DosDetection

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1 i523 Big Data Analytics Project

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1.1 * Big Data Analytics in Detection of DDoS (Distributed Denial-of-Service) attacks * With the increase in internet traffic, threats on the network have also increased. Denial-of-service attacks are cyber attacks wherein a perpetrator, due to any kind of malicious intent, tries to make a resource on the network unavailable to its intended users and carries it out by swamping the system or resource with excess requests in order to overload it and prevent users from accessing it. A much more dangerous variety of such an attack is if it is distributed i.e. coming from various sources. Big Data analytics, however, can be used to detect such attacks by having the ability to store the voluminous logs of such attacks and using the data and machine learning techniques to design an anomaly detection system (using a classification model) to detect and prevent these attacks. This project will aim to explore such classification models, design and train the most optimum model and display its effects using a DDoS logs dataset.

1.1.1 Data Description

- We will be using the dataset used for the KDD Cup of 1999, which has been derived from the 1998 DARPA Intrusion Detection Evaluation Program dataset. This was prepared and managed by MIT Lincoln Labs. The objective was to survey and evaluate research in intrusion detection. The data includes a wide variety of intrusions simulated in a military network environment.
- Lincoln Labs set up an environment to acquire nine weeks of raw TCP dump data for a local-area network (LAN) simulating a typical U.S. Air Force LAN. They operated the LAN as if it were a true Air Force environment, but peppered it with multiple attacks. The raw training data was about four gigabytes of compressed binary TCP dump data from seven weeks of network traffic. This was processed into about five million connection records.
- KDD Cup 1999 data link: link_here
- Original DARPA datasets link: link_here
- For the data analysis and demonstration of our model, we will use 10 percent of the KDD Cup'99 training dataset (~500k rows) and test it on 10 percent of the test dataset (~300k rows).
- The data consists of five types of network traffic logs: normal traffic, DOS/DDoS - Denial of Service traffic, R2L- unauthorized access from a remote machine, U2R- unauthorized access to local superuser (root) privileges and probing- surveillance and other probing. This makes

the task of analysis and prediction much more realistic, as we attempt to classify the "bad traffic" from the "normal traffic". Another important point to note is that the datasets contain a total of 24 training attack types (subsets of the above four), with an additional 14 types in the test data only. The purpose behind adding the 14 extra types in the test dataset was to prove that most new attacks are just variants of pre-existing attack types and hence can be sufficiently detected using data from the latter.

In [1]:
```
# Reading dataset using Pandas
#Datasets being used for the analysis are the 10 percent datasets placed on Google Drive
#Place the code and datasets in your default directory for Jupyter Notebook

#Loading the 10 percent training dataset
import pandas as pd
labels_data = ["duration","protocol_type","service","flag","src_bytes", "dst_bytes","lan
    "logged_in","num_compromised","root_shell","su_attempted","num_root","num_file_creat
    "is_host_login","is_guest_login","count","srv_count","serror_rate","srv_serror_rate"
    "diff_srv_rate","srv_diff_host_rate","dst_host_count","dst_host_srv_count","dst_host
    "dst_host_srv_diff_host_rate","dst_host_serror_rate","dst_host_srv_serror_rate","dst
kdd_train_10percent = pd.read_csv("kddcup_data_10_percent.csv", header=None, names = lab
kdd_train_10percent.head(10)
```

Out[1]:
```
   duration protocol_type service flag  src_bytes  dst_bytes  land  \
0         0           tcp    http   SF        181       5450     0
1         0           tcp    http   SF        239        486     0
2         0           tcp    http   SF        235       1337     0
3         0           tcp    http   SF        219       1337     0
4         0           tcp    http   SF        217       2032     0
5         0           tcp    http   SF        217       2032     0
6         0           tcp    http   SF        212       1940     0
7         0           tcp    http   SF        159       4087     0
8         0           tcp    http   SF        210        151     0
9         0           tcp    http   SF        212        786     0

   wrong_fragment  urgent  hot      ...       dst_host_srv_count  \
0               0       0    0      ...                        9
1               0       0    0      ...                       19
2               0       0    0      ...                       29
3               0       0    0      ...                       39
4               0       0    0      ...                       49
5               0       0    0      ...                       59
6               0       0    0      ...                       69
7               0       0    0      ...                       79
8               0       0    0      ...                       89
9               0       0    1      ...                       99

   dst_host_same_srv_rate  dst_host_diff_srv_rate  \
0                     1.0                     0.0
1                     1.0                     0.0
```

```
2                    1.0                      0.0
3                    1.0                      0.0
4                    1.0                      0.0
5                    1.0                      0.0
6                    1.0                      0.0
7                    1.0                      0.0
8                    1.0                      0.0
9                    1.0                      0.0

   dst_host_same_src_port_rate  dst_host_srv_diff_host_rate  \
0                         0.11                         0.00
1                         0.05                         0.00
2                         0.03                         0.00
3                         0.03                         0.00
4                         0.02                         0.00
5                         0.02                         0.00
6                         1.00                         0.04
7                         0.09                         0.04
8                         0.12                         0.04
9                         0.12                         0.05

   dst_host_serror_rate  dst_host_srv_serror_rate  dst_host_rerror_rate  \
0                   0.0                       0.0                   0.0
1                   0.0                       0.0                   0.0
2                   0.0                       0.0                   0.0
3                   0.0                       0.0                   0.0
4                   0.0                       0.0                   0.0
5                   0.0                       0.0                   0.0
6                   0.0                       0.0                   0.0
7                   0.0                       0.0                   0.0
8                   0.0                       0.0                   0.0
9                   0.0                       0.0                   0.0

   dst_host_srv_rerror_rate  attack_type
0                       0.0      normal.
1                       0.0      normal.
2                       0.0      normal.
3                       0.0      normal.
4                       0.0      normal.
5                       0.0      normal.
6                       0.0      normal.
7                       0.0      normal.
8                       0.0      normal.
9                       0.0      normal.

[10 rows x 42 columns]
```

In [2]:
```
kdd_train_10percent.describe()
```

Out[2]:
```
             duration     src_bytes     dst_bytes           land  \
count  494021.000000  4.940210e+05  4.940210e+05  494021.000000
mean       47.979302  3.025610e+03  8.685324e+02       0.000045
std       707.746472  9.882181e+05  3.304000e+04       0.006673
min         0.000000  0.000000e+00  0.000000e+00       0.000000
25%         0.000000  4.500000e+01  0.000000e+00       0.000000
50%         0.000000  5.200000e+02  0.000000e+00       0.000000
75%         0.000000  1.032000e+03  0.000000e+00       0.000000
max     58329.000000  6.933756e+08  5.155468e+06       1.000000

       wrong_fragment         urgent            hot  num_failed_logins  \
count   494021.000000  494021.000000  494021.000000      494021.000000
mean         0.006433       0.000014       0.034519           0.000152
std          0.134805       0.005510       0.782103           0.015520
min          0.000000       0.000000       0.000000           0.000000
25%          0.000000       0.000000       0.000000           0.000000
50%          0.000000       0.000000       0.000000           0.000000
75%          0.000000       0.000000       0.000000           0.000000
max          3.000000       3.000000      30.000000           5.000000

           logged_in  num_compromised              ...               \
count  494021.000000    494021.000000              ...
mean        0.148247         0.010212              ...
std         0.355345         1.798326              ...
min         0.000000         0.000000              ...
25%         0.000000         0.000000              ...
50%         0.000000         0.000000              ...
75%         0.000000         0.000000              ...
max         1.000000       884.000000              ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   494021.000000       494021.000000           494021.000000
mean       232.470778          188.665670                0.753780
std         64.745380          106.040437                0.410781
min          0.000000            0.000000                0.000000
25%        255.000000           46.000000                0.410000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           494021.000000                494021.000000
mean                 0.030906                     0.601935
std                  0.109259                     0.481309
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.040000                     1.000000
```

```
max                    1.000000                        1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                494021.000000         494021.000000
mean                      0.006684              0.176754
std                       0.042133              0.380593
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
75%                       0.000000              0.000000
max                       1.000000              1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             494021.000000         494021.000000
mean                   0.176443              0.058118
std                    0.380919              0.230590
min                    0.000000              0.000000
25%                    0.000000              0.000000
50%                    0.000000              0.000000
75%                    0.000000              0.000000
max                    1.000000              1.000000

       dst_host_srv_rerror_rate
count             494021.000000
mean                   0.057412
std                    0.230140
min                    0.000000
25%                    0.000000
50%                    0.000000
75%                    0.000000
max                    1.000000

[8 rows x 38 columns]
```

In [2]:
```
#Loading the 10 percent testing dataset
kdd_test_10percent = pd.read_csv("corrected.csv", header=None, names = labels_data)
kdd_test_10percent.head(10)
```

Out[2]:
```
   duration protocol_type   service flag  src_bytes  dst_bytes  land  \
0         0           udp   private   SF        105        146     0
1         0           udp   private   SF        105        146     0
2         0           udp   private   SF        105        146     0
3         0           udp   private   SF        105        146     0
4         0           udp   private   SF        105        146     0
5         0           udp   private   SF        105        146     0
6         0           udp  domain_u   SF         29          0     0
7         0           udp   private   SF        105        146     0
8         0           udp   private   SF        105        146     0
```

```
9         0           tcp      http   SF        223        185     0

   wrong_fragment  urgent  hot        ...        dst_host_srv_count  \
0               0       0    0        ...                       254
1               0       0    0        ...                       254
2               0       0    0        ...                       254
3               0       0    0        ...                       254
4               0       0    0        ...                       254
5               0       0    0        ...                       255
6               0       0    0        ...                         3
7               0       0    0        ...                       253
8               0       0    0        ...                       254
9               0       0    0        ...                       255

   dst_host_same_srv_rate  dst_host_diff_srv_rate  \
0                    1.00                    0.01
1                    1.00                    0.01
2                    1.00                    0.01
3                    1.00                    0.01
4                    1.00                    0.01
5                    1.00                    0.00
6                    0.30                    0.30
7                    0.99                    0.01
8                    1.00                    0.01
9                    1.00                    0.00

   dst_host_same_src_port_rate  dst_host_srv_diff_host_rate  \
0                         0.00                         0.00
1                         0.00                         0.00
2                         0.00                         0.00
3                         0.00                         0.00
4                         0.01                         0.00
5                         0.01                         0.00
6                         0.30                         0.00
7                         0.00                         0.00
8                         0.00                         0.00
9                         0.01                         0.01

   dst_host_serror_rate  dst_host_srv_serror_rate  dst_host_rerror_rate  \
0                   0.0                       0.0                   0.0
1                   0.0                       0.0                   0.0
2                   0.0                       0.0                   0.0
3                   0.0                       0.0                   0.0
4                   0.0                       0.0                   0.0
5                   0.0                       0.0                   0.0
6                   0.0                       0.0                   0.0
7                   0.0                       0.0                   0.0
8                   0.0                       0.0                   0.0
```

```
9                   0.0                        0.0                     0.0

   dst_host_srv_rerror_rate     attack_type
0                       0.0         normal.
1                       0.0         normal.
2                       0.0         normal.
3                       0.0  snmpgetattack.
4                       0.0  snmpgetattack.
5                       0.0  snmpgetattack.
6                       0.0         normal.
7                       0.0         normal.
8                       0.0  snmpgetattack.
9                       0.0         normal.

[10 rows x 42 columns]
```

In [4]:
```
kdd_test_10percent.describe()
```

Out[4]:
```
            duration     src_bytes     dst_bytes           land  \
count  311029.000000  3.110290e+05  3.110290e+05  311029.000000
mean       17.902736  1.731702e+03  7.479937e+02       0.000029
std       407.644400  1.276567e+05  1.612018e+04       0.005379
min         0.000000  0.000000e+00  0.000000e+00       0.000000
25%         0.000000  1.050000e+02  0.000000e+00       0.000000
50%         0.000000  5.200000e+02  0.000000e+00       0.000000
75%         0.000000  1.032000e+03  0.000000e+00       0.000000
max     57715.000000  6.282565e+07  5.203179e+06       1.000000

       wrong_fragment         urgent            hot  num_failed_logins  \
count   311029.000000  311029.000000  311029.000000      311029.000000
mean         0.000762       0.000051       0.014677           0.002363
std          0.040367       0.009821       0.312068           0.049990
min          0.000000       0.000000       0.000000           0.000000
25%          0.000000       0.000000       0.000000           0.000000
50%          0.000000       0.000000       0.000000           0.000000
75%          0.000000       0.000000       0.000000           0.000000
max          3.000000       3.000000     101.000000           4.000000

           logged_in  num_compromised              ...               \
count  311029.000000    311029.000000              ...
mean        0.172476         0.011243              ...
std         0.377794         1.958325              ...
min         0.000000         0.000000              ...
25%         0.000000         0.000000              ...
50%         0.000000         0.000000              ...
75%         0.000000         0.000000              ...
max         1.000000       796.000000              ...
```

	dst_host_count	dst_host_srv_count	dst_host_same_srv_rate	\
count	311029.000000	311029.000000	311029.000000	
mean	235.282681	199.193914	0.793494	
std	60.913298	100.306470	0.387090	
min	0.000000	0.000000	0.000000	
25%	255.000000	244.000000	0.970000	
50%	255.000000	255.000000	1.000000	
75%	255.000000	255.000000	1.000000	
max	255.000000	255.000000	1.000000	

	dst_host_diff_srv_rate	dst_host_same_src_port_rate	\
count	311029.000000	311029.000000	
mean	0.024953	0.547919	
std	0.096003	0.491963	
min	0.000000	0.000000	
25%	0.000000	0.000000	
50%	0.000000	1.000000	
75%	0.010000	1.000000	
max	1.000000	1.000000	

	dst_host_srv_diff_host_rate	dst_host_serror_rate	\
count	311029.000000	311029.000000	
mean	0.004566	0.058764	
std	0.035773	0.231296	
min	0.000000	0.000000	
25%	0.000000	0.000000	
50%	0.000000	0.000000	
75%	0.000000	0.000000	
max	1.000000	1.000000	

	dst_host_srv_serror_rate	dst_host_rerror_rate	\
count	311029.000000	311029.000000	
mean	0.058791	0.142659	
std	0.232997	0.344380	
min	0.000000	0.000000	
25%	0.000000	0.000000	
50%	0.000000	0.000000	
75%	0.000000	0.000000	
max	1.000000	1.000000	

	dst_host_srv_rerror_rate
count	311029.000000
mean	0.141693
std	0.346573
min	0.000000
25%	0.000000
50%	0.000000
75%	0.000000

```
max                     1.000000

[8 rows x 38 columns]
```

1.1.2 Data Exploration

We now proceed with some basic data exploration on the training dataset. All modifications made on the training dataset (feauture engineering) will be replicated on the test dataset (to ensure apples-to-apples comparison).

```
In [3]: import matplotlib.pyplot as plt
        import numpy as np
        import math
        import seaborn as sns

        %matplotlib inline

In [4]: from IPython.core.interactiveshell import InteractiveShell
        InteractiveShell.ast_node_interactivity = "all"

In [7]: #Checking for null values in train and test datasets

        kdd_train_10percent.isnull().any().any()
        kdd_test_10percent.isnull().any().any()

        #No nulls found

Out[7]: False

Out[7]: False

In [8]: #Comparing categorical variables across train and test datasets

        len(kdd_train_10percent.protocol_type.unique())
        sorted(kdd_train_10percent.protocol_type.unique())

Out[8]: 3

Out[8]: ['icmp', 'tcp', 'udp']

In [9]: len(kdd_test_10percent.protocol_type.unique())
        sorted(kdd_test_10percent.protocol_type.unique())

Out[9]: 3

Out[9]: ['icmp', 'tcp', 'udp']

In [10]: len(kdd_train_10percent.service.unique())
         sorted(kdd_train_10percent.service.unique())
```

```
Out[10]: 66

Out[10]: ['IRC',
          'X11',
          'Z39_50',
          'auth',
          'bgp',
          'courier',
          'csnet_ns',
          'ctf',
          'daytime',
          'discard',
          'domain',
          'domain_u',
          'echo',
          'eco_i',
          'ecr_i',
          'efs',
          'exec',
          'finger',
          'ftp',
          'ftp_data',
          'gopher',
          'hostnames',
          'http',
          'http_443',
          'imap4',
          'iso_tsap',
          'klogin',
          'kshell',
          'ldap',
          'link',
          'login',
          'mtp',
          'name',
          'netbios_dgm',
          'netbios_ns',
          'netbios_ssn',
          'netstat',
          'nnsp',
          'nntp',
          'ntp_u',
          'other',
          'pm_dump',
          'pop_2',
          'pop_3',
          'printer',
          'private',
```

```
 'red_i',
 'remote_job',
 'rje',
 'shell',
 'smtp',
 'sql_net',
 'ssh',
 'sunrpc',
 'supdup',
 'systat',
 'telnet',
 'tftp_u',
 'tim_i',
 'time',
 'urh_i',
 'urp_i',
 'uucp',
 'uucp_path',
 'vmnet',
 'whois']
```

```
In [11]: len(kdd_test_10percent.service.unique())
         sorted(kdd_test_10percent.service.unique())
```

```
Out[11]: 65
```

```
Out[11]: ['IRC',
          'X11',
          'Z39_50',
          'auth',
          'bgp',
          'courier',
          'csnet_ns',
          'ctf',
          'daytime',
          'discard',
          'domain',
          'domain_u',
          'echo',
          'eco_i',
          'ecr_i',
          'efs',
          'exec',
          'finger',
          'ftp',
          'ftp_data',
          'gopher',
          'hostnames',
```

```
 'http',
 'http_443',
 'icmp',
 'imap4',
 'iso_tsap',
 'klogin',
 'kshell',
 'ldap',
 'link',
 'login',
 'mtp',
 'name',
 'netbios_dgm',
 'netbios_ns',
 'netbios_ssn',
 'netstat',
 'nnsp',
 'nntp',
 'ntp_u',
 'other',
 'pm_dump',
 'pop_2',
 'pop_3',
 'printer',
 'private',
 'remote_job',
 'rje',
 'shell',
 'smtp',
 'sql_net',
 'ssh',
 'sunrpc',
 'supdup',
 'systat',
 'telnet',
 'tftp_u',
 'tim_i',
 'time',
 'urp_i',
 'uucp',
 'uucp_path',
 'vmnet',
 'whois']
```

In [12]:
```
len(kdd_train_10percent.flag.unique())
sorted(kdd_train_10percent.flag.unique())
```

Out[12]:
```
11
```

```
Out[12]: ['OTH', 'REJ', 'RSTO', 'RSTOS0', 'RSTR', 'S0', 'S1', 'S2', 'S3', 'SF', 'SH']
```

```
In [13]: len(kdd_test_10percent.flag.unique())
         sorted(kdd_test_10percent.flag.unique())
```

```
Out[13]: 11
```

```
Out[13]: ['OTH', 'REJ', 'RSTO', 'RSTOS0', 'RSTR', 'S0', 'S1', 'S2', 'S3', 'SF', 'SH']
```

We see that the "service" column has one less type in the test dataset than in the train dataset. We would not have been aware of this if we had not checked the test dataset. For simplicity, we remove the categorical variable columns for our analysis.

```
In [5]: #Removing the categorical variable columns
        new_labels = ["duration","src_bytes", "dst_bytes","land","wrong_fragment","urgent","hot"
            "logged_in","num_compromised","root_shell","su_attempted","num_root","num_file_creat
            "is_host_login","is_guest_login","count","srv_count","serror_rate","srv_serror_rate"
            "diff_srv_rate","srv_diff_host_rate","dst_host_count","dst_host_srv_count","dst_host
            "dst_host_srv_diff_host_rate","dst_host_serror_rate","dst_host_srv_serror_rate","dst
        kdd_train_10per_mod = kdd_train_10percent[new_labels]
        kdd_train_10per_mod.shape
        kdd_train_10per_mod.describe()
```

```
Out[5]: (494021, 39)
```

```
Out[5]:             duration     src_bytes     dst_bytes           land  \
        count  494021.000000  4.940210e+05  4.940210e+05  494021.000000
        mean       47.979302  3.025610e+03  8.685324e+02       0.000045
        std       707.746472  9.882181e+05  3.304000e+04       0.006673
        min         0.000000  0.000000e+00  0.000000e+00       0.000000
        25%         0.000000  4.500000e+01  0.000000e+00       0.000000
        50%         0.000000  5.200000e+02  0.000000e+00       0.000000
        75%         0.000000  1.032000e+03  0.000000e+00       0.000000
        max     58329.000000  6.933756e+08  5.155468e+06       1.000000

               wrong_fragment         urgent            hot  num_failed_logins  \
        count   494021.000000  494021.000000  494021.000000      494021.000000
        mean         0.006433       0.000014       0.034519           0.000152
        std          0.134805       0.005510       0.782103           0.015520
        min          0.000000       0.000000       0.000000           0.000000
        25%          0.000000       0.000000       0.000000           0.000000
        50%          0.000000       0.000000       0.000000           0.000000
        75%          0.000000       0.000000       0.000000           0.000000
        max          3.000000       3.000000      30.000000           5.000000

                   logged_in  num_compromised             ...              \
        count  494021.000000    494021.000000             ...
        mean        0.148247         0.010212             ...
        std         0.355345         1.798326             ...
```

```
min         0.000000          0.000000              ...
25%         0.000000          0.000000              ...
50%         0.000000          0.000000              ...
75%         0.000000          0.000000              ...
max         1.000000        884.000000              ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   494021.000000       494021.000000           494021.000000
mean       232.470778          188.665670                0.753780
std         64.745380          106.040437                0.410781
min          0.000000            0.000000                0.000000
25%        255.000000           46.000000                0.410000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           494021.000000                494021.000000
mean                 0.030906                     0.601935
std                  0.109259                     0.481309
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.040000                     1.000000
max                  1.000000                     1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                494021.000000         494021.000000
mean                      0.006684              0.176754
std                       0.042133              0.380593
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
75%                       0.000000              0.000000
max                       1.000000              1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             494021.000000         494021.000000
mean                   0.176443              0.058118
std                    0.380919              0.230590
min                    0.000000              0.000000
25%                    0.000000              0.000000
50%                    0.000000              0.000000
75%                    0.000000              0.000000
max                    1.000000              1.000000

       dst_host_srv_rerror_rate
count             494021.000000
```

```
mean                   0.057412
std                    0.230140
min                    0.000000
25%                    0.000000
50%                    0.000000
75%                    0.000000
max                    1.000000

[8 rows x 38 columns]
```

