Basic Data Processing

In [248]:

```
import numpy as npy
import pandas as pds
import matplotlib.pyplot as plt
from sklearn.cluster import KMeans

dataFrame_1 = pds.read_csv('Dataset_1.csv')

grouped_sIPs = dataFrame_1.groupby('sourceIP').count()
grouped_dIPs = dataFrame_1.groupby('destIP').count()
grouped_clfs = dataFrame_1.groupby('classification').count()
```

In [249]:

```
distict_sIPs_count = grouped_sIPs.shape[0]
distict_dIPs_count = grouped_dIPs.shape[0]
distict_clfs_count = grouped_clfs.shape[0]

print("Distict Source IP addresses are: " + str(distict_sIPs_count))
print("Distict Destination IP addresses are: " + str(distict_dIPs_count))
print("Distict Classifications are: " + str(distict_clfs_count))
```

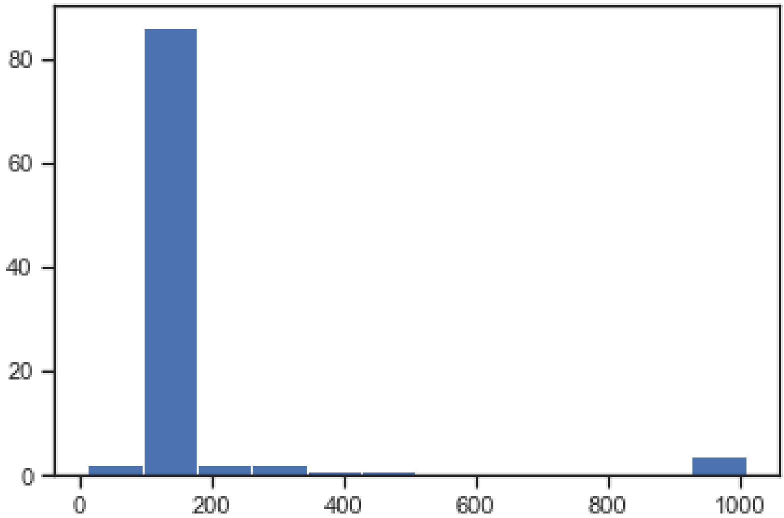
```
Distict Source IP addresses are: 98
Distict Destination IP addresses are: 261
Distict Classifications are: 3
```

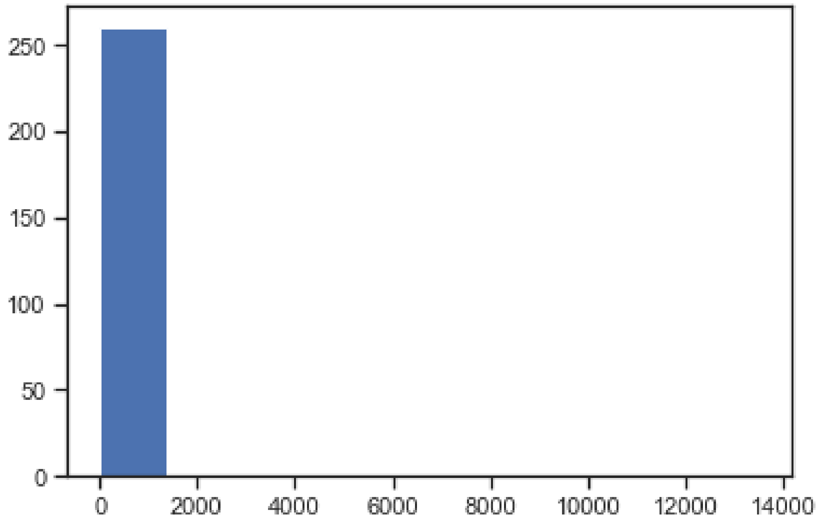
Basic Data Analysis and Visualisation

In [250]:

```
sIP_dict = dataFrame_1.groupby('sourceIP').groups
dIP_dict = dataFrame_1.groupby('destIP').groups

distict_sIPs_keys = list(sIP_dict.keys()) # Distinct Source IPs list
distict_dIPs_keys = list(dIP_dict.keys()) # Distinct Destination IPs list


distict_sIPs_values = list(map(lambda x: x.size, sIP_dict.values()))  # Di
stinct Source IPs Frequency of appearance
distict_dIPs_values = list(map(lambda x: x.size, dIP_dict.values()))  # Di
stinct Destination IPs Frequency of appearance

sIPs_df = pd.DataFrame(list(zip(distict_sIPs_keys, distict_sIPs_values)),
               columns =['SourceIPs', 'Frequency'])

dIPs_df = pd.DataFrame(list(zip(distict_dIPs_keys, distict_dIPs_values)),
             columns =['DestinationIPs', 'Frequency'])

sIPs_df['IndexColumn'] = sIPs_df.index
dIPs_df['IndexColumn'] = dIPs_df.index

# Dataframe with distinct Source IPs and their Frequency of appearance
print(sIPs_df)

# Dataframe with distinct Destination IPs and their Frequency of appearanc
e
print(dIPs_df)

plt.hist(sIPs_df['Frequency'], bins=12)  # Histogram plot of 12 bins
plt.show()

plt.hist(dIPs_df['Frequency'], bins=10)
plt.show()
```

```
        SourceIPs  Frequency  IndexColumn
0      10.32.5.51        319            0
1      10.32.5.52        299            1
2      10.32.5.53        966            2
3      10.32.5.54       1008            3
4      10.32.5.55        959            4
..            ...        ...          ...
93   172.23.5.115        146           93
94   172.23.5.117        148           94
95   172.23.5.120        146           95
96   172.23.5.121        146           96
97   172.23.5.124        146           97

[98 rows x 3 columns]
    DestinationIPs  Frequency  IndexColumn
0      172.23.0.10      13505            0
1     172.23.0.108         74            1
2     172.23.0.109          2            2
3     172.23.0.110          1            3
4     172.23.1.168         63            4
..             ...        ...          ...
256  172.23.240.36          1          256
257  172.23.240.37          1          257
258  172.23.240.38          2          258
259  172.23.252.10         31          259
260  172.23.254.80          1          260

[261 rows x 3 columns]
```

