Microsoft Malware detection

1.Business/Real-world Problem

1.1. What is Malware?

The term malware is a contraction of malicious software. Put simply, malware is any piece of software that was written with the intent of doing harm to data, devices or to people.
Source: https://www.avg.com/en/signal/what-is-malware (https://www.avg.com/en/signal/what-is-malware)

1.2. Problem Statement

In the past few years, the malware industry has grown very rapidly that, the syndicates invest heavily in technologies to evade traditional protection, forcing the anti-malware groups/communities to build more robust softwares to detect and terminate these attacks. The major part of protecting a computer system from a malware attack is to **identify whether a given piece of file/software is a malware.**

1.3 Source/Useful Links

Microsoft has been very active in building anti-malware products over the years and it runs it's anti-malware utilities over **150 million computers** around the world. This generates tens of millions of daily data points to be analyzed as potential malware. In order to be effective in analyzing and classifying such large amounts of data, we need to be able to group them into groups and identify their respective families.

This dataset provided by Microsoft contains about 9 classes of malware. ,

Source: https://www.kaggle.com/c/malware-classification (https://www.kaggle.com/c/malware-classification)

1.4. Real-world/Business objectives and constraints.

1. Minimize multi-class error.
2. Multi-class probability estimates.
3. Malware detection should not take hours and block the user's computer. It should fininsh in a few seconds or a minute.

2. Machine Learning Problem

2.1. Data

2.1.1. Data Overview

- Source : https://www.kaggle.com/c/malware-classification/data (https://www.kaggle.com/c/malware-classification/data)
- For every malware, we have two files
  1. .asm file (read more: https://www.reviversoft.com/file-extensions/asm (https://www.reviversoft.com/file-extensions/asm))
  2. .bytes file (the raw data contains the hexadecimal representation of the file's binary content, without the PE header)

- Total train dataset consist of 200GB data out of which 50Gb of data is .bytes files and 150GB of data is .asm files:
- **Lots of Data for a single-box/computer.**
- There are total 10,868 .bytes files and 10,868 asm files total 21,736 files
- There are 9 types of malwares (9 classes) in our give data
- Types of Malware:
  1. Ramnit
  2. Lollipop
  3. Kelihos_ver3
  4. Vundo
  5. Simda
  6. Tracur
  7. Kelihos_ver1
  8. Obfuscator.ACY
  9. Gatak

2.1.2. Example Data Point

.asm file

```
.text:00401000                                         assume es:nothing, ss:nothin
g, ds:_data,    fs:nothing, gs:nothing
.text:00401000 56                                     push    esi
.text:00401001 8D 44 24    08                                 lea     eax, [esp+8]
.text:00401005 50                                     push    eax
.text:00401006 8B F1                                     mov     esi, ecx
.text:00401008 E8 1C 1B    00 00                                 call    ??0exceptio
n@std@@QAE@ABQBD@Z ; std::exception::exception(char const * const &)
.text:0040100D C7 06 08    BB 42 00                             mov     dword ptr [e
si],    offset off_42BB08
.text:00401013 8B C6                                     mov     eax, esi
.text:00401015 5E                                     pop     esi
.text:00401016 C2 04 00                                     retn    4
.text:00401016                               ; -----------------------------------
----------------------------------------
.text:00401019 CC CC CC    CC CC CC CC                              align 10h
.text:00401020 C7 01 08    BB 42 00                             mov     dword ptr [e
cx],    offset off_42BB08
.text:00401026 E9 26 1C    00 00                                 jmp     sub_402C51
.text:00401026                               ; -----------------------------------
----------------------------------------
.text:0040102B CC CC CC    CC CC                                 align 10h
.text:00401030 56                                     push    esi
.text:00401031 8B F1                                     mov     esi, ecx
.text:00401033 C7 06 08    BB 42 00                             mov     dword ptr [e
si],    offset off_42BB08
.text:00401039 E8 13 1C    00 00                                 call    sub_402C51
.text:0040103E F6 44 24    08 01                                 test    byte ptr
[esp+8], 1
.text:00401043 74 09                                     jz      short loc_40104E
.text:00401045 56                                     push    esi
.text:00401046 E8 6C 1E    00 00                                 call    ??3@YAXPAX@
Z    ; operator delete(void *)
.text:0040104B 83 C4 04                                     add     esp, 4
.text:0040104E
.text:0040104E                               loc_40104E:                    ; CODE
XREF: .text:00401043□j
.text:0040104E 8B C6                                     mov     eax, esi
.text:00401050 5E                                     pop     esi
.text:00401051 C2 04 00                                     retn    4
.text:00401051                               ; -----------------------------------
----------------------------------------
```

.bytes file

```
00401000 00 00 80 40 40 28 00 1C 02 42 00 C4 00 20 04 20
00401010 00 00 20 09 2A 02 00 00 00 00 8E 10 41 0A 21 01
00401020 40 00 02 01 00 90 21 00 32 40 00 1C 01 40 C8 18
00401030 40 82 02 63 20 00 00 09 10 01 02 21 00 82 00 04
00401040 82 20 08 83 00 08 00 00 00 00 02 00 60 80 10 80
00401050 18 00 00 20 A9 00 00 00 00 04 04 78 01 02 70 90
00401060 00 02 00 08 20 12 00 00 00 40 10 00 80 00 40 19
00401070 00 00 00 00 11 20 80 04 80 10 00 20 00 00 25 00
00401080 00 00 01 00 00 04 00 10 02 C1 80 80 00 20 20 00
00401090 08 A0 01 01 44 28 00 00 08 10 20 00 02 08 00 00
004010A0 00 40 00 00 00 34 40 40 00 04 00 08 80 08 00 08
004010B0 10 00 40 00 68 02 40 04 E1 00 28 14 00 08 20 0A
004010C0 06 01 02 00 40 00 00 00 00 00 00 20 00 02 00 04
004010D0 80 18 90 00 00 10 A0 00 45 09 00 10 04 40 44 82
004010E0 90 00 26 10 00 00 04 00 82 00 00 00 20 40 00 00
004010F0 B4 00 00 40 00 02 20 25 08 00 00 00 00 00 00 00
00401100 08 00 00 50 00 08 40 50 00 02 06 22 08 85 30 00
00401110 00 80 00 80 60 00 09 00 04 20 00 00 00 00 00 00
00401120 00 82 40 02 00 11 46 01 4A 01 8C 01 E6 00 86 10
00401130 4C 01 22 00 64 00 AE 01 EA 01 2A 11 E8 10 26 11
00401140 4E 11 8E 11 C2 00 6C 00 0C 11 60 01 CA 00 62 10
00401150 6C 01 A0 11 CE 10 2C 11 4E 10 8C 00 CE 01 AE 01
00401160 6C 10 6C 11 A2 01 AE 00 46 11 EE 10 22 00 A8 00
00401170 EC 01 08 11 A2 01 AE 10 6C 00 6E 00 AC 11 8C 00
00401180 EC 01 2A 10 2A 01 AE 00 40 00 C8 10 48 01 4E 11
00401190 0E 00 EC 11 24 10 4A 10 04 01 C8 11 E6 01 C2 00
```

2.2. Mapping the real-world problem to an ML problem

2.2.1. Type of Machine Learning Problem

There are nine different classes of malware that we need to classify a given a data point => Multi class classification problem

2.2.2. Performance Metric

Source: [https://www.kaggle.com/c/malware-classification#evaluation (https://www.kaggle.com/c/malware-classification#evaluation)](https://www.kaggle.com/c/malware-classification#evaluation)

Metric(s):

- Multi class log-loss
- Confusion matrix

2.2.3. Machine Learing Objectives and Constraints

Objective: Predict the probability of each data-point belonging to each of the nine classes.

Constraints:

- Class probabilities are needed.
- Penalize the errors in class probabilites => Metric is Log-loss.
- Some Latency constraints.

2.3. Train and Test Dataset

Split the dataset randomly into three parts train, cross validation and test with 64%,16%, 20% of data respectively

2.4. Useful blogs, videos and reference papers

http://blog.kaggle.com/2015/05/26/microsoft-malware-winners-interview-1st-place-no-to-overfitting/ (http://blog.kaggle.com/2015/05/26/microsoft-malware-winners-interview-1st-place-no-to-overfitting/)
https://arxiv.org/pdf/1511.04317.pdf (https://arxiv.org/pdf/1511.04317.pdf)
First place solution in Kaggle competition: https://www.youtube.com/watch?v=VLQTRlLGz5Y (https://www.youtube.com/watch?v=VLQTRlLGz5Y)
https://github.com/dchad/malware-detection (https://github.com/dchad/malware-detection)
http://vizsec.org/files/2011/Nataraj.pdf (http://vizsec.org/files/2011/Nataraj.pdf)
https://www.dropbox.com/sh/gfqzv0ckgs4l1bf/AAB6EelnEjvvuQg2nu_pIB6ua?dl=0 (https://www.dropbox.com/sh/gfqzv0ckgs4l1bf/AAB6EelnEjvvuQg2nu_pIB6ua?dl=0)
" Cross validation is more trustworthy than domain knowledge."

3. Exploratory Data Analysis

In [1]:

```
#importing all the necessary lib
import warnings
warnings.filterwarnings("ignore")
import shutil
import os
import pandas as pd
#import matplotlib
#matplotlib.use(u'nbAgg')
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pickle
from sklearn.manifold import TSNE
from sklearn import preprocessing
import pandas as pd
from multiprocessing import Process# this is used for multithreading
import multiprocessing
import codecs# this is used for file operations
import random as r
from xgboost import XGBClassifier
from sklearn.model_selection import RandomizedSearchCV
from sklearn.tree import DecisionTreeClassifier
from sklearn.calibration import CalibratedClassifierCV
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import log_loss
from sklearn.metrics import confusion_matrix
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
import datetime
from tqdm import tqdm
import sqlite3 as sq
from sqlalchemy import create_engine
from collections import defaultdict
import pickle
import csv
from sklearn.preprocessing import StandardScaler
from prettytable import PrettyTable
```

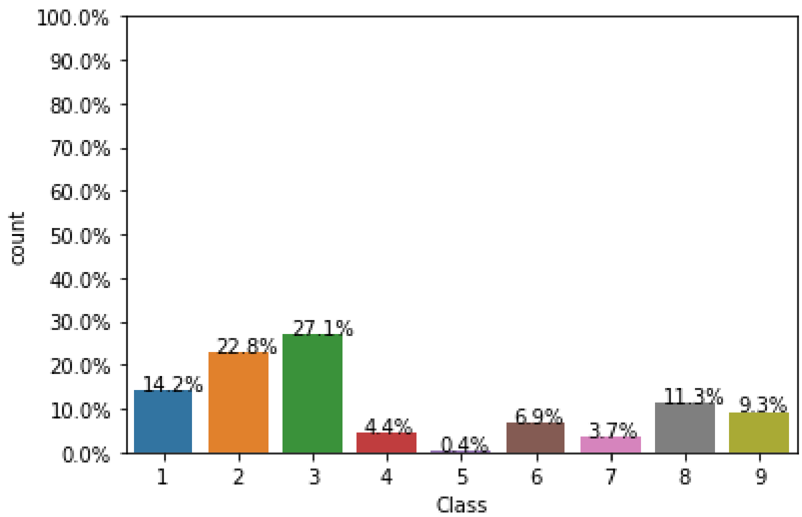
In [2]:

```
#separating byte files and asm files

source = 'train'
destination = 'byteFiles'

# we will check if the folder 'byteFiles' exists if it not there we will create a folder wi
if not os.path.isdir(destination):
    os.makedirs(destination)

# if we have folder called 'train' (train folder contains both .asm files and .bytes files)
# for every file that we have in our 'asmFiles' directory we check if it is ending with .by
# 'byteFiles' folder

# so by the end of this snippet we will separate all the .byte files and .asm files
if os.path.isdir(source):
    os.rename(source,'asmFiles')
    source='asmFiles'
    data_files = os.listdir(source)
    for file in data_files:
        if (file.endswith("bytes")):
            shutil.move('asmFiles/'+file,destination)
```

3.1. Distribution of malware classes in whole data set

In [2]:

```
Y=pd.read_csv("trainLabels.csv")# loading the train labels
total = len(Y)*1.

ax=sns.countplot(x="Class", data=Y)
for p in ax.patches:
        ax.annotate('{:.1f}%'.format(100*p.get_height()/total), (p.get_x()+0.1, p.get_heigh

#put 11 ticks (therefore 10 steps), from 0 to the total number of rows in the dataframe
ax.yaxis.set_ticks(np.linspace(0, total, 11))

#adjust the ticklabel to the desired format, without changing the position of the ticks.
ax.set_yticklabels(map('{:.1f}%'.format, 100*ax.yaxis.get_majorticklocs()/total))
plt.show()
```



In [19]:

```
Y.columns = ['ID','Class']
Y['Class'].value_counts()
```

Out[19]:

```
3    2942
2    2478
1    1541
8    1228
9    1013
6     751
4     475
7     398
5      42
Name: Class, dtype: int64
```

Observation: Given dataset is imbalanced

3.2. Feature extraction

3.2.1 File size of byte files as a feature

In [3]:

```
#file sizes of byte files

files=os.listdir('byteFiles')
filenames=Y['Id'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=3561571700, st_nlink=1,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_stat.htm
    statinfo=os.stat('byteFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file name
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
data_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (data_size_byte.head())
```

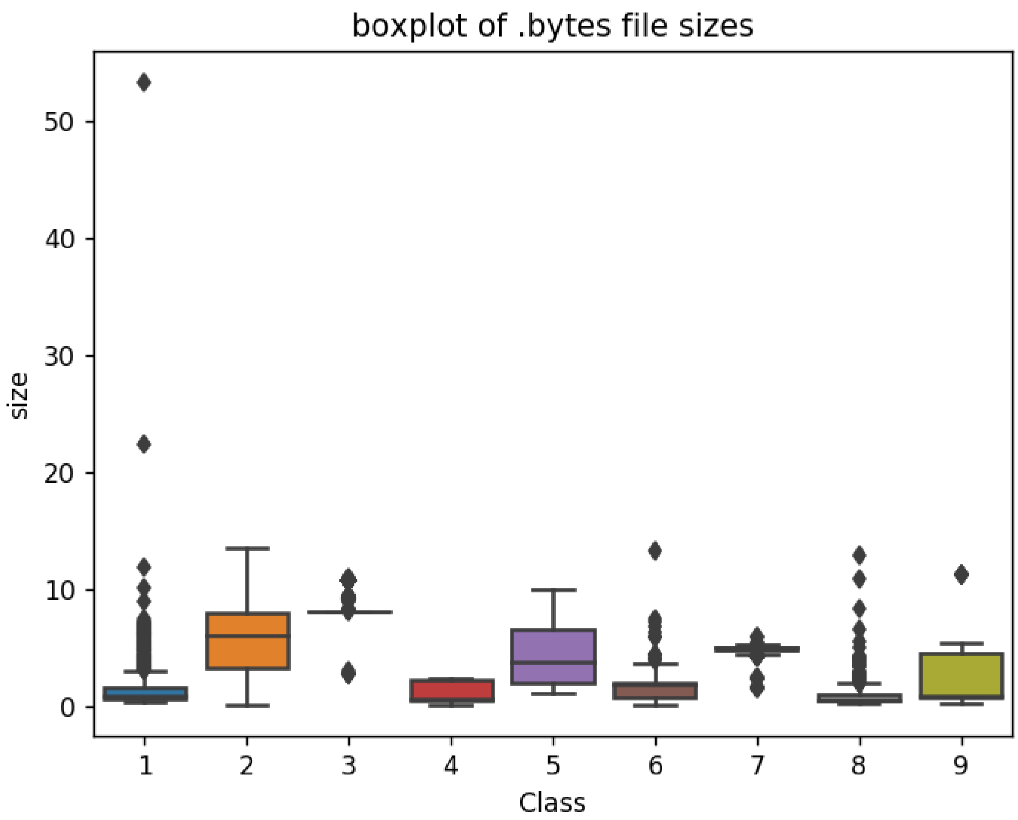
```
                     ID      size  Class
0  01azqd4InC7m9JpocGv5  4.321289      9
1  01IsoiSMh5gxyDYTl4CB  5.651855      2
2  01jsnpXSAlgw6aPeDxrU  3.967285      9
3  01kcPWA9K2BOxQeS5Rju  0.585938      1
4  01SuzwMJEIXsK7A8dQbl  0.378418      8
```

3.2.2 box plots of file size (.byte files) feature

In [72]:

```
#boxplot of byte files
ax = sns.boxplot(x="Class", y="size", data=data_size_byte)
plt.title("boxplot of .bytes file sizes")
plt.show()
```

<IPython.core.display.Javascript object>



3.2.3 feature extraction from byte files

In [73]:

```
#removal of addres from byte files
# contents of .byte files
# ----------------
#00401000 56 8D 44 24 08 50 8B F1 E8 1C 1B 00 00 C7 06 08
#-------------------
#we remove the starting address 00401000
start = datetime.datetime.now()
files = os.listdir('byteFiles')
filenames=[]
array=[]
for f in files:
    if(f.endswith("bytes")):
        file=f.split('.')[0]
        text_file = open('byteFiles/'+file+".txt", 'w+')
        with open('byteFiles/'+file+".bytes" ,"r") as fp:
            lines=""
            for line in fp:
                a=line.rstrip().split(" ")[1:]
                b=' ' + ' '.join(a)
                b=b+"\n"
                text_file.write(b)
            fp.close()
            os.remove('byteFiles/'+file+".bytes")
        text_file.close()
print("Time required to run this cell:", datetime.datetime.now() - start)
```

```
Time required to run this cell: 1:14:10.898163
```

UNIGRAM for BYTE FILE

In [38]:

```
#Obtaining the unigram corpus
ngram = 1
words_file = defaultdict(lambda: 0) # default dict to saving the unigram corpus
files = os.listdir("byteFiles/")
for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
            for lines in byte_flie:
                split=lines.replace("\n","").split(" ")
                for ng in range(ngram-1,ngram):
                    for j in range (ng+1,len(split) ):
                        str_to_pass=""
                        for s in range (0,-ng-1,-1 ):
                            str_to_pass+=split[j+s]
                            if str_to_pass not in words_file: # if word not present in curr
                                words_file[str_to_pass]+=1
                            else:
                                words_file[str_to_pass]+=1
```

```
100%|████████████████████████████████████████████████████████████
███| 10868/10868 [3:07:43<00:00,  4.95it/s]
```

In [42]:

```
# saving the unigram corpus

with open('unigramTrainKeys.pickle', 'wb') as handle:
    pickle.dump(list(words_file.keys()), handle, protocol=pickle.HIGHEST_PROTOCOL)
with open('unigramTrainValues.pickle', 'wb') as handle:
    pickle.dump(list(words_file.values()), handle, protocol=pickle.HIGHEST_PROTOCOL)
```

In [84]:

```
unigra = ['ID']
with open('unigramTrainKeys.pickle','rb') as handle:
    unigra +=  pickle.load(handle)
```