In [6]:
```
#Do the same for test data to keep the columns consistent

kdd_test_10per_mod = kdd_test_10percent[new_labels]
kdd_test_10per_mod.shape
kdd_test_10per_mod.describe()
```

Out[6]:
```
(311029, 39)
```

Out[6]:
```
              duration     src_bytes     dst_bytes           land  \
count  311029.000000  3.110290e+05  3.110290e+05  311029.000000
mean       17.902736  1.731702e+03  7.479937e+02       0.000029
std       407.644400  1.276567e+05  1.612018e+04       0.005379
min         0.000000  0.000000e+00  0.000000e+00       0.000000
25%         0.000000  1.050000e+02  0.000000e+00       0.000000
50%         0.000000  5.200000e+02  0.000000e+00       0.000000
75%         0.000000  1.032000e+03  0.000000e+00       0.000000
max     57715.000000  6.282565e+07  5.203179e+06       1.000000

       wrong_fragment         urgent            hot  num_failed_logins  \
count   311029.000000  311029.000000  311029.000000      311029.000000
mean         0.000762       0.000051       0.014677           0.002363
std          0.040367       0.009821       0.312068           0.049990
min          0.000000       0.000000       0.000000           0.000000
25%          0.000000       0.000000       0.000000           0.000000
50%          0.000000       0.000000       0.000000           0.000000
75%          0.000000       0.000000       0.000000           0.000000
max          3.000000       3.000000     101.000000           4.000000

            logged_in  num_compromised            ...             \
count  311029.000000    311029.000000            ...
mean        0.172476         0.011243            ...
std         0.377794         1.958325            ...
min         0.000000         0.000000            ...
25%         0.000000         0.000000            ...
50%         0.000000         0.000000            ...
75%         0.000000         0.000000            ...
max         1.000000       796.000000            ...
```

	dst_host_count	dst_host_srv_count	dst_host_same_srv_rate \
count	311029.000000	311029.000000	311029.000000
mean	235.282681	199.193914	0.793494
std	60.913298	100.306470	0.387090
min	0.000000	0.000000	0.000000
25%	255.000000	244.000000	0.970000
50%	255.000000	255.000000	1.000000
75%	255.000000	255.000000	1.000000
max	255.000000	255.000000	1.000000

	dst_host_diff_srv_rate	dst_host_same_src_port_rate \
count	311029.000000	311029.000000
mean	0.024953	0.547919
std	0.096003	0.491963
min	0.000000	0.000000
25%	0.000000	0.000000
50%	0.000000	1.000000
75%	0.010000	1.000000
max	1.000000	1.000000

	dst_host_srv_diff_host_rate	dst_host_serror_rate \
count	311029.000000	311029.000000
mean	0.004566	0.058764
std	0.035773	0.231296
min	0.000000	0.000000
25%	0.000000	0.000000
50%	0.000000	0.000000
75%	0.000000	0.000000
max	1.000000	1.000000

	dst_host_srv_serror_rate	dst_host_rerror_rate \
count	311029.000000	311029.000000
mean	0.058791	0.142659
std	0.232997	0.344380
min	0.000000	0.000000
25%	0.000000	0.000000
50%	0.000000	0.000000
75%	0.000000	0.000000
max	1.000000	1.000000

	dst_host_srv_rerror_rate
count	311029.000000
mean	0.141693
std	0.346573
min	0.000000
25%	0.000000
50%	0.000000
75%	0.000000

```
max                      1.000000

[8 rows x 38 columns]
```

In [7]:
```
#Exploring the target variable
#According to the data documentation the attack types can be divided into "normal" and 4

attack_labs_all = kdd_train_10per_mod['attack_type'].copy()
len(attack_labs_all.unique())

dos_list = ["back.","land.","neptune.","pod.","smurf.","teardrop."]
utr_list = ["buffer_overflow.","loadmodule.","perl.","rootkit."]
rtl_list = ["ftp_write.","guess_passwd.","imap.","multihop.","phf.","spy.","warezclient.
probe_list = ["ipsweep.","nmap.","portsweep.","satan."]

attack_labs_all[attack_labs_all.isin(dos_list)] = "DOS."
attack_labs_all[attack_labs_all.isin(utr_list)] = "U2R"
attack_labs_all[attack_labs_all.isin(rtl_list)] = "R2L."
attack_labs_all[attack_labs_all.isin(probe_list)] = "probe."

df = attack_labs_all.value_counts()
print(df)
plt.figure()
df.plot(kind='bar')
plt.xlabel("Attack Types in Training Data")
plt.ylabel("Value Counts")

#We see that majority of the attacks are DOS attacks (98.67 percent)
#So for simplicity we will just classify the labels as "normal." and "bad." attacks

#Checking in the test dataset as well (has extra attack types too)
attack_labs_tall = kdd_test_10per_mod['attack_type'].copy()
len(attack_labs_tall.unique())

dos_list = ["back.","land.","neptune.","pod.","smurf.","teardrop.","apache2.","mailbomb.
utr_list = ["buffer_overflow.","loadmodule.","perl.","rootkit.","ps.","sqlattack.","xter
rtl_list = ["ftp_write.","guess_passwd.","imap.","multihop.","phf.","spy.","warezclient.
            "sendmail.","snmpgetattack.","snmpguess.","worm.","xlock.","xsnoop."]
probe_list = ["ipsweep.","nmap.","portsweep.","satan.","mscan.","saint."]

attack_labs_tall[attack_labs_tall.isin(dos_list)] = "DOS."
attack_labs_tall[attack_labs_tall.isin(utr_list)] = "U2R"
attack_labs_tall[attack_labs_tall.isin(rtl_list)] = "R2L."
attack_labs_tall[attack_labs_tall.isin(probe_list)] = "probe."

df = attack_labs_tall.value_counts()
print(df)
plt.figure()
```

```
df.plot(kind='bar')
plt.xlabel("Attack Types in Test Data")
plt.ylabel("Value Counts")

#Here too we see extra attack types but maximum of the labels (out of all attack types)
```

Out[7]: 23

```
DOS.       391458
normal.     97278
probe.       4107
R2L.         1126
U2R            52
Name: attack_type, dtype: int64
```

Out[7]: <matplotlib.figure.Figure at 0x221cd5c54a8>

Out[7]: <matplotlib.axes._subplots.AxesSubplot at 0x221cd5c5c50>

Out[7]: Text(0.5,0,'Attack Types in Training Data')

Out[7]: Text(0,0.5,'Value Counts')

Out[7]: 38

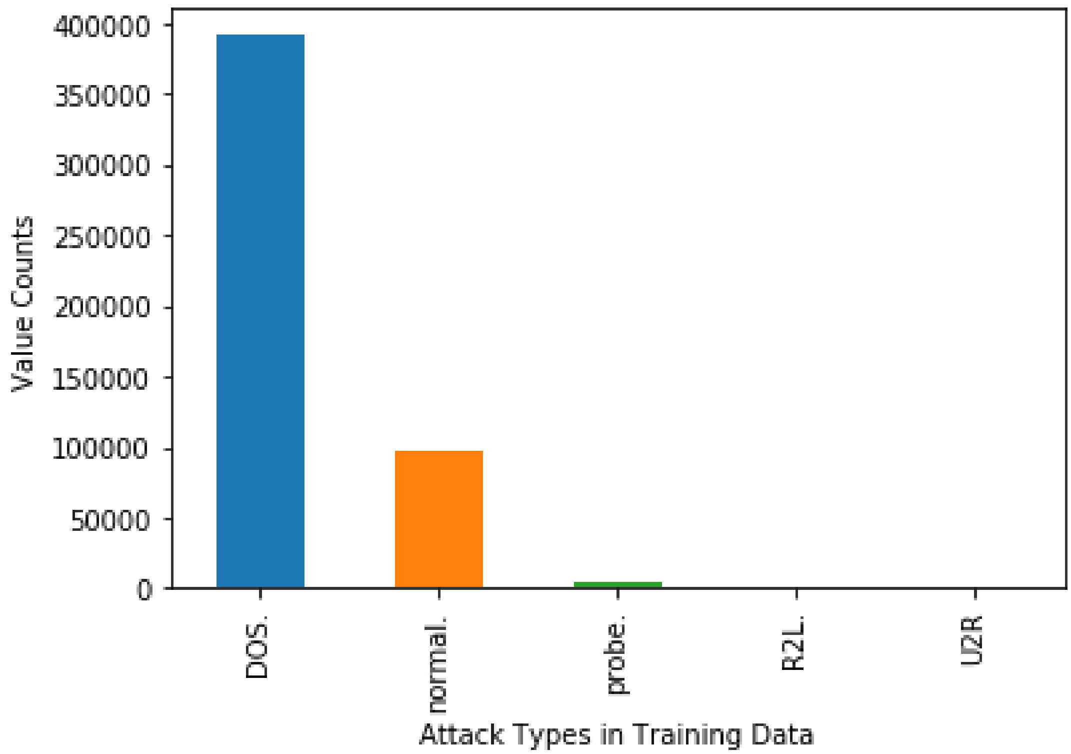
```
DOS.       229853
normal.     60593
R2L.        16189
probe.       4166
U2R           228
Name: attack_type, dtype: int64
```

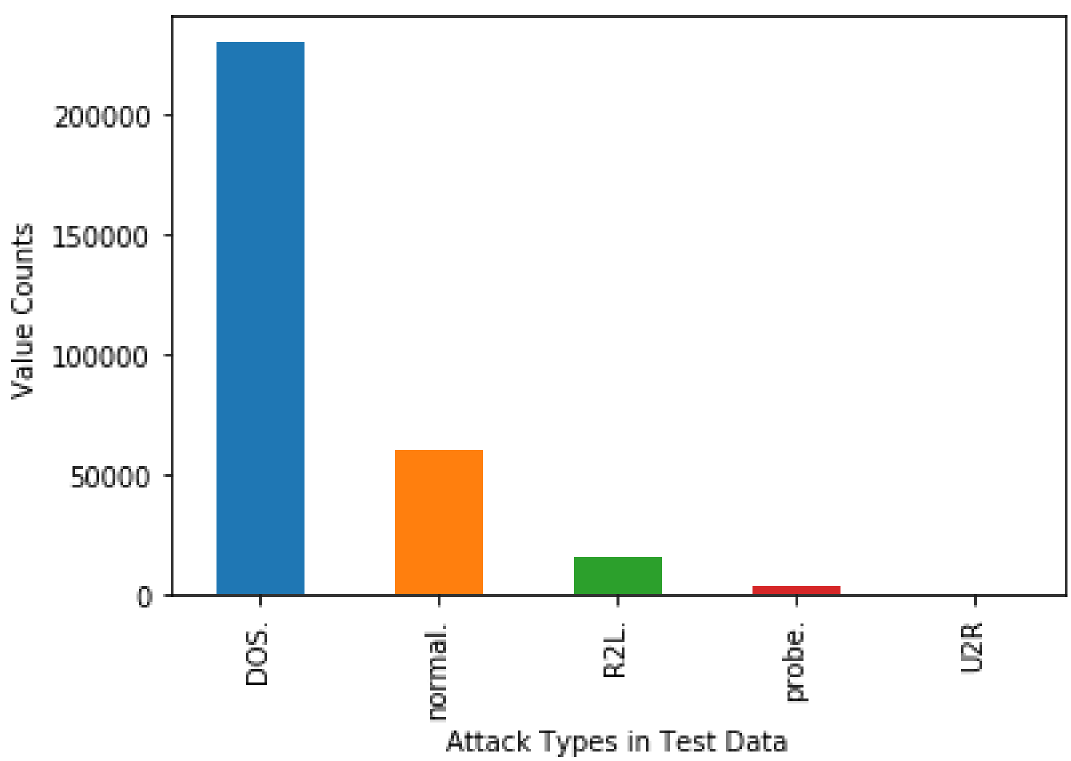
Out[7]: <matplotlib.figure.Figure at 0x221cdf1f630>

Out[7]: <matplotlib.axes._subplots.AxesSubplot at 0x221cdebed68>

Out[7]: Text(0.5,0,'Attack Types in Test Data')

Out[7]: Text(0,0.5,'Value Counts')


Value Counts
400000
350000
300000
250000
200000
150000
100000
50000
0
DOS.
normal.
probe.
R2L.
U2R
Attack Types in Training Data

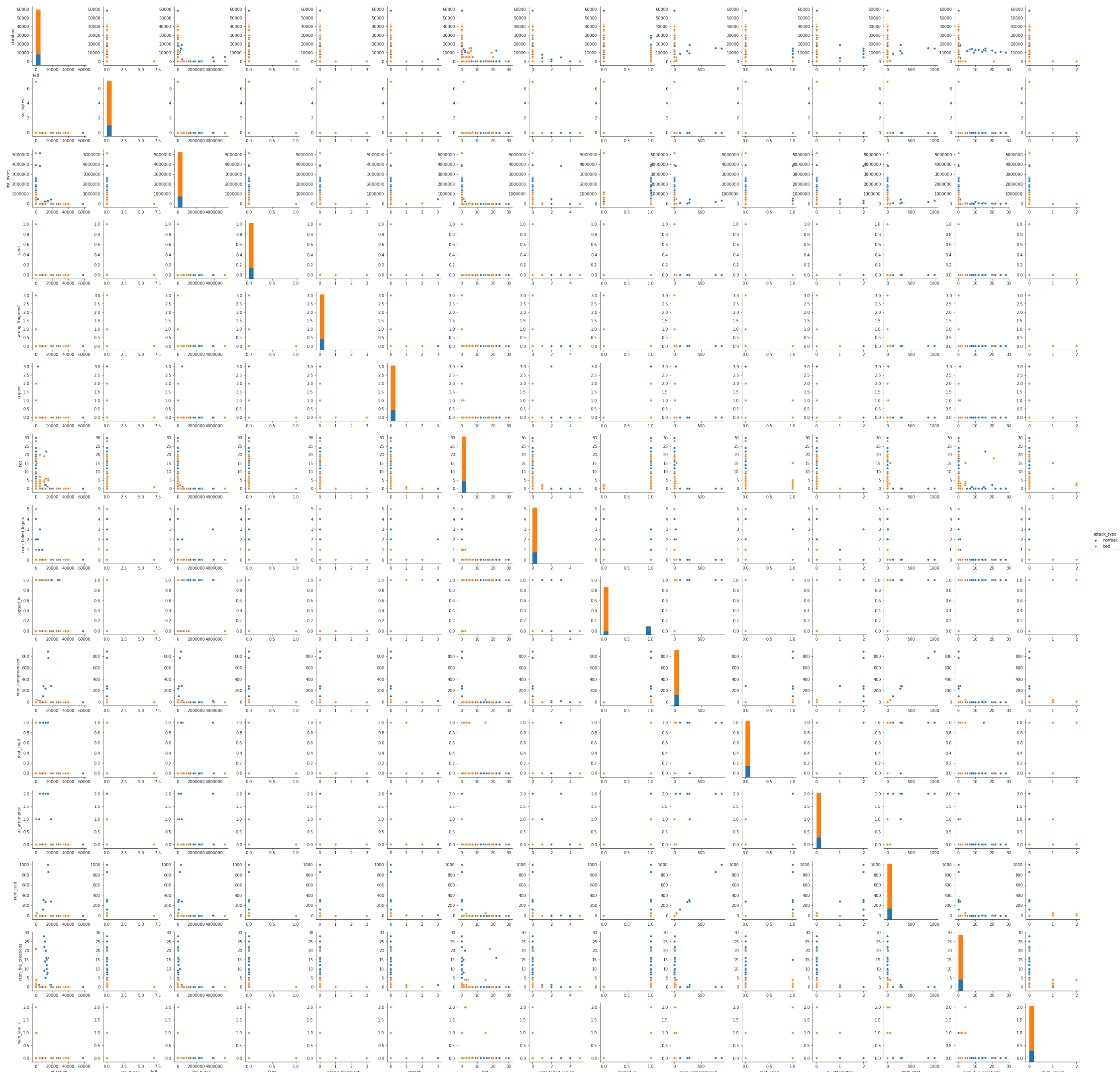

Value Counts
200000
150000
100000
50000
0
DOS.
normal.
R2L.
probe.
U2R
Attack Types in Test Data

In [13]:
```
#change the labels to only show 'normal' and 'bad' as the attack types
attack_labs = kdd_train_10per_mod['attack_type'].copy()
attack_labs[attack_labs!='normal.'] = 'bad.'
attack_labs.value_counts()
```

Out[13]:
```
bad.       396743
normal.     97278
Name: attack_type, dtype: int64
```

In [21]:
```
#Creating pairplots for some continuous variables (first 15) in the training dataset
train_data_for_pairplot = pd.concat([kdd_train_10per_mod.iloc[:,0:15],attack_labs], axi

#Pairplot
var_plot = sns.pairplot(data = train_data_for_pairplot, hue = "attack_type", kind='scat
plt.show()
#var_plot.savefig("pairplot.png")
```

Out[21]:
```
bad.       396743
normal.     97278
Name: attack_type, dtype: int64
```



Even though we have plotted the distributions and correlations for the first few variables, we can make two important observations: the data seems skewed and there do not seem to be a lot of strong linear correlations visible between these variables. Since we will be using machine learning techniques like K-Nearest Neighbors (involving distance metrics) along with other algorithms and will also be verifying results using clustering (unsupervised check), we should scale the continuous variables.