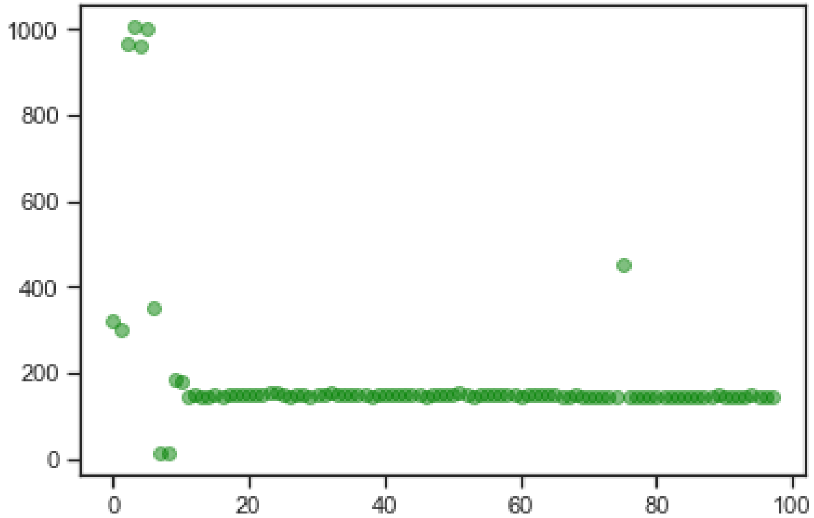


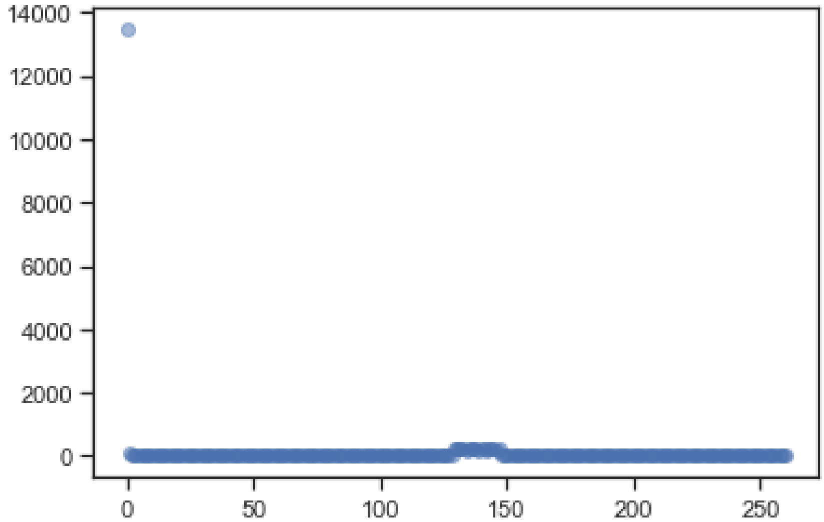


Clustering

In [251]:

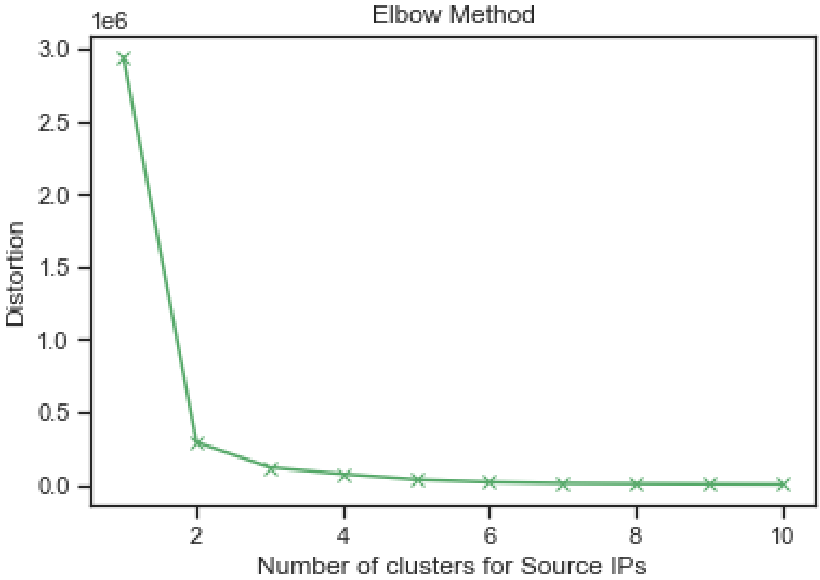
```
# Data distribution Scatter Plots of Destination and Source IPs
color_source = ("green")
color_destin = ("red")

plt.scatter(sIPs_df['IndexColumn'], sIPs_df['Frequency'], c=color_source, alpha=0.5)
plt.show()

plt.scatter(dIPs_df['IndexColumn'], dIPs_df['Frequency'], alpha=0.5)
plt.show()
```

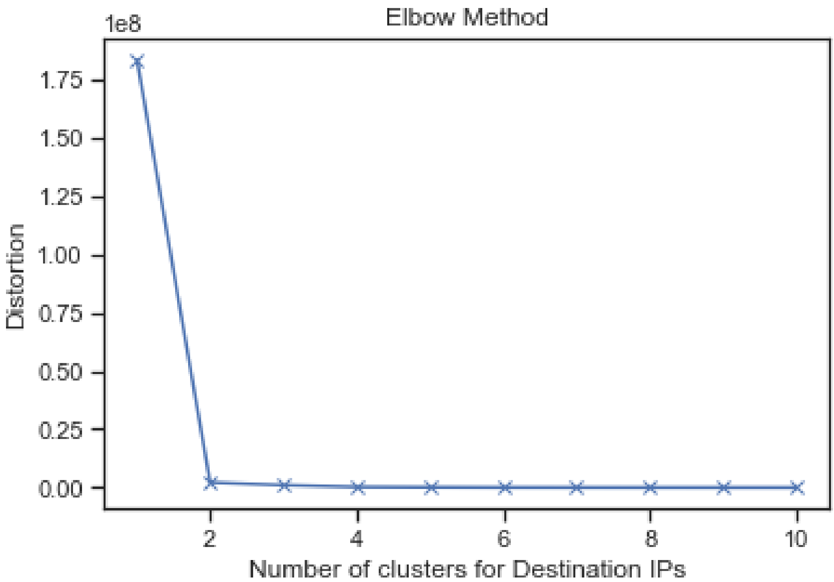




In [252]:

```
# K-means: Finding the optimal number of clusters with Elbow Plot

wcss_s = []
for i in range(1, 11):
    kmeans = KMeans(n_clusters=i, init='k-means++', max_iter=300, n_init=1
0, random_state=0)
    kmeans.fit(sIPs_df[['IndexColumn', 'Frequency']])
    wcss_s.append(kmeans.inertia_)
plt.plot(range(1, 11), wcss_s, 'gx-')
plt.title('Elbow Method')
plt.xlabel('Number of clusters for Source IPs')
plt.ylabel('Distortion')
plt.show()

wcss_d = []
for i in range(1, 11):
    kmeans = KMeans(n_clusters=i, init='k-means++', max_iter=300, n_init=1
0, random_state=0)
    kmeans.fit(dIPs_df[['IndexColumn', 'Frequency']])
    wcss_d.append(kmeans.inertia_)
plt.plot(range(1, 11), wcss_d, 'x-')
plt.title('Elbow Method')
plt.xlabel('Number of clusters for Destination IPs')
plt.ylabel('Distortion')
plt.show()
```