In [103]:

```
#Unigram calculations
ngram = 1
byte_feature_file=open('result_byte_feat.csv','w+')
files = os.listdir("byteFiles/")
f = open('result_byte.csv', 'w')  # Just use 'w' mode in 3.x
w = csv.DictWriter(f, unigra) # creating a csv file with header of the csv file as file ID
w.writeheader()
    #w.writerow(my_dict)


for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
        words_file = defaultdict(lambda: 0)
        fs = file.split(".")[0]
        words_file['ID'] = fs
        for lines in byte_flie:
            split=lines.replace("\n","").split(" ")
            for ng in range(ngram-1,ngram):
                for j in range (ng+1,len(split) ):
                    str_to_pass=""
                    for s in range (0,-ng-1,-1 ):
                        str_to_pass+=split[j+s]
                    if str_to_pass not in words_file: # if word not present in current
                        words_file[str_to_pass]+=1
                    else:
                        words_file[str_to_pass]+=1


        w.writerow(words_file)
```

```
100%|████████████████████████████████████████
███| 10868/10868 [6:22:43<00:00,  4.54it/s]
```

In [4]:

```
df_unigram_byte = pd.read_csv("result_byte.csv")
df_unigram_byte.head()
```

Out[4]:

	ID	E8	0B	00	E9	16	90	B9	25
0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.0	4002.0
1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.0	301.0
2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.0	2327.0
3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.0	566.0
4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.0	486.0

5 rows × 258 columns

In [11]:

```
df_unigram_byte.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10862 entries, 0 to 10861
Columns: 258 entries, ID to ??
dtypes: float64(257), object(1)
memory usage: 21.4+ MB
```

In [12]:

```
df_unigram_byte.describe()
```

Out[12]:

	E8	0B	00	E9	16	90
count	10853.000000	1.085100e+04	1.085300e+04	10849.000000	10853.000000	10846.000000
mean	4292.678154	4.263032e+03	5.419881e+04	2960.274956	3237.459965	2823.297437
std	4945.292715	2.838994e+04	1.012207e+05	3389.377291	18095.944592	9718.301838
min	16.000000	1.000000e+00	6.100000e+01	1.000000	1.000000	1.000000
25%	958.000000	4.010000e+02	1.126200e+04	504.000000	313.000000	420.000000
50%	3216.000000	2.151000e+03	2.183200e+04	2204.000000	715.000000	1162.000000
75%	4902.000000	3.266000e+03	6.094200e+04	3232.000000	3147.000000	3191.000000
max	141825.000000	1.821532e+06	2.290304e+06	73222.000000	843056.000000	232188.000000

8 rows × 257 columns

Bi -Gram Calculation for the byte file

In [109]:

```
#Obtaining the bi-gram corpus
ngram = 2
words_file = defaultdict(lambda: 0) # default dict to store the bi gram features
files = os.listdir("byteFiles/")
for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
            for lines in byte_flie:
                split=lines.replace("\n","").split(" ")
                for ng in range(ngram-1,ngram):
                    for j in range (ng+1,len(split) ):
                        str_to_pass=""
                        for s in range (0,-2,-1 ):
                            str_to_pass+=split[j+s]

                        if str_to_pass not in words_file: # if word not present in current
                            words_file[str_to_pass]+=1
                        else:
                            words_file[str_to_pass]+=1
```

```
100%|████████████████████████████████████████████████████████████████████████████████████
███| 10868/10868 [3:20:35<00:00,  4.49it/s]
```

In [110]:

```
# saving the unigram corpus

with open('bigramTrainKeys.pickle', 'wb') as handle:
    pickle.dump(list(words_file.keys()), handle, protocol=pickle.HIGHEST_PROTOCOL)
with open('bigramTrainValues.pickle', 'wb') as handle:
    pickle.dump(list(words_file.values()), handle, protocol=pickle.HIGHEST_PROTOCOL)
```

In [3]:

```
with open('bigramTrainValues.pickle', 'rb') as handle:
    bi_gram_values = pickle.load(handle)
with open('bigramTrainKeys.pickle', 'rb') as handle:
    bi_gram_keys = pickle.load(handle)
```

In [4]:

```
bi_gram_sorted = sorted(bi_gram_values,reverse= True)
```

In [5]:

```
#total bigram are 65,536. To reduce the computational time and complexity, I have used top
#Selecting the top 200 bi gram features based on count.
index = []
for i in bi_gram_sorted[:200]:
    index.append(bi_gram_values.index(i))


bi_gram_top_2000_list = ['ID']
for x in index:
    bi_gram_top_2000_list.append(bi_gram_keys[x])
```

In [7]:

```
print(bi_gram_top_2000_list)
```

```
['ID', '????', '0000', 'CCCC', 'FFFF', '00FF', 'FF00', '0001', 'F0F0', '8B0
0', '0100', '9090', '0004', '0002', '0020', '0101', '0040', '2000', '8300',
'0202', '0010', '01F0', '0041', '1000', '75FF', '0003', '7400', 'E800', '040
4', '1010', '2020', '0043', '0008', '458B', '0400', '8000', 'C483', '0200',
'8900', '0606', '8BFF', '0303', 'FFFE', '0300', 'F2F2', 'F001', '4040', '333
3', '5000', '0800', '8D00', '0074', '5959', 'E8E8', '6800', '006A', '0006',
'0005', '5656', '0808', '5050', 'C085', '7474', '8D8D', '8B8B', '0F00', '444
4', '0F0F', '2444', '0080', 'FEFE', '5353', '0505', '2424', '7500', '3300',
'0065', '000B', '0C0C', '6A00', '0016', '0707', 'FCFC', 'FDFD', 'C0C0', '000
C', '8080', '8500', 'F8F8', '4000', '83FF', '15FF', '4D8B', '5757', '8585',
'0B0B', '1818', '0044', '8383', 'FF8B', 'F1F1', '5900', '3939', '4343', '000
7', '1600', 'C033', '0600', '6868', '7575', '6A6A', '0030', '1200', '8888',
'0500', '3B3B', 'ECEC', '3000', 'C000', 'C7C7', '0045', '5600', '4545', 'C3C
3', '1414', 'C700', '4646', '5300', '008B', '5E5E', 'EB00', 'F790', '0068',
'000F', '0050', 'C6C6', 'EBEB', 'C4C4', '01F2', '8484', '4589', 'C1C1', '555
5', '0072', '01F1', '4848', 'B6B6', '8989', '4D4D', '0C00', 'E9E9', '0056',
'00E8', '5D5D', '0033', '8B55', '00C0', '3D3D', '0700', '0014', '0046', '007
3', 'F000', '6500', '0075', 'FF50', '5700', '0061', '8BFD', '7D7D', '0018',
'0052', 'FFFD', '2C2C', '0B00', '00FC', '0024', '3838', '0069', '4300', '005
7', '6969', '55FF', '0042', '8B08', '4400', '7200', '1800', '6900', '0012',
'3B00', '0063', '1212', '0053', '0085', '5F00', '008D', '5500', '00C7', 'E90
0', 'EC8B']
```

Top 200 bigrams that are selected

In [9]:

```
#bigram calculations
ngram = 2

files = os.listdir("byteFiles/")
f = open('result_byte_bigram.csv', 'w')  # Just use 'w' mode in 3.x
w = csv.DictWriter(f, bi_gram_top_2000_list)
w.writeheader()
    #w.writerow(my_dict)

for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
        words_file = dict.fromkeys(list(bi_gram_top_2000_list), 0)
        fs = file.split(".")[0]
        words_file['ID'] = fs
        for lines in byte_flie:
            split=lines.replace("\n","").split(" ")
            for ng in range(1,ngram):
                for j in range (3,len(split) ):
                    str_to_pass=""
                    for s in range (0,-2,-1 ):
                        str_to_pass+=split[j+s]
                    if str_to_pass in bi_gram_top_2000_list: # if word not present in curre
                        words_file[str_to_pass]+=1

                    else:
                        pass
```

```
100%|██████████████████████████████████████████████████
███| 10868/10868 [7:14:39<00:00,  2.40it/s]
```

In [5]:

```
df_bigram_byte = pd.read_csv("result_byte_bigram.csv")
df_bigram_byte.head()
```

Out[5]:

	ID	????	0000	CCCC	FFFF	00FF	FF00	0001	F0F0	8B00	...
0	01azqd4InC7m9JpocGv5	1593	271912	98	779	1498	1542	1778	84	1777	...
1	01IsoiSMh5gxyDYTl4CB	7510	18639	732	4234	2007	862	730	21	282	...
2	01jsnpXSAlgw6aPeDxrU	402	14131	7	1826	2240	2283	433	3	1047	...
3	01kcPWA9K2BOxQeS5Rju	12194	9170	22	1082	628	637	157	11	304	...
4	01SuzwMJEIXsK7A8dQbl	7880	14283	31	71	22	52	225	1	362	...

5 rows × 201 columns

In [4]:

```
df_bigram_byte.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10864 entries, 0 to 10863
Columns: 201 entries, ID to EC8B
dtypes: int64(200), object(1)
memory usage: 16.7+ MB
```

In [8]:

```
df_bigram_byte.describe()
```

Out[8]:

	????	0000	CCCC	FFFF	00FF	FF00
count	1.086400e+04	1.086400e+04	10864.000000	10864.000000	10864.000000	10864.000000
mean	4.364992e+05	2.428387e+04	9169.319219	2763.858432	743.194035	752.565538
std	6.304190e+05	4.899751e+04	43712.764899	9276.251070	1366.024183	1612.480995
min	0.000000e+00	0.000000e+00	0.000000	0.000000	0.000000	0.000000
25%	7.774250e+03	5.447750e+03	12.000000	86.000000	103.000000	53.750000
50%	1.512100e+04	1.422700e+04	31.000000	654.000000	280.000000	191.000000
75%	1.303815e+06	2.399775e+04	318.000000	3269.000000	684.500000	840.000000
max	1.239472e+07	2.000608e+06	596902.000000	630396.000000	30182.000000	84185.000000

8 rows × 200 columns

N- Gram calculation for the byte file (N = 3)

In [2]:

```
#Obtaining the N-gram corpus for N = 3
ngram = 3
words_file = defaultdict(lambda: 0)
files = os.listdir("byteFiles/")
for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
            for lines in byte_flie:
                split=lines.replace("\n","").split(" ")
                for ng in range(ngram-1,ngram):
                    for j in range (ng+1,len(split) ):
                        str_to_pass=""
                        for s in range (0,-ng-1,-1 ):
                            str_to_pass+=split[j+s]

                        if str_to_pass not in words_file: # if word not present in current
                            words_file[str_to_pass]+=1
                        else:
                            words_file[str_to_pass]+=1
```

```
100%|██████████████████████████████████████████████████████████████████████
███| 10868/10868 [7:06:50<00:00,  3.52it/s]
```

In [3]:

```
# saving the unigram corpus

with open('ngramTrainKeys.pickle', 'wb') as handle:
    pickle.dump(list(words_file.keys()), handle, protocol=pickle.HIGHEST_PROTOCOL)
with open('ngramTrainValues.pickle', 'wb') as handle:
    pickle.dump(list(words_file.values()), handle, protocol=pickle.HIGHEST_PROTOCOL)
```

In [3]:

```
with open('ngramTrainValues.pickle', 'rb') as handle:
    n_gram_values = pickle.load(handle)
with open('ngramTrainKeys.pickle', 'rb') as handle:
    n_gram_keys = pickle.load(handle)
```

In [4]:

```
n_gram_sorted = sorted(n_gram_values,reverse= True)
```

In [5]:

```
#Selecting top 200 N grams based on counts to reduce computation complexity
index = []
for i in n_gram_sorted[:200]:
    index.append(n_gram_values.index(i))


n_gram_top_2000_list = ['ID']
for x in index:
    n_gram_top_2000_list.append(n_gram_keys[x])
```

In [6]:

```
print(n_gram_top_2000_list)
```

```
['ID', '??????', '000000', 'CCCCCC', 'FFFFFF', '000001', '0000FF', '909090',
'000100', '00FFFF', '8B0000', '002000', 'FFFF00', 'FF0000', '01F0F0', '01000
0', '00FF00', 'FF00FF', '000004', 'F0F0F0', '000002', '830000', 'FFFFFE', 'F
0F001', 'F001F0', '000010', 'EC8B55', '000003', '8BFFFF', '001000', '83FFF
F', '000020', '800000', '890000', '000400', '010101', '00000B', '55FF8B', '8
B55FF', 'E80000', '030000', '007400', '000080', 'FFFFFD', 'C483FF', '00020
0', '001600', '000016', '74C085', '006500', '000008', '000005', '040000', '0
00040', '000300', '200000', '008000', '000800', 'C48300', '590000', '00690
0', '007200', '8D0000', '0F0000', '740000', '24448B', '080000', '100000', '0
00007', '120000', '500000', '007300', '59FFFF', '08458B', 'F00000', '00000
6', '00000D', '006100', '003000', '00000A', 'EB0000', '000028', '000500', '0
00009', '330000', '400000', '006A00', '680000', '006800', '004000', '02000
0', '020202', 'C70000', '160000', '00000C', '00000F', '06FA06', '000065', '0
40404', '000041', '007500', '000700', '202020', '0CC483', '090000', '28000
0', '6A0000', '850000', '000C00', '005300', '006F00', '0000F0', '000074', 'C
00000', '0875FF', '660000', '004400', '000F00', '00003F', '004300', 'F2F2F
2', '244C8B', '043D04', '005000', '002800', 'F79090', '004160', '042C04', '7
50000', '530000', '005F00', '01F2F2', '000600', '01F1F1', '004500', '01F1F
0', '01F0F1', '01F0F2', '01F1F2', '01F2F0', '01F2F1', '060606', '000B00', '0
00068', 'FF8BC3', '003300', '83EC8B', '00DF00', '050000', '00006C', '00001
4', '00C000', '0000C0', '000011', '020102', 'FDFDFD', '200001', '810000', '0
0B500', '004600', '767661', '004D00', '001800', 'EC83EC', '000043', '00240
0', '617676', '008400', '3B0000', '766176', '044A04', '023802', '04C483', '0
05500', '560000', '004800', '000027', '000072', '000073', '000024', '00008
8', '570000', '0000C3', '006E00', '000050', '001400', '000025', '00001C', '0
03900', '005600', 'E90000', '040004', '00006E', '00F000', '000030', '04800
4', '044604', '008B00', '008800', '008D00', '000064']
```

In [8]:

```
#Unigram calculations
ngram = 3

files = os.listdir("byteFiles/")
f = open('result_byte_ngram.csv', 'w')  # Just use 'w' mode in 3.x
w = csv.DictWriter(f, n_gram_top_2000_list)
w.writeheader()
    #w.writerow(my_dict)

for file in tqdm(files):
    with open("byteFiles/"+file,"r") as byte_flie:
        words_file = dict.fromkeys(list(n_gram_top_2000_list), 0)
        fs = file.split(".")[0]
        words_file['ID'] = fs
        for lines in byte_flie:
            split=lines.replace("\n","").split(" ")
            for ng in range(1,ngram):
                for j in range (3,len(split) ):
                    str_to_pass=""
                    for s in range (0,-3,-1 ):
                        str_to_pass+=split[j+s]
                    if str_to_pass in n_gram_top_2000_list: # if word not present in curren
                        words_file[str_to_pass]+=1

                    else:
                        pass


        w.writerow(words_file)
```

```
100%|████████████████████████████████████████████████████████████
██| 10868/10868 [17:41:16<00:00,  1.14it/s]
```

In [6]:

```
df_ngram_byte = pd.read_csv("result_byte_ngram.csv")
df_ngram_byte.head()
```

Out[6]:

	ID	??????	000000	CCCCCC	FFFFFF	000001	0000FF	909090	0001
0	01azqd4InC7m9JpocGv5	3180	29808	18	76	2142	2684	2622	
1	01IsoiSMh5gxyDYTl4CB	15012	29658	1254	3388	398	1022	0	11
2	01jsnpXSAlgw6aPeDxrU	792	19336	4	236	98	58	0	
3	01kcPWA9K2BOxQeS5Rju	24384	12728	30	428	152	208	0	1
4	01SuzwMJEIXsK7A8dQbl	15752	26806	50	28	110	40	0	

5 rows × 201 columns

In [7]:

```
#Merging the unigram and bigram features
result_byte = pd.merge(df_unigram_byte, df_bigram_byte,on='ID', how='left')
result_byte.head()
```

Out[7]:

	ID	E8	0B	00	E9	16	90	B9	25
0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.0	4002.0
1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.0	301.0
2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.0	2327.0
3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.0	566.0
4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.0	486.0

5 rows × 458 columns

In [8]:

```
#Merging the Ngram feature with unigram and bigram features of byte file
result_byte_ = pd.merge(result_byte,df_ngram_byte,on = 'ID',how='left')
```

In [9]:

```
#Merging size of byte file feature to unigram,bigram and Ngram
result_byte_final = pd.merge(result_byte_,data_size_byte,on='ID',how='left')
result_byte_final.head()
```

Out[9]:

	ID	E8	0B	00	E9	16	90	B9	25
0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.0	4002.0
1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.0	301.0
2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.0	2327.0
3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.0	566.0
4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.0	486.0

5 rows × 660 columns

In [10]:

```
result_byte_final.to_csv('result_byte_final.csv') # saving the features of byte file to a c
```

In [49]:

```
result_byte_final = pd.read_csv('result_byte_final.csv') # reading the csv file having all
result_byte_final.head(4)
```

Out[49]:

	Unnamed: 0	ID	E8	0B	00	E9	16	90	B
0	0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.
1	1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.
2	2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.
3	3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.