1.1.3 Data Preprocessing : Scaling

In this step, we scale the continuous variables in our training dataset as part of the data preprocessing. We will later use the same transformation for the test data.

```
In [8]: #Creating train dataset without the target column for scaling

        kdd_train_10per_var = kdd_train_10per_mod.iloc[:,0:38]
```

```
kdd_train_10per_var.shape
kdd_train_10per_var.describe()
kdd_train_10per_var.head(10)
type(kdd_train_10per_var)

#Scaling only for continuous variables -- so we remove the discrete variables
#Creating a list of the discrete valued columns (mentioned in the documentation for the
cont_labels = ["duration","src_bytes", "dst_bytes","wrong_fragment","urgent","hot","num_
    "num_compromised","num_root","num_file_creations","num_shells","num_access_files","n
    "count","srv_count","serror_rate","srv_serror_rate","rerror_rate","srv_rerror_rate",
    "diff_srv_rate","srv_diff_host_rate","dst_host_count","dst_host_srv_count","dst_host
    "dst_host_srv_diff_host_rate","dst_host_serror_rate","dst_host_srv_serror_rate","dst
other_labels = ["land","logged_in","root_shell","su_attempted","is_host_login","is_guest
kdd_train_10per_forscale = kdd_train_10per_mod[cont_labels]
kdd_train_10per_forscale.shape
kdd_train_10per_forscale.describe()

kdd_train_10per_others = kdd_train_10per_mod[other_labels]
kdd_train_10per_others.shape
kdd_train_10per_others.describe()
```

Out[8]: (494021, 38)

Out[8]:

```
            duration     src_bytes     dst_bytes           land  \
count  494021.000000  4.940210e+05  4.940210e+05  494021.000000
mean       47.979302  3.025610e+03  8.685324e+02       0.000045
std       707.746472  9.882181e+05  3.304000e+04       0.006673
min         0.000000  0.000000e+00  0.000000e+00       0.000000
25%         0.000000  4.500000e+01  0.000000e+00       0.000000
50%         0.000000  5.200000e+02  0.000000e+00       0.000000
75%         0.000000  1.032000e+03  0.000000e+00       0.000000
max     58329.000000  6.933756e+08  5.155468e+06       1.000000

       wrong_fragment         urgent            hot  num_failed_logins  \
count   494021.000000  494021.000000  494021.000000      494021.000000
mean         0.006433       0.000014       0.034519           0.000152
std          0.134805       0.005510       0.782103           0.015520
min          0.000000       0.000000       0.000000           0.000000
25%          0.000000       0.000000       0.000000           0.000000
50%          0.000000       0.000000       0.000000           0.000000
75%          0.000000       0.000000       0.000000           0.000000
max          3.000000       3.000000      30.000000           5.000000

           logged_in  num_compromised              ...               \
count  494021.000000    494021.000000              ...
mean        0.148247         0.010212              ...
std         0.355345         1.798326              ...
min         0.000000         0.000000              ...
```

```
25%          0.000000        0.000000               ...
50%          0.000000        0.000000               ...
75%          0.000000        0.000000               ...
max          1.000000      884.000000               ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   494021.000000       494021.000000           494021.000000
mean       232.470778          188.665670                0.753780
std         64.745380          106.040437                0.410781
min          0.000000            0.000000                0.000000
25%        255.000000           46.000000                0.410000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           494021.000000                494021.000000
mean                 0.030906                     0.601935
std                  0.109259                     0.481309
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.040000                     1.000000
max                  1.000000                     1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                494021.000000         494021.000000
mean                      0.006684              0.176754
std                       0.042133              0.380593
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
75%                       0.000000              0.000000
max                       1.000000              1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             494021.000000         494021.000000
mean                   0.176443              0.058118
std                    0.380919              0.230590
min                    0.000000              0.000000
25%                    0.000000              0.000000
50%                    0.000000              0.000000
75%                    0.000000              0.000000
max                    1.000000              1.000000

       dst_host_srv_rerror_rate
count             494021.000000
mean                   0.057412
```

```
std                      0.230140
min                      0.000000
25%                      0.000000
50%                      0.000000
75%                      0.000000
max                      1.000000

[8 rows x 38 columns]
```

Out[8]:

```
   duration  src_bytes  dst_bytes  land  wrong_fragment  urgent  hot  \
0         0        181       5450     0               0       0    0
1         0        239        486     0               0       0    0
2         0        235       1337     0               0       0    0
3         0        219       1337     0               0       0    0
4         0        217       2032     0               0       0    0
5         0        217       2032     0               0       0    0
6         0        212       1940     0               0       0    0
7         0        159       4087     0               0       0    0
8         0        210        151     0               0       0    0
9         0        212        786     0               0       0    1

   num_failed_logins  logged_in  num_compromised         ...           \
0                  0          1                0         ...
1                  0          1                0         ...
2                  0          1                0         ...
3                  0          1                0         ...
4                  0          1                0         ...
5                  0          1                0         ...
6                  0          1                0         ...
7                  0          1                0         ...
8                  0          1                0         ...
9                  0          1                0         ...

   dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
0               9                   9                     1.0
1              19                  19                     1.0
2              29                  29                     1.0
3              39                  39                     1.0
4              49                  49                     1.0
5              59                  59                     1.0
6               1                  69                     1.0
7              11                  79                     1.0
8               8                  89                     1.0
9               8                  99                     1.0

   dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
0                     0.0                         0.11
1                     0.0                         0.05
```

```
2                     0.0                        0.03
3                     0.0                        0.03
4                     0.0                        0.02
5                     0.0                        0.02
6                     0.0                        1.00
7                     0.0                        0.09
8                     0.0                        0.12
9                     0.0                        0.12

   dst_host_srv_diff_host_rate  dst_host_serror_rate  \
0                         0.00                   0.0
1                         0.00                   0.0
2                         0.00                   0.0
3                         0.00                   0.0
4                         0.00                   0.0
5                         0.00                   0.0
6                         0.04                   0.0
7                         0.04                   0.0
8                         0.04                   0.0
9                         0.05                   0.0

   dst_host_srv_serror_rate  dst_host_rerror_rate  dst_host_srv_rerror_rate
0                       0.0                   0.0                       0.0
1                       0.0                   0.0                       0.0
2                       0.0                   0.0                       0.0
3                       0.0                   0.0                       0.0
4                       0.0                   0.0                       0.0
5                       0.0                   0.0                       0.0
6                       0.0                   0.0                       0.0
7                       0.0                   0.0                       0.0
8                       0.0                   0.0                       0.0
9                       0.0                   0.0                       0.0

[10 rows x 38 columns]
```

Out[8]:
```
pandas.core.frame.DataFrame
```

Out[8]:
```
(494021, 32)
```

Out[8]:
```
             duration     src_bytes     dst_bytes  wrong_fragment  \
count  494021.000000  4.940210e+05  4.940210e+05   494021.000000
mean       47.979302  3.025610e+03  8.685324e+02        0.006433
std       707.746472  9.882181e+05  3.304000e+04        0.134805
min         0.000000  0.000000e+00  0.000000e+00        0.000000
25%         0.000000  4.500000e+01  0.000000e+00        0.000000
50%         0.000000  5.200000e+02  0.000000e+00        0.000000
75%         0.000000  1.032000e+03  0.000000e+00        0.000000
max     58329.000000  6.933756e+08  5.155468e+06        3.000000
```

```
              urgent            hot  num_failed_logins  num_compromised  \
count  494021.000000  494021.000000      494021.000000    494021.000000
mean        0.000014       0.034519           0.000152         0.010212
std         0.005510       0.782103           0.015520         1.798326
min         0.000000       0.000000           0.000000         0.000000
25%         0.000000       0.000000           0.000000         0.000000
50%         0.000000       0.000000           0.000000         0.000000
75%         0.000000       0.000000           0.000000         0.000000
max         3.000000      30.000000           5.000000       884.000000

            num_root  num_file_creations             ...             \
count  494021.000000       494021.000000             ...
mean        0.011352            0.001083             ...
std         2.012718            0.096416             ...
min         0.000000            0.000000             ...
25%         0.000000            0.000000             ...
50%         0.000000            0.000000             ...
75%         0.000000            0.000000             ...
max       993.000000           28.000000             ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   494021.000000       494021.000000           494021.000000
mean       232.470778          188.665670                0.753780
std         64.745380          106.040437                0.410781
min          0.000000            0.000000                0.000000
25%        255.000000           46.000000                0.410000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           494021.000000                494021.000000
mean                 0.030906                     0.601935
std                  0.109259                     0.481309
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.040000                     1.000000
max                  1.000000                     1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                494021.000000         494021.000000
mean                      0.006684              0.176754
std                       0.042133              0.380593
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
```

```
75%                        0.000000               0.000000
max                        1.000000               1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             494021.000000         494021.000000
mean                   0.176443              0.058118
std                    0.380919              0.230590
min                    0.000000              0.000000
25%                    0.000000              0.000000
50%                    0.000000              0.000000
75%                    0.000000              0.000000
max                    1.000000              1.000000

       dst_host_srv_rerror_rate
count             494021.000000
mean                   0.057412
std                    0.230140
min                    0.000000
25%                    0.000000
50%                    0.000000
75%                    0.000000
max                    1.000000

[8 rows x 32 columns]
```

Out[8]: (494021, 6)

Out[8]:

```
                land      logged_in     root_shell   su_attempted  \
count  494021.000000  494021.000000  494021.000000  494021.000000
mean        0.000045       0.148247       0.000111       0.000036
std         0.006673       0.355345       0.010551       0.007793
min         0.000000       0.000000       0.000000       0.000000
25%         0.000000       0.000000       0.000000       0.000000
50%         0.000000       0.000000       0.000000       0.000000
75%         0.000000       0.000000       0.000000       0.000000
max         1.000000       1.000000       1.000000       2.000000

       is_host_login  is_guest_login
count       494021.0   494021.000000
mean             0.0        0.001387
std              0.0        0.037211
min              0.0        0.000000
25%              0.0        0.000000
50%              0.0        0.000000
75%              0.0        0.000000
max              0.0        1.000000
```

In [9]:

```
#Now we scale the training dataset
```

```python
from sklearn import preprocessing

#Keeping the scaling parameters from the training dataset to be later applied to the tes
train_scaler = preprocessing.StandardScaler().fit(kdd_train_10per_forscale)
train_scaler

train_scaler.mean_
train_scaler.scale_

#scaling the train dataset
kdd_train_10per_scaled1 = pd.DataFrame(data = train_scaler.transform(kdd_train_10per_for
kdd_train_10per_scaled1.shape
kdd_train_10per_scaled1.describe()
kdd_train_10per_scaled1.head(10)

#adding the binary valued variable columns
kdd_train_10per_scaled = pd.concat([kdd_train_10per_scaled1,kdd_train_10per_others], axi
kdd_train_10per_scaled.shape
kdd_train_10per_scaled.describe()
kdd_train_10per_scaled.head(10)
```

Out[9]:
```
StandardScaler(copy=True, with_mean=True, with_std=True)
```

Out[9]:
```
array([  4.79793025e+01,   3.02561030e+03,   8.68532425e+02,
         6.43292492e-03,   1.41694381e-05,   3.45187755e-02,
         1.51815409e-04,   1.02121165e-02,   1.13517442e-02,
         1.08294992e-03,   1.09307094e-04,   1.00805431e-03,
         0.00000000e+00,   3.32285690e+02,   2.92906557e+02,
         1.76686659e-01,   1.76608808e-01,   5.74334087e-02,
         5.77189431e-02,   7.91547343e-01,   2.09823874e-02,
         2.89968038e-02,   2.32470778e+02,   1.88665670e+02,
         7.53779698e-01,   3.09057307e-02,   6.01934756e-01,
         6.68350131e-03,   1.76753964e-01,   1.76442621e-01,
         5.81176104e-02,   5.74116687e-02])
```

Out[9]:
```
array([  7.07745756e+02,   9.88217101e+05,   3.30399678e+04,
         1.34805112e-01,   5.51025235e-03,   7.82101790e-01,
         1.55195812e-02,   1.79832444e+00,   2.01271629e+00,
         9.64157811e-02,   1.10199990e-02,   3.64816531e-02,
         1.00000000e+00,   2.13147196e+02,   2.46322568e+02,
         3.80716571e-01,   3.81016199e-01,   2.31623239e-01,
         2.32146746e-01,   3.88189100e-01,   8.22054097e-02,
         1.42397323e-01,   6.47453148e+01,   1.06040330e+02,
         4.10780562e-01,   1.09259002e-01,   4.81308764e-01,
         4.21328318e-02,   3.80592712e-01,   3.80919063e-01,
         2.30589274e-01,   2.30140091e-01])
```

Out[9]:
```
(494021, 32)
```

Out[9]:

	duration	src_bytes	dst_bytes	wrong_fragment	urgent	\
count	4.940210e+05	4.940210e+05	4.940210e+05	4.940210e+05	4.940210e+05	
mean	-3.625574e-14	-1.320064e-14	-5.498890e-14	-6.073146e-15	-1.529804e-14	
std	1.000001e+00	1.000001e+00	1.000001e+00	1.000001e+00	1.000001e+00	
min	-6.779172e-02	-3.061686e-03	-2.628733e-02	-4.772019e-02	-2.571468e-03	
25%	-6.779172e-02	-3.016149e-03	-2.628733e-02	-4.772019e-02	-2.571468e-03	
50%	-6.779172e-02	-2.535486e-03	-2.628733e-02	-4.772019e-02	-2.571468e-03	
75%	-6.779172e-02	-2.017381e-03	-2.628733e-02	-4.772019e-02	-2.571468e-03	
max	8.234740e+01	7.016400e+02	1.560110e+02	2.220663e+01	5.444371e+02	

	hot	num_failed_logins	num_compromised	num_root	\
count	4.940210e+05	4.940210e+05	4.940210e+05	4.940210e+05	
mean	-6.957988e-14	-8.038565e-14	-1.113045e-14	-1.364308e-14	
std	1.000001e+00	1.000001e+00	1.000001e+00	1.000001e+00	
min	-4.413591e-02	-9.782185e-03	-5.678684e-03	-5.640012e-03	
25%	-4.413591e-02	-9.782185e-03	-5.678684e-03	-5.640012e-03	
50%	-4.413591e-02	-9.782185e-03	-5.678684e-03	-5.640012e-03	
75%	-4.413591e-02	-9.782185e-03	-5.678684e-03	-5.640012e-03	
max	3.831404e+01	3.221639e+02	4.915630e+02	4.933575e+02	

	num_file_creations	...	dst_host_count	\
count	4.940210e+05	...	4.940210e+05	
mean	1.653658e-14	...	-7.353653e-13	
std	1.000001e+00	...	1.000001e+00	
min	-1.123208e-02	...	-3.590542e+00	
25%	-1.123208e-02	...	3.479668e-01	
50%	-1.123208e-02	...	3.479668e-01	
75%	-1.123208e-02	...	3.479668e-01	
max	2.903977e+02	...	3.479668e-01	

	dst_host_srv_count	dst_host_same_srv_rate	dst_host_diff_srv_rate	\
count	4.940210e+05	4.940210e+05	4.940210e+05	
mean	1.953080e-13	3.799918e-13	-1.392772e-13	
std	1.000001e+00	1.000001e+00	1.000001e+00	
min	-1.779188e+00	-1.834994e+00	-2.828667e-01	
25%	-1.345391e+00	-8.368938e-01	-2.828667e-01	
50%	6.255576e-01	5.993962e-01	-2.828667e-01	
75%	6.255576e-01	5.993962e-01	8.323588e-02	
max	6.255576e-01	5.993962e-01	8.869697e+00	

	dst_host_same_src_port_rate	dst_host_srv_diff_host_rate	\
count	4.940210e+05	4.940210e+05	
mean	7.581150e-13	2.700207e-13	
std	1.000001e+00	1.000001e+00	
min	-1.250621e+00	-1.586293e-01	
25%	-1.250621e+00	-1.586293e-01	
50%	8.270476e-01	-1.586293e-01	
75%	8.270476e-01	-1.586293e-01	

```
max                   8.270476e-01                 2.357583e+01

       dst_host_serror_rate  dst_host_srv_serror_rate  dst_host_rerror_rate  \
count          4.940210e+05              4.940210e+05          4.940210e+05
mean           2.263813e-13              3.603748e-13          6.990594e-13
std            1.000001e+00              1.000001e+00          1.000001e+00
min           -4.644176e-01             -4.632024e-01         -2.520395e-01
25%           -4.644176e-01             -4.632024e-01         -2.520395e-01
50%           -4.644176e-01             -4.632024e-01         -2.520395e-01
75%           -4.644176e-01             -4.632024e-01         -2.520395e-01
max            2.163063e+00              2.162027e+00          4.084676e+00

       dst_host_srv_rerror_rate
count              4.940210e+05
mean              -9.654619e-14
std                1.000001e+00
min               -2.494640e-01
25%               -2.494640e-01
50%               -2.494640e-01
75%               -2.494640e-01
max                4.095715e+00

[8 rows x 32 columns]
```

Out[9]:

```
   duration  src_bytes  dst_bytes  wrong_fragment    urgent       hot  \
0 -0.067792  -0.002879   0.138664        -0.04772 -0.002571 -0.044136
1 -0.067792  -0.002820  -0.011578        -0.04772 -0.002571 -0.044136
2 -0.067792  -0.002824   0.014179        -0.04772 -0.002571 -0.044136
3 -0.067792  -0.002840   0.014179        -0.04772 -0.002571 -0.044136
4 -0.067792  -0.002842   0.035214        -0.04772 -0.002571 -0.044136
5 -0.067792  -0.002842   0.035214        -0.04772 -0.002571 -0.044136
6 -0.067792  -0.002847   0.032429        -0.04772 -0.002571 -0.044136
7 -0.067792  -0.002901   0.097411        -0.04772 -0.002571 -0.044136
8 -0.067792  -0.002849  -0.021717        -0.04772 -0.002571 -0.044136
9 -0.067792  -0.002847  -0.002498        -0.04772 -0.002571  1.234470

   num_failed_logins  num_compromised  num_root  num_file_creations  \
0          -0.009782        -0.005679  -0.00564           -0.011232
1          -0.009782        -0.005679  -0.00564           -0.011232
2          -0.009782        -0.005679  -0.00564           -0.011232
3          -0.009782        -0.005679  -0.00564           -0.011232
4          -0.009782        -0.005679  -0.00564           -0.011232
5          -0.009782        -0.005679  -0.00564           -0.011232
6          -0.009782        -0.005679  -0.00564           -0.011232
7          -0.009782        -0.005679  -0.00564           -0.011232
8          -0.009782        -0.005679  -0.00564           -0.011232
9          -0.009782        -0.005679  -0.00564           -0.011232
```

	...	dst_host_count	dst_host_srv_count	\
0	...	-3.451536	-1.694315	
1	...	-3.297085	-1.600011	
2	...	-3.142633	-1.505707	
3	...	-2.988182	-1.411403	
4	...	-2.833731	-1.317100	
5	...	-2.679279	-1.222796	
6	...	-3.575097	-1.128492	
7	...	-3.420646	-1.034188	
8	...	-3.466981	-0.939885	
9	...	-3.466981	-0.845581	

	dst_host_same_srv_rate	dst_host_diff_srv_rate	\
0	0.599396	-0.282867	
1	0.599396	-0.282867	
2	0.599396	-0.282867	
3	0.599396	-0.282867	
4	0.599396	-0.282867	
5	0.599396	-0.282867	
6	0.599396	-0.282867	
7	0.599396	-0.282867	
8	0.599396	-0.282867	
9	0.599396	-0.282867	

	dst_host_same_src_port_rate	dst_host_srv_diff_host_rate	\
0	-1.022077	-0.158629	
1	-1.146737	-0.158629	
2	-1.188291	-0.158629	
3	-1.188291	-0.158629	
4	-1.209067	-0.158629	
5	-1.209067	-0.158629	
6	0.827048	0.790749	
7	-1.063631	0.790749	
8	-1.001301	0.790749	
9	-1.001301	1.028094	

	dst_host_serror_rate	dst_host_srv_serror_rate	dst_host_rerror_rate	\
0	-0.464418	-0.463202	-0.25204	
1	-0.464418	-0.463202	-0.25204	
2	-0.464418	-0.463202	-0.25204	
3	-0.464418	-0.463202	-0.25204	
4	-0.464418	-0.463202	-0.25204	
5	-0.464418	-0.463202	-0.25204	
6	-0.464418	-0.463202	-0.25204	
7	-0.464418	-0.463202	-0.25204	
8	-0.464418	-0.463202	-0.25204	
9	-0.464418	-0.463202	-0.25204	

```
   dst_host_srv_rerror_rate
0                 -0.249464
1                 -0.249464
2                 -0.249464
3                 -0.249464
4                 -0.249464
5                 -0.249464
6                 -0.249464
7                 -0.249464
8                 -0.249464
9                 -0.249464

[10 rows x 32 columns]
```

Out[9]:
```
(494021, 38)
```

Out[9]:
```
           duration     src_bytes     dst_bytes  wrong_fragment        urgent  \
count  4.940210e+05  4.940210e+05  4.940210e+05    4.940210e+05  4.940210e+05
mean  -3.625574e-14 -1.320064e-14 -5.498890e-14   -6.073146e-15 -1.529804e-14
std    1.000001e+00  1.000001e+00  1.000001e+00    1.000001e+00  1.000001e+00
min   -6.779172e-02 -3.061686e-03 -2.628733e-02   -4.772019e-02 -2.571468e-03
25%   -6.779172e-02 -3.016149e-03 -2.628733e-02   -4.772019e-02 -2.571468e-03
50%   -6.779172e-02 -2.535486e-03 -2.628733e-02   -4.772019e-02 -2.571468e-03
75%   -6.779172e-02 -2.017381e-03 -2.628733e-02   -4.772019e-02 -2.571468e-03
max    8.234740e+01  7.016400e+02  1.560110e+02    2.220663e+01  5.444371e+02

                hot  num_failed_logins  num_compromised      num_root  \
count  4.940210e+05       4.940210e+05     4.940210e+05  4.940210e+05
mean  -6.957988e-14      -8.038565e-14    -1.113045e-14 -1.364308e-14
std    1.000001e+00       1.000001e+00     1.000001e+00  1.000001e+00
min   -4.413591e-02      -9.782185e-03    -5.678684e-03 -5.640012e-03
25%   -4.413591e-02      -9.782185e-03    -5.678684e-03 -5.640012e-03
50%   -4.413591e-02      -9.782185e-03    -5.678684e-03 -5.640012e-03
75%   -4.413591e-02      -9.782185e-03    -5.678684e-03 -5.640012e-03
max    3.831404e+01       3.221639e+02     4.915630e+02  4.933575e+02

       num_file_creations       ...        dst_host_serror_rate  \
count        4.940210e+05       ...                4.940210e+05
mean         1.653658e-14       ...                2.263813e-13
std          1.000001e+00       ...                1.000001e+00
min         -1.123208e-02       ...               -4.644176e-01
25%         -1.123208e-02       ...               -4.644176e-01
50%         -1.123208e-02       ...               -4.644176e-01
75%         -1.123208e-02       ...               -4.644176e-01
max          2.903977e+02       ...                2.163063e+00

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count              4.940210e+05          4.940210e+05
```

```
mean              3.603748e-13        6.990594e-13
std               1.000001e+00        1.000001e+00
min              -4.632024e-01       -2.520395e-01
25%              -4.632024e-01       -2.520395e-01
50%              -4.632024e-01       -2.520395e-01
75%              -4.632024e-01       -2.520395e-01
max               2.162027e+00        4.084676e+00

       dst_host_srv_rerror_rate           land      logged_in     root_shell  \
count              4.940210e+05  494021.000000  494021.000000  494021.000000
mean              -9.654619e-14       0.000045       0.148247       0.000111
std                1.000001e+00       0.006673       0.355345       0.010551
min               -2.494640e-01       0.000000       0.000000       0.000000
25%               -2.494640e-01       0.000000       0.000000       0.000000
50%               -2.494640e-01       0.000000       0.000000       0.000000
75%               -2.494640e-01       0.000000       0.000000       0.000000
max                4.095715e+00       1.000000       1.000000       1.000000

        su_attempted  is_host_login  is_guest_login
count  494021.000000       494021.0   494021.000000
mean        0.000036            0.0        0.001387
std         0.007793            0.0        0.037211
min         0.000000            0.0        0.000000
25%         0.000000            0.0        0.000000
50%         0.000000            0.0        0.000000
75%         0.000000            0.0        0.000000
max         2.000000            0.0        1.000000

[8 rows x 38 columns]
```