Elbow Method
1e6
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Distortion
2
4
6
8
10
Number of clusters for Source IPs

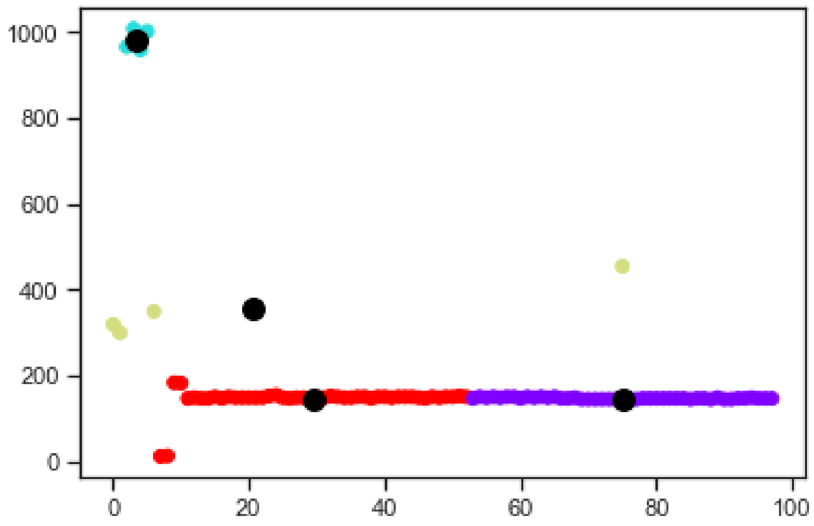

Elbow Method
1e8
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Distortion
2
4
6
8
10
Number of clusters for Destination IPs

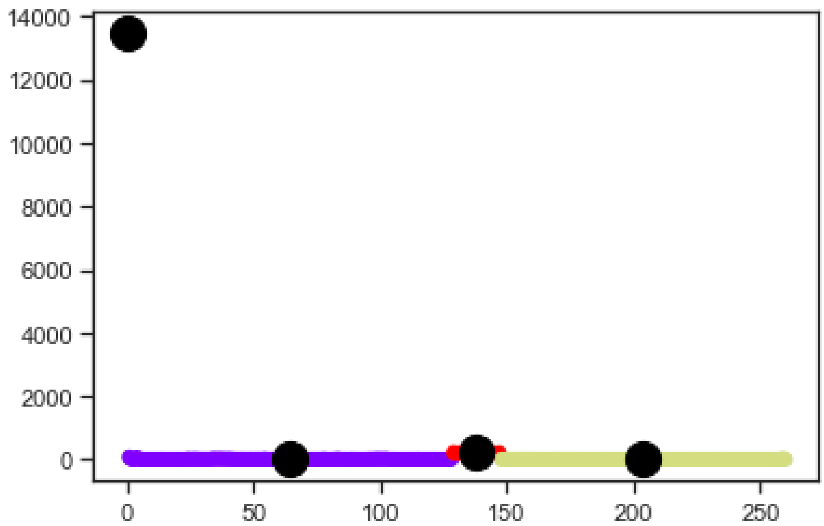
In [ ]:

```

```

In [253]:

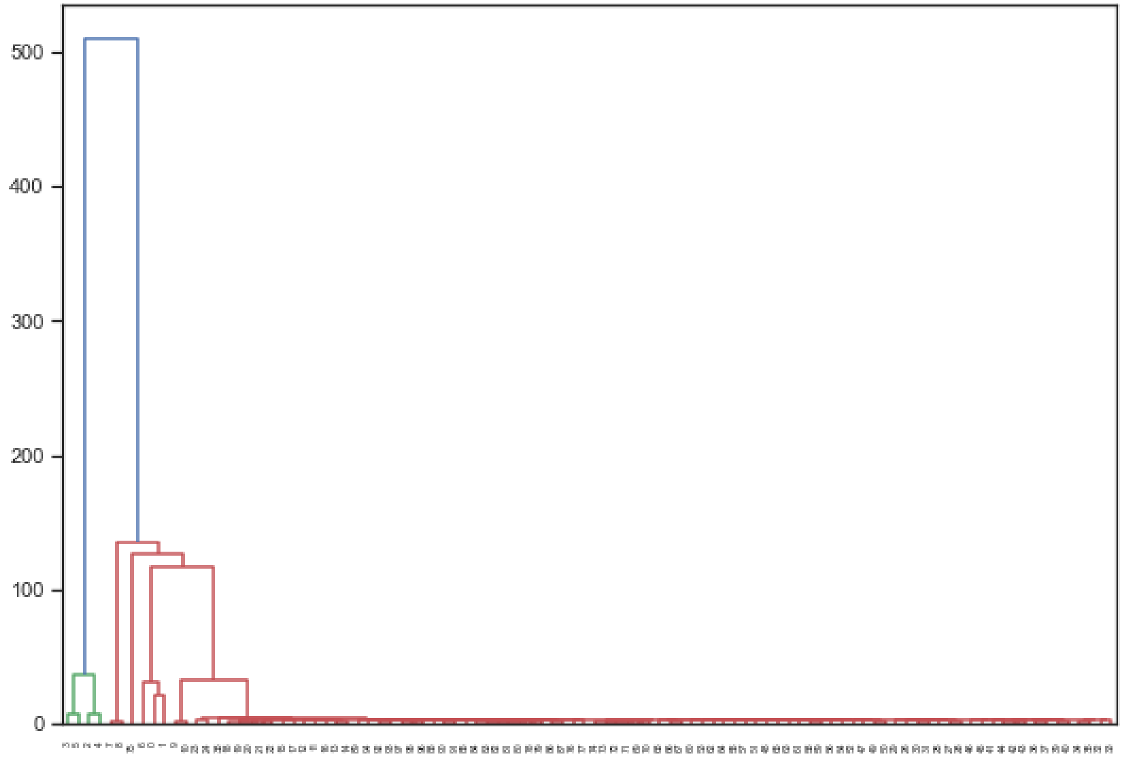
```
# K-means clustering with 4 clusters for both Source and Destination IPs

kmeans = KMeans(n_clusters=4, init='k-means++')
pred_y = kmeans.fit_predict(sIPs_df[['IndexColumn', 'Frequency']])
plt.scatter(sIPs_df['IndexColumn'], sIPs_df['Frequency'], c=kmeans.labels_
, cmap='rainbow')
plt.scatter(kmeans.cluster_centers_[:, 0], kmeans.cluster_centers_[:, 1],
s=sIPs_df.shape[0], c='black')
plt.show()


kmeans = KMeans(n_clusters=4, init='k-means++')
pred_y = kmeans.fit_predict(dIPs_df[['IndexColumn', 'Frequency']])
plt.scatter(dIPs_df['IndexColumn'], dIPs_df['Frequency'], c=kmeans.labels_
, cmap='rainbow')
plt.scatter(kmeans.cluster_centers_[:, 0], kmeans.cluster_centers_[:, 1],
s=dIPs_df.shape[0], c='black')
plt.show()
```