4 rows × 661 columns

In [50]:

```
# https://stackoverflow.com/a/29651514
#Performing normalizing
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - min_value
    return result1
```

In [51]:

```
result_byte_final_normalized = normalize(result_byte_final)
result_byte_final_normalized.head()
```

Out[51]:

	Unnamed: 0	ID	E8	0B	00	E9	16	
0	0.000000	01azqd4InC7m9JpocGv5	0.033101	0.001946	0.262786	0.041423	0.003776	0.019
1	0.000092	01IsoiSMh5gxyDYTl4CB	0.052818	0.003650	0.017332	0.093921	0.000413	0.003
2	0.000184	01jsnpXSAlgw6aPeDxrU	0.157169	0.001465	0.040801	0.034321	0.002855	0.010
3	0.000276	01kcPWA9K2BOxQeS5Rju	0.020330	0.000244	0.009182	0.009792	0.000489	0.002
4	0.000368	01SuzwMJEIXsK7A8dQbl	0.003737	0.000124	0.008603	0.007402	0.000283	0.001

5 rows × 661 columns

In [52]:

```
result_byte_final_normalized.shape
```

Out[52]:

```
(10862, 661)
```

Total number of features of byte are 661(256 unigram features + 200 bigram features + 200 N-gram features + size + ID + class)

In [53]:

```
# Checking for any NaN values in the byte feature and removing them
result_byte_final_normalized.dropna(how = 'any')
result_byte_final_normalized.shape
```

Out[53]:

```
(10862, 661)
```

In [60]:

```
#checking for infinite values which might have resulted due to divide by zero and removing
result_byte_final_normalized.replace([np.inf, -np.inf], np.nan)
result_byte_final_normalized.dropna(inplace=True,how='any')
result_byte_final_normalized.drop(['Unnamed: 0','ID'],axis = 1,inplace=True)
data_y = result_byte_final_normalized['Class']
result_byte_final_normalized.shape
```

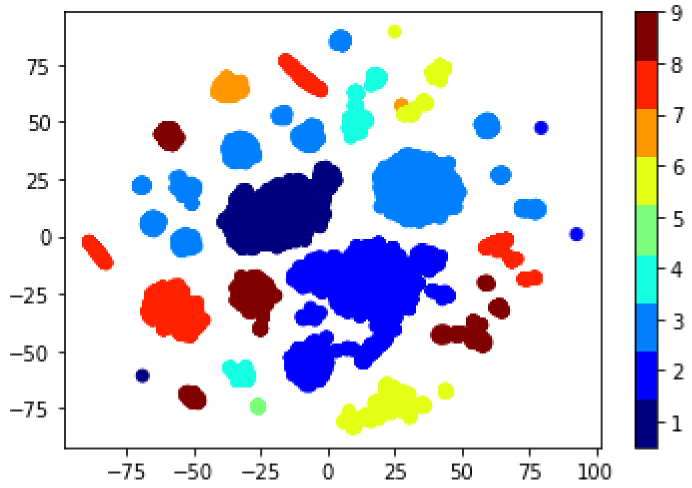
Out[60]:

```
(10603, 659)
```

3.2.4 Multivariate Analysis

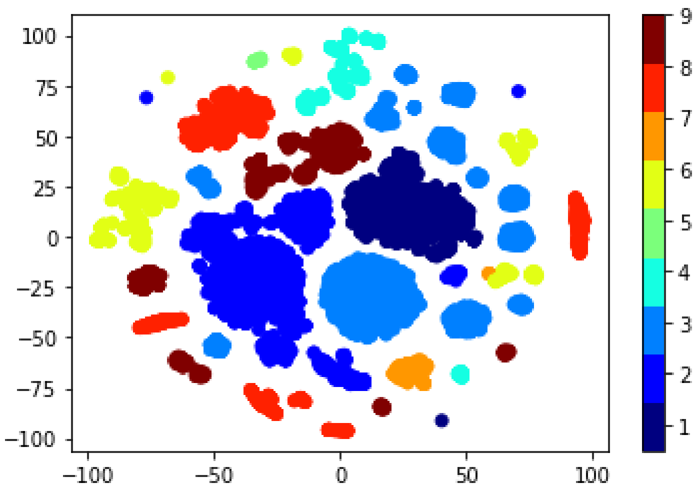
In [61]:

```
#multivariate analysis on byte files
#this is with perplexity 50
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_byte_final_normalized)
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



In [62]:

```
#this is with perplexity 30
xtsne=TSNE(perplexity=30)
results=xtsne.fit_transform(result_byte_final_normalized)
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```



Train Test split

In [63]:

```
# split the data into test and train by maintaining same distribution of output varaible 'y
X_train, X_test, y_train, y_test = train_test_split(result_byte_final_normalized, data_y,st
# split the train data into train and cross validation by maintaining same distribution of 
X_train, X_cv, y_train, y_cv = train_test_split(X_train, y_train,stratify=y_train,test_size
```

In [64]:

```
print('Number of data points in train data:', X_train.shape[0])
print('Number of data points in test data:', X_test.shape[0])
print('Number of data points in cross validation data:', X_cv.shape[0])
```

```
Number of data points in train data: 6785
Number of data points in test data: 2121
Number of data points in cross validation data: 1697
```

In [65]:

```
def plot_confusion_matrix(test_y, predict_y):
    C = confusion_matrix(test_y, predict_y)
    print("Number of misclassified points ",(len(test_y)-np.trace(C))/len(test_y)*100)
    # C = 9,9 matrix, each cell (i,j) represents number of points of class i are predicted

    A =(((C.T)/(C.sum(axis=1))).T)
    #divid each element of the confusion matrix with the sum of elements in that column

    # C = [[1, 2],
    #     [3, 4]]
    # C.T = [[1, 3],
    #        [2, 4]]
    # C.sum(axis = 1)  axis=0 corresonds to columns and axis=1 corresponds to rows in two d
    # C.sum(axix =1) = [[3, 7]]
    # ((C.T)/(C.sum(axis=1))) = [[1/3, 3/7]
    #                            [2/3, 4/7]]

    # ((C.T)/(C.sum(axis=1))).T = [[1/3, 2/3]
    #                            [3/7, 4/7]]
    # sum of row elements = 1

    B =(C/C.sum(axis=0))
    #divid each element of the confusion matrix with the sum of elements in that row
    # C = [[1, 2],
    #     [3, 4]]
    # C.sum(axis = 0)  axis=0 corresonds to columns and axis=1 corresponds to rows in two d
    # C.sum(axix =0) = [[4, 6]]
    # (C/C.sum(axis=0)) = [[1/4, 2/6],
    #                       [3/4, 4/6]]

    labels = [1,2,3,4,5,6,7,8,9]
    cmap=sns.light_palette("green")
    # representing A in heatmap format
    print("-"*50, "Confusion matrix", "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(C, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()

    print("-"*50, "Precision matrix", "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(B, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of columns in precision matrix",B.sum(axis=0))

    # representing B in heatmap format
    print("-"*50, "Recall matrix"    , "-"*50)
    plt.figure(figsize=(10,5))
    sns.heatmap(A, annot=True, cmap=cmap, fmt=".3f", xticklabels=labels, yticklabels=labels
    plt.xlabel('Predicted Class')
    plt.ylabel('Original Class')
    plt.show()
    print("Sum of rows in precision matrix",A.sum(axis=1))
```

Machine Learning Models

Machine Leaning Models on bytes files

Random Model

In [66]:

```
# we need to generate 9 numbers and the sum of numbers should be 1
# one solution is to genarate 9 numbers and divide each of the numbers by their sum
# ref: https://stackoverflow.com/a/18662466/4084039

test_data_len = X_test.shape[0]
cv_data_len = X_cv.shape[0]

# we create a output array that has exactly same size as the CV data
cv_predicted_y = np.zeros((cv_data_len,9))
for i in range(cv_data_len):
    rand_probs = np.random.rand(1,9)
    cv_predicted_y[i] = ((rand_probs/sum(sum(rand_probs)))[0])
print("Log loss on Cross Validation Data using Random Model",log_loss(y_cv,cv_predicted_y,


# Test-Set error.
#we create a output array that has exactly same as the test data
test_predicted_y = np.zeros((test_data_len,9))
for i in range(test_data_len):
    rand_probs = np.random.rand(1,9)
    test_predicted_y[i] = ((rand_probs/sum(sum(rand_probs)))[0])
print("Log loss on Test Data using Random Model",log_loss(y_test,test_predicted_y, eps=1e-1

predicted_y =np.argmax(test_predicted_y, axis=1)
plot_confusion_matrix(y_test, predicted_y+1)
```

```
Log loss on Cross Validation Data using Random Model 2.5067846839858796
Log loss on Test Data using Random Model 2.5103159028550284
Number of misclassified points  88.4016973125884
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

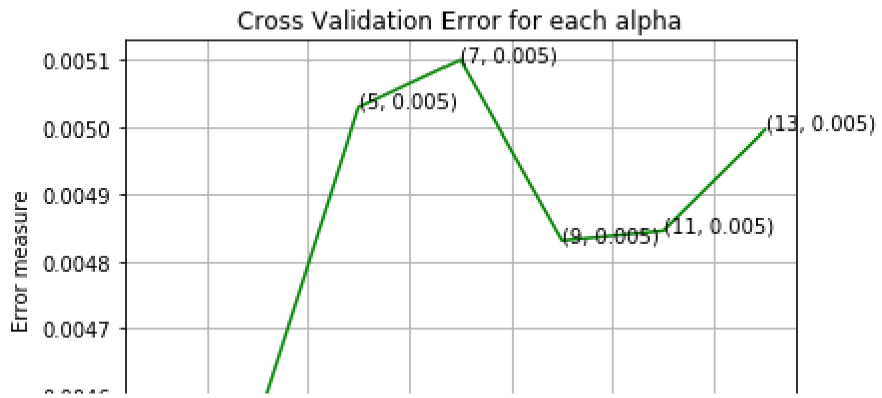
4.1.2. K Nearest Neighbour Classification

In [67]:

```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/modules/genera
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

# methods of
# fit(X, y) : Fit the model using X as training data and y as target values
# predict(X):Predict the class labels for the provided data
# predict_proba(X):Return probability estimates for the test data X.
#-------------------------------------
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/k-nea
#-------------------------------------


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/gen
# ----------------------------
# default paramters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight])    Fit the calibrated model
# get_params([deep])    Get parameters for this estimator.
# predict(X)    Predict the target of new samples.
# predict_proba(X)  Posterior probabilities of classification
#-------------------------------------
# video link:
#-------------------------------------

alpha = [x for x in range(1, 15, 2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i,n_jobs=-1)
    k_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    loss = log_loss(y_cv, predict_y, labels=k_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print ('log_loss for k = ',i,'is',loss)

#for i in range(len(cv_log_error_array)):
 #   print ('log_loss for k = ',alpha[i],'is',cv_log_error_array[i])

best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha],n_jobs=-1)
k_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
```

```
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for k =  1 is 0.004510868853506051
log_loss for k =  3 is 0.004557205040696172
log_loss for k =  5 is 0.005029519145523039
log_loss for k =  7 is 0.00510030238641321
log_loss for k =  9 is 0.004831606347209l915
log_loss for k =  11 is 0.004846343957120577
log_loss for k =  13 is 0.004996232337912015
```



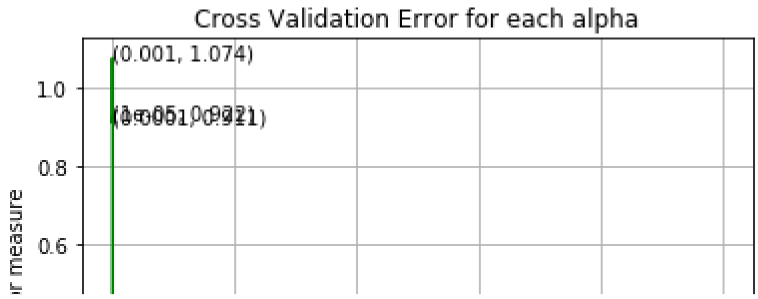
4.1.3. Logistic Regression

In [68]:

```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklea
# -------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …]) Fit linear model with Stochastic Gradient Desce
# predict(X)    Predict class labels for samples in X.

#-------------------------------
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/geome
#-------------------------------

alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    loss = log_loss(y_cv, predict_y, labels=logisticR.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print ('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='balanced')
logisticR.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
sig_clf.fit(X_train, y_train)
pred_y=sig_clf.predict(X_test)

predict_y = sig_clf.predict_proba(X_train)
print ('log loss for train data',log_loss(y_train, predict_y, labels=logisticR.classes_, ep
predict_y = sig_clf.predict_proba(X_cv)
print ('log loss for cv data',log_loss(y_cv, predict_y, labels=logisticR.classes_, eps=1e-1
predict_y = sig_clf.predict_proba(X_test)
print ('log loss for test data',log_loss(y_test, predict_y, labels=logisticR.classes_, eps=
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  1e-05 is 0.9215344825234812
log_loss for c =  0.0001 is 0.9105346545113124
log_loss for c =  0.001 is 1.0744964466237623
log_loss for c =  0.01 is 0.4136552678651763
```

```
log_loss for c =  0.1 is 0.2256356395708307
log_loss for c =  1 is 0.12328536788837237
log_loss for c =  10 is 0.08384659910202807
log_loss for c =  100 is 0.06747625152846469
log_loss for c =  1000 is 0.06755068869401172
```



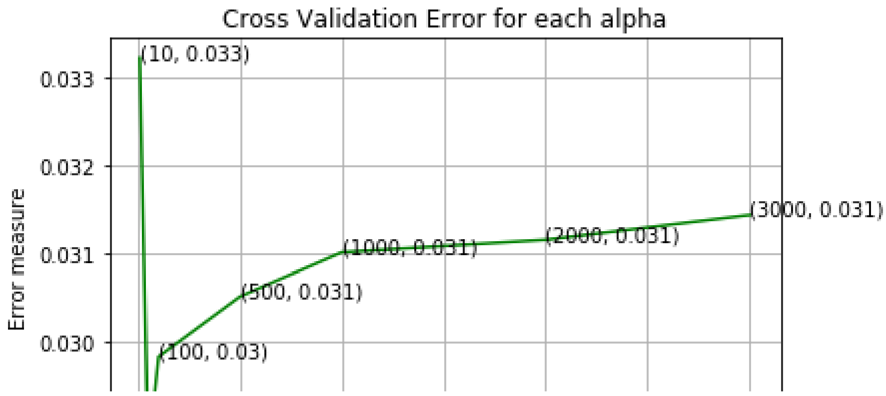
4.1.4. Random Forest Classifier

In [69]:

```
# -------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# -------------------------------
# video link: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/rando
# -------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
train_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train,y_train)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train, y_train)
    predict_y = sig_clf.predict_proba(X_cv)
    loss = log_loss(y_cv, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print ('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show(block=False)
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train,y_train)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train, y_train)

predict_y = sig_clf.predict_proba(X_train)
print('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(y
predict_y = sig_clf.predict_proba(X_cv)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test)
```

```
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test, sig_clf.predict(X_test))
```

```
log_loss for c =  10 is 0.03322305642935828
log_loss for c =  50 is 0.02874030435462668
log_loss for c =  100 is 0.029838486911465022
log_loss for c =  500 is 0.030519994616390874
log_loss for c =  1000 is 0.031021455633208753
log_loss for c =  2000 is 0.03116218703454003
log_loss for c =  3000 is 0.0314427835577681
```



4.1.5. XgBoost Classification

4.1.5. XgBoost Classification with best hyper parameters using RandomSearch

In [70]:

```
# https://www.analyticsvidhya.com/blog/2016/03/complete-guide-parameter-tuning-xgboost-with
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl1=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl1.fit(X_train,y_train)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed:  2.0min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  5.0min remaining:  8.
6min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  6.5min remaining:  6.
5min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  9.1min remaining:  5.
2min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 10.6min remaining:  3.
2min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 11.2min remaining:  1.
2min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 11.7min finished
```

Out[70]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [71]:

```
print (random_cfl1.best_params_)
```

```
{'subsample': 0.5, 'n_estimators': 100, 'max_depth': 3, 'learning_rate': 0.
1, 'colsample_bytree': 0.5}
```

In [72]:

```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what
# -----------------------

x_cfl=XGBClassifier(n_estimators=random_cfl.best_params_['n_estimators'],max_depth=random_c
                    learning_rate=random_cfl.best_params_['learning_rate'],colsample_bytree
                    subsample=random_cfl.best_params_['subsample'],n_jobs=-1)
x_cfl.fit(X_train,y_train)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train,y_train)

predict_y = c_cfl.predict_proba(X_train)
print ('train loss',log_loss(y_train, predict_y))
predict_y = c_cfl.predict_proba(X_cv)
print ('cv loss',log_loss(y_cv, predict_y))
predict_y = c_cfl.predict_proba(X_test)
print ('test loss',log_loss(y_test, predict_y))
```

```
train loss 0.0048845653372152405
cv loss 0.006449748921470773
test loss 0.008751829364442121
```

4.2 Modeling with .asm files

```
There are 10868 files of asm
All the files make up about 150 GB
The asm files contains :
1. Address
2. Segments
3. Opcodes
4. Registers
5. function calls
6. APIs
With the help of parallel processing we extracted all the features.In parallel we
can use all the cores that are present in our computer.
```

```
Here we extracted 52 features from all the asm files which are important.

We read the top solutions and handpicked the features from those papers/videos/blo
gs.
 Refer:https://www.kaggle.com/c/malware-classification/discussion
```

4.2.1 Feature extraction from asm files

- To extract the unigram features from the .asm files we need to process ~150GB of data
- **Note: Below two cells will take lot of time (over 48 hours to complete)**
- We will provide you the output file of these two cells, which you can directly use it

In [ ]:

```
#intially create five folders
#first
#second
#thrid
#fourth
#fifth
#this code tells us about random split of files into five folders
folder_1 ='first'
folder_2 ='second'
folder_3 ='third'
folder_4 ='fourth'
folder_5 ='fifth'
folder_6 = 'output'
for i in [folder_1,folder_2,folder_3,folder_4,folder_5,folder_6]:
    if not os.path.isdir(i):
        os.makedirs(i)

source='train/'
files = os.listdir('train')
ID=df['Id'].tolist()
data=range(0,10868)
r.shuffle(data)
count=0
for i in range(0,10868):
    if i % 5==0:
        shutil.move(source+files[data[i]],'first')
    elif i%5==1:
        shutil.move(source+files[data[i]],'second')
    elif i%5 ==2:
        shutil.move(source+files[data[i]],'thrid')
    elif i%5 ==3:
        shutil.move(source+files[data[i]],'fourth')
    elif i%5==4:
        shutil.move(source+files[data[i]],'fifth')
```

In [ ]:

```
#http://flint.cs.yale.edu/cs421/papers/x86-asm/asm.html

def firstprocess():
    #The prefixes tells about the segments that are present in the asm files
    #There are 450 segments(approx) present in all asm files.
    #this prefixes are best segments that gives us best values.
    #https://en.wikipedia.org/wiki/Data_segment

    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdata:','.edata:','
    #this are opcodes that are used to get best results
    #https://en.wikipedia.org/wiki/X86_instruction_listings

    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub', 'inc', 'de
    #best keywords that are taken from different blogs
    keywords = ['.dll','std::',':dword']
    #Below taken registers are general purpose registers and special registers
    #All the registers which are taken are best
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\asmsmallfile.txt","w+")
    files = os.listdir('first')
    for f in files:
        #filling the values with zeros into the arrays
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        # https://docs.python.org/3/library/codecs.html#codecs.ignore_errors
        # https://docs.python.org/3/library/codecs.html#codecs.Codec.encode
        with codecs.open('first/'+f,encoding='cp1252',errors ='replace') as fli:
            for lines in fli:
                # https://www.tutorialspoint.com/python3/string_rstrip.htm
                line=lines.rstrip().split()
                l=line[0]
                #counting the prefixs in each and every line
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                #counting the opcodes in each and every line
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                #counting registers in the line
                for i in range(len(registers)):
                    for li in line:
                        # we will use registers only in 'text' and 'CODE' segments
                        if registers[i] in li and ('text' in l or 'CODE' in l):
                            registerscount[i]+=1
                #counting keywords in the line
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
```

```
        #pushing the values into the file after reading whole file
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


#same as above
def secondprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdata:','.edata:','
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub', 'inc', 'de
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\mediumasmfile.txt","w+")
    files = os.listdir('second')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('second/'+f,encoding='cp1252',errors ='replace') as fli:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()
```

```python
# same as smallprocess() functions
def thirdprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdata:','.edata:','
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub', 'inc', 'de
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\largeasmfile.txt","w+")
    files = os.listdir('thrid')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('thrid/'+f,encoding='cp1252',errors ='replace') as fli:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def fourthprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdata:','.edata:','
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub', 'inc', 'de
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\hugeasmfile.txt","w+")
    files = os.listdir('fourth/')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
```

```
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('fourth/'+f,encoding='cp1252',errors ='replace') as fli:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def fifthprocess():
    prefixes = ['HEADER:','.text:','.Pav:','.idata:','.data:','.bss:','.rdata:','.edata:','
    opcodes = ['jmp', 'mov', 'retf', 'push', 'pop', 'xor', 'retn', 'nop', 'sub', 'inc', 'de
    keywords = ['.dll','std::',':dword']
    registers=['edx','esi','eax','ebx','ecx','edi','ebp','esp','eip']
    file1=open("output\trainasmfile.txt","w+")
    files = os.listdir('fifth/')
    for f in files:
        prefixescount=np.zeros(len(prefixes),dtype=int)
        opcodescount=np.zeros(len(opcodes),dtype=int)
        keywordcount=np.zeros(len(keywords),dtype=int)
        registerscount=np.zeros(len(registers),dtype=int)
        features=[]
        f2=f.split('.')[0]
        file1.write(f2+",")
        opcodefile.write(f2+" ")
        with codecs.open('fifth/'+f,encoding='cp1252',errors ='replace') as fli:
            for lines in fli:
                line=lines.rstrip().split()
                l=line[0]
                for i in range(len(prefixes)):
                    if prefixes[i] in line[0]:
                        prefixescount[i]+=1
                line=line[1:]
                for i in range(len(opcodes)):
```