Out[9]:

```
   duration  src_bytes  dst_bytes  wrong_fragment    urgent       hot  \
0 -0.067792  -0.002879   0.138664        -0.04772 -0.002571 -0.044136
1 -0.067792  -0.002820  -0.011578        -0.04772 -0.002571 -0.044136
2 -0.067792  -0.002824   0.014179        -0.04772 -0.002571 -0.044136
3 -0.067792  -0.002840   0.014179        -0.04772 -0.002571 -0.044136
4 -0.067792  -0.002842   0.035214        -0.04772 -0.002571 -0.044136
5 -0.067792  -0.002842   0.035214        -0.04772 -0.002571 -0.044136
6 -0.067792  -0.002847   0.032429        -0.04772 -0.002571 -0.044136
7 -0.067792  -0.002901   0.097411        -0.04772 -0.002571 -0.044136
8 -0.067792  -0.002849  -0.021717        -0.04772 -0.002571 -0.044136
9 -0.067792  -0.002847  -0.002498        -0.04772 -0.002571  1.234470

   num_failed_logins  num_compromised  num_root  num_file_creations  \
0          -0.009782        -0.005679  -0.00564           -0.011232
1          -0.009782        -0.005679  -0.00564           -0.011232
2          -0.009782        -0.005679  -0.00564           -0.011232
3          -0.009782        -0.005679  -0.00564           -0.011232
4          -0.009782        -0.005679  -0.00564           -0.011232
```

```
5         -0.009782        -0.005679  -0.00564           -0.011232
6         -0.009782        -0.005679  -0.00564           -0.011232
7         -0.009782        -0.005679  -0.00564           -0.011232
8         -0.009782        -0.005679  -0.00564           -0.011232
9         -0.009782        -0.005679  -0.00564           -0.011232

        ...        dst_host_serror_rate  dst_host_srv_serror_rate  \
0       ...                   -0.464418                 -0.463202
1       ...                   -0.464418                 -0.463202
2       ...                   -0.464418                 -0.463202
3       ...                   -0.464418                 -0.463202
4       ...                   -0.464418                 -0.463202
5       ...                   -0.464418                 -0.463202
6       ...                   -0.464418                 -0.463202
7       ...                   -0.464418                 -0.463202
8       ...                   -0.464418                 -0.463202
9       ...                   -0.464418                 -0.463202

   dst_host_rerror_rate  dst_host_srv_rerror_rate  land  logged_in  \
0              -0.25204                 -0.249464     0          1
1              -0.25204                 -0.249464     0          1
2              -0.25204                 -0.249464     0          1
3              -0.25204                 -0.249464     0          1
4              -0.25204                 -0.249464     0          1
5              -0.25204                 -0.249464     0          1
6              -0.25204                 -0.249464     0          1
7              -0.25204                 -0.249464     0          1
8              -0.25204                 -0.249464     0          1
9              -0.25204                 -0.249464     0          1

   root_shell  su_attempted  is_host_login  is_guest_login
0           0             0              0               0
1           0             0              0               0
2           0             0              0               0
3           0             0              0               0
4           0             0              0               0
5           0             0              0               0
6           0             0              0               0
7           0             0              0               0
8           0             0              0               0
9           0             0              0               0

[10 rows x 38 columns]
```

In [10]:
```
#Applying the same transformations on the test dataset

kdd_test_10per_var = kdd_test_10per_mod.iloc[:,0:38]
kdd_test_10per_var.shape
```

```
kdd_test_10per_var.describe()
kdd_test_10per_var.head(10)
type(kdd_test_10per_var)

#Creating a list of the discrete valued columns (mentioned in the documentation for the
cont_labels = ["duration","src_bytes", "dst_bytes","wrong_fragment","urgent","hot","num
    "num_compromised","num_root","num_file_creations","num_shells","num_access_files","
    "count","srv_count","serror_rate","srv_serror_rate","rerror_rate","srv_rerror_rate"
    "diff_srv_rate","srv_diff_host_rate","dst_host_count","dst_host_srv_count","dst_hos
    "dst_host_srv_diff_host_rate","dst_host_serror_rate","dst_host_srv_serror_rate","ds
other_labels = ["land","logged_in","root_shell","su_attempted","is_host_login","is_gues
kdd_test_10per_forscale = kdd_test_10per_mod[cont_labels]
kdd_test_10per_forscale.shape
kdd_test_10per_forscale.describe()

kdd_test_10per_others = kdd_test_10per_mod[other_labels]
kdd_test_10per_others.shape
kdd_test_10per_others.describe()

#scaling the test dataset
kdd_test_10per_scaled1 = pd.DataFrame(data = train_scaler.transform(kdd_test_10per_fors
kdd_test_10per_scaled1.shape
kdd_test_10per_scaled1.describe()
kdd_test_10per_scaled1.head(10)

#adding the binary valued variable columns
kdd_test_10per_scaled = pd.concat([kdd_test_10per_scaled1,kdd_test_10per_others], axis=
kdd_test_10per_scaled.shape
kdd_test_10per_scaled.describe()
kdd_test_10per_scaled.head(10)
```

Out[10]: (311029, 38)

Out[10]:

```
            duration     src_bytes     dst_bytes           land  \
count  311029.000000  3.110290e+05  3.110290e+05  311029.000000
mean       17.902736  1.731702e+03  7.479937e+02       0.000029
std       407.644400  1.276567e+05  1.612018e+04       0.005379
min         0.000000  0.000000e+00  0.000000e+00       0.000000
25%         0.000000  1.050000e+02  0.000000e+00       0.000000
50%         0.000000  5.200000e+02  0.000000e+00       0.000000
75%         0.000000  1.032000e+03  0.000000e+00       0.000000
max     57715.000000  6.282565e+07  5.203179e+06       1.000000

       wrong_fragment         urgent            hot  num_failed_logins  \
count   311029.000000  311029.000000  311029.000000      311029.000000
mean         0.000762       0.000051       0.014677           0.002363
std          0.040367       0.009821       0.312068           0.049990
min          0.000000       0.000000       0.000000           0.000000
```

```
25%         0.000000      0.000000      0.000000            0.000000
50%         0.000000      0.000000      0.000000            0.000000
75%         0.000000      0.000000      0.000000            0.000000
max         3.000000      3.000000    101.000000            4.000000

           logged_in  num_compromised            ...              \
count  311029.000000    311029.000000            ...
mean        0.172476         0.011243            ...
std         0.377794         1.958325            ...
min         0.000000         0.000000            ...
25%         0.000000         0.000000            ...
50%         0.000000         0.000000            ...
75%         0.000000         0.000000            ...
max         1.000000       796.000000            ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   311029.000000       311029.000000           311029.000000
mean       235.282681          199.193914                0.793494
std         60.913298          100.306470                0.387090
min          0.000000            0.000000                0.000000
25%        255.000000          244.000000                0.970000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           311029.000000                311029.000000
mean                 0.024953                     0.547919
std                  0.096003                     0.491963
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.010000                     1.000000
max                  1.000000                     1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                311029.000000         311029.000000
mean                      0.004566              0.058764
std                       0.035773              0.231296
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
75%                       0.000000              0.000000
max                       1.000000              1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             311029.000000         311029.000000
mean                   0.058791              0.142659
```

```
std                       0.232997             0.344380
min                       0.000000             0.000000
25%                       0.000000             0.000000
50%                       0.000000             0.000000
75%                       0.000000             0.000000
max                       1.000000             1.000000

       dst_host_srv_rerror_rate
count             311029.000000
mean                   0.141693
std                    0.346573
min                    0.000000
25%                    0.000000
50%                    0.000000
75%                    0.000000
max                    1.000000

[8 rows x 38 columns]
```

Out[10]:

```
   duration  src_bytes  dst_bytes  land  wrong_fragment  urgent  hot  \
0         0        105        146     0               0       0    0
1         0        105        146     0               0       0    0
2         0        105        146     0               0       0    0
3         0        105        146     0               0       0    0
4         0        105        146     0               0       0    0
5         0        105        146     0               0       0    0
6         0         29          0     0               0       0    0
7         0        105        146     0               0       0    0
8         0        105        146     0               0       0    0
9         0        223        185     0               0       0    0

   num_failed_logins  logged_in  num_compromised            ...            \
0                  0          0                0            ...
1                  0          0                0            ...
2                  0          0                0            ...
3                  0          0                0            ...
4                  0          0                0            ...
5                  0          0                0            ...
6                  0          0                0            ...
7                  0          0                0            ...
8                  0          0                0            ...
9                  0          1                0            ...

   dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
0             255                 254                    1.00
1             255                 254                    1.00
2             255                 254                    1.00
3             255                 254                    1.00
```

```
4            255                  254                      1.00
5            255                  255                      1.00
6             10                    3                      0.30
7            255                  253                      0.99
8            255                  254                      1.00
9             71                  255                      1.00

   dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
0                    0.01                         0.00
1                    0.01                         0.00
2                    0.01                         0.00
3                    0.01                         0.00
4                    0.01                         0.01
5                    0.00                         0.01
6                    0.30                         0.30
7                    0.01                         0.00
8                    0.01                         0.00
9                    0.00                         0.01

   dst_host_srv_diff_host_rate  dst_host_serror_rate  \
0                         0.00                   0.0
1                         0.00                   0.0
2                         0.00                   0.0
3                         0.00                   0.0
4                         0.00                   0.0
5                         0.00                   0.0
6                         0.00                   0.0
7                         0.00                   0.0
8                         0.00                   0.0
9                         0.01                   0.0

   dst_host_srv_serror_rate  dst_host_rerror_rate  dst_host_srv_rerror_rate
0                       0.0                   0.0                       0.0
1                       0.0                   0.0                       0.0
2                       0.0                   0.0                       0.0
3                       0.0                   0.0                       0.0
4                       0.0                   0.0                       0.0
5                       0.0                   0.0                       0.0
6                       0.0                   0.0                       0.0
7                       0.0                   0.0                       0.0
8                       0.0                   0.0                       0.0
9                       0.0                   0.0                       0.0

[10 rows x 38 columns]
```

Out[10]: pandas.core.frame.DataFrame

Out[10]: (311029, 32)

Out[10]:

```
            duration     src_bytes     dst_bytes  wrong_fragment  \
count  311029.000000  3.110290e+05  3.110290e+05   311029.000000
mean       17.902736  1.731702e+03  7.479937e+02        0.000762
std       407.644400  1.276567e+05  1.612018e+04        0.040367
min         0.000000  0.000000e+00  0.000000e+00        0.000000
25%         0.000000  1.050000e+02  0.000000e+00        0.000000
50%         0.000000  5.200000e+02  0.000000e+00        0.000000
75%         0.000000  1.032000e+03  0.000000e+00        0.000000
max     57715.000000  6.282565e+07  5.203179e+06        3.000000

              urgent            hot  num_failed_logins  num_compromised  \
count  311029.000000  311029.000000      311029.000000    311029.000000
mean        0.000051       0.014677           0.002363         0.011243
std         0.009821       0.312068           0.049990         1.958325
min         0.000000       0.000000           0.000000         0.000000
25%         0.000000       0.000000           0.000000         0.000000
50%         0.000000       0.000000           0.000000         0.000000
75%         0.000000       0.000000           0.000000         0.000000
max         3.000000     101.000000           4.000000       796.000000

            num_root  num_file_creations            ...             \
count  311029.000000       311029.000000            ...
mean        0.008359            0.000958            ...
std         2.165196            0.193119            ...
min         0.000000            0.000000            ...
25%         0.000000            0.000000            ...
50%         0.000000            0.000000            ...
75%         0.000000            0.000000            ...
max       878.000000          100.000000            ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   311029.000000       311029.000000           311029.000000
mean       235.282681          199.193914                0.793494
std         60.913298          100.306470                0.387090
min          0.000000            0.000000                0.000000
25%        255.000000          244.000000                0.970000
50%        255.000000          255.000000                1.000000
75%        255.000000          255.000000                1.000000
max        255.000000          255.000000                1.000000

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           311029.000000                311029.000000
mean                 0.024953                     0.547919
std                  0.096003                     0.491963
min                  0.000000                     0.000000
25%                  0.000000                     0.000000
50%                  0.000000                     1.000000
75%                  0.010000                     1.000000
```

```
max                    1.000000                         1.000000

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                311029.000000         311029.000000
mean                      0.004566              0.058764
std                       0.035773              0.231296
min                       0.000000              0.000000
25%                       0.000000              0.000000
50%                       0.000000              0.000000
75%                       0.000000              0.000000
max                       1.000000              1.000000

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             311029.000000         311029.000000
mean                   0.058791              0.142659
std                    0.232997              0.344380
min                    0.000000              0.000000
25%                    0.000000              0.000000
50%                    0.000000              0.000000
75%                    0.000000              0.000000
max                    1.000000              1.000000

       dst_host_srv_rerror_rate
count             311029.000000
mean                   0.141693
std                    0.346573
min                    0.000000
25%                    0.000000
50%                    0.000000
75%                    0.000000
max                    1.000000

[8 rows x 32 columns]
```

Out[10]: (311029, 6)

Out[10]:

```
                land      logged_in     root_shell   su_attempted  \
count  311029.000000  311029.000000  311029.000000  311029.000000
mean        0.000029       0.172476       0.000199       0.000023
std         0.005379       0.377794       0.014117       0.005947
min         0.000000       0.000000       0.000000       0.000000
25%         0.000000       0.000000       0.000000       0.000000
50%         0.000000       0.000000       0.000000       0.000000
75%         0.000000       0.000000       0.000000       0.000000
max         1.000000       1.000000       1.000000       2.000000

       is_host_login  is_guest_login
count  311029.000000   311029.000000
```

```
mean       0.000039       0.002424
std        0.006211       0.049177
min        0.000000       0.000000
25%        0.000000       0.000000
50%        0.000000       0.000000
75%        0.000000       0.000000
max        1.000000       1.000000
```

Out[10]: (311029, 32)

Out[10]:
```
            duration      src_bytes      dst_bytes  wrong_fragment  \
count  311029.000000  311029.000000  311029.000000   311029.000000
mean       -0.042496      -0.001309      -0.003648       -0.042068
std         0.575976       0.129179       0.487899        0.299447
min        -0.067792      -0.003062      -0.026287       -0.047720
25%        -0.067792      -0.002955      -0.026287       -0.047720
50%        -0.067792      -0.002535      -0.026287       -0.047720
75%        -0.067792      -0.002017      -0.026287       -0.047720
max        81.479854      63.571681     157.455071       22.206629

              urgent            hot  num_failed_logins  num_compromised  \
count  311029.000000  311029.000000      311029.000000    311029.000000
mean        0.006764      -0.025370           0.142485         0.000573
std         1.782311       0.399013           3.221101         1.088972
min        -0.002571      -0.044136          -0.009782        -0.005679
25%        -0.002571      -0.044136          -0.009782        -0.005679
50%        -0.002571      -0.044136          -0.009782        -0.005679
75%        -0.002571      -0.044136          -0.009782        -0.005679
max       544.437104     129.095065         257.729132       442.628578

            num_root  num_file_creations             ...              \
count  311029.000000       311029.000000             ...
mean       -0.001487           -0.001295             ...
std         1.075758            2.002976             ...
min        -0.005640           -0.011232             ...
25%        -0.005640           -0.011232             ...
50%        -0.005640           -0.011232             ...
75%        -0.005640           -0.011232             ...
max       436.220770         1037.163376             ...

       dst_host_count  dst_host_srv_count  dst_host_same_srv_rate  \
count   311029.000000       311029.000000           311029.000000
mean         0.043430            0.099285                0.096681
std          0.940814            0.945928                0.942328
min         -3.590542           -1.779188               -1.834994
25%          0.347967            0.521823                0.526364
50%          0.347967            0.625558                0.599396
75%          0.347967            0.625558                0.599396
```

```
max          0.347967            0.625558                0.599396

       dst_host_diff_srv_rate  dst_host_same_src_port_rate  \
count           311029.000000                311029.000000
mean                -0.054486                    -0.112228
std                  0.878676                     1.022135
min                 -0.282867                    -1.250621
25%                 -0.282867                    -1.250621
50%                 -0.282867                     0.827048
75%                 -0.191341                     0.827048
max                  8.869697                     0.827048

       dst_host_srv_diff_host_rate  dst_host_serror_rate  \
count                311029.000000         311029.000000
mean                     -0.050252             -0.310016
std                       0.849060              0.607725
min                      -0.158629             -0.464418
25%                      -0.158629             -0.464418
50%                      -0.158629             -0.464418
75%                      -0.158629             -0.464418
max                      23.575830              2.163063

       dst_host_srv_serror_rate  dst_host_rerror_rate  \
count             311029.000000         311029.000000
mean                  -0.308862              0.366631
std                    0.611671              1.493477
min                   -0.463202             -0.252040
25%                   -0.463202             -0.252040
50%                   -0.463202             -0.252040
75%                   -0.463202             -0.252040
max                    2.162027              4.084676

       dst_host_srv_rerror_rate
count             311029.000000
mean                   0.366219
std                    1.505923
min                   -0.249464
25%                   -0.249464
50%                   -0.249464
75%                   -0.249464
max                    4.095715

[8 rows x 32 columns]
```

Out[10]:

```
   duration  src_bytes  dst_bytes  wrong_fragment    urgent       hot  \
0 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
1 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
2 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
```

```
3 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
4 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
5 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
6 -0.067792  -0.003032  -0.026287        -0.04772 -0.002571 -0.044136
7 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
8 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
9 -0.067792  -0.002836  -0.020688        -0.04772 -0.002571 -0.044136

   num_failed_logins  num_compromised  num_root  num_file_creations  \
0          -0.009782        -0.005679  -0.00564           -0.011232
1          -0.009782        -0.005679  -0.00564           -0.011232
2          -0.009782        -0.005679  -0.00564           -0.011232
3          -0.009782        -0.005679  -0.00564           -0.011232
4          -0.009782        -0.005679  -0.00564           -0.011232
5          -0.009782        -0.005679  -0.00564           -0.011232
6          -0.009782        -0.005679  -0.00564           -0.011232
7          -0.009782        -0.005679  -0.00564           -0.011232
8          -0.009782        -0.005679  -0.00564           -0.011232
9          -0.009782        -0.005679  -0.00564           -0.011232

             ...            dst_host_count  dst_host_srv_count  \
0            ...                  0.347967            0.616127
1            ...                  0.347967            0.616127
2            ...                  0.347967            0.616127
3            ...                  0.347967            0.616127
4            ...                  0.347967            0.616127
5            ...                  0.347967            0.625558
6            ...                 -3.436091           -1.750897
7            ...                  0.347967            0.606697
8            ...                  0.347967            0.616127
9            ...                 -2.493938            0.625558

   dst_host_same_srv_rate  dst_host_diff_srv_rate  \
0                0.599396               -0.191341
1                0.599396               -0.191341
2                0.599396               -0.191341
3                0.599396               -0.191341
4                0.599396               -0.191341
5                0.599396               -0.282867
6               -1.104677                2.462903
7                0.575052               -0.191341
8                0.599396               -0.191341
9                0.599396               -0.282867

   dst_host_same_src_port_rate  dst_host_srv_diff_host_rate  \
0                    -1.250621                    -0.158629
1                    -1.250621                    -0.158629
2                    -1.250621                    -0.158629
```

```
3                    -1.250621                    -0.158629
4                    -1.229844                    -0.158629
5                    -1.229844                    -0.158629
6                    -0.627320                    -0.158629
7                    -1.250621                    -0.158629
8                    -1.250621                    -0.158629
9                    -1.229844                     0.078715

   dst_host_serror_rate  dst_host_srv_serror_rate  dst_host_rerror_rate  \
0             -0.464418                 -0.463202              -0.25204
1             -0.464418                 -0.463202              -0.25204
2             -0.464418                 -0.463202              -0.25204
3             -0.464418                 -0.463202              -0.25204
4             -0.464418                 -0.463202              -0.25204
5             -0.464418                 -0.463202              -0.25204
6             -0.464418                 -0.463202              -0.25204
7             -0.464418                 -0.463202              -0.25204
8             -0.464418                 -0.463202              -0.25204
9             -0.464418                 -0.463202              -0.25204

   dst_host_srv_rerror_rate
0                 -0.249464
1                 -0.249464
2                 -0.249464
3                 -0.249464
4                 -0.249464
5                 -0.249464
6                 -0.249464
7                 -0.249464
8                 -0.249464
9                 -0.249464

[10 rows x 32 columns]
```