In [254]:

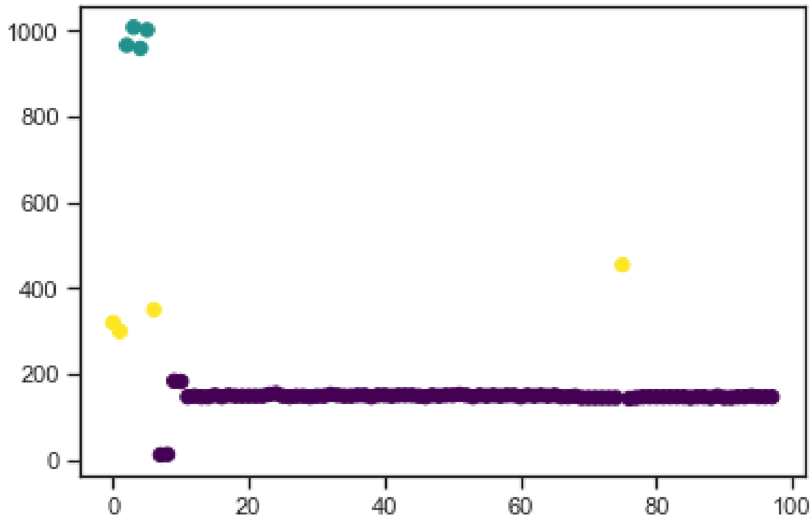
```
# Hierarchial Clustering of Source IPs
from scipy.cluster.hierarchy import dendrogram, linkage
x= np.array(sIPs_df[['IndexColumn', 'Frequency']])
linked = linkage(x, 'single')
labelList = range(0, len(x))
plt.figure(figsize=(10, 7))
dendrogram(linked,labels=labelList)
plt.show()

# Gaussian Mixture Clustering of Source IPs
'''Gaussian Mixture Clustering of SourceIPs'''
from sklearn.mixture import GaussianMixture as GMM
gmm = GMM(n_components=3).fit(x)
print(gmm.means_)
print(gmm.covariances_)
print(gmm.weights_)
labels = gmm.predict(x)
plt.scatter(x[:, 0], x[:, 1], c=labels, s=40, cmap='viridis')
```




```
[[ 51.74444444 145.26666667]
 [  3.5         983.75      ]
 [ 20.5         355.25      ]]
[[[6.91723581e+02 7.36125926e+01]
  [7.36125926e+01 4.38417779e+02]]

 [[1.25000100e+00 7.37500000e+00]
  [7.37500000e+00 4.62187501e+02]]

 [[9.95250001e+02 1.82812500e+03]
  [1.82812500e+03 3.56718750e+03]]]
[0.91836735 0.04081633 0.04081633]
```

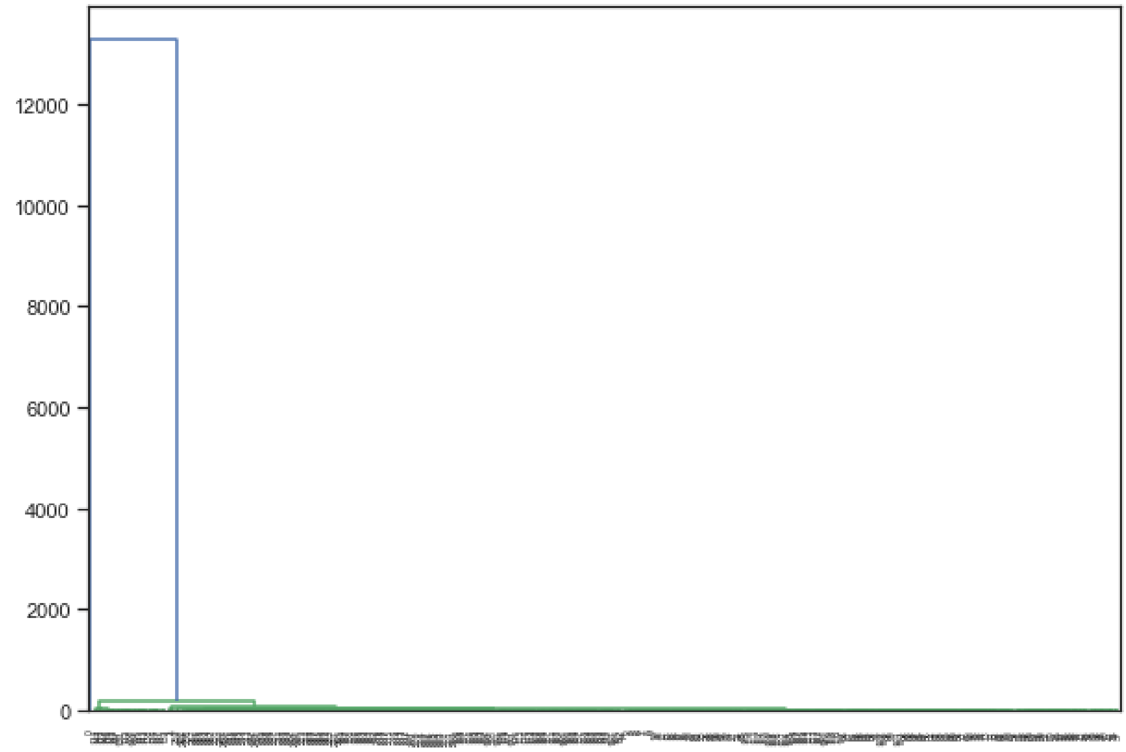
Out[254]:

```
<matplotlib.collections.PathCollection at 0x122884af0>
```



In [255]:

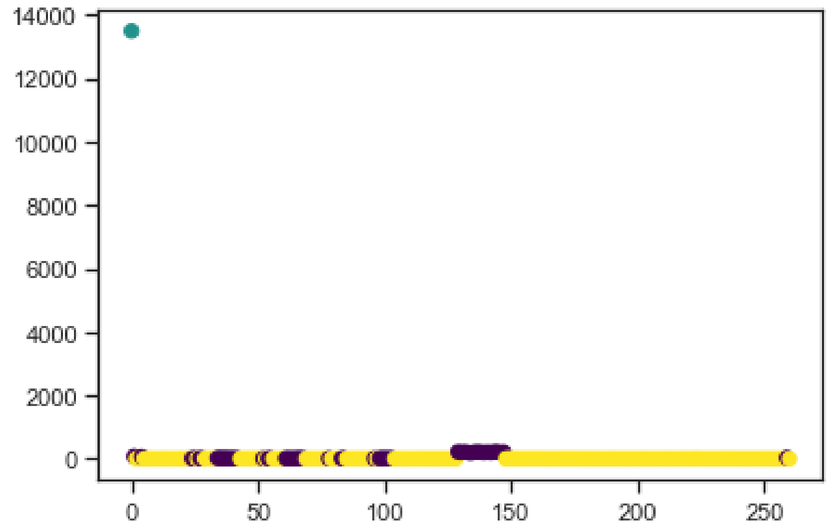
```
'''Hierarchial Clustering of Destination IPs'''
from scipy.cluster.hierarchy import dendrogram, linkage
y= np.array(dIPs_df[['IndexColumn', 'Frequency']])
linked = linkage(y, 'single')
labelList = range(0, len(y))
plt.figure(figsize=(10, 7))
dendrogram(linked,labels=labelList)
plt.show()

'''Gaussian Mixture Clustering of Destination'''
from sklearn.mixture import GaussianMixture as GMM
gmm = GMM(n_components=3).fit(y)
print(gmm.means_)
print(gmm.covariances_)
print(gmm.weights_)
labels = gmm.predict(y)
plt.scatter(y[:, 0], y[:, 1], c=labels, s=40, cmap='viridis')
```




```
[[8.68030450e+01 7.80896815e+01]
 [0.00000000e+00 1.35050000e+04]
 [1.43156438e+02 1.81079216e+00]]
[[[ 2.47142430e+03  3.14871927e+03]
  [ 3.14871927e+03  8.30181306e+03]]

 [[ 1.00000000e-06  0.00000000e+00]
  [ 0.00000000e+00  1.00000000e-06]]

 [[ 5.83581173e+03 -1.50969072e+01]
  [-1.50969072e+01  1.25015235e+00]]]
[0.22373002 0.00383142 0.77243856]
```

Out[255]:

```
<matplotlib.collections.PathCollection at 0x126f01e20>
```



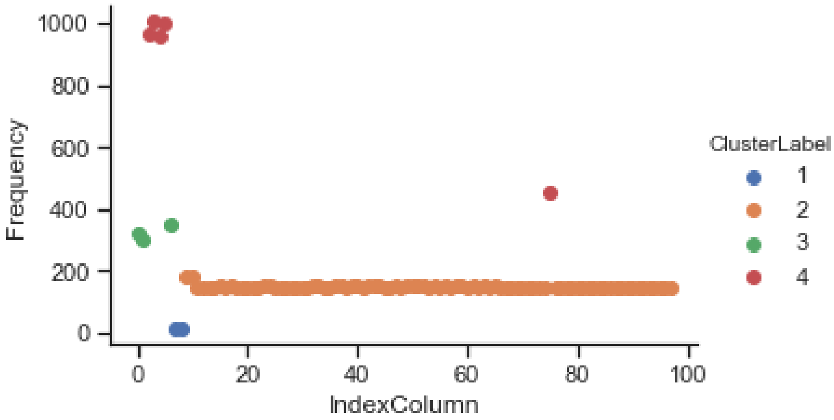
In [ ]:

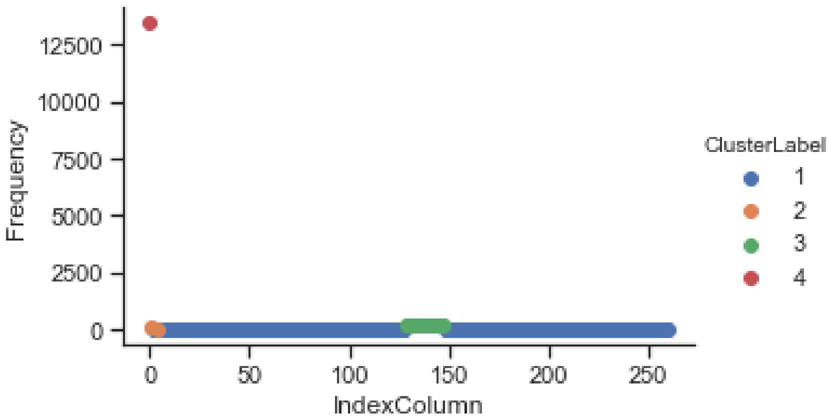
```

```

Relationships

In [256]:

```
import seaborn
seaborn.set(style='ticks')

def clusterSourceIPs (row):
    if row['Frequency'] <21:
        cluster = 1
    elif row['Frequency'] >20 and row['Frequency'] <201:
        cluster = 2
    elif row['Frequency'] >200 and row['Frequency'] <401:
        cluster = 3
    else:
        cluster = 4
    return cluster

def clusterDestinationIPs (row):
    if row['Frequency'] <41:
        cluster = 1
    elif row['Frequency'] >40 and row['Frequency'] <101:
        cluster = 2
    elif row['Frequency'] >100 and row['Frequency'] <401:
        cluster = 3
    else:
        cluster = 4
    return cluster

sIPs_df['ClusterLabel'] = sIPs_df.apply(clusterSourceIPs, axis=1)  #  CRea
te a new column with cluster labels for SourceIPs
dIPs_df['ClusterLabel'] = dIPs_df.apply(clusterDestinationIPs, axis=1) #
 CReate a new column with cluster labels for DestinationIPs


#  Plot the clusters now.....
cluster_range= [1,2,3,4]
sp = seaborn.FacetGrid(data=sIPs_df[['IndexColumn','Frequency','ClusterLab
el']], hue='ClusterLabel', hue_order=cluster_range, aspect=1.61)
sp.map(plt.scatter, 'IndexColumn', 'Frequency').add_legend()
plt.show()

dp = seaborn.FacetGrid(data=dIPs_df[['IndexColumn','Frequency','ClusterLab
el']], hue='ClusterLabel', hue_order=cluster_range, aspect=1.61)
dp.map(plt.scatter, 'IndexColumn', 'Frequency').add_legend()
plt.show()
```