```
                    if any(opcodes[i]==li for li in line):
                        features.append(opcodes[i])
                        opcodescount[i]+=1
                for i in range(len(registers)):
                    for li in line:
                        if registers[i] in li and ('text' in l or 'CODE' in l):
                            registerscount[i]+=1
                for i in range(len(keywords)):
                    for li in line:
                        if keywords[i] in li:
                            keywordcount[i]+=1
        for prefix in prefixescount:
            file1.write(str(prefix)+",")
        for opcode in opcodescount:
            file1.write(str(opcode)+",")
        for register in registerscount:
            file1.write(str(register)+",")
        for key in keywordcount:
            file1.write(str(key)+",")
        file1.write("\n")
    file1.close()


def main():
    #the below code is used for multiprogramming
    #the number of process depends upon the number of cores present System
    #process is used to call multiprogramming
    manager=multiprocessing.Manager()
    p1=Process(target=firstprocess)
    p2=Process(target=secondprocess)
    p3=Process(target=thirdprocess)
    p4=Process(target=fourthprocess)
    p5=Process(target=fifthprocess)
    #p1.start() is used to start the thread execution
    p1.start()
    p2.start()
    p3.start()
    p4.start()
    p5.start()
    #After completion all the threads are joined
    p1.join()
    p2.join()
    p3.join()
    p4.join()
    p5.join()

if __name__=="__main__":
    main()
```

In [6]:

```
# asmoutputfile.csv(output genarated from the above two cells) will contain all the extract
# this file will be uploaded in the drive, you can directly use this
dfasm=pd.read_csv("asmoutputfile.csv")
Y.columns = ['ID', 'Class']
result_asm = pd.merge(dfasm, Y,on='ID', how='left')
result_asm.head()
```

Out[6]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 53 columns

4.2.1.1 Files sizes of each .asm file

In [25]:

```
#file sizes of byte files

files=os.listdir('asmFiles')
filenames=Y['ID'].tolist()
class_y=Y['Class'].tolist()
class_bytes=[]
sizebytes=[]
fnames=[]
for file in files:
    # print(os.stat('byteFiles/0A32eTdBKayjCWhZqDOQ.txt'))
    # os.stat_result(st_mode=33206, st_ino=1125899906874507, st_dev=3561571700, st_nlink=1,
    # st_size=3680109, st_atime=1519638522, st_mtime=1519638522, st_ctime=1519638522)
    # read more about os.stat: here https://www.tutorialspoint.com/python/os_stat.htm
    statinfo=os.stat('asmFiles/'+file)
    # split the file name at '.' and take the first part of it i.e the file name
    file=file.split('.')[0]
    if any(file == filename for filename in filenames):
        i=filenames.index(file)
        class_bytes.append(class_y[i])
        # converting into Mb's
        sizebytes.append(statinfo.st_size/(1024.0*1024.0))
        fnames.append(file)
asm_size_byte=pd.DataFrame({'ID':fnames,'size':sizebytes,'Class':class_bytes})
print (asm_size_byte.head())
```

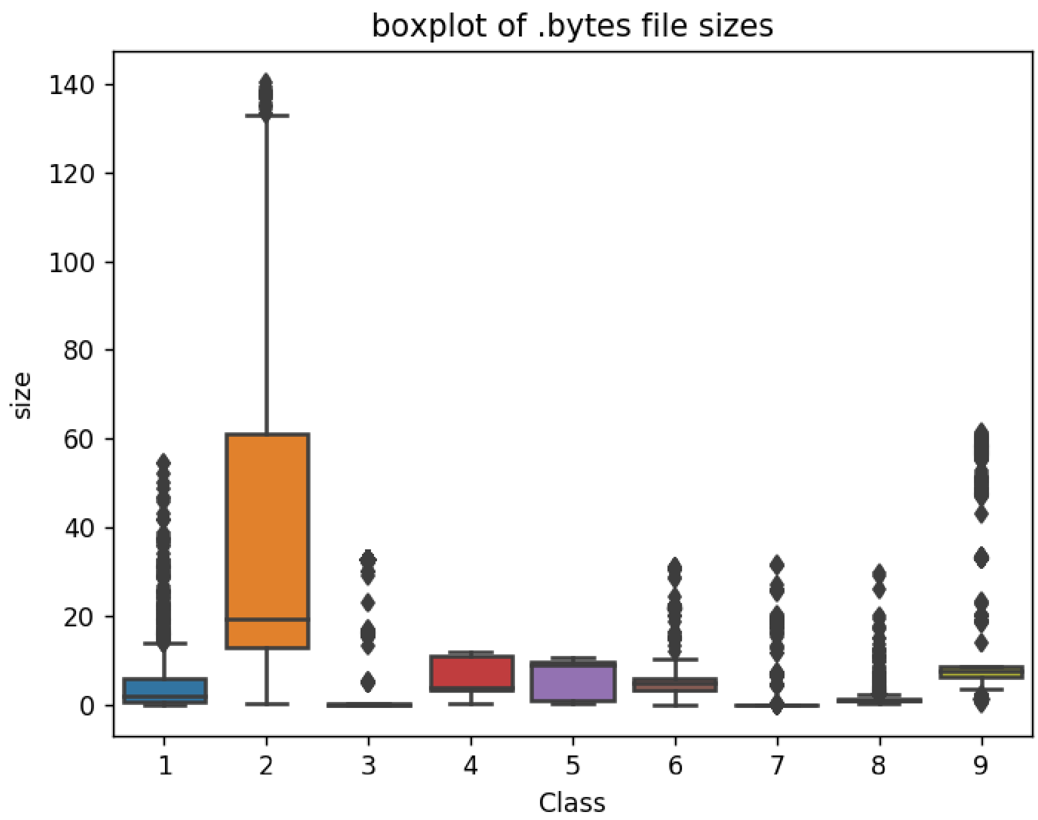
```
                     ID       size  Class
0  01azqd4InC7m9JpocGv5  56.229886      9
1  01IsoiSMh5gxyDYTl4CB  13.999378      2
2  01jsnpXSAlgw6aPeDxrU   8.507785      9
3  01kcPWA9K2BOxQeS5Rju   0.078190      1
4  01SuzwMJEIXsK7A8dQbl   0.996723      8
```

4.2.1.2 Distribution of .asm file sizes

In [26]:

```
#boxplot of asm files
ax = sns.boxplot(x="Class", y="size", data=asm_size_byte)
plt.title("boxplot of .bytes file sizes")
plt.show()
```

<IPython.core.display.Javascript object>



In [27]:

```
# add the file size feature to previous extracted features
print(result_asm.shape)
print(asm_size_byte.shape)
result_asm = pd.merge(result_asm, asm_size_byte.drop(['Class'], axis=1),on='ID', how='left'
result_asm.head()
```

```
(10868, 53)
(10868, 3)
```

Out[27]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 54 columns

In [28]:

```
# we normalize the data each column
result_asm = normalize(result_asm)
result_asm.head()
```

Out[28]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.e
0	01kcPWA9K2BOxQeS5Rju	0.107345	0.001092	0.0	0.000761	0.000023	0.0	0.000084	
1	1E93CpP60RHFNiT5Qfvn	0.096045	0.001230	0.0	0.000617	0.000019	0.0	0.000000	
2	3ekVow2ajZHbTnBcsDfX	0.096045	0.000627	0.0	0.000300	0.000017	0.0	0.000038	
3	3X2nY7iQaPBIWDrAZqJe	0.096045	0.000333	0.0	0.000258	0.000008	0.0	0.000000	
4	46OZzdsSKDCFV8h7XWxf	0.096045	0.000590	0.0	0.000353	0.000068	0.0	0.000000	

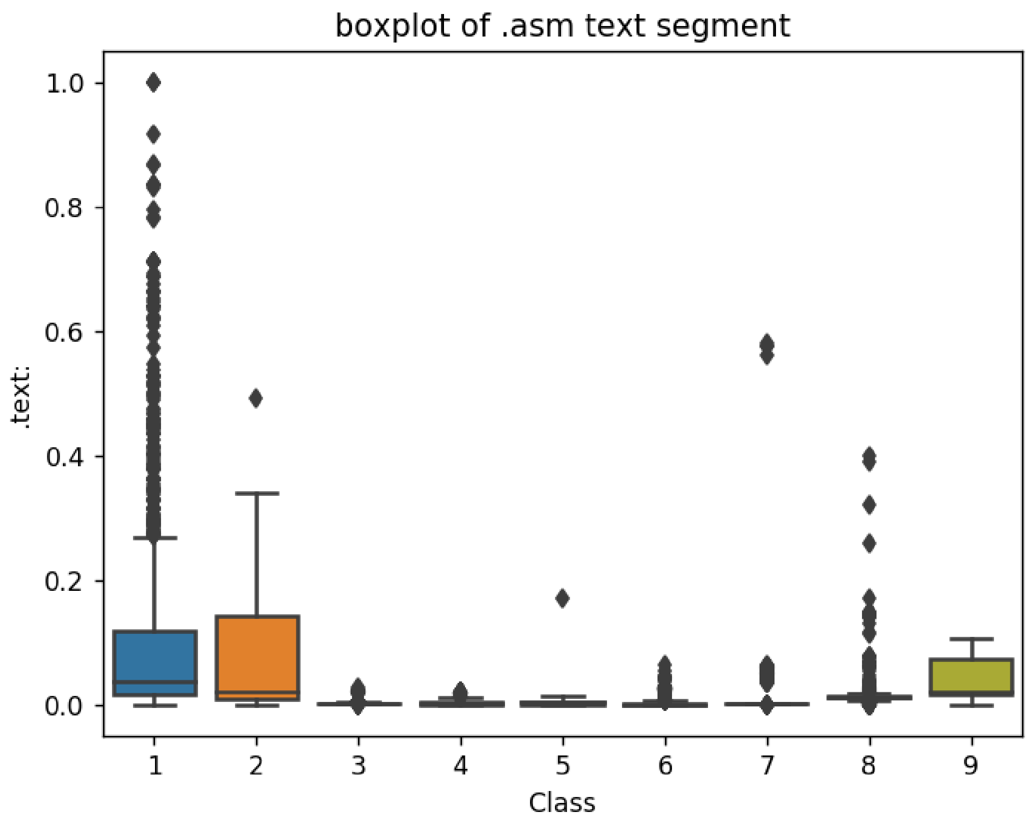
5 rows × 54 columns

4.2.2 Univariate analysis on asm file features

In [146]:

```
ax = sns.boxplot(x="Class", y=".text:", data=result_asm)
plt.title("boxplot of .asm text segment")
plt.show()
```

```
<IPython.core.display.Javascript object>
```

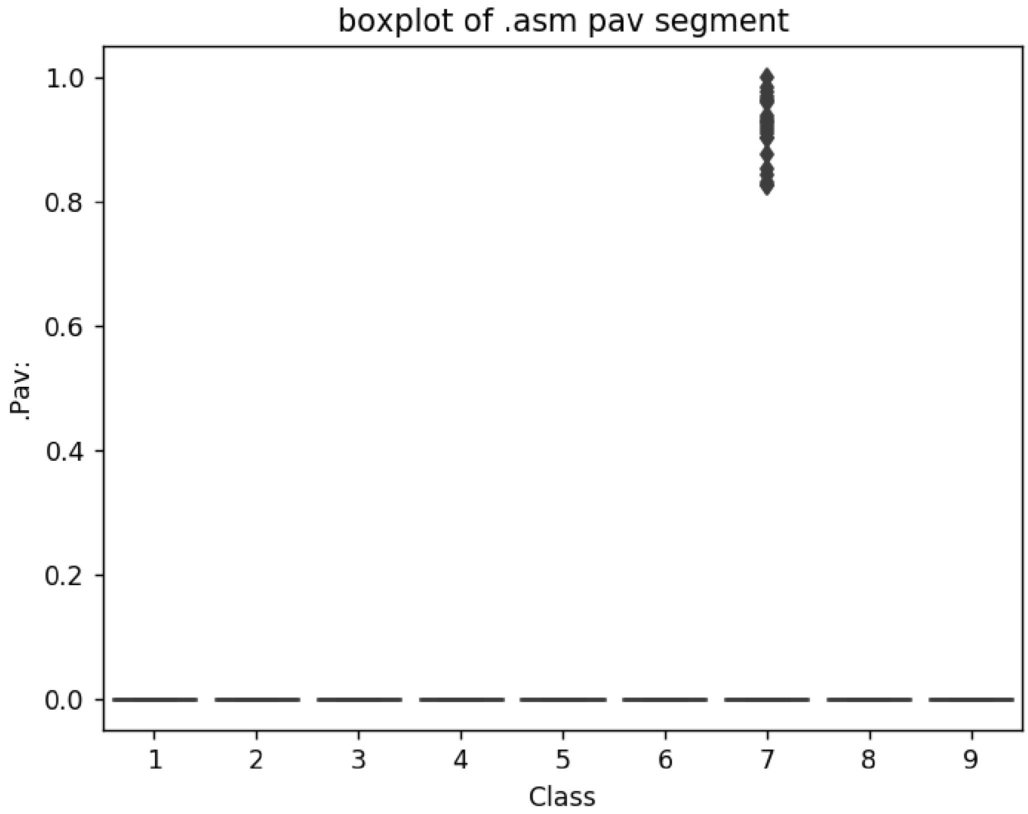



```
The plot is between Text and class
Class 1,2 and 9 can be easly separated
```

In [115]:

```
ax = sns.boxplot(x="Class", y=".Pav:", data=result_asm)
plt.title("boxplot of .asm pav segment")
plt.show()
```

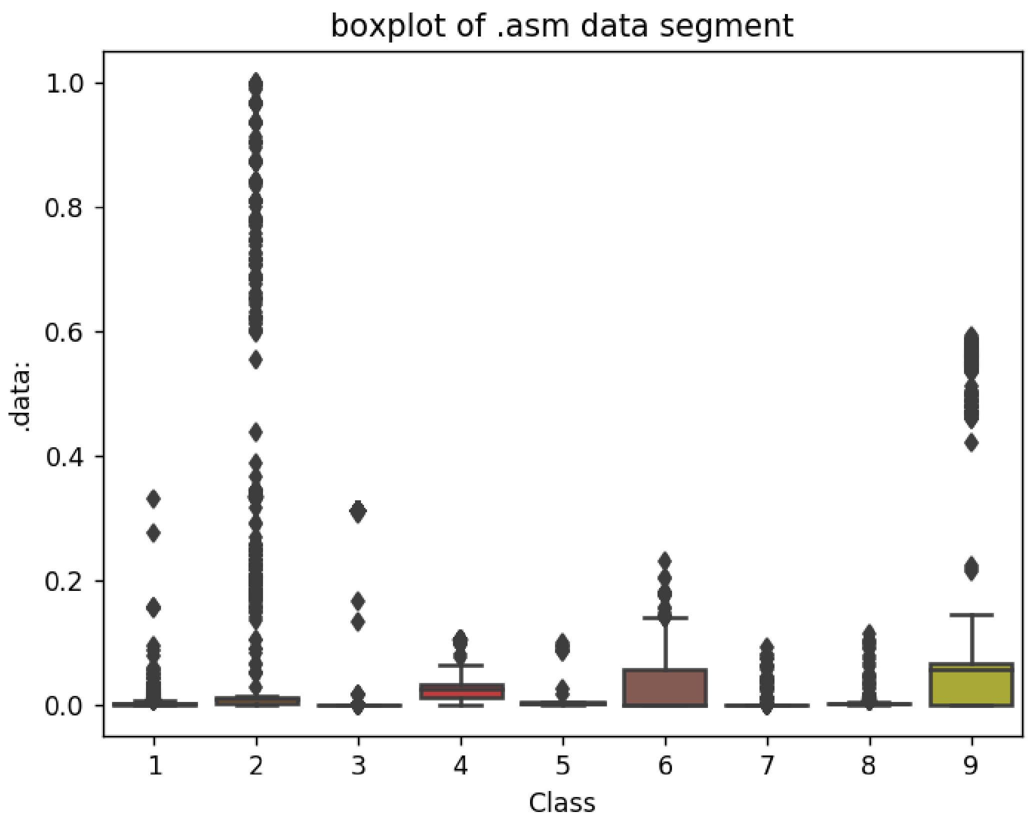
<IPython.core.display.Javascript object>



In [116]:

```
ax = sns.boxplot(x="Class", y=".data:", data=result_asm)
plt.title("boxplot of .asm data segment")
plt.show()
```

```
<IPython.core.display.Javascript object>
```

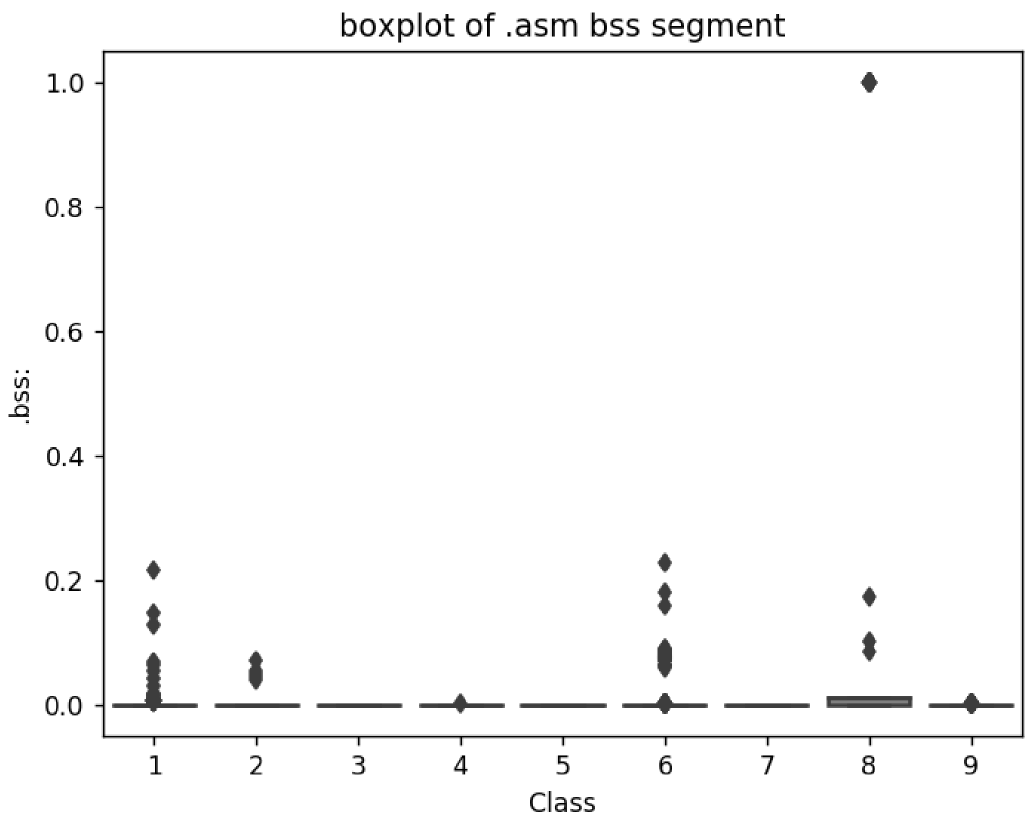