Out[10]:
```
(311029, 38)
```

Out[10]:
```
            duration      src_bytes      dst_bytes  wrong_fragment  \
count  311029.000000  311029.000000  311029.000000   311029.000000
mean       -0.042496      -0.001309      -0.003648       -0.042068
std         0.575976       0.129179       0.487899        0.299447
min        -0.067792      -0.003062      -0.026287       -0.047720
25%        -0.067792      -0.002955      -0.026287       -0.047720
50%        -0.067792      -0.002535      -0.026287       -0.047720
75%        -0.067792      -0.002017      -0.026287       -0.047720
max        81.479854      63.571681     157.455071       22.206629

              urgent            hot  num_failed_logins  num_compromised  \
count  311029.000000  311029.000000      311029.000000    311029.000000
```

```
mean      0.006764    -0.025370        0.142485      0.000573
std       1.782311     0.399013        3.221101      1.088972
min      -0.002571    -0.044136       -0.009782     -0.005679
25%      -0.002571    -0.044136       -0.009782     -0.005679
50%      -0.002571    -0.044136       -0.009782     -0.005679
75%      -0.002571    -0.044136       -0.009782     -0.005679
max     544.437104   129.095065      257.729132    442.628578

            num_root  num_file_creations      ...        \
count  311029.000000       311029.000000      ...
mean       -0.001487           -0.001295      ...
std         1.075758            2.002976      ...
min        -0.005640           -0.011232      ...
25%        -0.005640           -0.011232      ...
50%        -0.005640           -0.011232      ...
75%        -0.005640           -0.011232      ...
max       436.220770         1037.163376      ...

       dst_host_serror_rate  dst_host_srv_serror_rate  dst_host_rerror_rate  \
count         311029.000000             311029.000000         311029.000000
mean              -0.310016                 -0.308862              0.366631
std                0.607725                  0.611671              1.493477
min               -0.464418                 -0.463202             -0.252040
25%               -0.464418                 -0.463202             -0.252040
50%               -0.464418                 -0.463202             -0.252040
75%               -0.464418                 -0.463202             -0.252040
max                2.163063                  2.162027              4.084676

       dst_host_srv_rerror_rate           land      logged_in     root_shell  \
count             311029.000000  311029.000000  311029.000000  311029.000000
mean                   0.366219       0.000029       0.172476       0.000199
std                    1.505923       0.005379       0.377794       0.014117
min                   -0.249464       0.000000       0.000000       0.000000
25%                   -0.249464       0.000000       0.000000       0.000000
50%                   -0.249464       0.000000       0.000000       0.000000
75%                   -0.249464       0.000000       0.000000       0.000000
max                    4.095715       1.000000       1.000000       1.000000

        su_attempted  is_host_login  is_guest_login
count  311029.000000  311029.000000   311029.000000
mean        0.000023       0.000039        0.002424
std         0.005947       0.006211        0.049177
min         0.000000       0.000000        0.000000
25%         0.000000       0.000000        0.000000
50%         0.000000       0.000000        0.000000
75%         0.000000       0.000000        0.000000
max         2.000000       1.000000        1.000000
```

```
   [8 rows x 38 columns]
```

Out[10]:

```
   duration  src_bytes  dst_bytes  wrong_fragment    urgent       hot  \
0 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
1 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
2 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
3 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
4 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
5 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
6 -0.067792  -0.003032  -0.026287        -0.04772 -0.002571 -0.044136
7 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
8 -0.067792  -0.002955  -0.021868        -0.04772 -0.002571 -0.044136
9 -0.067792  -0.002836  -0.020688        -0.04772 -0.002571 -0.044136

   num_failed_logins  num_compromised  num_root  num_file_creations  \
0          -0.009782        -0.005679  -0.00564           -0.011232
1          -0.009782        -0.005679  -0.00564           -0.011232
2          -0.009782        -0.005679  -0.00564           -0.011232
3          -0.009782        -0.005679  -0.00564           -0.011232
4          -0.009782        -0.005679  -0.00564           -0.011232
5          -0.009782        -0.005679  -0.00564           -0.011232
6          -0.009782        -0.005679  -0.00564           -0.011232
7          -0.009782        -0.005679  -0.00564           -0.011232
8          -0.009782        -0.005679  -0.00564           -0.011232
9          -0.009782        -0.005679  -0.00564           -0.011232

         ...        dst_host_serror_rate  dst_host_srv_serror_rate  \
0        ...                   -0.464418                 -0.463202
1        ...                   -0.464418                 -0.463202
2        ...                   -0.464418                 -0.463202
3        ...                   -0.464418                 -0.463202
4        ...                   -0.464418                 -0.463202
5        ...                   -0.464418                 -0.463202
6        ...                   -0.464418                 -0.463202
7        ...                   -0.464418                 -0.463202
8        ...                   -0.464418                 -0.463202
9        ...                   -0.464418                 -0.463202

   dst_host_rerror_rate  dst_host_srv_rerror_rate  land  logged_in  \
0              -0.25204                 -0.249464     0          0
1              -0.25204                 -0.249464     0          0
2              -0.25204                 -0.249464     0          0
3              -0.25204                 -0.249464     0          0
4              -0.25204                 -0.249464     0          0
5              -0.25204                 -0.249464     0          0
6              -0.25204                 -0.249464     0          0
7              -0.25204                 -0.249464     0          0
8              -0.25204                 -0.249464     0          0
```

```
9              -0.25204                 -0.249464     0          1

   root_shell  su_attempted  is_host_login  is_guest_login
0           0             0              0               0
1           0             0              0               0
2           0             0              0               0
3           0             0              0               0
4           0             0              0               0
5           0             0              0               0
6           0             0              0               0
7           0             0              0               0
8           0             0              0               0
9           0             0              0               0

[10 rows x 38 columns]
```

1.1.4 Data Analysis

Now we use the final datasets to train and run models based on the following algorithms and evaluate the best one for detection and prediction purposes: - Logistic Regression - K-Nearest Neighbors - Support Vector Machine - Random Forest - Neural Networks - Ensemble Modeling - Unsupervised Learning - Clustering

Since there are several different attack types mentioned in the "attack_type" label, we first classify them into "normal" and "bad" (as done in the Data Exploration section) and try to develop a model that detects "bad" logs (majority of them being DoS attacks) in the test dataset. We also implement multi-class detection for these models as well.

```
In [11]: #Importing the required packages

         from sklearn import metrics
         from sklearn.linear_model import LogisticRegression
         from sklearn.neighbors import KNeighborsClassifier
         from scipy import stats
         import pylab as pl
         from sklearn.svm import SVC
         from sklearn.ensemble import RandomForestClassifier
         from sklearn.cluster import KMeans
         from sklearn.ensemble import BaggingClassifier
         from sklearn.neural_network import MLPClassifier
         from sklearn.ensemble import VotingClassifier
         from sklearn import tree
```

1.1.5 Logistic Regression

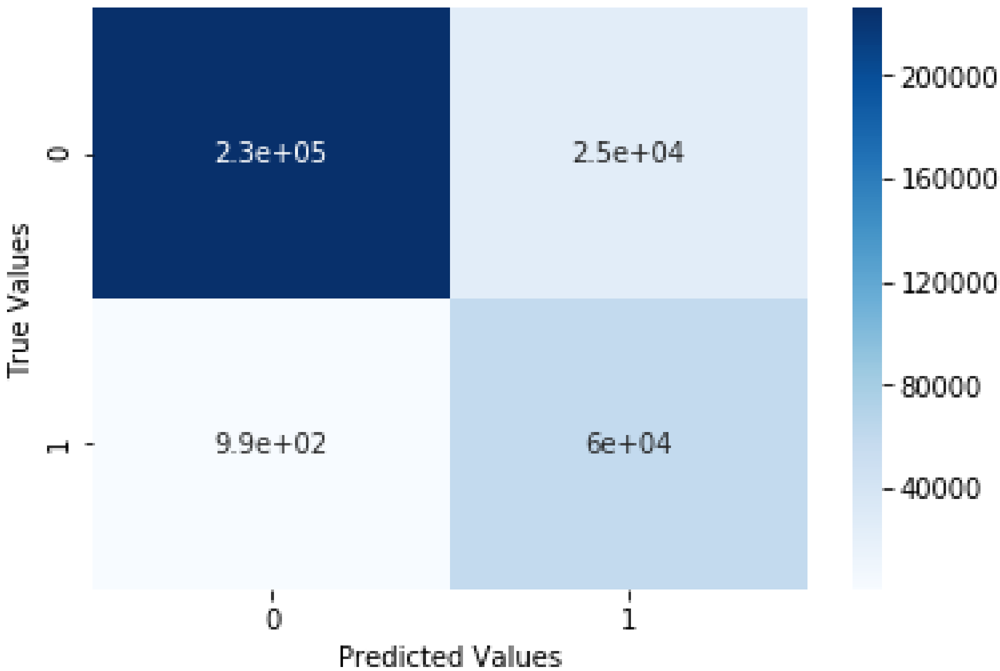
We use a logistic regression model trained on the training dataset to predict "normal" and "bad" as well as multi-class labels for the test dataset.

```
In [14]: #Creating the "normal" and "bad" labels for test dataset as well
         attack_labs_test = kdd_test_10per_mod['attack_type'].copy()
```

```
attack_labs_test[attack_labs_test!='normal.'] = 'bad.'
attack_labs_test.value_counts()

#Logistic Regression Model -- 2 labels
logrmodel = LogisticRegression(C=0.01)
logrmodel.fit(kdd_train_10per_scaled, attack_labs)
log_preds = logrmodel.predict(kdd_test_10per_scaled)
print(log_preds)

#Logistic Regression Model -- multi-labels
logrmodel1 = LogisticRegression(C=0.01,solver='sag',multi_class='ovr')
logrmodel1.fit(kdd_train_10per_scaled, attack_labs_all)
log_preds1 = logrmodel1.predict(kdd_test_10per_scaled)
print(log_preds1)

#Calculating test metrics to evaluate the model -- 2 labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_test, log_preds))
print(metrics.accuracy_score(attack_labs_test, log_preds))
print(metrics.recall_score(attack_labs_test, log_preds,average='macro'))
print(metrics.precision_score(attack_labs_test, log_preds,average='macro'))
print(metrics.f1_score(attack_labs_test, log_preds,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, log_preds)), a
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))


#Calculating test metrics to evaluate the model -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, log_preds1))
print(metrics.accuracy_score(attack_labs_tall, log_preds1))
print(metrics.recall_score(attack_labs_tall, log_preds1,average='macro'))
print(metrics.precision_score(attack_labs_tall, log_preds1,average='macro'))
print(metrics.f1_score(attack_labs_tall, log_preds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, log_preds1)),
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()
```

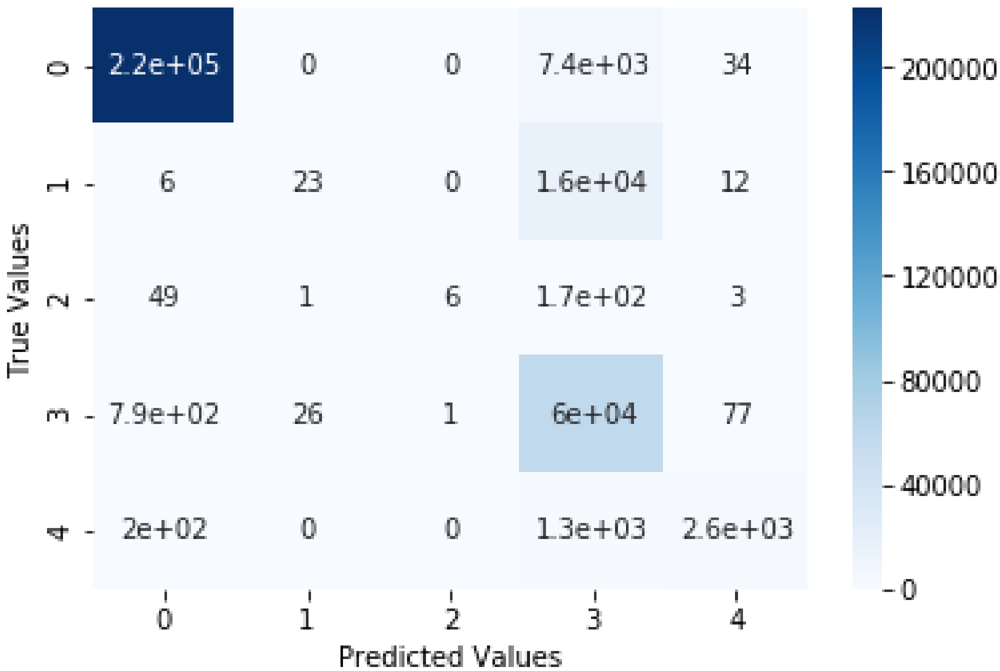
```
#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

```
Out[14]: bad.       250436
         normal.     60593
         Name: attack_type, dtype: int64

Out[14]: LogisticRegression(C=0.01, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
                   penalty='l2', random_state=None, solver='liblinear', tol=0.0001,
                   verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']


C:\Users\Neha Rawat\Anaconda3\lib\site-packages\sklearn\linear_model\sag.py:326: ConvergenceWarn
  "the coef_ did not converge", ConvergenceWarning)


Out[14]: LogisticRegression(C=0.01, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, max_iter=100, multi_class='ovr', n_jobs=1,
                   penalty='l2', random_state=None, solver='sag', tol=0.0001,
                   verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
[[225627  24809]
 [   994  59599]]
0.917039890171
0.942266115551
0.850848092029
0.883980813408


Out[14]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99561382  0.70608236]
recall: [ 0.90093677  0.98359546]
fscore: [ 0.94591212  0.8220495 ]
support: [250436  60593]
[[222373      0      0   7446     34]
 [     6     23      0  16148     12]
 [    49      1      6    169      3]
 [   790     26      1  59699     77]
 [   200      0      0   1341   2625]]
0.915432323031
0.522108121159
0.794127347192
0.523056025877
```

```
Out[14]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99532267  0.46        0.85714286  0.70397274  0.95419847]
recall: [ 0.96745746  0.00142072  0.02631579  0.98524582  0.63010082]
fscore: [ 0.98119227  0.00283269  0.05106383  0.82119178  0.75899957]
support: [229853  16189    228  60593   4166]
```

We see that the accuracy (91.70 percent) and F1 scores (88.39 percent) for 2-label predictions are good enough. Through the precision_recall_fscore_support matrix we can also see that correct prediction of "bad" labels is higher, due to higher proportion of these labels in the test as well as training data. When we try to fit a multi-class problem using logistic regression, we observe that the recall for "R2L" and "U2R" labels is very less (due to small proportion of these labels in the training dataset), whereas predictions for DOS and "normal" labels is quite good. Therefore, we will proceed to try other algorithms to try and achieve better and more balanced prediction scores.

1.1.6 K-Nearest Neighbors

We use a K-Nearest Neighbors model (with k=5 and Manhattan Distance Metric) trained on the training dataset to predict "normal" and "bad" as well as multi-class labels for the test dataset.

```
In [15]: #K-Nearest Neighbors
         #We run the K-nearest neighbors model for k = 5
         #Takes a lot of time -- around two hours

         #K=5 -- 2 labels
         knn_mod1 = KNeighborsClassifier(n_neighbors = 5, algorithm = 'ball_tree', leaf_size=600
```

```
knn_mod1.fit(kdd_train_10per_scaled, attack_labs)
knn_preds1 = knn_mod1.predict(kdd_test_10per_scaled)
print(knn_preds1)

#Multi-labels
knn_mod2 = KNeighborsClassifier(n_neighbors = 5, algorithm = 'ball_tree', leaf_size=600
knn_mod2.fit(kdd_train_10per_scaled, attack_labs_all)
knn_preds2 = knn_mod2.predict(kdd_test_10per_scaled)
print(knn_preds2)
```

Out[15]:
```
KNeighborsClassifier(algorithm='ball_tree', leaf_size=600, metric='manhattan',
                     metric_params=None, n_jobs=-1, n_neighbors=5, p=2,
                     weights='uniform')
```

```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

Out[15]:
```
KNeighborsClassifier(algorithm='ball_tree', leaf_size=600, metric='manhattan',
                     metric_params=None, n_jobs=-1, n_neighbors=5, p=2,
                     weights='uniform')
```

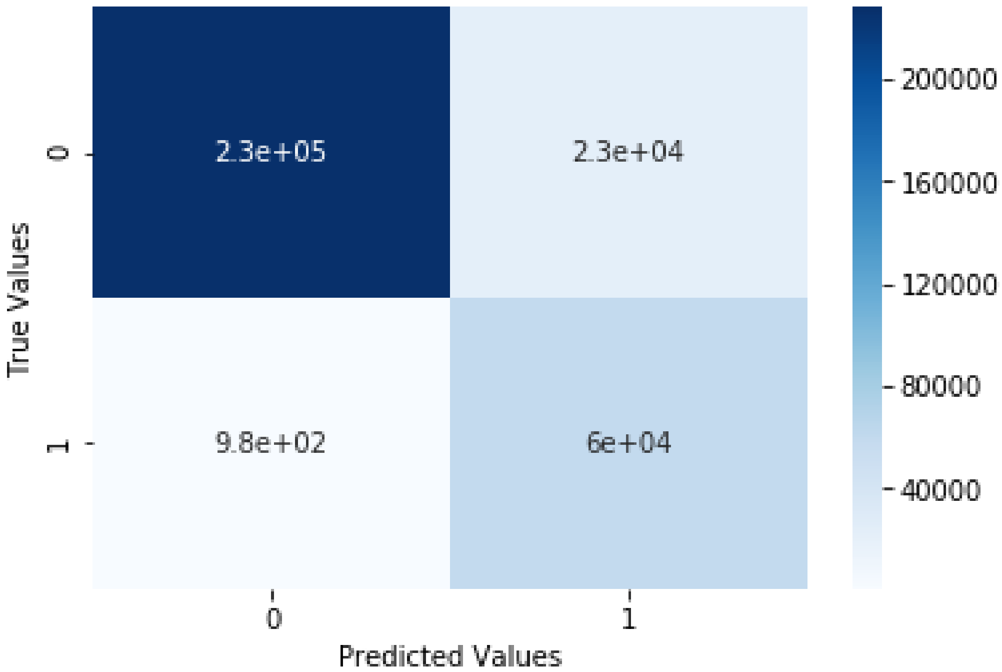
```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

In [16]:
```
#Evaluation Metrics for KNN k=5 -- 2 labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_test, knn_preds1))
print(metrics.accuracy_score(attack_labs_test, knn_preds1))
print(metrics.recall_score(attack_labs_test, knn_preds1,average='macro'))
print(metrics.precision_score(attack_labs_test, knn_preds1,average='macro'))
print(metrics.f1_score(attack_labs_test, knn_preds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, knn_preds1)),
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))

#Evaluation Metrics for KNN k=5 -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, knn_preds2))
print(metrics.accuracy_score(attack_labs_tall, knn_preds2))
print(metrics.recall_score(attack_labs_tall, knn_preds2,average='macro'))
```

```python
print(metrics.precision_score(attack_labs_tall, knn_preds2,average='macro'))
print(metrics.f1_score(attack_labs_tall, knn_preds2,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, knn_preds2)),
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

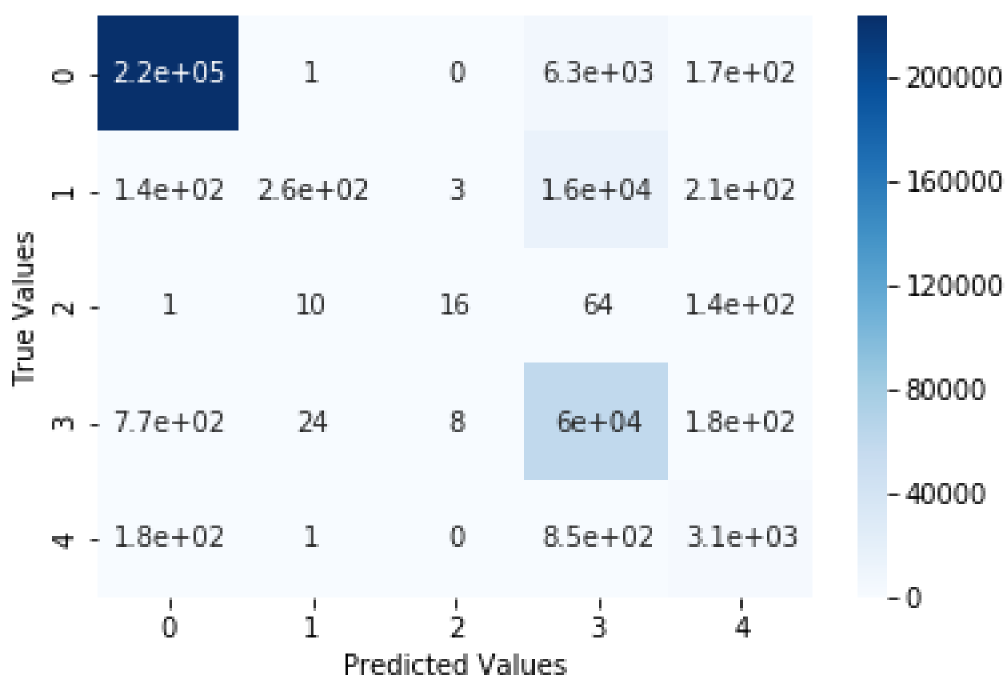
```
[[227642  22794]
 [   977  59616]]
0.923573043028
0.946429379698
0.859566933948
0.892076055409
```

```
Out[16]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```



```
precision: [ 0.99572651  0.72340735]
recall: [ 0.90898273  0.98387603]
fscore: [ 0.95037939  0.83377272]
support: [250436  60593]
[[223384      1      0   6301    167]
 [   135    258      3  15582    211]
 [     1     10     16     64    137]
 [   768     24      8  59617    176]
 [   178      1      0    849   3138]]
0.920856254561
0.55902023168
0.801650312904
0.551786905652
```

Out[16]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]




```
precision: [ 0.99517967  0.87755102  0.59259259  0.72339315  0.81953513]
recall: [ 0.97185593  0.01593675  0.07017544  0.98389253  0.75324052]
fscore: [ 0.98337952  0.03130498  0.1254902   0.83376921  0.78499062]
support: [229853  16189    228  60593   4166]
```

We see that with the use of KNN (k=5) and Manhattan Distance metric we are able to improve the accuracy (92.357 percent) and F1 score (89.20 percent) slightly more than in logistic regression for a 2-label classification. For multi-label classification as well, we see an improvement in recall scores overall and especially for "R2L" and "U2R" categories (as compared to logistic regression). Also, we see that the F1 score for "normal" labels has increased too.

1.1.7 Support Vector Machine

We use a Support Vector Machine (using a linear and polynomial kernel) model trained on the training dataset to predict "normal" and "bad" as well as multi-class labels on the test dataset.