Frequency
1000
800
600
400
200
0
0
20
40
60
80
100
IndexColumn
ClusterLabel
1
2
3
4


Frequency
12500
10000
7500
5000
2500
0
0
50
100
150
200
250
IndexColumn
ClusterLabel
1
2
3
4

In [258]:

```
def createLabelForSource(row):
    ip = row['sourceIP']
    indexVal = sIPs_df[sIPs_df.SourceIPs == ip].index.item();
    '''print(indexVal)'''
    '''print(ip.head())'''
    '''print(sIPs_df.at[indexVal,'ClusterLabel'])'''
    return sIPs_df.at[indexVal,'ClusterLabel']

def createLabelForDestination(row):
    ip = row['destIP']
    indexVal = dIPs_df[dIPs_df.DestinationIPs == ip].index.item();
    '''print(indexVal)'''
    '''print(ip.head())'''
    '''print(sIPs_df.at[indexVal,'ClusterLabel'])'''
    return dIPs_df.at[indexVal,'ClusterLabel']

newDF = dataFrame_1[['sourceIP', 'destIP', 'classification']]
'''ddf = newDF[:3]'''

'''newDF.drop(['NewLabel'])'''
#  Create a dataframe of actual data merged with corresponding Source and
 Destination Labels for each IP
newDF['SourceLabel'] = newDF.apply(createLabelForSource, axis=1)
newDF['DestinationLabel'] = newDF.apply(createLabelForDestination, axis=1)
print(newDF)
```

```
<ipython-input-258-6806422f6758>:22: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFr
ame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.or
g/pandas-docs/stable/user_guide/indexing.html#returning-a-view
-versus-a-copy
  newDF['SourceLabel'] = newDF.apply(createLabelForSource, axi
s=1)

          sourceIP          destIP  classification  SourceLabel
\
0      10.32.5.58  172.23.232.154   Misc activity            1
1      10.32.5.56   172.23.232.56   Misc activity            4
2      10.32.5.54    172.23.232.1   Misc activity            4
3      10.32.5.57   172.23.233.52   Misc activity            3
4      10.32.5.54   172.23.233.56   Misc activity            4
...           ...             ...             ...          ...
18425  10.32.5.51  172.23.134.216   Misc activity            3
18426  10.32.5.55  172.23.134.215   Misc activity            4
18427  10.32.5.53  172.23.134.219   Misc activity            4
18428  10.32.5.56   172.23.134.78   Misc activity            4
18429  10.32.5.54  172.23.128.118   Misc activity            4

       DestinationLabel
0                     1
1                     1
2                     1
3                     1
4                     1
...                 ...
18425                 3
18426                 3
18427                 3
18428                 3
18429                 1

[18430 rows x 5 columns]

<ipython-input-258-6806422f6758>:23: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFr
ame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.or
g/pandas-docs/stable/user_guide/indexing.html#returning-a-view
-versus-a-copy
  newDF['DestinationLabel'] = newDF.apply(createLabelForDestin
ation, axis=1)
```

In [259]:

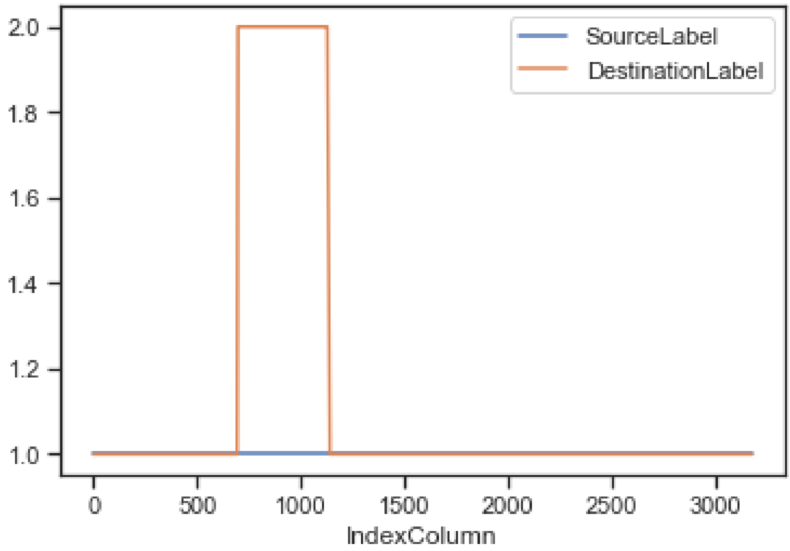
```
'''Create new columns for Source clusters and destination clusters.'''

copiedDF = dataFrame_1.copy()

copiedDF['SourceLabel'] = copiedDF.apply(createLabelForSource, axis=1)
copiedDF['DestinationLabel'] = copiedDF.apply(createLabelForDestination, a
xis=1)
copiedDF['IndexColumn'] = copiedDF.index

print(copiedDF.head())
```