```
The plot is between data segment and class label
class 6 and class 9 can be easily separated from given points
```

In [117]:

```
ax = sns.boxplot(x="Class", y=".bss:", data=result_asm)
plt.title("boxplot of .asm bss segment")
plt.show()
```

<IPython.core.display.Javascript object>

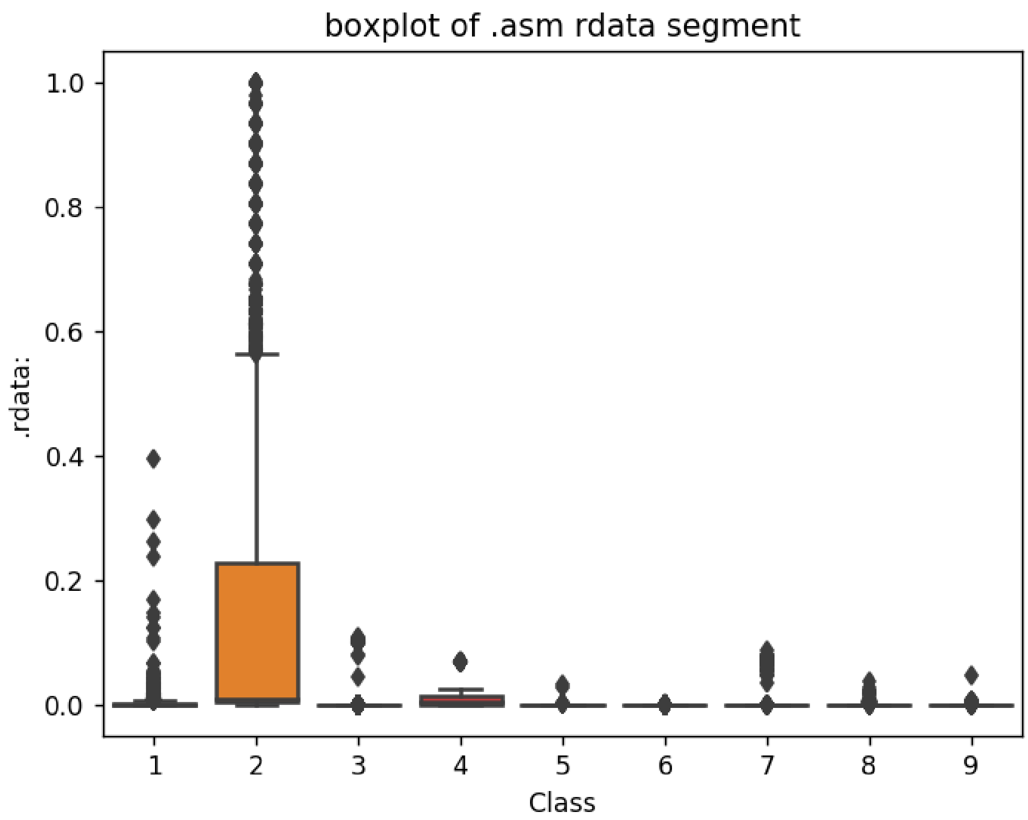



```
plot between bss segment and class label
very less number of files are having bss segment
```

In [118]:

```
ax = sns.boxplot(x="Class", y=".rdata:", data=result_asm)
plt.title("boxplot of .asm rdata segment")
plt.show()
```

<IPython.core.display.Javascript object>

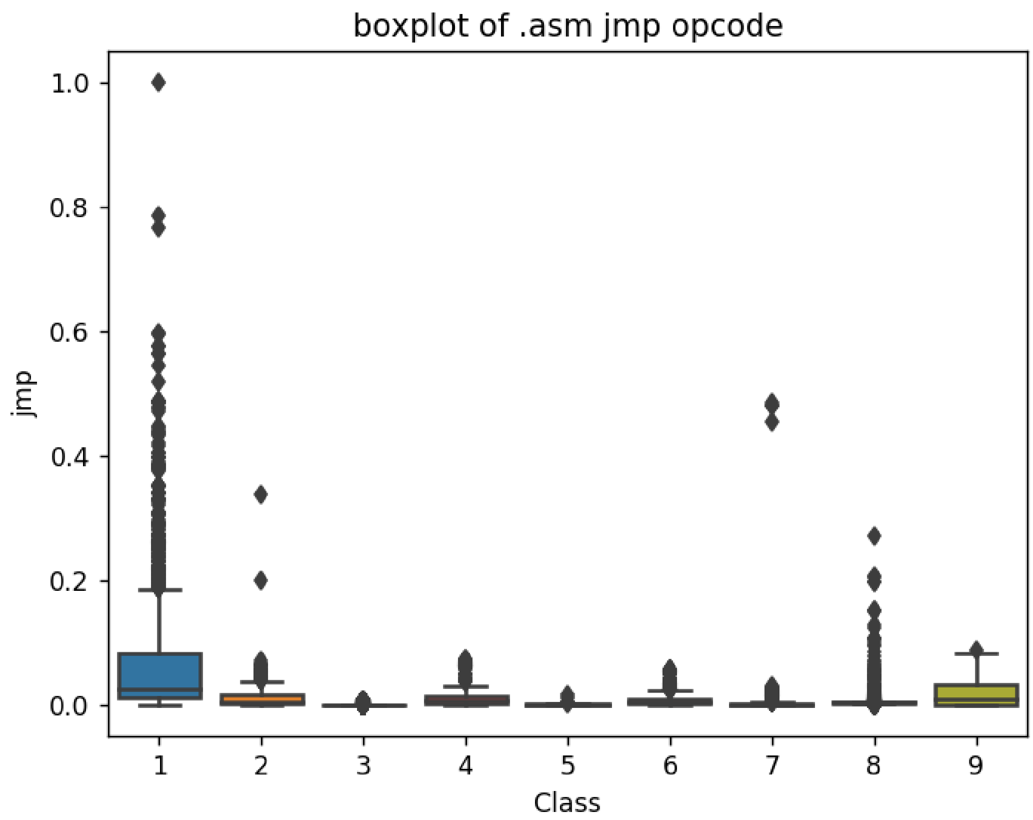


Plot between rdata segment and Class segment
Class 2 can be easily separated 75 pecentile files are having 1M rdata lines

In [119]:

```
ax = sns.boxplot(x="Class", y="jmp", data=result_asm)
plt.title("boxplot of .asm jmp opcode")
plt.show()
```

<IPython.core.display.Javascript object>

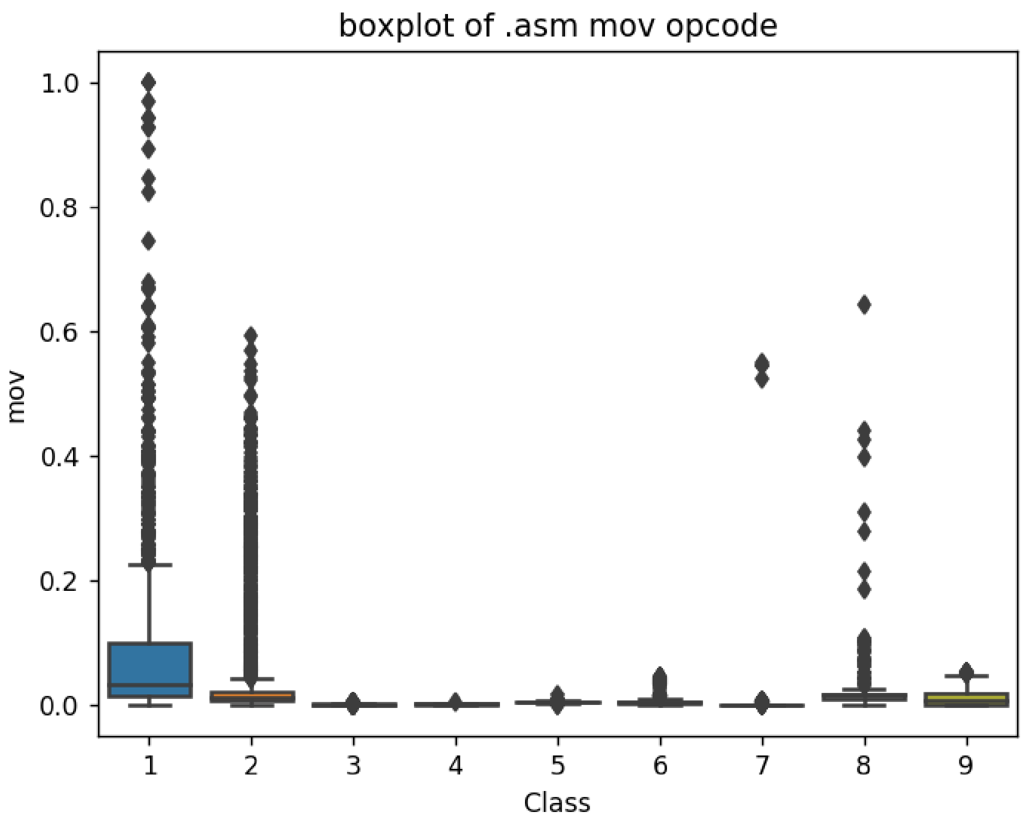


plot between jmp and Class label
Class 1 is having frequency of 2000 approx in 75 perentile of files

In [120]:

```
ax = sns.boxplot(x="Class", y="mov", data=result_asm)
plt.title("boxplot of .asm mov opcode")
plt.show()
```

<IPython.core.display.Javascript object>

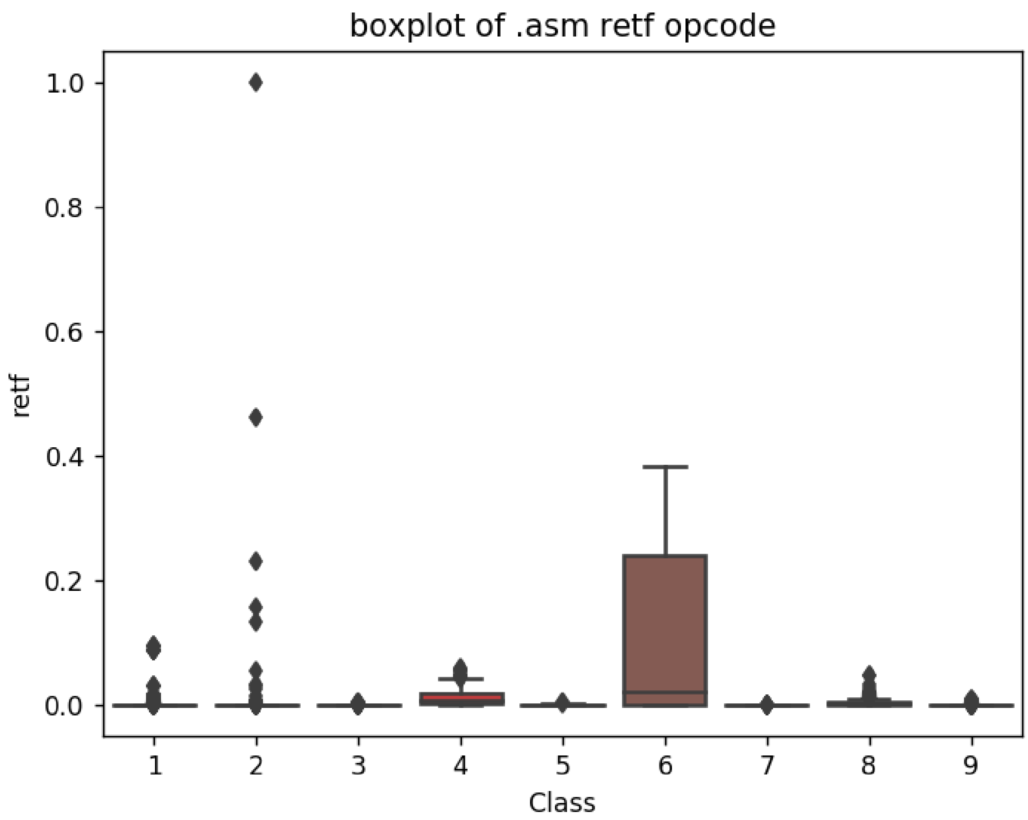



```
plot between Class label and mov opcode
Class 1 is having frequency of 2000 approx in 75 perentile of files
```

In [121]:

```
ax = sns.boxplot(x="Class", y="retf", data=result_asm)
plt.title("boxplot of .asm retf opcode")
plt.show()
```

<IPython.core.display.Javascript object>

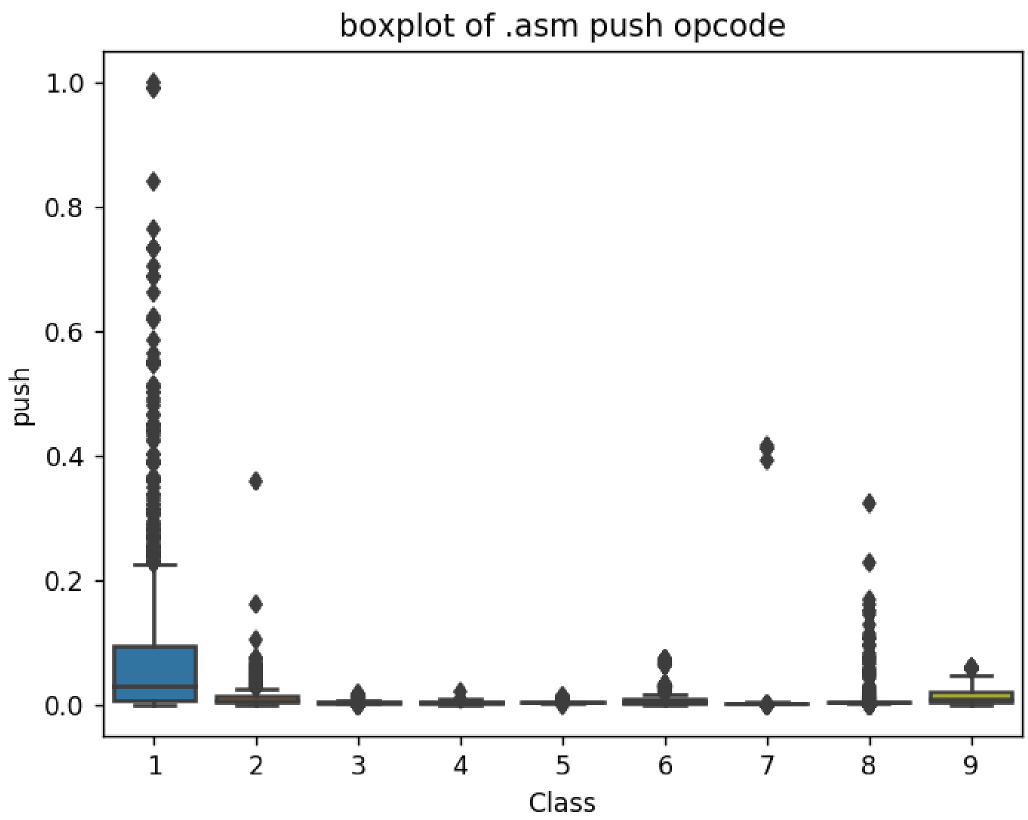



```
plot between Class label and retf
Class 6 can be easily separated with opcode retf
The frequency of retf is approx of 250.
```

In [122]:

```
ax = sns.boxplot(x="Class", y="push", data=result_asm)
plt.title("boxplot of .asm push opcode")
plt.show()
```

<IPython.core.display.Javascript object>



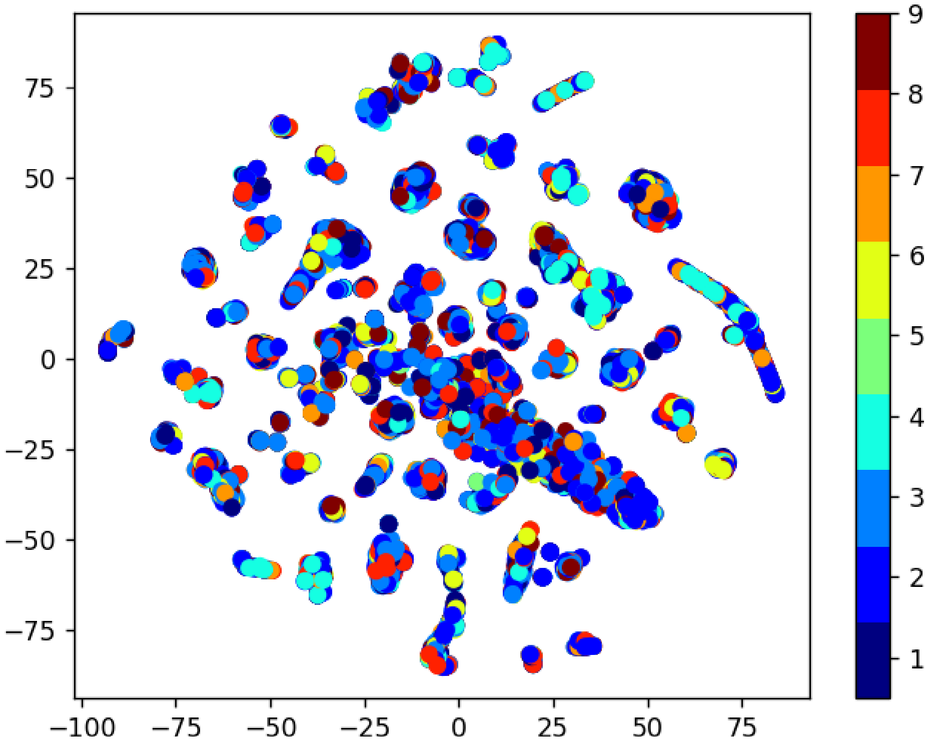

```
plot between push opcode and Class label
Class 1 is having 75 precentile files with push opcodes of frequency 1000
```

4.2.2 Multivariate Analysis on .asm file features

In [129]:

```
# check out the course content for more explantion on tsne algorithm
# https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/t-distributed-stc

#multivariate analysis on byte files
#this is with perplexity 50
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_asm.drop(['ID','Class'], axis=1).fillna(0))
vis_x = results[:, 0]
vis_y = results[:, 1   ]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```

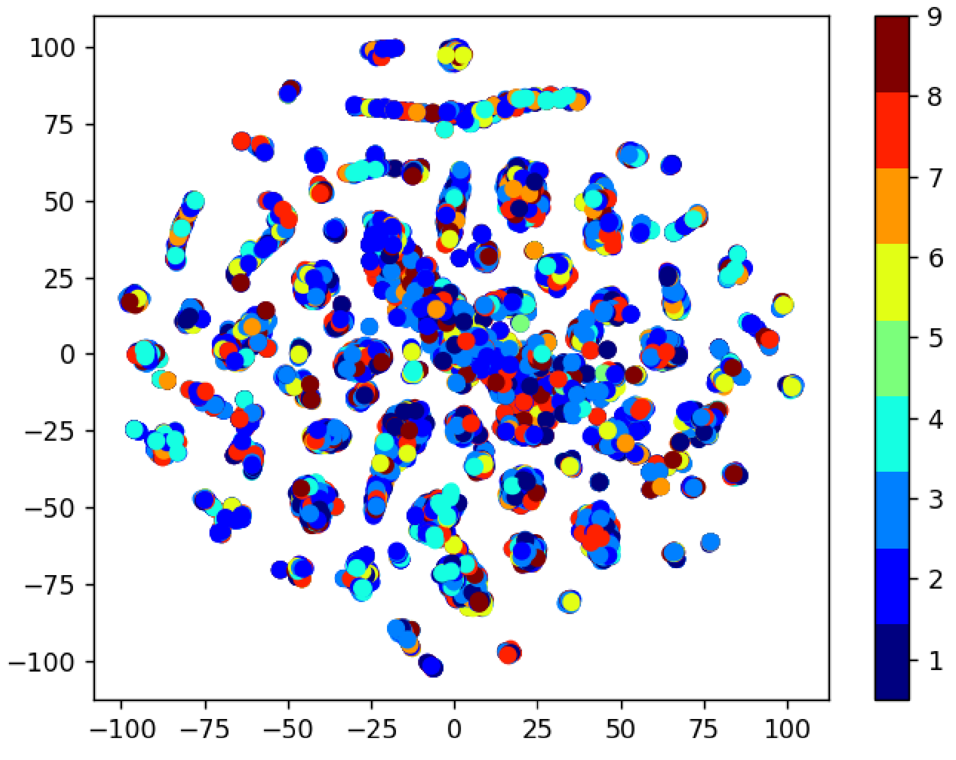
<IPython.core.display.Javascript object>



In [147]:

```
# by univariate analysis on the .asm file features we are getting very negligible informati
# 'rtn', '.BSS:' '.CODE' features, so heare we are trying multivariate analysis after remov
# the plot looks very messy

xtsne=TSNE(perplexity=30)
results=xtsne.fit_transform(result_asm.drop(['ID','Class', 'rtn', '.BSS:', '.CODE','size'],
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=data_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(10))
plt.clim(0.5, 9)
plt.show()
```

```
<IPython.core.display.Javascript object>
```




```
TSNE for asm data with perplexity 50
```

4.2.3 Conclusion on EDA

- We have taken only 52 features from asm files (after reading through many blogs and research papers)
- The univariate analysis was done only on few important features.
- Take-aways
  - 1. Class 3 can be easily separated because of the frequency of segments,opcodes and keywords being less
  - 2. Each feature has its unique importance in separating the Class labels.