```
In [17]: #Training using an SVM model (kernel = linear) -- 2 labels

         svm_mod1 = BaggingClassifier(SVC(kernel='linear'),max_samples = 0.1, n_jobs=-1)
         svm_mod1.fit(kdd_train_10per_scaled, attack_labs)
         svm_preds1 = svm_mod1.predict(kdd_test_10per_scaled)
         print(svm_preds1)

         #Training using an SVM model (kernel = linear) -- multi-labels
         svm_mod2 = BaggingClassifier(SVC(kernel='linear'),max_samples = 0.1, n_jobs=-1)
         svm_mod2.fit(kdd_train_10per_scaled, attack_labs_all)
         svm_preds2 = svm_mod2.predict(kdd_test_10per_scaled)
         print(svm_preds2)
```

```
Out[17]: BaggingClassifier(base_estimator=SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.
           decision_function_shape='ovr', degree=3, gamma='auto', kernel='linear',
           max_iter=-1, probability=False, random_state=None, shrinking=True,
           tol=0.001, verbose=False),
                  bootstrap=True, bootstrap_features=False, max_features=1.0,
                  max_samples=0.1, n_estimators=10, n_jobs=-1, oob_score=False,
                  random_state=None, verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

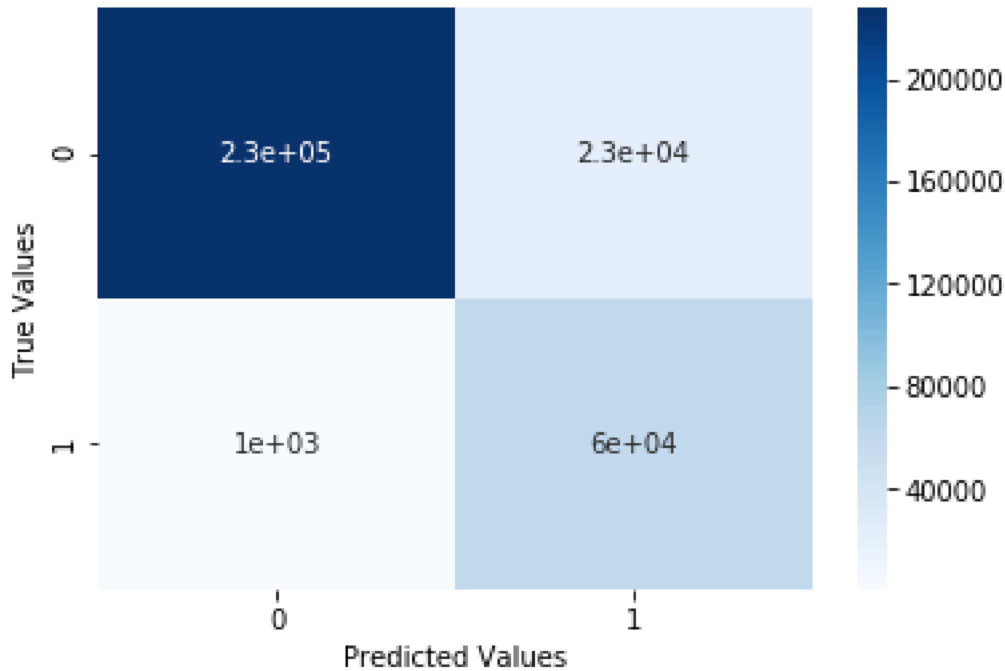
```
Out[17]: BaggingClassifier(base_estimator=SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.
           decision_function_shape='ovr', degree=3, gamma='auto', kernel='linear',
           max_iter=-1, probability=False, random_state=None, shrinking=True,
           tol=0.001, verbose=False),
                  bootstrap=True, bootstrap_features=False, max_features=1.0,
                  max_samples=0.1, n_estimators=10, n_jobs=-1, oob_score=False,
                  random_state=None, verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

```
In [18]: #Evaluation Metrics for SVM (kernel = linear) -- 2 labels
         #Confusion Matrix, accuracy, recall, precision and f1-score
         print(metrics.confusion_matrix(attack_labs_test, svm_preds1))
         print(metrics.accuracy_score(attack_labs_test, svm_preds1))
         print(metrics.recall_score(attack_labs_test, svm_preds1,average='macro'))
```

```python
print(metrics.precision_score(attack_labs_test, svm_preds1,average='macro'))
print(metrics.f1_score(attack_labs_test, svm_preds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, svm_preds1)),
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))

#Evaluation Metrics for SVM (kernel = linear) -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, svm_preds2))
print(metrics.accuracy_score(attack_labs_tall, svm_preds2))
print(metrics.recall_score(attack_labs_tall, svm_preds2,average='macro'))
print(metrics.precision_score(attack_labs_tall, svm_preds2,average='macro'))
print(metrics.f1_score(attack_labs_tall, svm_preds2,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, svm_preds2)),
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

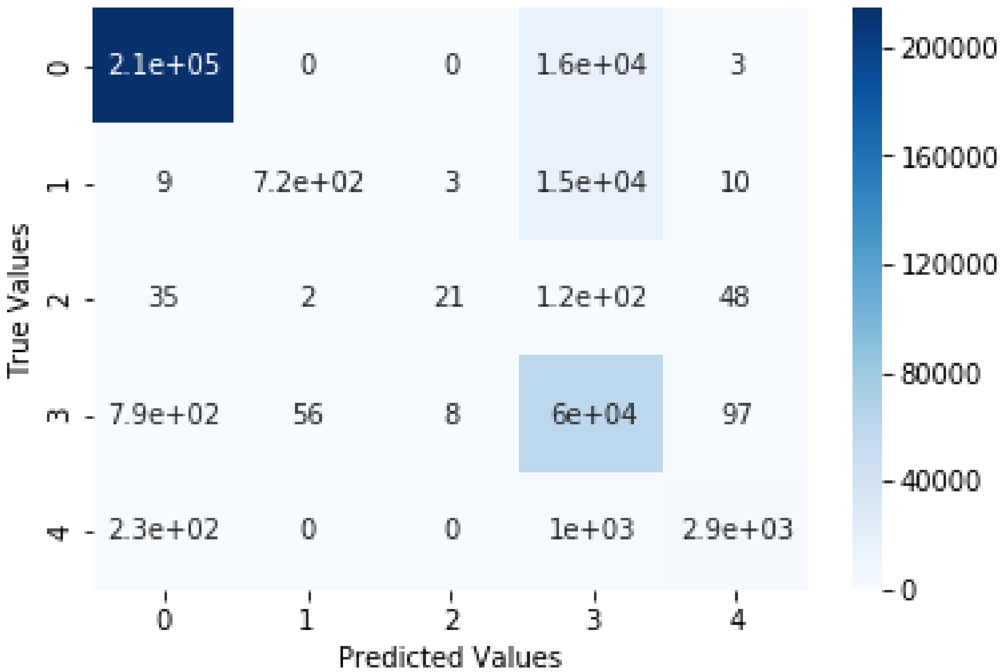
```
[[227261  23175]
 [  1003  59590]]
0.922264483376
0.945454160077
0.857798149551
0.890418839275
```

Out[18]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]




```
precision: [ 0.99560597  0.71999033]
recall: [ 0.90746139  0.98344693]
fscore: [ 0.94949238  0.8313453 ]
support: [250436  60593]
[[213998      0      0  15852      3]
 [     9    718      3  15449     10]
 [    35      2     21    122     48]
 [   794     56      8  59638     97]
 [   229      0      0   1046   2891]]
0.891447421302
0.549133526469
0.834442449644
0.558129727845
```

```
Out[18]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99503871  0.92525773  0.65625     0.64748608  0.94817973]
recall: [ 0.93102113  0.0443511   0.09210526  0.9842391   0.69395103]
fscore: [ 0.96196603  0.08464486  0.16153846  0.78111329  0.801386  ]
support: [229853  16189    228  60593   4166]
```

In [19]:
```
#SVM using a polynomial kernel -- 2 labels
svm_mod3 = BaggingClassifier(SVC(kernel='poly',cache_size=7000),max_samples = 0.1, n_jo
svm_mod3.fit(kdd_train_10per_scaled, attack_labs)
svm_preds3 = svm_mod3.predict(kdd_test_10per_scaled)
print(svm_preds3)

#SVM using a polynomial kernel -- multi-labels
svm_mod4 = BaggingClassifier(SVC(kernel='poly',cache_size=7000),max_samples = 0.1, n_jo
svm_mod4.fit(kdd_train_10per_scaled, attack_labs_all)
svm_preds4 = svm_mod4.predict(kdd_test_10per_scaled)
print(svm_preds4)
```

Out[19]:
```
BaggingClassifier(base_estimator=SVC(C=1.0, cache_size=7000, class_weight=None, coef0=0
  decision_function_shape='ovr', degree=3, gamma='auto', kernel='poly',
  max_iter=-1, probability=False, random_state=None, shrinking=True,
  tol=0.001, verbose=False),
         bootstrap=True, bootstrap_features=False, max_features=1.0,
         max_samples=0.1, n_estimators=10, n_jobs=-1, oob_score=False,
         random_state=None, verbose=0, warm_start=False)
```

```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

```
Out[19]: BaggingClassifier(base_estimator=SVC(C=1.0, cache_size=7000, class_weight=None, coef0=0
           decision_function_shape='ovr', degree=3, gamma='auto', kernel='poly',
           max_iter=-1, probability=False, random_state=None, shrinking=True,
           tol=0.001, verbose=False),
                  bootstrap=True, bootstrap_features=False, max_features=1.0,
                  max_samples=0.1, n_estimators=10, n_jobs=-1, oob_score=False,
                  random_state=None, verbose=0, warm_start=False)
```

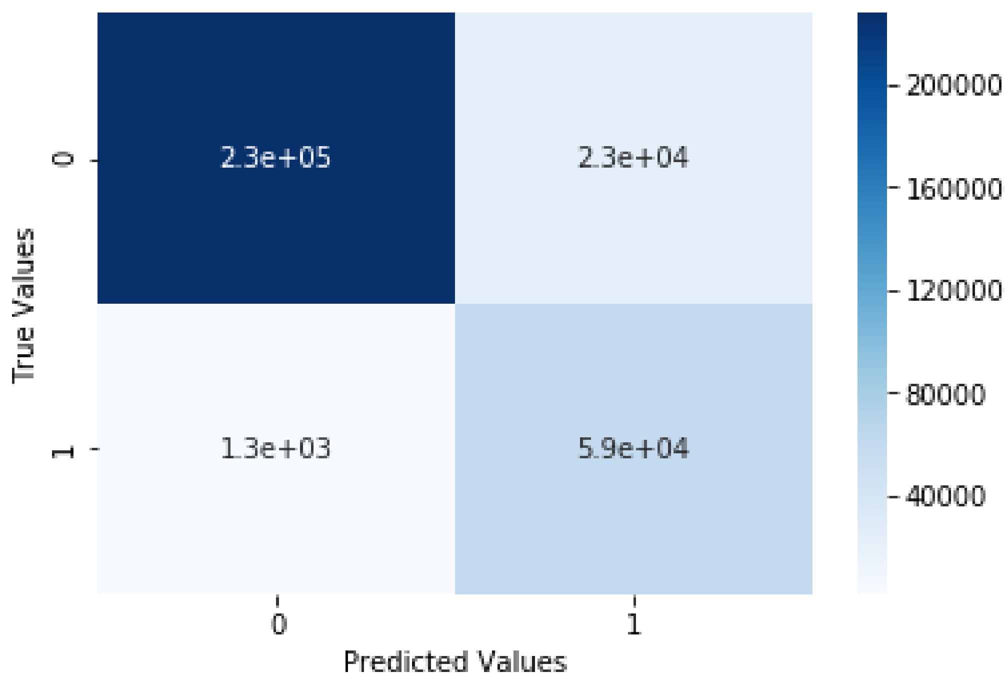
```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

```
In [20]: #Evaluation Metrics for SVM (kernel = polynomial) -- 2 labels
         #Confusion Matrix, accuracy, recall, precision and f1-score
         print(metrics.confusion_matrix(attack_labs_test, svm_preds3))
         print(metrics.accuracy_score(attack_labs_test, svm_preds3))
         print(metrics.recall_score(attack_labs_test, svm_preds3,average='macro'))
         print(metrics.precision_score(attack_labs_test, svm_preds3,average='macro'))
         print(metrics.f1_score(attack_labs_test, svm_preds3,average='macro'))

         ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, svm_preds3)),
         ht.set(xlabel='Predicted Values', ylabel='True Values')
         plt.show()

         #Another way to view these metrics for every class label
         precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

         print('precision: {}'.format(precision))
         print('recall: {}'.format(recall))
         print('fscore: {}'.format(fscore))
         print('support: {}'.format(support))

         #Evaluation Metrics for SVM (kernel = polynomial) -- multi-labels
         #Confusion Matrix, accuracy, recall, precision and f1-score
         print(metrics.confusion_matrix(attack_labs_tall, svm_preds4))
         print(metrics.accuracy_score(attack_labs_tall, svm_preds4))
         print(metrics.recall_score(attack_labs_tall, svm_preds4,average='macro'))
         print(metrics.precision_score(attack_labs_tall, svm_preds4,average='macro'))
         print(metrics.f1_score(attack_labs_tall, svm_preds4,average='macro'))

         ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, svm_preds4)),
         ht.set(xlabel='Predicted Values', ylabel='True Values')
         plt.show()

         #Another way to view these metrics for every class label
         precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab
```

```
print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

```
[[227707  22729]
 [  1274  59319]]
0.922827131875
0.94410837523
0.858707725634
0.890828669199
```

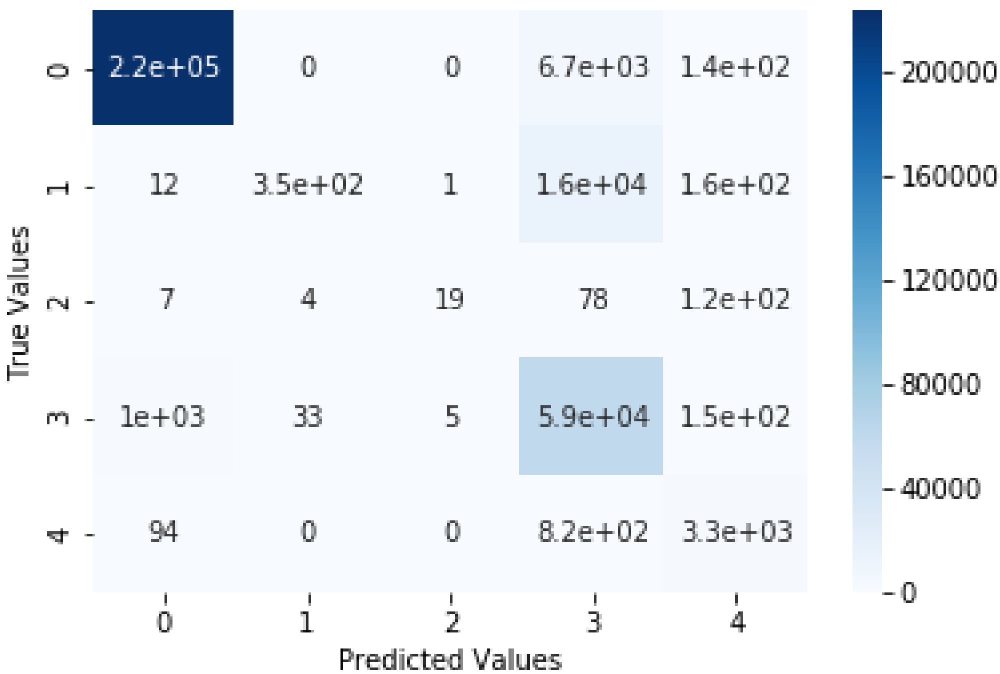
```
Out[20]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99443622  0.72297923]
recall: [ 0.90924228  0.97897447]
fscore: [ 0.94993294  0.8317244 ]
support: [250436  60593]
[[222993      0      0   6723    137]
 [    12    354      1  15660    162]
 [     7      4     19     78    120]
 [  1049     33      5  59357    149]
 [    94      0      0    815   3257]]
```

```
0.919464101418
0.567352312799
0.846002193356
0.563851067765
```

```
Out[20]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99481609  0.90537084  0.76        0.71832077  0.85150327]
recall: [ 0.97015484  0.0218667   0.08333333  0.9796016   0.78180509]
fscore: [ 0.98233071  0.04270205  0.15019763  0.82885789  0.81516706]
support: [229853  16189    228  60593   4166]
```

We see that the polynomial SVM performs better than logistic regression but almost similar to KNN.

1.1.8 Random Forest

We now use a Random Forest model trained on the training dataset to predict "normal" and "bad" as well as multi-class labels on the test dataset.