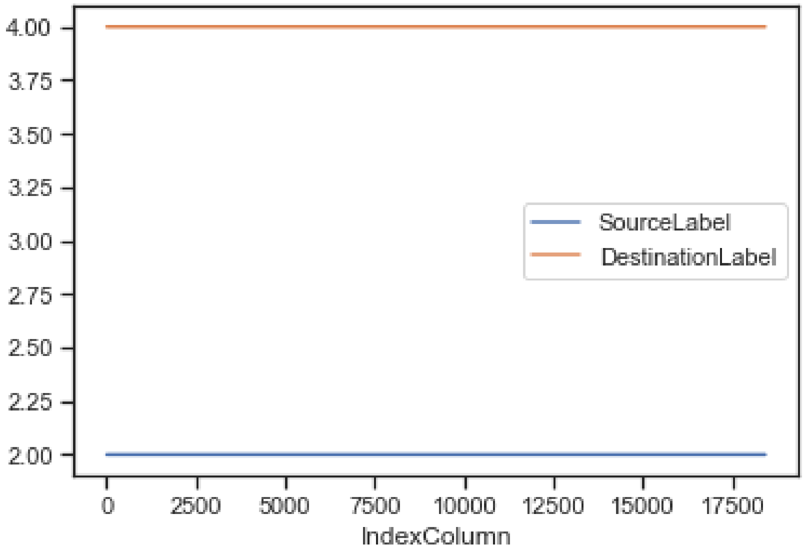
```
              time    sourceIP  sourcePort         destIP  de
stPort  \
0  4/14/2016 17:23  10.32.5.58        6667  172.23.232.154
23005
1  4/14/2016 17:23  10.32.5.56        6667   172.23.232.56
23008
2  4/14/2016 17:23  10.32.5.54        6667    172.23.232.1
23012
3  4/14/2016 17:23  10.32.5.57        6667   172.23.233.52
23769
4  4/14/2016 17:23  10.32.5.54        6667   172.23.233.56
23771

   classification  priority  \
0   Misc activity         3
1   Misc activity         3
2   Misc activity         3
3   Misc activity         3
4   Misc activity         3

                                               label  \
0   [1:2000355:5] ET POLICY IRC authorization mes...
1   [1:2000355:5] ET POLICY IRC authorization mes...
2   [1:2000355:5] ET POLICY IRC authorization mes...
3   [1:2000355:5] ET POLICY IRC authorization mes...
4   [1:2000355:5] ET POLICY IRC authorization mes...

                                         packet info  \
0  TCP TTL:128 TOS:0x0 ID:23022 IpLen:20 DgmLen:1...
1  TCP TTL:128 TOS:0x0 ID:4665 IpLen:20 DgmLen:14...
2  TCP TTL:128 TOS:0x0 ID:54185 IpLen:20 DgmLen:1...
3  TCP TTL:128 TOS:0x0 ID:23105 IpLen:20 DgmLen:1...
4  TCP TTL:128 TOS:0x0 ID:54223 IpLen:20 DgmLen:1...

                                  packet info cont'd  \
0  ***AP*** Seq: 0x52C70265  Ack: 0x63D8AD8D  Win...
1  ***AP*** Seq: 0x11B2F26A  Ack: 0x9870C2A5  Win...
2  ***AP*** Seq: 0x86E9D451  Ack: 0xE1B0CBA6  Win...
3  ***AP*** Seq: 0x2F32E763  Ack: 0xC06CADAB  Win...
4  ***AP*** Seq: 0xDEEFD0F5  Ack: 0xEE7B1E92  Win...

                                               xref  SourceLab
el  \
0  [Xref => http://doc.emergingthreats.net/2000355]
1
1  [Xref => http://doc.emergingthreats.net/2000355]
4
2  [Xref => http://doc.emergingthreats.net/2000355]
4
3  [Xref => http://doc.emergingthreats.net/2000355]
3
4  [Xref => http://doc.emergingthreats.net/2000355]
4

   DestinationLabel  IndexColumn
0                 1            0
```

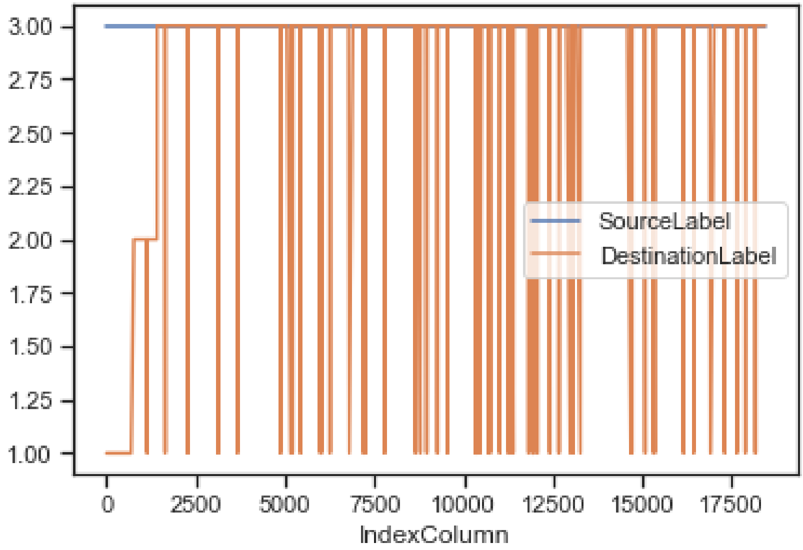
1	1	1
2	1	2
3	1	3
4	1	4

In [260]:

```
# Source and Destination Clusters Relationship...


copiedDF[copiedDF['SourceLabel'] == 1].plot('IndexColumn',y=['SourceLabel'
,'DestinationLabel'])
plt.show()

copiedDF[copiedDF['SourceLabel'] == 2].plot('IndexColumn',y=['SourceLabel'
,'DestinationLabel'])
plt.show()

copiedDF[copiedDF['SourceLabel'] == 3].plot('IndexColumn',y=['SourceLabel'
,'DestinationLabel'])
plt.show()
```


2.0
1.8
1.6
1.4
1.2
1.0
SourceLabel
DestinationLabel
0
500
1000
1500
2000
2500
3000
IndexColumn


4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
SourceLabel
DestinationLabel
0
2500
5000
7500
10000
12500
15000
17500
IndexColumn


3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
SourceLabel
DestinationLabel
0
2500
5000
7500
10000
12500
15000
17500
IndexColumn

In [261]:

```
#  Conditional Probability Calculations
''''''

cond_prob = pd.DataFrame((copiedDF.groupby('SourceLabel')['DestinationLabe
l'].value_counts()/ copiedDF.groupby('SourceLabel')['DestinationLabel'].co
unt()*100))
print(cond_prob)
```

```
                               DestinationLabel
SourceLabel DestinationLabel                  
1           1                        60.869565
            2                        39.130435
2           4                       100.000000
3           3                        90.279214
            1                         6.721820
            2                         2.998966
4           3                        70.198223
            1                        17.202096
            4                        10.344042
            2                         2.255639
```