4.3 Train and test split

In [29]:

```
asm_y = result_asm['Class']
asm_x = result_asm.drop(['ID','Class','.BSS:','rtn','.CODE'], axis=1)
```

In [30]:

```
X_train_asm, X_test_asm, y_train_asm, y_test_asm = train_test_split(asm_x,asm_y ,stratify=a
X_train_asm, X_cv_asm, y_train_asm, y_cv_asm = train_test_split(X_train_asm, y_train_asm,st
```

In [31]:

```
print( X_cv_asm.isnull().all())
```

```
HEADER:    False
.text:     False
.Pav:      False
.idata:    False
.data:     False
.bss:      False
.rdata:    False
.edata:    False
.rsrc:     False
.tls:      False
.reloc:    False
jmp        False
mov        False
retf       False
push       False
pop        False
xor        False
retn       False
nop        False
sub        False
inc        False
dec        False
add        False
imul       False
xchg       False
or         False
shr        False
cmp        False
call       False
shl        False
ror        False
rol        False
jnb        False
jz         False
lea        False
movzx      False
.dll       False
std::      False
:dword     False
edx        False
esi        False
eax        False
ebx        False
ecx        False
edi        False
ebp        False
esp        False
eip        False
size       False
dtype: bool
```

4.4. Machine Learning models on features of .asm files

4.4.1 K-Nearest Neigbors

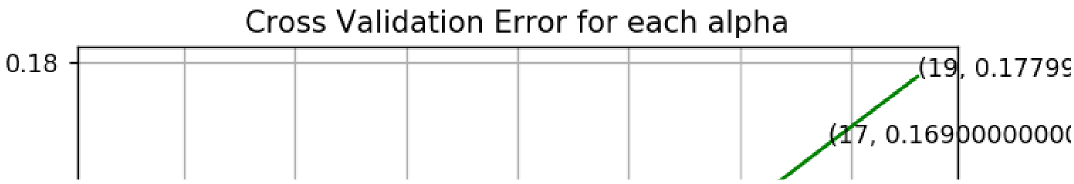
In [159]:

```
# find more about KNeighborsClassifier() here http://scikit-learn.org/stable/modules/genera
# -------------------------
# default parameter
# KNeighborsClassifier(n_neighbors=5, weights='uniform', algorithm='auto', leaf_size=30, p=
# metric='minkowski', metric_params=None, n_jobs=1, **kwargs)

# methods of
# fit(X, y) : Fit the model using X as training data and y as target values
# predict(X):Predict the class labels for the provided data
# predict_proba(X):Return probability estimates for the test data X.
#-------------------------------------
#
#-------------------------------------


# find more about CalibratedClassifierCV here at http://scikit-learn.org/stable/modules/gen
# ----------------------------
# default paramters
# sklearn.calibration.CalibratedClassifierCV(base_estimator=None, method='sigmoid', cv=3)
#
# some of the methods of CalibratedClassifierCV()
# fit(X, y[, sample_weight])    Fit the calibrated model
# get_params([deep])    Get parameters for this estimator.
# predict(X)    Predict the target of new samples.
# predict_proba(X)  Posterior probabilities of classification
#-------------------------------------
# video link:
#-------------------------------------

alpha = [x for x in range(1, 21,2)]
cv_log_error_array=[]
for i in alpha:
    k_cfl=KNeighborsClassifier(n_neighbors=i)
    k_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    loss = log_loss(y_cv_asm, predict_y, labels=k_cfl.classes_, eps=1e-15)
    cv_log_error_array.append()
    print ('log_loss for k = ',i,'is',loss)
for i in range(len(cv_log_error_array)):


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

k_cfl=KNeighborsClassifier(n_neighbors=alpha[best_alpha])
k_cfl.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(k_cfl, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)
```

```
pred_y=sig_clf.predict(X_test_asm)


predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',log_loss(y_train_asm, predict_y))
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',log_loss(y_cv_asm, predict_y))
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',log_loss(y_test_asm, predict_y))
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

```
log_loss for k =  1 is 0.104531321344
log_loss for k =  3 is 0.0958800580948
log_loss for k =  5 is 0.0995466557335
log_loss for k =  7 is 0.107227274345
log_loss for k =  9 is 0.119239543547
log_loss for k =  11 is 0.133926642781
log_loss for k =  13 is 0.147643793967
log_loss for k =  15 is 0.159439699615
log_loss for k =  17 is 0.16878376444
log_loss for k =  19 is 0.178020728839
```

<IPython.core.display.Javascript object>



4.4.2 Logistic Regression

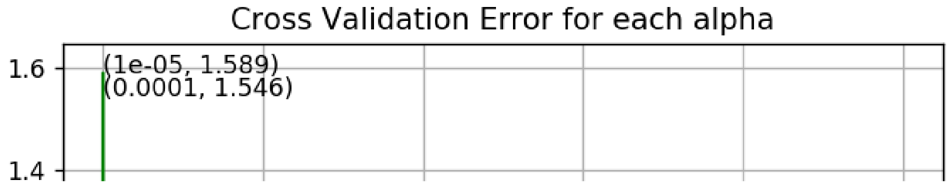
In [160]:

```
# read more about SGDClassifier() at http://scikit-learn.org/stable/modules/generated/sklea
# ------------------------------
# default parameters
# SGDClassifier(loss='hinge', penalty='l2', alpha=0.0001, l1_ratio=0.15, fit_intercept=True
# shuffle=True, verbose=0, epsilon=0.1, n_jobs=1, random_state=None, learning_rate='optimal
# class_weight=None, warm_start=False, average=False, n_iter=None)

# some of methods
# fit(X, y[, coef_init, intercept_init, …]) Fit linear model with Stochastic Gradient Desce
# predict(X)    Predict class labels for samples in X.

#-------------------------------

#------------------------------


alpha = [10 ** x for x in range(-5, 4)]
cv_log_error_array=[]
for i in alpha:
    logisticR=LogisticRegression(penalty='l2',C=i,class_weight='balanced')
    logisticR.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=logisticR.classes_, eps=

for i in range(len(cv_log_error_array)):
    print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])

best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

logisticR=LogisticRegression(penalty='l2',C=alpha[best_alpha],class_weight='balanced')
logisticR.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(logisticR, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)

predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',(log_loss(y_train_asm, predict_y, labels=logisticR.classes
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=logisticR.classes_, eps
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',(log_loss(y_test_asm, predict_y, labels=logisticR.classes_,
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

```
log_loss for c =  1e-05 is 1.58867274165
log_loss for c =  0.0001 is 1.54560797884
log_loss for c =  0.001 is 1.30137786807
log_loss for c =  0.01 is 1.33317456931
```

```
log_loss for c =  0.1 is 1.16705751378
log_loss for c =  1 is 0.757667807779
log_loss for c =  10 is 0.546533939819
log_loss for c =  100 is 0.438414998062
log_loss for c =  1000 is 0.424423536526
```

```
<IPython.core.display.Javascript object>
```



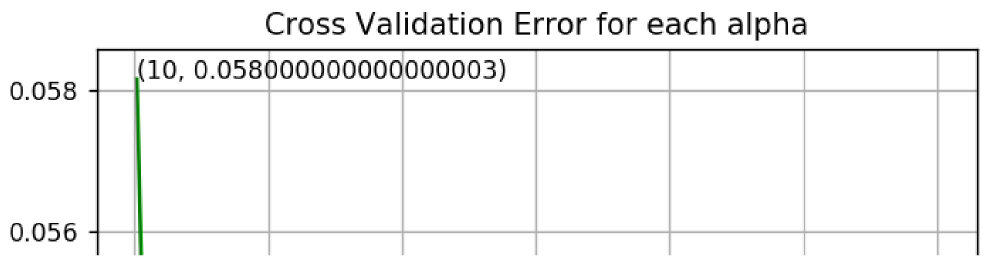
4.4.3 Random Forest Classifier

In [161]:

```
# ----------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# ----------------------------------

# ----------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=r_cfl.classes_, eps=1e-1

for i in range(len(cv_log_error_array)):
    print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)
predict_y = sig_clf.predict_proba(X_train_asm)
print ('log loss for train data',(log_loss(y_train_asm, predict_y, labels=sig_clf.classes_,
predict_y = sig_clf.predict_proba(X_cv_asm)
print ('log loss for cv data',(log_loss(y_cv_asm, predict_y, labels=sig_clf.classes_, eps=1
predict_y = sig_clf.predict_proba(X_test_asm)
print ('log loss for test data',(log_loss(y_test_asm, predict_y, labels=sig_clf.classes_, e
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

```
log_loss for c =  10 is 0.0581657906023
log_loss for c =  50 is 0.0515443148419
log_loss for c =  100 is 0.0513084973231
log_loss for c =  500 is 0.0499021761479
log_loss for c =  1000 is 0.0497972474298
log_loss for c =  2000 is 0.0497091690815
log_loss for c =  3000 is 0.0496706817633
```

```
<IPython.core.display.Javascript object>
```



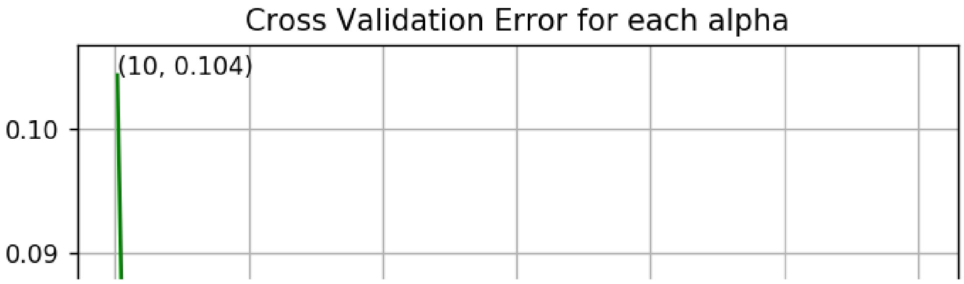
4.4.4 XgBoost Classifier

In [162]:

```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------
# video link2: https://www.appliedaicourse.com/course/applied-ai-course-online/lessons/what
# -----------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,nthread=-1)
    x_cfl.fit(X_train_asm,y_train_asm)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train_asm, y_train_asm)
    predict_y = sig_clf.predict_proba(X_cv_asm)
    cv_log_error_array.append(log_loss(y_cv_asm, predict_y, labels=x_cfl.classes_, eps=1e-1

for i in range(len(cv_log_error_array)):
    print ('log_loss for c = ',alpha[i],'is',cv_log_error_array[i])


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

x_cfl=XGBClassifier(n_estimators=alpha[best_alpha],nthread=-1)
x_cfl.fit(X_train_asm,y_train_asm)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_asm, y_train_asm)

predict_y = sig_clf.predict_proba(X_train_asm)

print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_asm)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_asm)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_asm,sig_clf.predict(X_test_asm))
```

```
log_loss for c =  10 is 0.104344888454
log_loss for c =  50 is 0.0567190635611
log_loss for c =  100 is 0.056075038646
log_loss for c =  500 is 0.057336051683
log_loss for c =  1000 is 0.0571265109903
log_loss for c =  2000 is 0.057103406781
log_loss for c =  3000 is 0.0567993215778
```

```
<IPython.core.display.Javascript object>
```



4.4.5 Xgboost Classifier with best hyperparameters

In [163]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_asm,y_train_asm)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Done   2 tasks      | elapsed:    8.1s
[Parallel(n_jobs=-1)]: Done   9 tasks      | elapsed:   32.8s
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  1.1min remaining:   3
9.3s
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  1.3min remaining:   2
3.0s
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  1.4min remaining:
9.2s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  2.3min finished
```

Out[163]:

```
RandomizedSearchCV(cv=None, error_score='raise',
          estimator=XGBClassifier(base_score=0.5, colsample_bylevel=1, colsa
mple_bytree=1,
       gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=3,
       min_child_weight=1, missing=None, n_estimators=100, nthread=-1,
       objective='binary:logistic', reg_alpha=0, reg_lambda=1,
       scale_pos_weight=1, seed=0, silent=True, subsample=1),
          fit_params=None, iid=True, n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score=True, scoring=None, verbose=10)
```

In [164]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 200, 'max_depth': 5, 'learning_rate': 0.15,
'colsample_bytree': 0.5}
```

In [170]:

```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------

# -----------------------

x_cfl=XGBClassifier(n_estimators=200,subsample=0.5,learning_rate=0.15,colsample_bytree=0.5,
x_cfl.fit(X_train_asm,y_train_asm)
c_cfl=CalibratedClassifierCV(x_cfl,method='sigmoid')
c_cfl.fit(X_train_asm,y_train_asm)

predict_y = c_cfl.predict_proba(X_train_asm)
print ('train loss',log_loss(y_train_asm, predict_y))
predict_y = c_cfl.predict_proba(X_cv_asm)
print ('cv loss',log_loss(y_cv_asm, predict_y))
predict_y = c_cfl.predict_proba(X_test_asm)
print ('test loss',log_loss(y_test_asm, predict_y))
```

```
train loss 0.0102661325822
cv loss 0.0501201796687
test loss 0.0483908764397
```

4.5 Machine Learning models on call graph features obtained from .asm file

In [20]:

```
result_call_graph = pd.read_csv("final_call_graph_features.csv")
result_call_graph.head() # dataframe containing byte features
```

Out[20]:

	Unnamed: 0	ID	vertex_count	edge_count	delta_max	density
0	0	8i6m0aVAwsdSY2FEfU59	115	100	33	0.201613
1	1	8lbD9QgPs01NR7STfAxH	222	307	126	0.097152
2	2	8iBGtATMYPI0cqpVC2d5	5285	5455	103	0.006000
3	3	8iDWJ4yKzNSAQjnxwO70	122	119	3	0.138211
4	4	8inLjyQfkReMHmNUE4qg	194	132	25	0.053119

In [21]:

```
result_call_graph.drop(['Unnamed: 0'],axis = 1,inplace= True)
result_call_graph = pd.merge(result_call_graph,Y,on ='ID')
result_call_graph.head()
```

Out[21]:

	ID	vertex_count	edge_count	delta_max	density	Class
0	8i6m0aVAwsdSY2FEfU59	115	100	33	0.201613	1
1	8lbD9QgPs01NR7STfAxH	222	307	126	0.097152	2
2	8iBGtATMYPI0cqpVC2d5	5285	5455	103	0.006000	1
3	8iDWJ4yKzNSAQjnxwO70	122	119	3	0.138211	7
4	8inLjyQfkReMHmNUE4qg	194	132	25	0.053119	2

In [22]:

```
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - min_value
    return result1
#result_byte_final_normalized = normalize(result_byte_final)
```

In [23]:

```
result_call_graph_normal = normalize(result_call_graph)
```

In [24]:

```
result_call_graph_normal.replace([np.inf, -np.inf], np.nan)

result_call_graph_normal.dropna(inplace=True,how='any')
result_call_graph_normal.shape
result_y = result_call_graph_normal['Class']
```

In [33]:

```
result_call_graph_normal.drop(['ID'],axis = 1,inplace=True)
result_call_graph_normal.shape
```

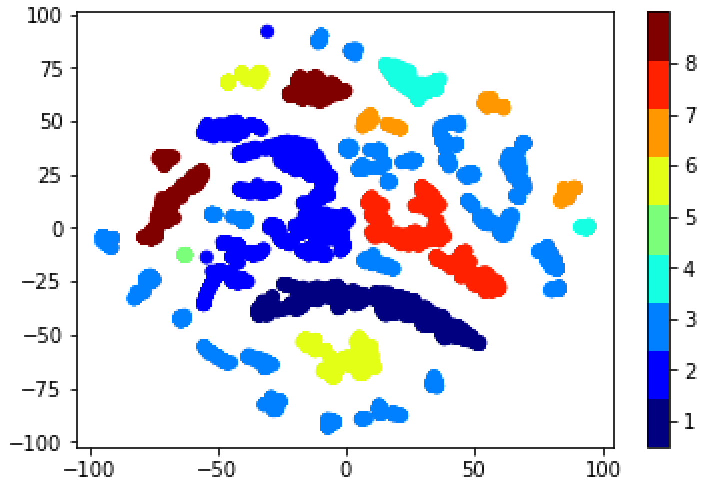
Out[33]:

```
(10868, 5)
```

Multivariate Analysis on final fearures

In [30]:

```
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_call)
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=result_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(9))
plt.clim(0.5, 9)
plt.show()
```



Train and Test split

In [34]:

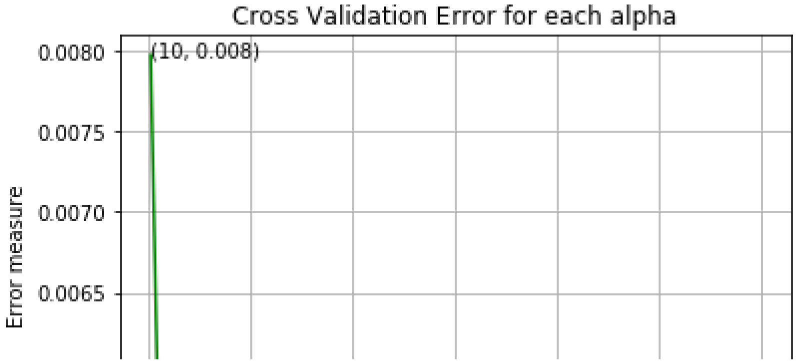
```
X_train, X_test_merge, y_train, y_test_merge = train_test_split(result_call_graph_normal, r
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, y_train,st
```

Random Forest Classifier on call graph features

In [37]:

```
# ------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# ------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.007976730821609157
log_loss for c =  50 is 0.005509055179544572
log_loss for c =  100 is 0.005667811819101597
log_loss for c =  500 is 0.005624384020965916
log_loss for c =  1000 is 0.005641432752218938
log_loss for c =  2000 is 0.0056371213982916975
log_loss for c =  3000 is 0.005672622781241106
```



XgBoost Classifier on call graph features with best hyper parameters using Random search

In [38]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed:   11.8s
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  1.1min remaining:  1.
9min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  1.4min remaining:  1.
4min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  1.8min remaining:  1.
0min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  2.0min remaining:   3
5.7s
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed:  2.0min remaining:   1
3.4s
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed:  2.2min finished
```

Out[38]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [39]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 200, 'max_depth': 3, 'learning_rate': 0.1,
'colsample_bytree': 0.5}
```

In [48]:

```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# ------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------


x_cfl=XGBClassifier(n_estimators=random_cfl.best_params_['n_estimators'],max_depth=random_c
                    learning_rate=random_cfl.best_params_['learning_rate'],colsample_bytree
                    subsample=random_cfl.best_params_['subsample'],n_jobs=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  50 The train log loss is: 0.00395823405784203
7
For values of best alpha =  50 The cross validation log loss is: 0.003976
519137368871
For values of best alpha =  50 The test log loss is: 0.003988905405599336
Number of misclassified points  0.0
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

In [ ]:

4.6. Machine Learning models on features of both .asm and .bytes files

Merging both asm and byte file features

In [103]:

```
result_byte_final = pd.read_csv("result_byte_final.csv")
result_byte_final.head() # dataframe containing byte features
```

Out[103]:

	Unnamed: 0	ID	E8	0B	00	E9	16	90	B
0	0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.
1	1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.
2	2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.
3	3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.
4	4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.

