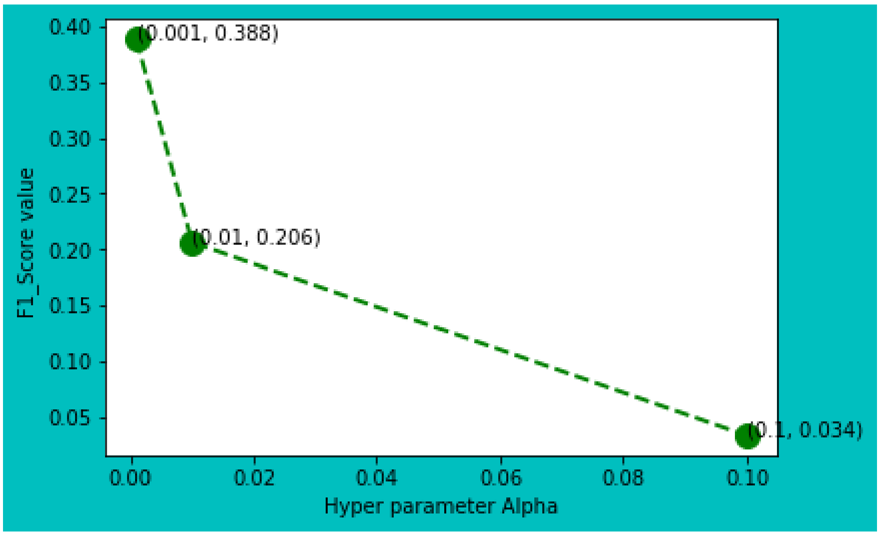
OneVsRestClassifier with SGDClassifier(penalty=l2, loss=log)==> {Logistic regression}

In [42]:

```
start = datetime.now()
import warnings
warnings.filterwarnings('ignore')

# hp1={'estimator__C':alpha}

alpha=[10**-3,10**-2,10**-1]

cv_scores = []
for i in alpha:
    print(i)
    hp1={'estimator__alpha':[i],
         'estimator__loss':['log'],
         'estimator__penalty':['l2']}
    print(hp1)
    classifier = OneVsRestClassifier(SGDClassifier())

    model11 =GridSearchCV(classifier,hp1,
                          cv=3, scoring='f1_micro',n_jobs=-1)
    print("Gridsearchcv")
    best_model1=model11.fit(question_bow_x_train_, y_train)
    print('fit model')
    Train_model_score=best_model1.score(question_bow_x_train_,
                                        y_train)
#print("best_model1")
    cv_scores.append(Train_model_score.mean())

fscore = [x for x in cv_scores]

# determining best alpha
optimal_alpha21 = alpha[fscore.index(max(fscore))]
print('\n The optimal value of alpha with penalty=l2 and loss= log is %d.' % optima

# Plots
fig4 = plt.figure( facecolor='c', edgecolor='k')
plt.plot(alpha, fscore,color='green', marker='o', linestyle='dashed',
linewidth=2, markersize=12)

for xy in zip(alpha, np.round(fscore,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Hyper parameter Alpha')
plt.ylabel('F1_Score value ')
plt.show()

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

```
0.001
{'estimator__alpha': [0.001], 'estimator__loss': ['log'], 'estimator_
_penalty': ['l2']}
Gridsearchcv
fit model
0.01
{'estimator__alpha': [0.01], 'estimator__loss': ['log'], 'estimator__
penalty': ['l2']}
Gridsearchcv
fit model
0.1
```

```
{'estimator__alpha': [0.1], 'estimator__loss': ['log'], 'estimator__p
enalty': ['l2']}
Gridsearchcv
fit model

 The optimal value of alpha with penalty=l2 and loss= log is 0.
```



```
Time taken to run this cell : 0:56:25.803343
```

In [43]:

```
print(optimal_alpha21)
```

```
0.001
```

In [45]:

```
start = datetime.now()
best_model1 = OneVsRestClassifier(SGDClassifier(loss='log', alpha=optimal_alpha21,
                                               penalty='l2'), n_jobs=-1)
best_model1.fit(question_bow_x_train_, y_train)
```

Out[45]:

```
OneVsRestClassifier(estimator=SGDClassifier(alpha=0.001, average=Fals
e,
                                            class_weight=None,
                                            early_stopping=False, eps
ilon=0.1,
                                            eta0=0.0, fit_intercept=T
rue,
                                            l1_ratio=0.15,
                                            learning_rate='optimal',
loss='log',
                                            max_iter=1000, n_iter_no_
change=5,
                                            n_jobs=None, penalty='l
2',
                                            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 [46]:

```
joblib.dump(best_model1, 'best_model1_LR.pkl')
```

Out[46]:

```
['best_model1_LR.pkl']
```

In [47]:

```
best_model1=joblib.load('best_model1_LR.pkl')
```

In [48]:

```
predictions = best_model1.predict (question_bow_x_test_)

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-averasge quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, rec

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(precision, rec

print (metrics.classification_report(y_test, predictions)) #printing classification
print("Time taken to run this cell :", datetime.now() - start)
```

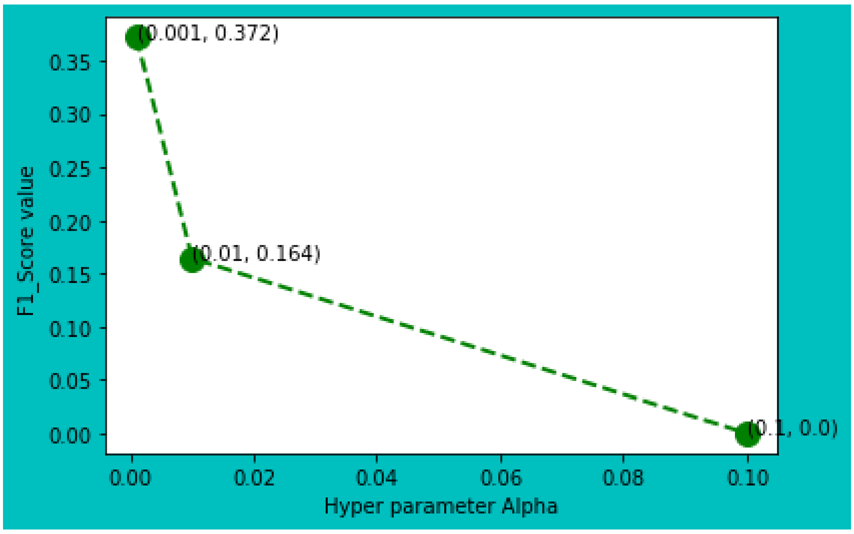
```
Accuracy : 0.1896186493644156
Hamming loss  0.0030892151486919144
Micro-averasge quality numbers
Precision: 0.6966, Recall: 0.2558, F1-measure: 0.3742
Macro-average quality numbers
Precision: 0.4868, Recall: 0.1383, F1-measure: 0.2032
              precision    recall  f1-score   support

           0       0.60      0.15      0.24     47524
           1       0.80      0.33      0.47     42561
           2       0.84      0.50      0.62     40426
           3       0.76      0.39      0.52     37964
           4       0.94      0.70      0.80     33571
           5       0.87      0.62      0.73     31779
           6       0.69      0.21      0.33     20526
           7       0.88      0.55      0.68     18810
           8       0.73      0.33      0.45     18365
           9       0.79      0.37      0.50     17933
          10       0.84      0.59      0.70     17263
          11       0.53      0.15      0.24     17103
```

OneVsRestClassifier with Logistic regression(penalty=l1)