```
In [21]: #Random Forest Model -- 2 labels
         rdforestmod = RandomForestClassifier(n_estimators=10,n_jobs=-1, random_state=0)
         rdforestmod.fit(kdd_train_10per_scaled, attack_labs)
```

```
rdpreds = rdforestmod.predict(kdd_test_10per_scaled)
print(rdpreds)

#Random Forest Model -- multi-labels
rdforestmod1 = RandomForestClassifier(n_estimators=10,n_jobs=-1, random_state=0)
rdforestmod1.fit(kdd_train_10per_scaled, attack_labs_all)
rdpreds1 = rdforestmod1.predict(kdd_test_10per_scaled)
print(rdpreds1)
```

```
Out[21]: RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                     max_depth=None, max_features='auto', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=-1,
                     oob_score=False, random_state=0, verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

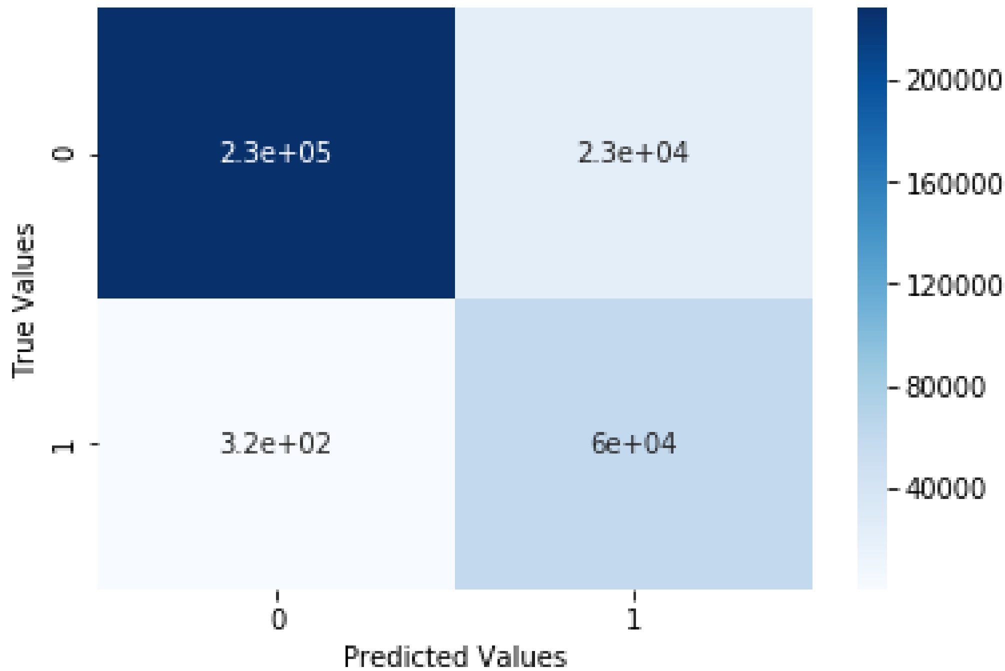

```
Out[21]: RandomForestClassifier(bootstrap=True, class_weight=None, criterion='gini',
                     max_depth=None, max_features='auto', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                     min_weight_fraction_leaf=0.0, n_estimators=10, n_jobs=-1,
                     oob_score=False, random_state=0, verbose=0, warm_start=False)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```


```
In [22]: #Evaluation Metrics for Random Forest -- 2 labels
         #Confusion Matrix, accuracy, recall, precision and f1-score
         print(metrics.confusion_matrix(attack_labs_test, rdpreds))
         print(metrics.accuracy_score(attack_labs_test, rdpreds))
         print(metrics.recall_score(attack_labs_test, rdpreds,average='macro'))
         print(metrics.precision_score(attack_labs_test, rdpreds,average='macro'))
         print(metrics.f1_score(attack_labs_test, rdpreds,average='macro'))

         ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, rdpreds)), ann
         ht.set(xlabel='Predicted Values', ylabel='True Values')
         plt.show()

         #Another way to view these metrics for every class label
         precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

         print('precision: {}'.format(precision))
         print('recall: {}'.format(recall))
         print('fscore: {}'.format(fscore))
         print('support: {}'.format(support))
```

```
#Evaluation Metrics for Random Forest -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, rdpreds1))
print(metrics.accuracy_score(attack_labs_tall, rdpreds1))
print(metrics.recall_score(attack_labs_tall, rdpreds1,average='macro'))
print(metrics.precision_score(attack_labs_tall, rdpreds1,average='macro'))
print(metrics.f1_score(attack_labs_tall, rdpreds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, rdpreds1)), an
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

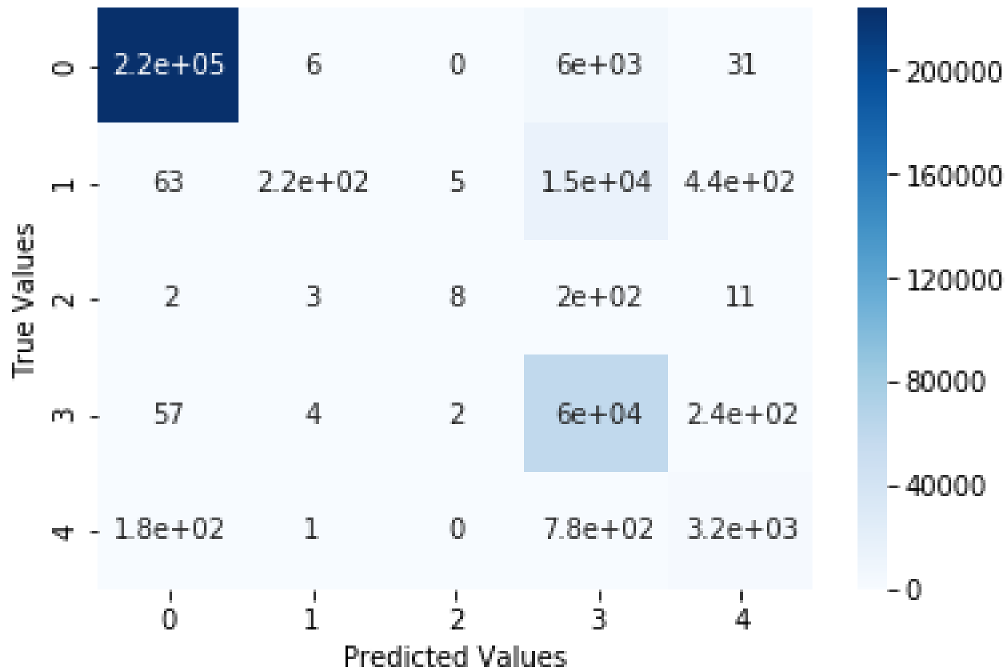
```
[[227882  22554]
 [   325  60268]]
0.926440942806
0.952288703459
0.863128452653
0.896335123835
```

```
Out[22]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99857585  0.72768105]
recall: [ 0.90994106  0.99463634]
fscore: [ 0.95220028  0.84046996]
support: [250436  60593]
[[223802      6      0   6014     31]
 [    63    223      5  15463    435]
 [     2      3      8    204     11]
 [    57      4      2  60295    235]
 [   178      1      0    781   3206]]
0.924460420089
0.557436410762
0.803955281697
0.542680957055
```

```
Out[22]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99866132  0.94092827  0.53333333  0.72857885  0.81827463]
recall: [ 0.97367448  0.01377479  0.03508772  0.99508194  0.76956313]
fscore: [ 0.98600963  0.02715208  0.06584362  0.84122776  0.7931717 ]
support: [229853  16189    228  60593   4166]
```

We see that the accuracy (92.64 percent) and F1 score (89.63 percent) for the 2-label classification has improved a lot as compared to the previous models. The F1 score for "normal" labels is also significantly higher (84.05 percent). However, in the multi-class classification, though the overall accuracy is higher, the recall values and F1 scores for "U2R" and "R2L" are low, leading to a lower F1 score overall.

1.1.9 Neural Networks

We now use a Neural Network model (Multi-Layer Perceptron) trained on the training dataset to predict "normal" and "bad" labels on the test dataset.

```
In [23]: #Multi Layer Perceptron Model -- 2 labels
         mlpmod = MLPClassifier(activation='tanh',random_state=0)
         mlpmod.fit(kdd_train_10per_scaled, attack_labs)
         mlppreds = mlpmod.predict(kdd_test_10per_scaled)
         print(mlppreds)

         #Multi Layer Perceptron Model -- multi-labels
         mlpmod1 = MLPClassifier(activation='tanh',random_state=0)
```

```
mlpmod1.fit(kdd_train_10per_scaled, attack_labs_all)
mlppreds1 = mlpmod1.predict(kdd_test_10per_scaled)
print(mlppreds1)
```

Out[23]:
```
MLPClassifier(activation='tanh', alpha=0.0001, batch_size='auto', beta_1=0.9,
       beta_2=0.999, early_stopping=False, epsilon=1e-08,
       hidden_layer_sizes=(100,), learning_rate='constant',
       learning_rate_init=0.001, max_iter=200, momentum=0.9,
       nesterovs_momentum=True, power_t=0.5, random_state=0, shuffle=True,
       solver='adam', tol=0.0001, validation_fraction=0.1, verbose=False,
       warm_start=False)
```

```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```


Out[23]:
```
MLPClassifier(activation='tanh', alpha=0.0001, batch_size='auto', beta_1=0.9,
       beta_2=0.999, early_stopping=False, epsilon=1e-08,
       hidden_layer_sizes=(100,), learning_rate='constant',
       learning_rate_init=0.001, max_iter=200, momentum=0.9,
       nesterovs_momentum=True, power_t=0.5, random_state=0, shuffle=True,
       solver='adam', tol=0.0001, validation_fraction=0.1, verbose=False,
       warm_start=False)
```

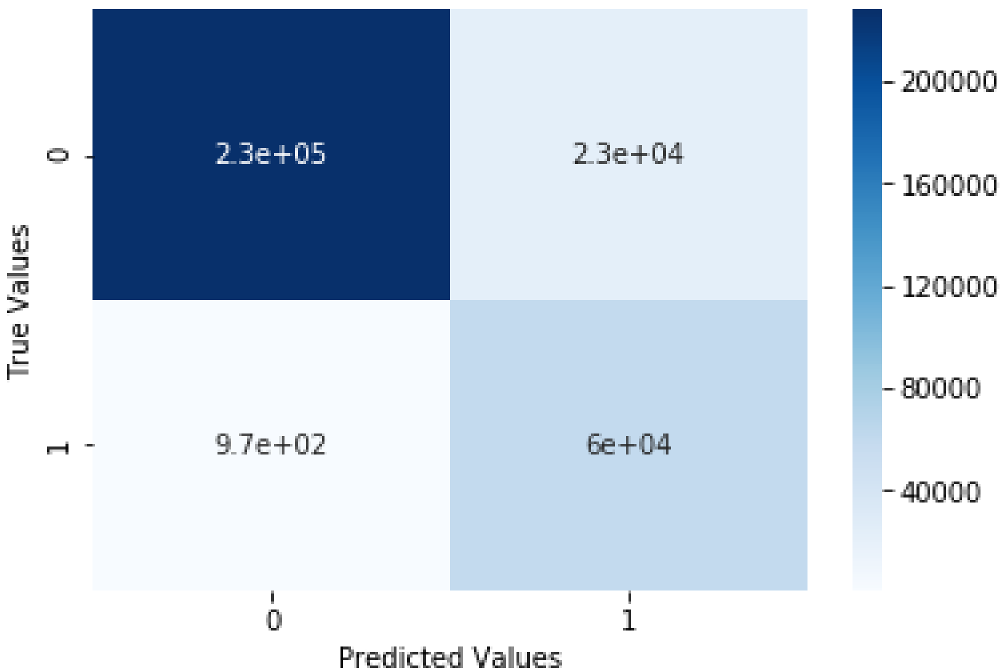
```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```


In [24]:
```
#Evaluation Metrics for an MLP Classifier -- 2 labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_test, mlppreds))
print(metrics.accuracy_score(attack_labs_test, mlppreds))
print(metrics.recall_score(attack_labs_test, mlppreds,average='macro'))
print(metrics.precision_score(attack_labs_test, mlppreds,average='macro'))
print(metrics.f1_score(attack_labs_test, mlppreds,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, mlppreds)), an
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))

#Evaluation Metrics for an MLP Classifier -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, mlppreds1))
```

```
print(metrics.accuracy_score(attack_labs_tall, mlppreds1))
print(metrics.recall_score(attack_labs_tall, mlppreds1,average='macro'))
print(metrics.precision_score(attack_labs_tall, mlppreds1,average='macro'))
print(metrics.f1_score(attack_labs_tall, mlppreds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, mlppreds1)), a
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

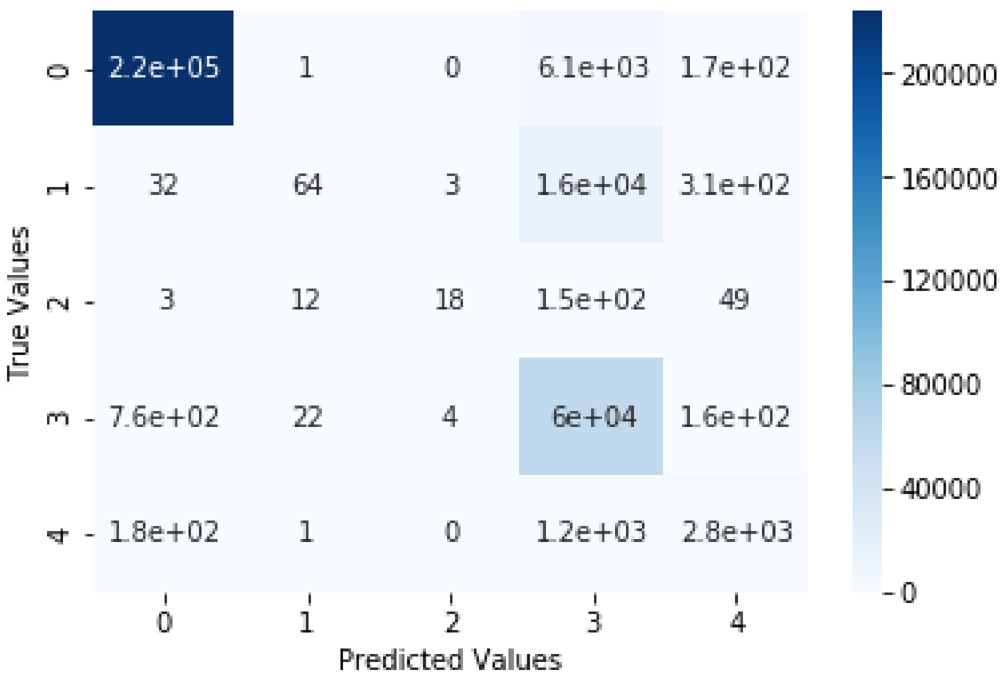
```
[[227791  22645]
 [   966  59627]]
0.924087464513
0.946817630451
0.860265825686
0.892729833571
```

```
Out[24]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```



```
precision: [ 0.99577718  0.72475447]
recall: [ 0.9095777   0.98405756]
fscore: [ 0.95072758  0.83473209]
support: [250436  60593]
[[223577      1      0   6106    169]
 [    32     64      3  15778    312]
 [     3     12     18    146     49]
 [   758     22      4  59647    162]
 [   181      1      0   1195   2789]]
0.91983384186
0.541890202544
0.775323506598
0.539030370367
```

```
Out[24]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]
```




```
precision: [ 0.99566246  0.64        0.72        0.71974853  0.80120655]
recall: [ 0.97269559  0.0039533   0.07894737  0.98438764  0.66946711]
fscore: [ 0.98404503  0.00785806  0.14229249  0.83151988  0.72943638]
support: [229853  16189    228  60593   4166]
```

We observe that the accuracy and F1 scores for a Multi-Layer Perceptron are very close to those for the Random Forest model for the 2-label as well as multi-label classification. The best performance that we observe from among the implemented learning models (based on accuracy) is of the Random Forest model, followed closely by the Multi-Layer Perceptron model. The best performance (based on recall and F1 score) for multi-class classification is by the polynomial SVM model.

1.1.10 Ensemble Modeling

As we have already observed, Random Forest models provide the best results for the 2-label detection problem. However, for the multi-class detection problem, Polynomial SVM seem to provide a better F1 score. Here, we attempt to design an ensemble model of two random forests and one polynomial SVM model in order to improve the accuracy of the results.

```
In [27]: #Ensemble Modeling - Three different learning models
         #Test on 2 label as well as multi-class

         rdforestmod = RandomForestClassifier(n_estimators=13,max_features='sqrt',n_jobs=-1, ran
         rdforestmod1 = RandomForestClassifier(n_estimators=13,max_features='log2',n_jobs=-1, ra
         polysvmmod = BaggingClassifier(SVC(kernel='poly',cache_size=7000),max_samples = 0.1, n_

         modelest = []
         modelest.append(('randomforest', rdforestmod))
         modelest.append(('randomforestanother', rdforestmod1))
         modelest.append(('polysvmmod', polysvmmod))

         ensemblemod = VotingClassifier(modelest,voting='soft')

         #2-label
         ensemblemod.fit(kdd_train_10per_scaled, attack_labs)
         enspreds = ensemblemod.predict(kdd_test_10per_scaled)
         print(enspreds)

         #multi-label
         ensemblemod1 = VotingClassifier(modelest,voting='soft')
         ensemblemod1.fit(kdd_train_10per_scaled, attack_labs_all)
         enspreds1 = ensemblemod1.predict(kdd_test_10per_scaled)
         print(enspreds1)
```

```
Out[27]: VotingClassifier(estimators=[('randomforest', RandomForestClassifier(bootstrap=True, cl
                     max_depth=None, max_features='sqrt', max_leaf_nodes=None,
                     min_impurity_decrease=0.0, min_impurity_split=None,
                     min_samples_leaf=1, min_samples_split=2,
                 ...stimators=10, n_jobs=-1, oob_score=False,
                  random_state=None, verbose=0, warm_start=False))],
                  flatten_transform=None, n_jobs=1, voting='soft', weights=None)
```

```
['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

```
Out[27]: VotingClassifier(estimators=[('randomforest', RandomForestClassifier(bootstrap=True, cl
                     max_depth=None, max_features='sqrt', max_leaf_nodes=None,
```

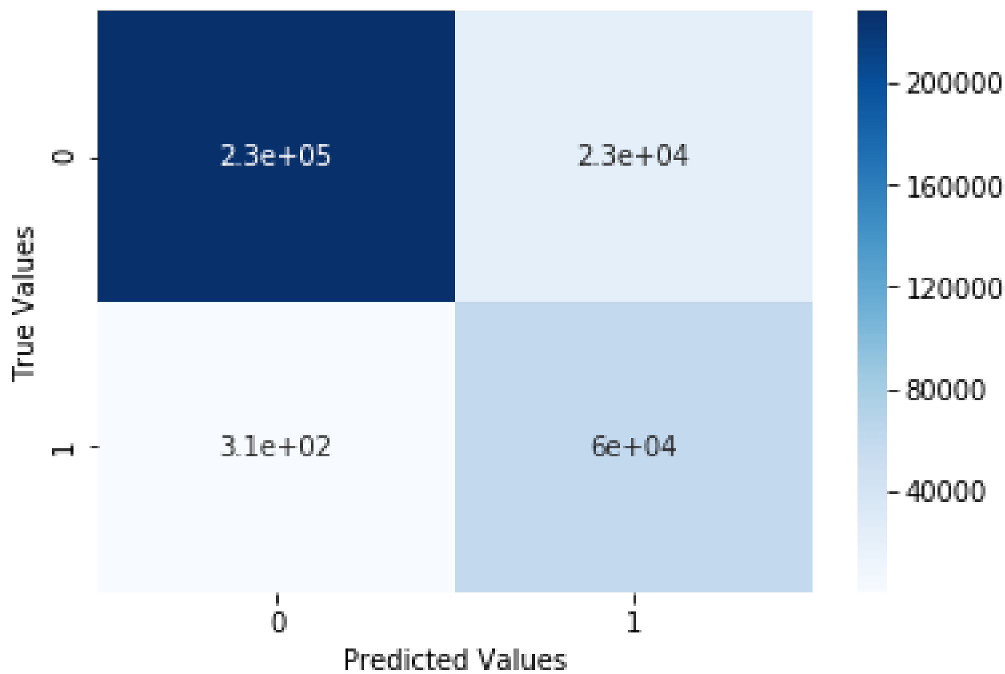
```
                    min_impurity_decrease=0.0, min_impurity_split=None,
                    min_samples_leaf=1, min_samples_split=2,
                ...stimators=10, n_jobs=-1, oob_score=False,
                 random_state=None, verbose=0, warm_start=False))],
                 flatten_transform=None, n_jobs=1, voting='soft', weights=None)

['normal.' 'normal.' 'normal.' ..., 'normal.' 'normal.' 'normal.']
```

In [28]:

```python
#Evaluation Metrics for the ensemble model -- 2 labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_test, enspreds))
print(metrics.accuracy_score(attack_labs_test, enspreds))
print(metrics.recall_score(attack_labs_test, enspreds,average='macro'))
print(metrics.precision_score(attack_labs_test, enspreds,average='macro'))
print(metrics.f1_score(attack_labs_test, enspreds,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_test, enspreds)), an
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))

#Evaluation Metrics for the ensemble model -- multi-labels
#Confusion Matrix, accuracy, recall, precision and f1-score
print(metrics.confusion_matrix(attack_labs_tall, enspreds1))
print(metrics.accuracy_score(attack_labs_tall, enspreds1))
print(metrics.recall_score(attack_labs_tall, enspreds1,average='macro'))
print(metrics.precision_score(attack_labs_tall, enspreds1,average='macro'))
print(metrics.f1_score(attack_labs_tall, enspreds1,average='macro'))

ht = sns.heatmap(pd.DataFrame(metrics.confusion_matrix(attack_labs_tall, enspreds1)), a
ht.set(xlabel='Predicted Values', ylabel='True Values')
plt.show()