5 rows × 661 columns

In [8]:

```
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - min_value
    return result1
#result_byte_final_normalized = normalize(result_byte_final)
```

In [104]:

```
result_asm = pd.read_csv('asmoutputfile.csv')
result_asm.head() # dataframe containing asm features
```

Out[104]:

	ID	HEADER:	.text:	.Pav:	.idata:	.data:	.bss:	.rdata:	.edata:	.rsrc:
0	01kcPWA9K2BOxQeS5Rju	19	744	0	127	57	0	323	0	3
1	1E93CpP60RHFNiT5Qfvn	17	838	0	103	49	0	0	0	3
2	3ekVow2ajZHbTnBcsDfX	17	427	0	50	43	0	145	0	3
3	3X2nY7iQaPBIWDrAZqJe	17	227	0	43	19	0	0	0	3
4	46OZzdsSKDCFV8h7XWxf	17	402	0	59	170	0	0	0	3

5 rows × 52 columns

In [105]:

```
print(result_byte_final.shape)
print(result_asm.shape)
```

```
(10862, 661)
(10868, 52)
```

In [206]:

```
#merging the byte and asm features
result_x = pd.merge(result_byte_final,result_asm, axis=1,on='ID', how='left')
#result_y = result_x['Class']
result_x = result_x.drop(['Unnamed: 0','ID','rtn','.BSS:','.CODE'], axis=1)
```

In [12]:

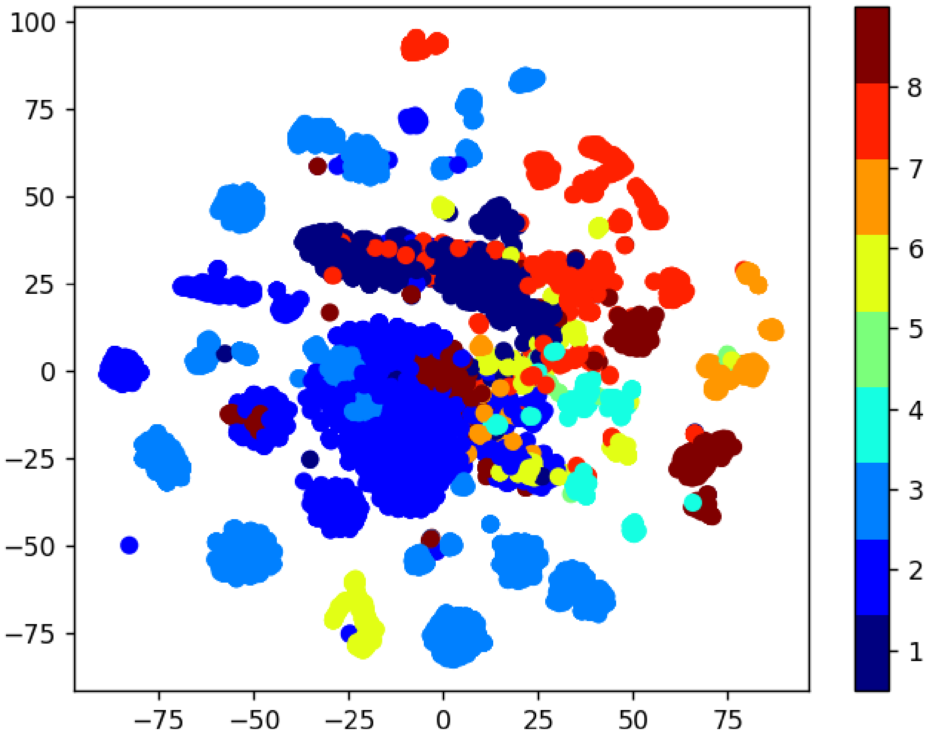
```
result_x.replace([np.inf, -np.inf], np.nan)

result_x.dropna(inplace=True,how='any')
result_x.shape
result_y = result_x['Class']
```

Multivariate Analysis on final fearures

In [181]:

```
xtsne=TSNE(perplexity=50)
results=xtsne.fit_transform(result_x, axis=1))
vis_x = results[:, 0]
vis_y = results[:, 1]
plt.scatter(vis_x, vis_y, c=result_y, cmap=plt.cm.get_cmap("jet", 9))
plt.colorbar(ticks=range(9))
plt.clim(0.5, 9)
plt.show()
```

```
<IPython.core.display.Javascript object>
```



Train and Test split

In [13]:

```
X_train, X_test_merge, y_train, y_test_merge = train_test_split(result_x, result_y,stratify
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, y_train,st
```

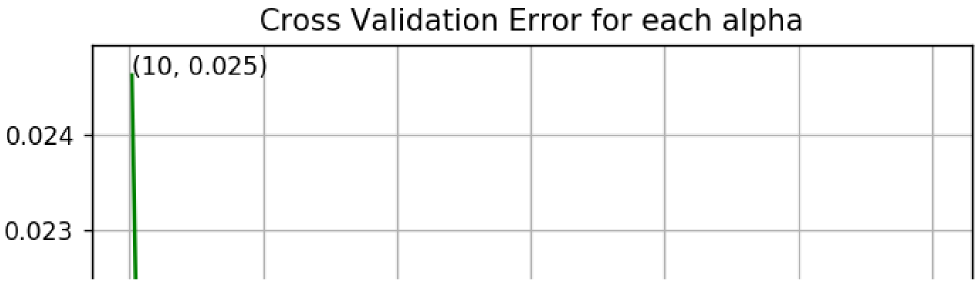
Random Forest Classifier on final features

In [81]:

```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# --------------------------------



alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.024630432837715748
log_loss for c =  50 is 0.018329922638091835
log_loss for c =  100 is 0.02020990473493168
log_loss for c =  500 is 0.02032819077720618
log_loss for c =  1000 is 0.020327701066057937
log_loss for c =  2000 is 0.020049945269992295
log_loss for c =  3000 is 0.020012478468403247
```

```
<IPython.core.display.Javascript object>
```



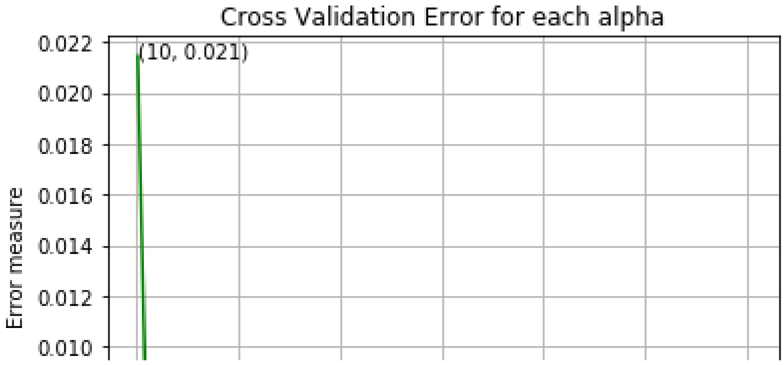
XgBoost Classifier on final features

In [14]:

```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------


alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,random_state= 42,n_jobs=-1)
    x_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=x_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print ('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

x_cfl=XGBClassifier(n_estimators=alpha[best_alpha],n_jobs=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.02144036875600191
```

```
log_loss for c =  50 is 0.007092903728924226
log_loss for c =  100 is 0.00600241779548082
log_loss for c =  500 is 0.00584672727684514
log_loss for c =  1000 is 0.005846985335989776
log_loss for c =  2000 is 0.0058469950114759155
log_loss for c =  3000 is 0.005846842975236974
```



XgBoost Classifier on final features with best hyper parameters using Random search

In [15]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed:   28.6s
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  2.1min remaining:  3.
6min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  2.9min remaining:  2.
9min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  6.6min remaining:  3.
8min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed:  8.8min remaining:  2.
7min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 10.8min remaining:  1.
2min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 11.8min finished
```

Out[15]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [16]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 0.5, 'n_estimators': 1000, 'max_depth': 10, 'learning_rate':
0.15, 'colsample_bytree': 0.5}
```

In [19]:

```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# ------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------


x_cfl=XGBClassifier(n_estimators=1000,max_depth=10,learning_rate=0.15,colsample_bytree=0.5,
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  500 The train log loss is: 0.0050914743629773
36
For values of best alpha =  500 The cross validation log loss is: 0.00489
9047087610139
For values of best alpha =  500 The test log loss is: 0.00710362792956918
2
Number of misclassified points  0.04714757190004715
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

4.6 Improving the Log Loss by using Call graph features in addition to combined byte and asm features used earlier

In [9]:

```
#Reading the csv file have the call graph features into a dataframe.
call_graph_asm = pd.read_csv('final_call_graph_features.csv')
call_graph_asm.head()
```

Out[9]:

	Unnamed: 0	ID	vertex_count	edge_count	delta_max	density
0	0	8i6m0aVAwsdSY2FEfU59	115	100	33	0.201613
1	1	8lbD9QgPs01NR7STfAxH	222	307	126	0.097152
2	2	8iBGtATMYPI0cqpVC2d5	5285	5455	103	0.006000
3	3	8iDWJ4yKzNSAQjnxwO70	122	119	3	0.138211
4	4	8inLjyQfkReMHmNUE4qg	194	132	25	0.053119

In [14]:

```
call_graph_asm.drop(['Unnamed: 0'],axis=1,inplace=True)
call_graph_asm.head()
```

Out[14]:

	ID	vertex_count	edge_count	delta_max	density
0	8i6m0aVAwsdSY2FEfU59	115	100	33	0.201613
1	8lbD9QgPs01NR7STfAxH	222	307	126	0.097152
2	8iBGtATMYPI0cqpVC2d5	5285	5455	103	0.006000
3	8iDWJ4yKzNSAQjnxwO70	122	119	3	0.138211
4	8inLjyQfkReMHmNUE4qg	194	132	25	0.053119

In [15]:

```
#merging the call graph features to combined byte features
result_byte_final_byte_Fea_call_graph_byte = pd.merge(result_byte_final,call_graph_asm,on='
result_byte_final_byte_Fea_call_graph_byte.head()
```

Out[15]:

	Unnamed: 0	ID	E8	0B	00	E9	16	90	B
0	0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.
1	1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.
2	2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.
3	3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.
4	4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.

5 rows × 665 columns

In [17]:

```
result_byte_final_byte_Fea_call_graph_byte.drop(["Unnamed: 0"],axis=1,inplace= True)
result_byte_final_byte_Fea_call_graph_byte.head()
```

Out[17]:

	ID	E8	0B	00	E9	16	90	B9	25
0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.0	4002.0
1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.0	301.0
2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.0	2327.0
3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.0	566.0
4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.0	486.0

5 rows × 664 columns

In [18]:

```
# merging with asm features with call graph and byte features
result_final = pd.merge(result_byte_final_byte_Fea_call_graph_byte,dfasm,on='ID',how='left'
result_final.head()
```

Out[18]:

	ID	E8	0B	00	E9	16	90	B9	25
0	01azqd4InC7m9JpocGv5	4710.0	3546.0	601905.0	3034.0	3184.0	4578.0	3502.0	4002.0
1	01IsoiSMh5gxyDYTl4CB	7506.0	6649.0	39755.0	6878.0	349.0	925.0	526.0	301.0
2	01jsnpXSAlgw6aPeDxrU	22304.0	2669.0	93506.0	2514.0	2408.0	2478.0	2658.0	2327.0
3	01kcPWA9K2BOxQeS5Rju	2899.0	445.0	21091.0	718.0	413.0	551.0	487.0	566.0
4	01SuzwMJEIXsK7A8dQbl	546.0	226.0	19764.0	543.0	240.0	242.0	296.0	486.0

5 rows × 715 columns

In [3]:

```
def normalize(df):
    result1 = df.copy()
    for feature_name in df.columns:
        if (str(feature_name) != str('ID') and str(feature_name)!=str('Class')):
            max_value = df[feature_name].max()
            min_value = df[feature_name].min()
            result1[feature_name] = (df[feature_name] - min_value) / (max_value - min_value
    return result1
```

In [25]:

```
#normalizing
result_final_normalized = normalize(result_final)
result_final_normalized.head()
```

Out[25]:

	ID	E8	0B	00	E9	16	90	
0	01azqd4InC7m9JpocGv5	0.033101	0.001946	0.262786	0.041423	0.003776	0.019713	0.0144
1	01IsoiSMh5gxyDYTl4CB	0.052818	0.003650	0.017332	0.093921	0.000413	0.003980	0.0021
2	01jsnpXSAlgw6aPeDxrU	0.157169	0.001465	0.040801	0.034321	0.002855	0.010668	0.0109
3	01kcPWA9K2BOxQeS5Rju	0.020330	0.000244	0.009182	0.009792	0.000489	0.002369	0.0020
4	01SuzwMJEIXsK7A8dQbl	0.003737	0.000124	0.008603	0.007402	0.000283	0.001038	0.0012

5 rows × 715 columns

In [26]:

```
#Dropping all the nan values
result_final_normalized.dropna(how = 'any')
result_final_normalized.shape
```

Out[26]:

```
(10862, 715)
```

In [27]:

```
#Dropping all the infinite values which ,ay have resulted due to divide zero during normali
result_final_normalized.replace([np.inf, -np.inf], np.nan)
result_final_normalized = result_final_normalized.drop(['ID','rtn','.BSS:','.CODE'], axis=1
result_final_normalized.dropna(inplace=True,how='any')
result_final_normalized.shape
```

Out[27]:

```
(10603, 711)
```

In [35]:

```
result_final_y.head()
```

Out[35]:

```
0    9
1    2
2    9
3    1
4    8
Name: Class, dtype: int64
```

In [34]:

```
result_final_y = result_final_normalized['Class']
result_final_normalized.shape
```

Out[34]:

```
(10603, 711)
```

In [36]:

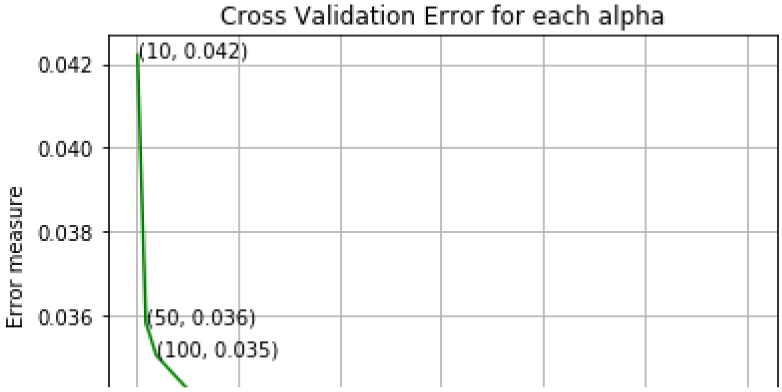
```
#performing train, cross validation and test split
X_train, X_test_merge, y_train, y_test_merge = train_test_split(result_final_normalized, re
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, y_train,st
```

4.5.4. Random Forest Classifier on final features

In [37]:

```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# --------------------------------


alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.042203575724378314
log_loss for c =  50 is 0.035829912540880395
log_loss for c =  100 is 0.035058470930008405
log_loss for c =  500 is 0.03296815383111179
log_loss for c =  1000 is 0.032972284699428776
log_loss for c =  2000 is 0.032940852230352785
log_loss for c =  3000 is 0.03276638229740042
```



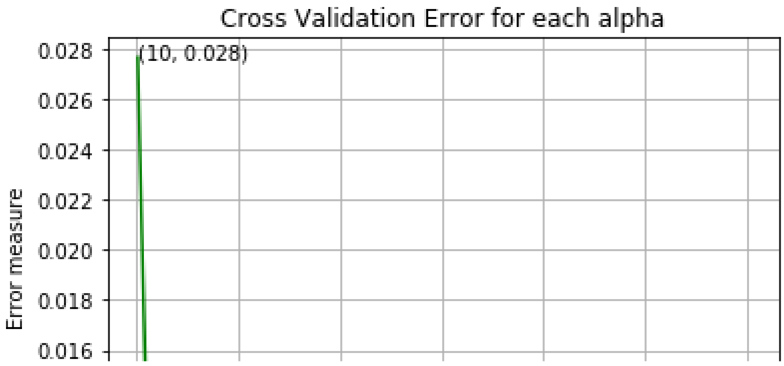
4.5.5. XgBoost Classifier on final features

In [38]:

```
# Training a hyper-parameter tuned Xg-Boost regressor on our train data

# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------


alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
for i in alpha:
    x_cfl=XGBClassifier(n_estimators=i,random_state= 42,n_jobs=-1)
    x_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=x_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print ('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()

x_cfl=XGBClassifier(n_estimators=alpha[best_alpha],n_jobs=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.027637398974818077
```

```
log_loss for c =  50 is 0.013845167895907989
log_loss for c =  100 is 0.011917938585116436
log_loss for c =  500 is 0.012636527374060532
log_loss for c =  1000 is 0.012635912348909204
log_loss for c =  2000 is 0.01263669535174256
log_loss for c =  3000 is 0.012636199818685002
```



4.5.5. XgBoost Classifier on final features with best hyper parameters using Random search

In [39]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed:  1.4min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed:  3.5min remaining:  6.
1min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed:  4.7min remaining:  4.
7min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed:  6.1min remaining:  3.
5min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 11.4min remaining:  3.
5min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 12.0min remaining:  1.
3min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 15.3min finished
```

Out[39]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [40]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 1000, 'max_depth': 10, 'learning_rate': 0.0
3, 'colsample_bytree': 1}
```

In [19]:

```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------

x_cfl=XGBClassifier(n_estimators=1000,max_depth=10,learning_rate=0.,colsample_bytree=0.5,su
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  500 The train log loss is: 0.0050914743629773
36
For values of best alpha =  500 The cross validation log loss is: 0.00489
9047087610139
For values of best alpha =  500 The test log loss is: 0.00710362792956918
2
Number of misclassified points  0.04714757190004715
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

Image Features

In [197]:

```
df_image_features = pd.read_csv("Image_features.csv")
df_image_features.head()
```

Out[197]:

	Unnamed: 0	pixel_0	pixel_1	pixel_2	pixel_3	pixel_4	pixel_5	pixel_6	pixel_7	pixel_8	...
0	0	72	69	65	68	69	82	58	49	48	...
1	1	46	122	101	110	99	58	48	48	52	...
2	2	72	69	65	68	69	82	58	49	48	...
3	3	72	69	65	68	69	82	58	48	48	...
4	4	46	116	101	120	116	58	48	48	52	...