In [50]:

```
start = datetime.now()
import warnings
warnings.filterwarnings('ignore')

# hp1={'estimator__C':alpha}

cv_scores = []
for i in alpha:
    print(i)
    hp1={'estimator__alpha':[i],
         'estimator__loss':['log'],
         'estimator__penalty':['l1']}
    print(hp1)
    classifier = OneVsRestClassifier(SGDClassifier())

    model11 =GridSearchCV(classifier,hp1,
                          cv=3, scoring='f1_micro',n_jobs=-1)
    print("Gridsearchcv")
    best_model1=model11.fit(question_bow_x_train_, y_train)
    print('fit model')
    Train_model_score=best_model1.score(question_bow_x_train_,
                                        y_train)
#print("best_model1")
    cv_scores.append(Train_model_score.mean())

fscore = [x for x in cv_scores]

# determining best alpha
optimal_alpha22 = alpha[fscore.index(max(fscore))]
print('\n The optimal value of alpha with penalty=l1 and loss= log is %d.' % optima

# Plots
fig4 = plt.figure( facecolor='c', edgecolor='k')
plt.plot(alpha, fscore,color='green', marker='o', linestyle='dashed',
linewidth=2, markersize=12)

for xy in zip(alpha, np.round(fscore,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Hyper parameter Alpha')
plt.ylabel('F1_Score value ')
plt.show()

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

```
0.001
{'estimator__alpha': [0.001], 'estimator__loss': ['log'], 'estimato
r__penalty': ['l1']}
Gridsearchcv
fit model
0.01
{'estimator__alpha': [0.01], 'estimator__loss': ['log'], 'estimator
__penalty': ['l1']}
Gridsearchcv
fit model
0.1
{'estimator__alpha': [0.1], 'estimator__loss': ['log'], 'estimator_
_penalty': ['l1']}
Gridsearchcv
fit model

 The optimal value of alpha with penalty=l1 and loss= log is 0.
```



```
Time taken to run this cell : 1:45:05.530338
```

In [51]:

```
optimal_alpha22
```

Out[51]:

```
0.001
```

In [52]:

```
start = datetime.now()
best_model2 = OneVsRestClassifier(SGDClassifier(loss='log', alpha=optimal_alpha22,
                                               penalty='l1'), n_jobs=-1)
best_model2.fit(question_bow_x_train_, y_train)
```

Out[52]:

```
OneVsRestClassifier(estimator=SGDClassifier(alpha=0.001, average=Fals
e,
                                            class_weight=None,
                                            early_stopping=False, eps
ilon=0.1,
                                            eta0=0.0, fit_intercept=T
rue,
                                            l1_ratio=0.15,
                                            learning_rate='optimal',
loss='log',
                                            max_iter=1000, n_iter_no_
change=5,
                                            n_jobs=None, penalty='l
1',
                                            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 [53]:

```
joblib.dump(best_model2, 'best_model2_LR.pkl')
```