#Another way to view these metrics for every class label
precision, recall, fscore, support = metrics.precision_recall_fscore_support(attack_lab

print('precision: {}'.format(precision))
print('recall: {}'.format(recall))
print('fscore: {}'.format(fscore))
print('support: {}'.format(support))
```

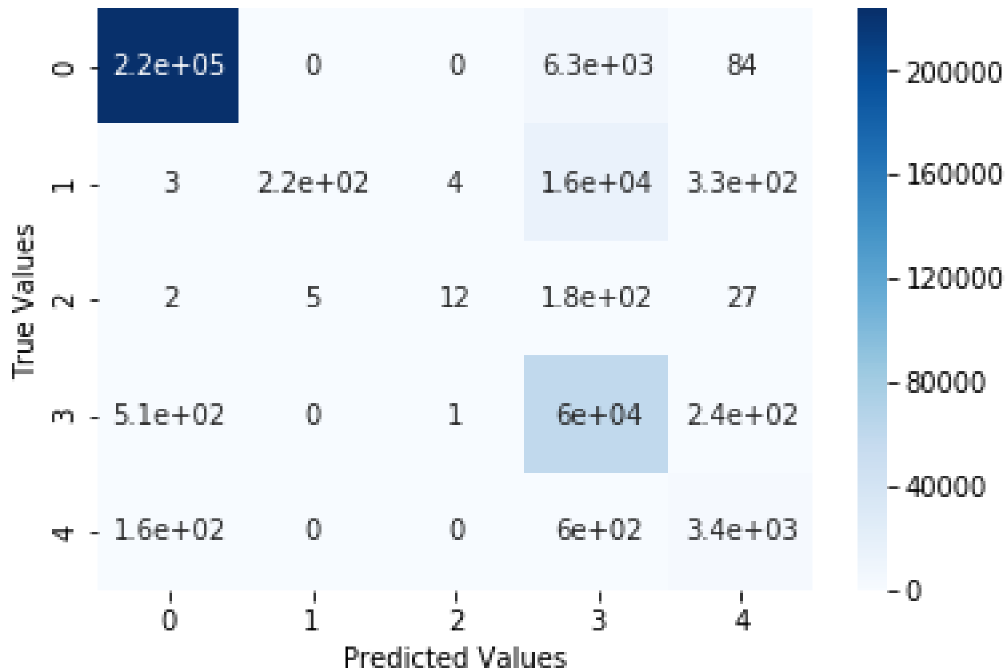
```
[[227909  22527]
 [   308  60285]]
0.926582408714
0.952482889678
0.863312306962
0.896529434911
```

Out[28]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]




```
precision: [ 0.99865041  0.72797421]
recall: [ 0.91004887  0.9949169 ]
fscore: [ 0.95229321  0.84076566]
support: [250436  60593]
[[223496      0      0   6273     84]
 [     3    223      4  15626    333]
 [     2      5     12    182     27]
 [   508      0      1  59845    239]
 [   162      0      0    603   3401]]
0.922669590295
0.568555103316
0.847768494849
0.554080472589
```

Out[28]: [Text(33,0.5,'True Values'), Text(0.5,15,'Predicted Values')]




```
precision: [ 0.99698891  0.97807018  0.70588235  0.72513904  0.832762   ]
recall: [ 0.97234319  0.01377479  0.05263158  0.98765534  0.81637062]
fscore: [ 0.98451183  0.02716696  0.09795918  0.83627954  0.82448485]
support: [229853  16189    228  60593   4166]
```

We observe that the accuracy and F1 score have improved significantly for the 2-label classification over the previous models by using an ensemble model system. The F1 scores for multi-class classification too are higher than the Random Forest classifier.

1.1.11 Unsupervised Learning - Clustering

The above learning methods trained a model on the training data and using the training labels, which was used later to predict the corresponding labels for the test data. Here, we try a different learning technique where we use a clustering algorithm on the test data to identify patterns which we can later verify using the already provided target labels.

In [74]:
```
#Clustering implemented using K-Means on test dataset (n=5 clusters)

kmeans_mod = KMeans(n_clusters=5)
kmeans_mod.fit(kdd_test_10per_scaled)
labels = kmeans_mod.labels_
```

```
Out[74]: KMeans(algorithm='auto', copy_x=True, init='k-means++', max_iter=300,
             n_clusters=5, n_init=10, n_jobs=1, precompute_distances='auto',
             random_state=None, tol=0.0001, verbose=0)
```

```
In [75]: pd.Series(labels).value_counts()
```

```
Out[75]: 3    164804
         0    101311
         1     44191
         2       722
         4         1
         dtype: int64
```

```
In [144]: #Check with target labels for the test dataset

          cluster_labels = pd.DataFrame(labels)
          clust_map = pd.concat([cluster_labels,attack_labs_test],axis=1)
          clust_map.columns = ['cluster','attack_type']
          type(clust_map)
          clust_map.head(10)

          df = clust_map.groupby(['cluster','attack_type']).size()
          df1 = pd.DataFrame(df).reset_index()
          df1.columns = ['cluster','attack_type','counts']
          df1.head(20)

          df.unstack().plot(kind='bar',stacked=True,  color=['red','blue'], grid=False)
          plt.xlabel('Clusters')
          plt.ylabel('Counts')
          plt.title('Cluster Distribution')
          plt.show()
```

```
Out[144]: pandas.core.frame.DataFrame
```

```
Out[144]:    cluster attack_type
          0        0     normal.
          1        0     normal.
          2        0     normal.
          3        0        bad.
          4        0        bad.
          5        0        bad.
          6        0     normal.
          7        0     normal.
          8        0        bad.
          9        0     normal.
```

```
Out[144]:    cluster attack_type  counts
          0        0        bad.   41572
          1        0     normal.   59739
```

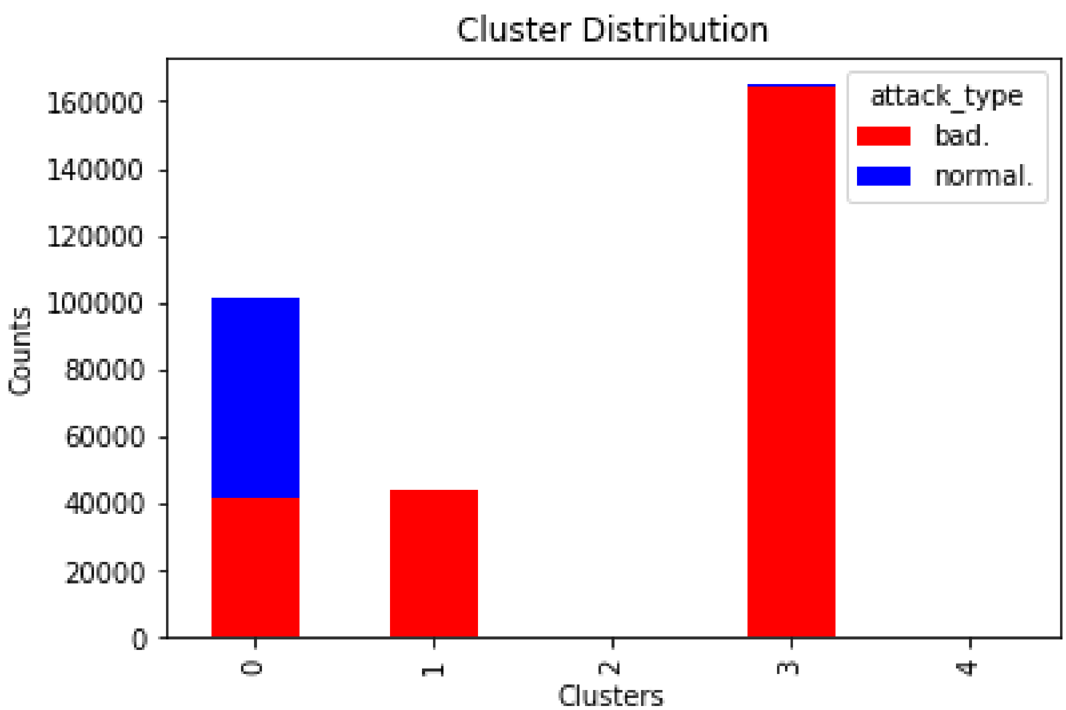
```
2        1       bad.   44076
3        1    normal.     115
4        2       bad.     717
5        2    normal.       5
6        3       bad.  164071
7        3    normal.     733
8        4    normal.       1
```

Out[144]: <matplotlib.axes._subplots.AxesSubplot at 0x266a648ca90>

Out[144]: Text(0.5,0,'Clusters')

Out[144]: Text(0,0.5,'Counts')

Out[144]: Text(0.5,1,'Cluster Distribution')



In [145]:
```
#Doing this for all major attack types in the test dataset

clust_map = pd.concat([cluster_labels,attack_labs_tall],axis=1)
clust_map.columns = ['cluster','attack_type']
type(clust_map)
clust_map.head(10)

df = clust_map.groupby(['cluster','attack_type']).size()
```

```
df1 = pd.DataFrame(df).reset_index()
df1.columns = ['cluster','attack_type','counts']
df1.head(20)

df.unstack().plot(kind='bar',stacked=True,  color=['red','blue','green','yellow','oran
plt.xlabel('Clusters')
plt.ylabel('Counts')
plt.title('Cluster Distribution')
plt.show()
```

Out[145]: pandas.core.frame.DataFrame

Out[145]:

	cluster	attack_type
0	0	normal.
1	0	normal.
2	0	normal.
3	0	R2L.
4	0	R2L.
5	0	R2L.
6	0	normal.
7	0	normal.
8	0	R2L.
9	0	normal.

Out[145]:

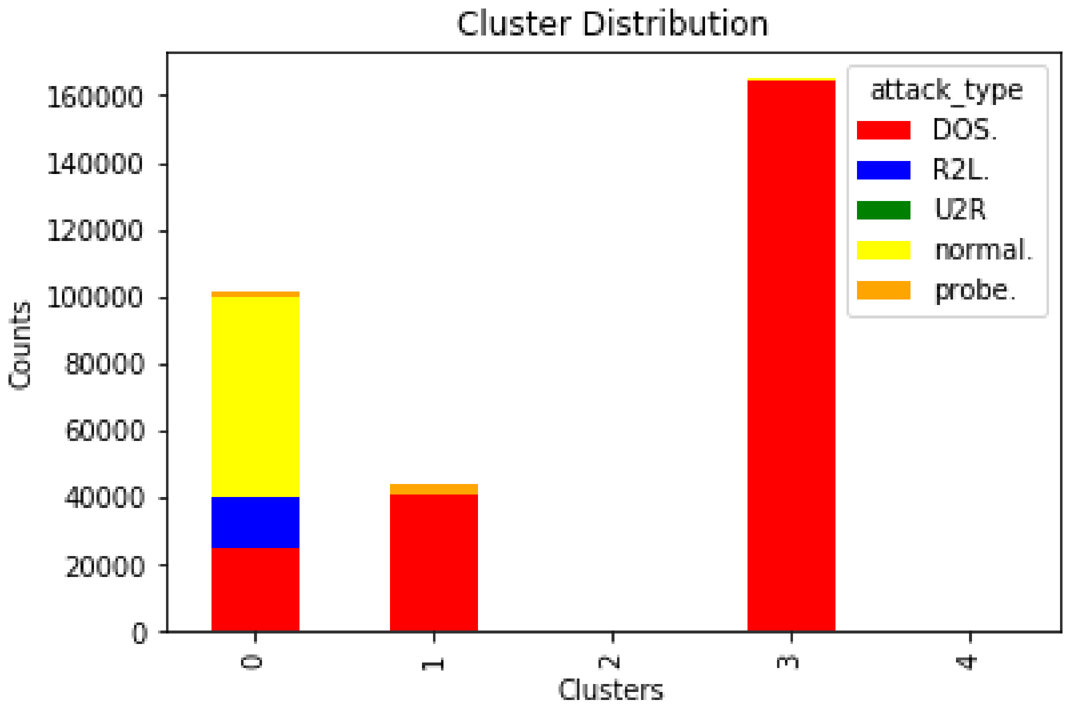
	cluster	attack_type	counts
0	0	DOS.	24831
1	0	R2L.	15465
2	0	U2R	89
3	0	normal.	59739
4	0	probe.	1187
5	1	DOS.	40955
6	1	R2L.	9
7	1	U2R	136
8	1	normal.	115
9	1	probe.	2976
10	2	R2L.	714
11	2	U2R	3
12	2	normal.	5
13	3	DOS.	164067
14	3	R2L.	1
15	3	normal.	733
16	3	probe.	3
17	4	normal.	1

Out[145]: <matplotlib.axes._subplots.AxesSubplot at 0x26746543c88>

Out[145]: Text(0.5,0,'Clusters')

Out[145]: Text(0,0.5,'Counts')

Out[145]: Text(0.5,1,'Cluster Distribution')



We see that most of the clusters show one particular type of attack or normal as the dominant type in the cluster. We can do it for more clusters for greater granularity.

In [148]:
```
#Clustering for n=10 clusters

kmeans_mod1 = KMeans(n_clusters=10)
kmeans_mod1.fit(kdd_test_10per_scaled)
labels1 = kmeans_mod1.labels_

#Check with target labels for the test dataset

cluster_labels1 = pd.DataFrame(labels1)
clust_map1 = pd.concat([cluster_labels1,attack_labs_tall],axis=1)
clust_map2 = pd.concat([cluster_labels1,attack_labs_test],axis=1)
clust_map1.columns = ['cluster','attack_type']
clust_map2.columns = ['cluster','attack_type']

df = clust_map2.groupby(['cluster','attack_type']).size()
df1 = pd.DataFrame(df).reset_index()
df1.columns = ['cluster','attack_type','counts']
df1.head(50)

df.unstack().plot(kind='bar',stacked=True,  color=['red','blue'], grid=False)
```

```
plt.xlabel('Clusters')
plt.ylabel('Counts')
plt.title('Cluster Distribution')
plt.show()

df = clust_map1.groupby(['cluster','attack_type']).size()
df1 = pd.DataFrame(df).reset_index()
df1.columns = ['cluster','attack_type','counts']
df1.head(50)

df.unstack().plot(kind='bar',stacked=True,  color=['red','blue','green','yellow','oran
plt.xlabel('Clusters')
plt.ylabel('Counts')
plt.title('Cluster Distribution')
plt.show()
```

Out[148]:
```
KMeans(algorithm='auto', copy_x=True, init='k-means++', max_iter=300,
    n_clusters=10, n_init=10, n_jobs=1, precompute_distances='auto',
    random_state=None, tol=0.0001, verbose=0)
```

Out[148]:

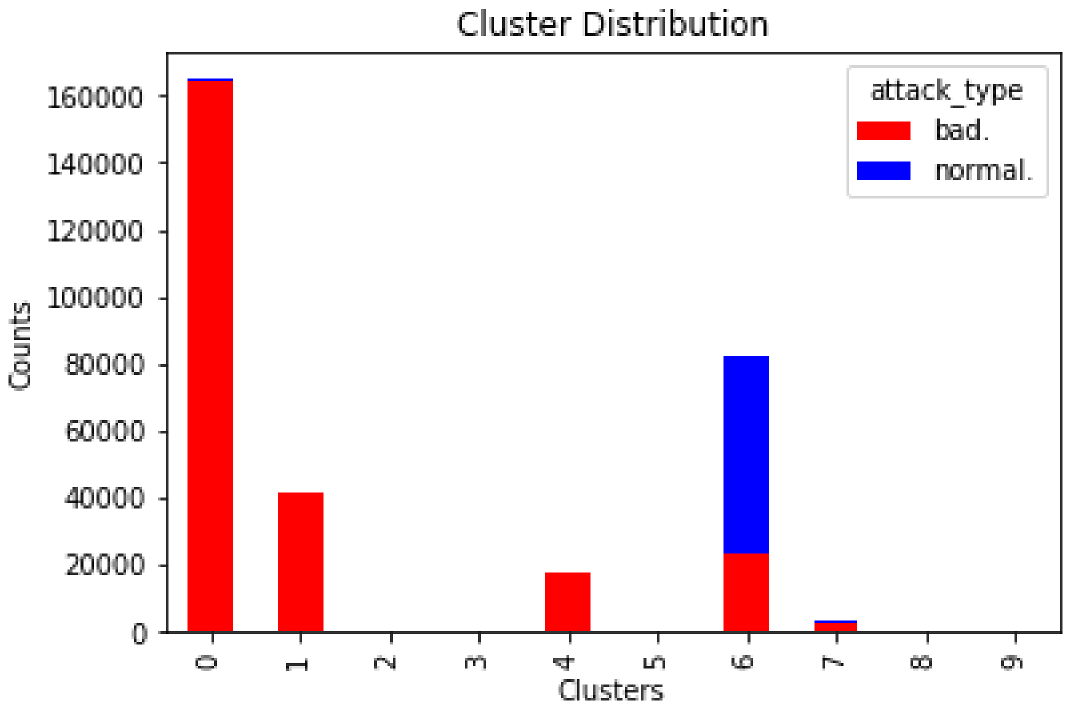
	cluster	attack_type	counts
0	0	bad.	164005
1	0	normal.	728
2	1	bad.	41470
3	1	normal.	95
4	2	bad.	717
5	2	normal.	5
6	3	bad.	5
7	4	bad.	18096
8	4	normal.	23
9	5	normal.	1
10	6	bad.	23043
11	6	normal.	59357
12	7	bad.	3081
13	7	normal.	380
14	8	normal.	3
15	9	bad.	19
16	9	normal.	1

Out[148]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x268bb5a8d30>
```

Out[148]:
```
Text(0.5,0,'Clusters')
```

Out[148]:
```
Text(0,0.5,'Counts')
```

Out[148]:
```
Text(0.5,1,'Cluster Distribution')
```

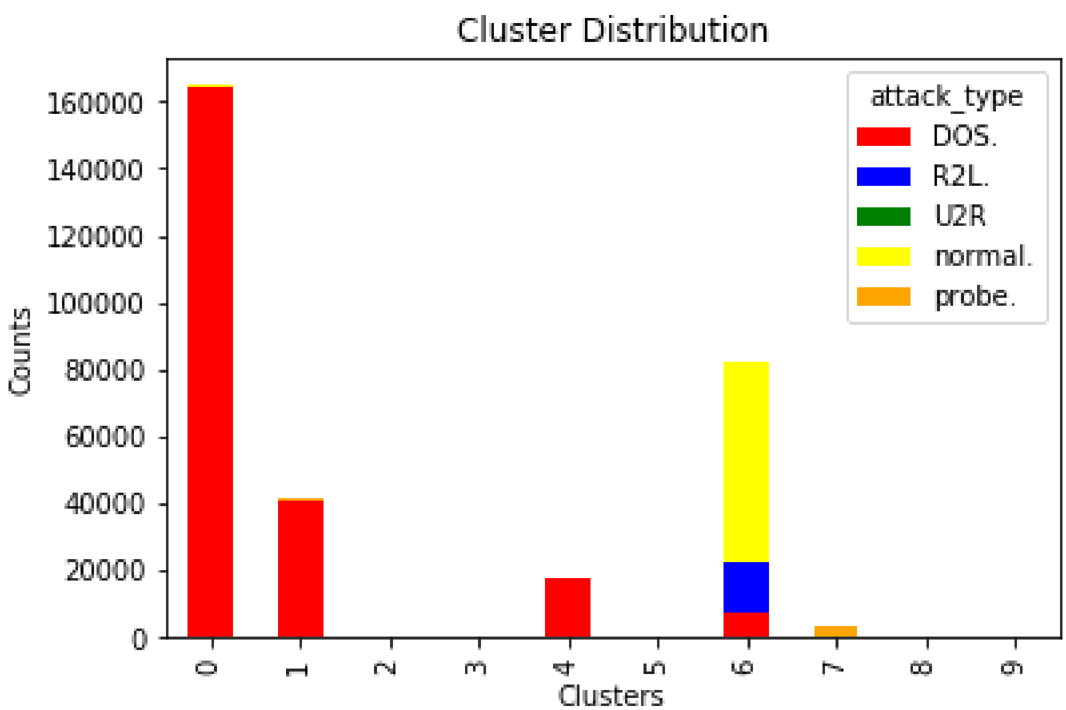


Out[148]:

	cluster	attack_type	counts
0	0	DOS.	164001
1	0	R2L.	1
2	0	normal.	728
3	0	probe.	3
4	1	DOS.	40905
5	1	R2L.	5
6	1	U2R	117
7	1	normal.	95
8	1	probe.	443
9	2	R2L.	714
10	2	U2R	3
11	2	normal.	5
12	3	U2R	5
13	4	DOS.	17813
14	4	R2L.	3
15	4	normal.	23
16	4	probe.	280
17	5	normal.	1
18	6	DOS.	7113
19	6	R2L.	15387
20	6	U2R	66
21	6	normal.	59357
22	6	probe.	477

```
23          7         DOS.       21
24          7         R2L.       77
25          7          U2R       20
26          7      normal.      380
27          7       probe.     2963
28          8      normal.        3
29          9         R2L.        2
30          9          U2R       17
31          9      normal.        1
```

```
Out[148]: <matplotlib.axes._subplots.AxesSubplot at 0x267463c2198>

Out[148]: Text(0.5,0,'Clusters')

Out[148]: Text(0,0.5,'Counts')

Out[148]: Text(0.5,1,'Cluster Distribution')
```



We observe similar results here as well. Hence, we see that even if we do not have a training dataset to train a supervised model on, unsupervised algorithms like clustering can give us a fairly good idea reagarding the classification of "bad" intrusions from "normal" traffic signatures.