5 rows × 801 columns

In [198]:

```
df_image_features.drop(["Unnamed: 0"],axis=1,inplace=True)
print(df_image_features.shape)
```

```
(10868, 800)
```

In [200]:

```
df_image_features['ID'] = Y['ID']
df_image_features['Class'] = Y['Class']
df_image_features.head()
```

Out[200]:

	pixel_0	pixel_1	pixel_2	pixel_3	pixel_4	pixel_5	pixel_6	pixel_7	pixel_8	pixel_9	...	pix
0	72	69	65	68	69	82	58	49	48	48	...	
1	46	122	101	110	99	58	48	48	52	48	...	
2	72	69	65	68	69	82	58	49	48	48	...	
3	72	69	65	68	69	82	58	48	48	52	...	
4	46	116	101	120	116	58	48	48	52	48	...	

5 rows × 802 columns

In [201]:

```
df_image_features_normalized = normalize(df_image_features)
df_image_features_normalized.head()
```

Out[201]:

	pixel_0	pixel_1	pixel_2	pixel_3	pixel_4	pixel_5	pixel_6	pixel_7	pixel_8	p
0	0.481928	0.302632	0.000000	0.277778	0.291667	0.500000	1.0	0.058824	0.000000	0.0
1	0.168675	1.000000	0.705882	0.861111	0.708333	0.147059	0.0	0.000000	0.181818	0.0
2	0.481928	0.302632	0.000000	0.277778	0.291667	0.500000	1.0	0.058824	0.000000	0.0
3	0.481928	0.302632	0.000000	0.277778	0.291667	0.500000	1.0	0.000000	0.000000	0.1
4	0.168675	0.921053	0.705882	1.000000	0.944444	0.147059	0.0	0.000000	0.181818	0.0

5 rows × 802 columns

In [202]:

```
df_image_features_normalized.replace([np.inf], np.nan)
df_image_features_normalized.dropna(how='any',axis=1,inplace=True)
df_image_features_normalized.shape
```

Out[202]:

```
(10868, 800)
```

In [203]:

```
y_image_feat = df_image_features_normalized['Class']
df_image_features_normalized.drop(['ID'],axis=1,inplace=True)
df_image_features_normalized.shape
```

Out[203]:

```
(10868, 799)
```

In [204]:

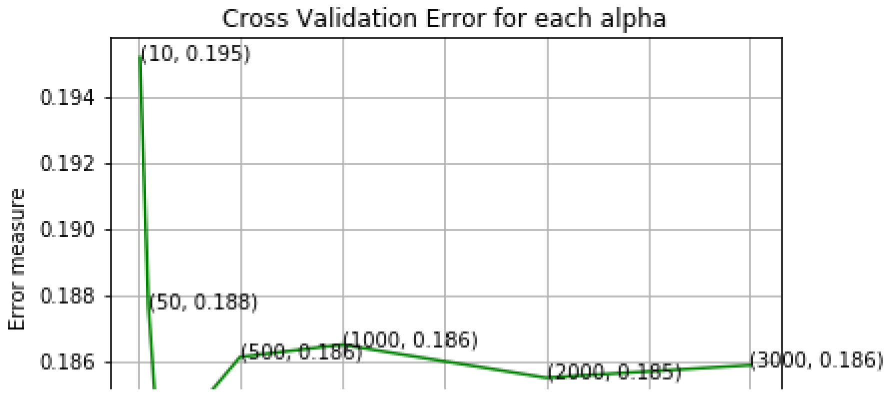
```
X_train, X_test_merge, y_train, y_test_merge = train_test_split(df_image_features_normalize
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, y_train,st
```

4.5.4. Random Forest Classifier on Image features

In [205]:

```
# --------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# --------------------------------


alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.19516926284670316
log_loss for c =  50 is 0.18763343800967439
log_loss for c =  100 is 0.18318801834098444
log_loss for c =  500 is 0.18611121486569585
log_loss for c =  1000 is 0.18648396203981923
log_loss for c =  2000 is 0.18548087736306942
log_loss for c =  3000 is 0.1858611829147577
```



4.5.5. XgBoost Classifier on ASM Image features with best hyper parameters using Random search

In [100]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed:  2.4min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed: 10.3min remaining: 17.
7min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed: 11.3min remaining: 11.
3min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed: 17.7min remaining: 10.
3min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 18.5min remaining:  5.
6min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 22.3min remaining:  2.
5min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 26.9min finished
```

Out[100]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [101]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 1, 'n_estimators': 2000, 'max_depth': 10, 'learning_rate': 0.
2, 'colsample_bytree': 1}
```

In [113]:

```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# -------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------


x_cfl=XGBClassifier(n_estimators=2000,max_depth=10,learning_rate=0.2,colsample_bytree=1,sub
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  100 The train log loss is: 0.0038853708421486
45
For values of best alpha =  100 The cross validation log loss is: 0.00388
5537004226813
For values of best alpha =  100 The test log loss is: 0.00388535708650680
55
Number of misclassified points  0.0
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

Final Model With Unigram, Bigram,N-gram features of Byte file, Call graph features of ASM file and Image Features of ASM file

In [78]:

```
df_byte = pd.read_csv('result_byte_final.csv')
df_call =pd.read_csv('final_call_graph_features.csv')
df_image = pd.read_csv('Image_features.csv')
df_image['ID'] = Y['ID']
```

In [80]:

```
df_final = pd.merge(df_byte,df_call,on='ID')
df_final = pd.merge(df_final,df_image,on='ID')
df_final.shape
```

Out[80]:

```
(10862, 1467)
```

In [123]:

```
df_normalized = normalize(df_final)
```

In [132]:

```
df_normalized.replace([np.inf, -np.inf],np.nan,inplace=True)
df_normalized.drop(['ID','Class'],axis = 1).dropna(how='any',inplace=True)
df_normalized.shape
```

Out[132]:

```
(10862, 1467)
```

In [150]:

```
df_ = np.nan_to_num(df_normalized.drop(['ID','Class'],axis =1),copy= False)
```

In [151]:

```
y_class = df_normalized['Class']
#df_normalized.drop(['ID','Class'],axis = 1,inplace = True)
```

In [152]:

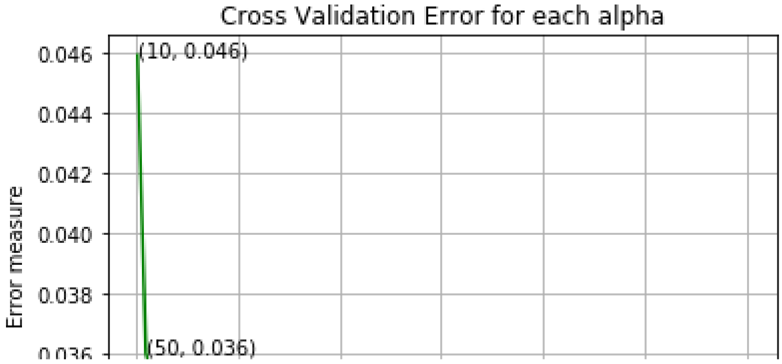
```
X_train, X_test_merge, y_train, y_test_merge = train_test_split(df_, y_class,stratify=y_cla
X_train_merge, X_cv_merge, y_train_merge, y_cv_merge = train_test_split(X_train, y_train,st
```

4.5.4. Random Forest Classifier on final features

In [153]:

```
# ----------------------------------
# default parameters
# sklearn.ensemble.RandomForestClassifier(n_estimators=10, criterion='gini', max_depth=None
# min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=Non
# min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=1, random_state=None, ve
# class_weight=None)

# Some of methods of RandomForestClassifier()
# fit(X, y, [sample_weight])    Fit the SVM model according to the given training data.
# predict(X)    Perform classification on samples in X.
# predict_proba (X) Perform classification on samples in X.

# some of attributes of  RandomForestClassifier()
# feature_importances_ : array of shape = [n_features]
# The feature importances (the higher, the more important the feature).

# ----------------------------------

alpha=[10,50,100,500,1000,2000,3000]
cv_log_error_array=[]
from sklearn.ensemble import RandomForestClassifier
for i in alpha:
    r_cfl=RandomForestClassifier(n_estimators=i,random_state=42,n_jobs=-1)
    r_cfl.fit(X_train_merge,y_train_merge)
    sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
    sig_clf.fit(X_train_merge, y_train_merge)
    predict_y = sig_clf.predict_proba(X_cv_merge)
    loss = log_loss(y_cv_merge, predict_y, labels=r_cfl.classes_, eps=1e-15)
    cv_log_error_array.append(loss)
    print('log_loss for c = ',i,'is',loss)


best_alpha = np.argmin(cv_log_error_array)

fig, ax = plt.subplots()
ax.plot(alpha, cv_log_error_array,c='g')
for i, txt in enumerate(np.round(cv_log_error_array,3)):
    ax.annotate((alpha[i],np.round(txt,3)), (alpha[i],cv_log_error_array[i]))
plt.grid()
plt.title("Cross Validation Error for each alpha")
plt.xlabel("Alpha i's")
plt.ylabel("Error measure")
plt.show()


r_cfl=RandomForestClassifier(n_estimators=alpha[best_alpha],random_state=42,n_jobs=-1)
r_cfl.fit(X_train_merge,y_train_merge)
sig_clf = CalibratedClassifierCV(r_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
log_loss for c =  10 is 0.045904640292778354
log_loss for c =  50 is 0.036046076405505695
log_loss for c =  100 is 0.03438576523877995
log_loss for c =  500 is 0.03289431736449906
log_loss for c =  1000 is 0.03289767285147134
log_loss for c =  2000 is 0.032953043680867065
log_loss for c =  3000 is 0.03277101076965345
```



4.5.5. XgBoost Classifier on Unigram,bigram and N-gram features of byte files and call graph ,Image features of ASM file with best hyper parameters using Random search

In [154]:

```
x_cfl=XGBClassifier()

prams={
    'learning_rate':[0.01,0.03,0.05,0.1,0.15,0.2],
     'n_estimators':[100,200,500,1000,2000],
     'max_depth':[3,5,10],
    'colsample_bytree':[0.1,0.3,0.5,1],
    'subsample':[0.1,0.3,0.5,1]
}
random_cfl=RandomizedSearchCV(x_cfl,param_distributions=prams,verbose=10,n_jobs=-1,)
random_cfl.fit(X_train_merge, y_train_merge)
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits

[Parallel(n_jobs=-1)]: Using backend LokyBackend with 12 concurrent workers.
[Parallel(n_jobs=-1)]: Done   1 tasks      | elapsed: 10.7min
[Parallel(n_jobs=-1)]: Done  11 out of  30 | elapsed: 51.0min remaining: 88.
1min
[Parallel(n_jobs=-1)]: Done  15 out of  30 | elapsed: 54.1min remaining: 54.
1min
[Parallel(n_jobs=-1)]: Done  19 out of  30 | elapsed: 60.8min remaining: 35.
2min
[Parallel(n_jobs=-1)]: Done  23 out of  30 | elapsed: 61.8min remaining: 18.
8min
[Parallel(n_jobs=-1)]: Done  27 out of  30 | elapsed: 62.1min remaining:  6.
9min
[Parallel(n_jobs=-1)]: Done  30 out of  30 | elapsed: 66.7min finished
```

Out[154]:

```
RandomizedSearchCV(cv='warn', error_score='raise-deprecating',
          estimator=XGBClassifier(base_score=0.5, booster='gbtree', colsampl
e_bylevel=1,
       colsample_bytree=1, gamma=0, learning_rate=0.1, max_delta_step=0,
       max_depth=3, min_child_weight=1, missing=None, n_estimators=100,
       n_jobs=1, nthread=None, objective='binary:logistic', random_state=0,
       reg_alpha=0, reg_lambda=1, scale_pos_weight=1, seed=None,
       silent=True, subsample=1),
          fit_params=None, iid='warn', n_iter=10, n_jobs=-1,
          param_distributions={'learning_rate': [0.01, 0.03, 0.05, 0.1, 0.1
5, 0.2], 'n_estimators': [100, 200, 500, 1000, 2000], 'max_depth': [3, 5, 1
0], 'colsample_bytree': [0.1, 0.3, 0.5, 1], 'subsample': [0.1, 0.3, 0.5,
1]},
          pre_dispatch='2*n_jobs', random_state=None, refit=True,
          return_train_score='warn', scoring=None, verbose=10)
```

In [155]:

```
print (random_cfl.best_params_)
```

```
{'subsample': 0.3, 'n_estimators': 2000, 'max_depth': 3, 'learning_rate': 0.
03, 'colsample_bytree': 1}
```

In [156]:

```
# find more about XGBClassifier function here http://xgboost.readthedocs.io/en/latest/pytho
# ------------------------
# default paramters
# class xgboost.XGBClassifier(max_depth=3, learning_rate=0.1, n_estimators=100, silent=True
# objective='binary:logistic', booster='gbtree', n_jobs=1, nthread=None, gamma=0, min_child
# max_delta_step=0, subsample=1, colsample_bytree=1, colsample_bylevel=1, reg_alpha=0, reg_
# scale_pos_weight=1, base_score=0.5, random_state=0, seed=None, missing=None, **kwargs)

# some of methods of RandomForestRegressor()
# fit(X, y, sample_weight=None, eval_set=None, eval_metric=None, early_stopping_rounds=None
# get_params([deep])    Get parameters for this estimator.
# predict(data, output_margin=False, ntree_limit=0) : Predict with data. NOTE: This functio
# get_score(importance_type='weight') -> get the feature importance
# -----------------------

x_cfl=XGBClassifier(n_estimators=random_cfl.best_params_['n_estimators'],max_depth=random_c
                    learning_rate=random_cfl.best_params_['learning_rate'],colsample_bytree
                    subsample=random_cfl.best_params_['subsample'],n_jobs=-1)
x_cfl.fit(X_train_merge,y_train_merge,verbose=True)
sig_clf = CalibratedClassifierCV(x_cfl, method="sigmoid")
sig_clf.fit(X_train_merge, y_train_merge)

predict_y = sig_clf.predict_proba(X_train_merge)
print ('For values of best alpha = ', alpha[best_alpha], "The train log loss is:",log_loss(
predict_y = sig_clf.predict_proba(X_cv_merge)
print('For values of best alpha = ', alpha[best_alpha], "The cross validation log loss is:"
predict_y = sig_clf.predict_proba(X_test_merge)
print('For values of best alpha = ', alpha[best_alpha], "The test log loss is:",log_loss(y_
plot_confusion_matrix(y_test_merge,sig_clf.predict(X_test_merge))
```

```
For values of best alpha =  3000 The train log loss is: 0.012906292422217
89
For values of best alpha =  3000 The cross validation log loss is: 0.0232
20146974251066
For values of best alpha =  3000 The test log loss is: 0.0396910177394838
4
Number of misclassified points  0.7823285780027611
-------------------------------------------------- Confusion matrix -----
---------------------------------------------
```

In [2]:

```
print("Log loss for different models using Byte features")
table = PrettyTable()
table.field_names= ['Model','log loss']
table.add_row(['Random Model', 2.510])
table.add_row(['K- NN', 0.004])
table.add_row(['Logistic Regression', 0.071])
table.add_row(['Random Forest classifier', 0.028])
table.add_row(['XgBoost Classifier', 0.008])
print(table,'\n')
print("Log loss for different models using .ASM features")
table1 = PrettyTable()
table1.field_names= ['Model','log loss']
table1.add_row(['K- NN', 0.089])
table1.add_row(['Logistic Regression',  0.415])
table1.add_row(['Random Forest classifier', 0.057])
table1.add_row(['XgBoost Classifier', 0.048])
print(table1,'\n')
print("Log loss for Random forest and XgBoost classifier for call graph features obtained f
table2 = PrettyTable()
table2.field_names= ['Model','log loss']
table2.add_row(['Random Forest classifier', 0.005])
table2.add_row(['XgBoost Classifier', 0.003])
print(table2,'\n')
print("Log loss for Random forest and XgBoost classifier for byte and asm features together
table3 = PrettyTable()
table3.field_names= ['Model','log loss']
table3.add_row(['Random Forest classifier', 0.028])
table3.add_row(['XgBoost Classifier', 0.007])
print(table3,'\n')
print("Log loss for Random forest and XgBoost classifier for byte and asm features together
table4 = PrettyTable()
table4.field_names= ['Model','log loss']
table4.add_row(['Random Forest classifier', 0.036])
table4.add_row(['XgBoost Classifier', 0.007])
print(table4,'\n')
print("Log loss for Random forest and XgBoost classifier on Image feature obtained from .AS
table5 = PrettyTable()
table5.field_names= ['Model','log loss']
table5.add_row(['Random Forest classifier', 0.153])
table5.add_row(['XgBoost Classifier', 0.003])
print(table5,'\n')
print("Log loss for Random forest and XgBoost classifier on byte (unigram,bi-gram,n-gram),
table6 = PrettyTable()
table6.field_names= ['Model','log loss']
table6.add_row(['Random Forest classifier', 0.045])
table6.add_row(['XgBoost Classifier', 0.039])
print(table6)
```

```
Log loss for different models using Byte features
+--------------------------+----------+
|          Model           | log loss |
+--------------------------+----------+
|       Random Model       |   2.51   |
|          K- NN           |  0.004   |
|   Logistic Regression    |  0.071   |
| Random Forest classifier |  0.028   |
|    XgBoost Classifier    |  0.008   |
```

Log loss for different models using .ASM features

Model	log loss
K- NN	0.089
Logistic Regression	0.415
Random Forest classifier	0.057
XgBoost Classifier	0.048

Log loss for Random forest and XgBoost classifier for call graph features obtained from .ASM features

Model	log loss
Random Forest classifier	0.005
XgBoost Classifier	0.003

Log loss for Random forest and XgBoost classifier for byte and asm features together

Model	log loss
Random Forest classifier	0.028
XgBoost Classifier	0.007

Log loss for Random forest and XgBoost classifier for byte and asm features together

Model	log loss
Random Forest classifier	0.036
XgBoost Classifier	0.007

Log loss for Random forest and XgBoost classifier on Image feature obtained from .ASM file

Model	log loss
Random Forest classifier	0.153
XgBoost Classifier	0.003

Log loss for Random forest and XgBoost classifier on byte (unigram,bi-gram,n-gram), .asm features, call graph and Image Features

Model	log loss
Random Forest classifier	0.045
XgBoost Classifier	0.039

Conclusion:

- XgBoost classifier performs the best as compared to other models.
- From the above table its clear that with call graph and Image features extracted from .ASM file gives the best log loss for XgBoost classifier.

END