Out[53]:

```
['best_model2_LR.pkl']
```

In [54]:

```
best_model2=joblib.load('best_model2_LR.pkl')
```

Logistic regression with l1 penalty

In [55]:

```
start = datetime.now()
#classifier = OneVsRestClassifier(LogisticRegression(penalty='l1'), n_jobs=-1)
#classifier.fit(x_train_multilabel, y_train)
predictions = best_model2.predict(question_bow_x_test_)
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(precision, rec

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(precision, rec

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

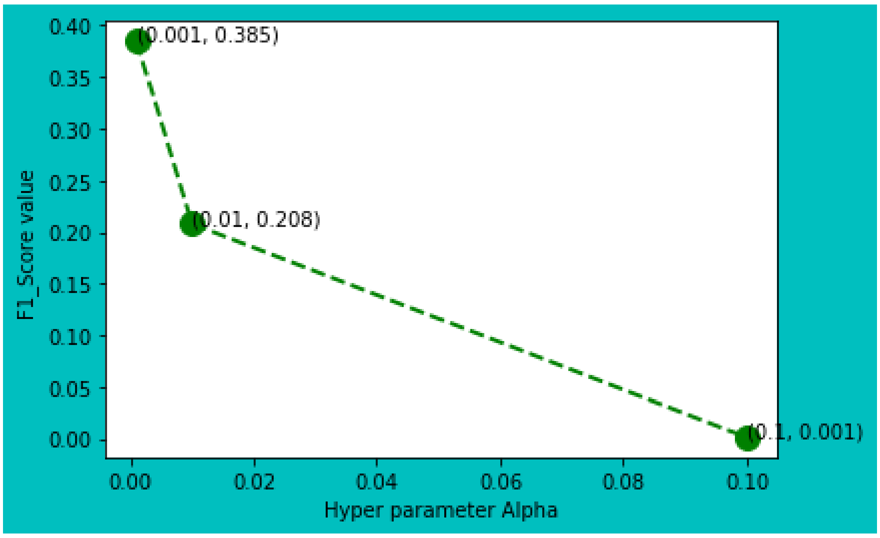
```
Accuracy : 0.18613864356440593
Hamming loss  0.0031306185510309183
Micro-average quality numbers
Precision: 0.6744, Recall: 0.2570, F1-measure: 0.3722
Macro-average quality numbers
Precision: 0.3972, Recall: 0.1512, F1-measure: 0.2012
              precision    recall  f1-score   support

           0       0.43      0.06      0.10     47524
           1       0.79      0.27      0.40     42561
           2       0.80      0.45      0.58     40426
           3       0.76      0.37      0.49     37964
           4       0.90      0.71      0.79     33571
           5       0.84      0.64      0.73     31779
           6       0.66      0.13      0.21     20526
           7       0.83      0.65      0.73     18810
           8       0.72      0.32      0.44     18365
           9       0.74      0.38      0.50     17933
          10       0.77      0.64      0.70     17263
```

OneVsRestClassifier with Linear-SVM (SGDClassifier with loss-hinge)

In [57]:

```
start = datetime.now()
import warnings
warnings.filterwarnings('ignore')

# hp1={'estimator__C':alpha}

cv_scores = []
for i in alpha:
    print(i)
    hp1={'estimator__alpha':[i],
         'estimator__loss':['hinge'],
         'estimator__penalty':['l1']}
    print(hp1)
    classifier = OneVsRestClassifier(SGDClassifier())

    model11 =GridSearchCV(classifier,hp1,
                          cv=3, scoring='f1_micro',n_jobs=-1)
    print("Gridsearchcv")
    best_model1=model11.fit(question_bow_x_train_, y_train)
    print('fit model')
    Train_model_score=best_model1.score(question_bow_x_train_,
                                        y_train)
#print("best_model1")
    cv_scores.append(Train_model_score.mean())

fscore = [x for x in cv_scores]

# determining best alpha
optimal_alpha23 = alpha[fscore.index(max(fscore))]
print('\n The optimal value of alpha with penalty=l1 and loss= log is %d.' % optima

# Plots
fig4 = plt.figure( facecolor='c', edgecolor='k')
plt.plot(alpha, fscore,color='green', marker='o', linestyle='dashed',
linewidth=2, markersize=12)

for xy in zip(alpha, np.round(fscore,3)):
    plt.annotate('(%s, %s)' % xy, xy=xy, textcoords='data')

plt.xlabel('Hyper parameter Alpha')
plt.ylabel('F1_Score value ')
plt.show()

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

```
0.001
{'estimator__alpha': [0.001], 'estimator__loss': ['hinge'], 'estima
tor__penalty': ['l1']}
Gridsearchcv
fit model
0.01
{'estimator__alpha': [0.01], 'estimator__loss': ['hinge'], 'estimat
or__penalty': ['l1']}
Gridsearchcv
fit model
0.1
{'estimator__alpha': [0.1], 'estimator__loss': ['hinge'], 'estimato
r__penalty': ['l1']}
Gridsearchcv
fit model

 The optimal value of alpha with penalty=l1 and loss= log is 0.
```



```
Time taken to run this cell : 1:49:39.366356
```

OneVsRestClassifier with SGDClassifier for optimal alpha with hinge loss

In [67]:

```
optimal_alpha23
```

Out[67]:

```
0.001
```

In [58]:

```
start = datetime.now()
classifier2 = OneVsRestClassifier(SGDClassifier(loss='hinge',
                                               alpha=optimal_alpha23,
                                               penalty='l1'))
classifier2=classifier2.fit(question_bow_x_train_, y_train)
```

In [59]:

```
joblib.dump(classifier2, 'classifier2.pkl')
```

Out[59]:

```
['classifier2.pkl']
```

In [60]:

```
classifier2=joblib.load('classifier2.pkl')
```

In [61]:

```


predictions = classifier2.predict (question_bow_x_test_)



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-averasge quality numbers")
print("Precision: {:.4f}, Recall: {:.4f}, F1-measure: {:.4f}".format(precision, rec

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(precision, rec

print (metrics.classification_report(y_test, predictions)) #printing classification
print("Time taken to run this cell :", datetime.now() - start)
```

```
Accuracy : 0.19663032771721287
Hamming loss  0.0030567784279640466
Micro-averasge quality numbers
Precision: 0.6985, Recall: 0.2698, F1-measure: 0.3893
Macro-average quality numbers
Precision: 0.2574, Recall: 0.1644, F1-measure: 0.1858
              precision    recall  f1-score   support

           0       0.56      0.03      0.05     47524
           1       0.73      0.44      0.55     42561
           2       0.72      0.61      0.66     40426
           3       0.70      0.46      0.55     37964
           4       0.92      0.68      0.78     33571
           5       0.80      0.72      0.76     31779
           6       0.71      0.11      0.19     20526
           7       0.82      0.61      0.70     18810
           8       0.69      0.37      0.48     18365
           9       0.73      0.44      0.55     17933
          10       0.74      0.63      0.68     17263
          11       0.00      0.00      0.00     17103
```

Result

In [71]:

```
from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["Sr.No", "MODEL","FEATURIZATION","PENALTY" ,"ALPHA",'LOSS','MICRO_
x.add_row(["1", 'OneVsRest+SGD Classifier', "Tf-idf","l1",0.0001,"log",0.4858])
x.add_row(["2", 'OneVsRest+SGD(log)=LR', "Bag-of-words","l2",0.001,"log",0.3742])
x.add_row(["3", 'OneVsRest+SGD(log)=LR', "Bag-of-words","l1",0.001,"log",0.3722])
x.add_row(["4", 'OneVsRest+SGD Classifier', "Bag-of-words","l1",0.001,"Hinge",0.389

print(x)
```

```
+-------+--------------------------+--------------+---------+-------
-+-------+----------------+
| Sr.No |          MODEL           | FEATURIZATION | PENALTY | ALPHA
|  LOSS | MICRO_F1_SCORE |
+-------+--------------------------+--------------+---------+-------
-+-------+----------------+
|   1   | OneVsRest+SGD Classifier |    Tf-idf    |    l1   | 0.0001
|  log  |     0.4858     |
|   2   |  OneVsRest+SGD(log)=LR   |  Bag-of-words |    l2   | 0.001
|  log  |     0.3742     |
|   3   |  OneVsRest+SGD(log)=LR   |  Bag-of-words |    l1   | 0.001
|  log  |     0.3722     |
|   4   | OneVsRest+SGD Classifier |  Bag-of-words |    l1   | 0.001
| Hinge |     0.3893     |
+-------+--------------------------+--------------+---------+-------
-+-------+----------------+
```

Observation

1. Best Micro F1-score is obtained from TFIDF vectorizer

2. Although we used BOW with ngram=(1,4), but still TFIDF vectorizer has perofrmed better