Decision Trees Implementation

In [262]:

```
def train_test_split(df, test_size):

    if isinstance(test_size, float):
        test_size = round(test_size * len(df))

    indices = df.index.tolist()
    test_indices = random.sample(population=indices, k=test_size)

    test_df = df.loc[test_indices]
    train_df = df.drop(test_indices)

    return train_df, test_df

def check_purity(data):

    label_column = data[:, -1]
    unique_classes = np.unique(label_column)

    if len(unique_classes) == 1:
        return True
    else:
        return False

def classify_data(data):

    label_column = data[:, -1]
    unique_classes, counts_unique_classes = np.unique(label_column, return
_counts=True)

    index = counts_unique_classes.argmax()
    classification = unique_classes[index]

    return classification

def get_potential_splits(data):

    potential_splits = {}
    _, n_columns = data.shape
    for column_index in range(n_columns - 1):
        values = data[:, column_index]
        unique_values = np.unique(values)

        potential_splits[column_index] = unique_values

    return potential_splits

def split_data(data, split_column, split_value):

    split_column_values = data[:, split_column]

    type_of_feature = FEATURE_TYPES[split_column]
    if type_of_feature == "continuous":
```

```
        data_below = data[split_column_values <= split_value]
        data_above = data[split_column_values >  split_value]

    # feature is categorical
    else:
        data_below = data[split_column_values == split_value]
        data_above = data[split_column_values != split_value]

    return data_below, data_above

def calculate_entropy(data):

    label_column = data[:, -1]
    _, counts = np.unique(label_column, return_counts=True)

    probabilities = counts / counts.sum()
    entropy = sum(probabilities * -np.log2(probabilities))

    return entropy

def calculate_overall_entropy(data_below, data_above):

    n = len(data_below) + len(data_above)
    p_data_below = len(data_below) / n
    p_data_above = len(data_above) / n

    overall_entropy =  (p_data_below * calculate_entropy(data_below)
                      + p_data_above * calculate_entropy(data_above))

    return overall_entropy

def determine_best_split(data, potential_splits):

    overall_entropy = 9999
    for column_index in potential_splits:
        for value in potential_splits[column_index]:
            data_below, data_above = split_data(data, split_column=column_
index, split_value=value)
            current_overall_entropy = calculate_overall_entropy(data_below
, data_above)

            if current_overall_entropy <= overall_entropy:
                overall_entropy = current_overall_entropy
                best_split_column = column_index
                best_split_value = value

    return best_split_column, best_split_value

def determine_type_of_feature(df):

    feature_types = []
    n_unique_values_treshold = 15
    for feature in df.columns:
        if feature != "label":
            unique_values = df[feature].unique()
            example_value = unique_values[0]
```

```
            if (isinstance(example_value, str)) or (len(unique_values) <=
n_unique_values_treshold):
                feature_types.append("categorical")
            else:
                feature_types.append("continuous")

    return feature_types

def decision_tree_algorithm(df, counter=0, min_samples=2, max_depth=5):

    # data preparations
    if counter == 0:
        global COLUMN_HEADERS, FEATURE_TYPES
        COLUMN_HEADERS = df.columns
        FEATURE_TYPES = determine_type_of_feature(df)
        data = df.values
    else:
        data = df


    # base cases
    if (check_purity(data)) or (len(data) < min_samples) or (counter == ma
x_depth):
        classification = classify_data(data)

        return classification


    # recursive part
    else:
        counter += 1

        # helper functions
        potential_splits = get_potential_splits(data)
        split_column, split_value = determine_best_split(data, potential_s
plits)
        data_below, data_above = split_data(data, split_column, split_valu
e)

        # check for empty data
        if len(data_below) == 0 or len(data_above) == 0:
            classification = classify_data(data)
            return classification

        # determine question
        feature_name = COLUMN_HEADERS[split_column]
        type_of_feature = FEATURE_TYPES[split_column]
        if type_of_feature == "continuous":
            question = "{} <= {}".format(feature_name, split_value)

        # feature is categorical
        else:
            question = "{} = {}".format(feature_name, split_value)

        # instantiate sub-tree
```

```
        sub_tree = {question: []}

        # find answers (recursion)
        yes_answer = decision_tree_algorithm(data_below, counter, min_samp
les, max_depth)
        no_answer = decision_tree_algorithm(data_above, counter, min_sampl
es, max_depth)

        # If the answers are the same, then there is no point in asking th
e qestion.
        # This could happen when the data is classified even though it is
 not pure
        # yet (min_samples or max_depth base case).
       # if yes_answer == no_answer:
            #sub_tree = yes_answer
        #else:
        sub_tree[question].append(yes_answer)
        sub_tree[question].append(no_answer)

        return sub_tree

def classify_example(example, tree):
    question = list(tree.keys())[0]
    feature_name, comparison_operator, value = question.split(" ")

    # ask question
    if comparison_operator == "<=":  # feature is continuous
        if example[feature_name] <= float(value):
            answer = tree[question][0]
        else:
            answer = tree[question][1]

    # feature is categorical
    else:
        if str(example[feature_name]) == value:
            answer = tree[question][0]
        else:
            answer = tree[question][1]

    # base case
    if not isinstance(answer, dict):
        return answer

    # recursive part
    else:
        residual_tree = answer
        return classify_example(example, residual_tree)

def calculate_accuracy(df, tree):

    df["classification"] = df.apply(classify_example, axis=1, args=(tree
,))
    df["classification_correct"] = df["classification"] == df["label"]

    accuracy = df["classification_correct"].mean()
```

```
    return accuracy
```

In [264]:

```
df = newDF.copy()
print (df)
```

```
          sourceIP          destIP  classification  SourceLabel  \
0       10.32.5.58  172.23.232.154    Misc activity            1
1       10.32.5.56   172.23.232.56    Misc activity            4
2       10.32.5.54    172.23.232.1    Misc activity            4
3       10.32.5.57   172.23.233.52    Misc activity            3
4       10.32.5.54   172.23.233.56    Misc activity            4
...            ...             ...              ...          ...
18425   10.32.5.51  172.23.134.216    Misc activity            3
18426   10.32.5.55  172.23.134.215    Misc activity            4
18427   10.32.5.53  172.23.134.219    Misc activity            4
18428   10.32.5.56   172.23.134.78    Misc activity            4
18429   10.32.5.54  172.23.128.118    Misc activity            4

       DestinationLabel
0                     1
1                     1
2                     1
3                     1
4                     1
...                 ...
18425                 3
18426                 3
18427                 3
18428                 3
18429                 1

[18430 rows x 5 columns]
```

In [265]:

```
df = df[['sourceIP', 'destIP', 'SourceLabel', 'DestinationLabel', 'classif
ication']]
print(df)
```

```
             sourceIP            destIP  SourceLabel  DestinationLab
el  \
0       10.32.5.58  172.23.232.154            1
1
1       10.32.5.56   172.23.232.56            4
1
2       10.32.5.54    172.23.232.1            4
1
3       10.32.5.57   172.23.233.52            3
1
4       10.32.5.54   172.23.233.56            4
1
...            ...             ...          ...
...
18425   10.32.5.51  172.23.134.216            3
3
18426   10.32.5.55  172.23.134.215            4
3
18427   10.32.5.53  172.23.134.219            4
3
18428   10.32.5.56   172.23.134.78            4
3
18429   10.32.5.54  172.23.128.118            4
1

       classification
0       Misc activity
1       Misc activity
2       Misc activity
3       Misc activity
4       Misc activity
...               ...
18425   Misc activity
18426   Misc activity
18427   Misc activity
18428   Misc activity
18429   Misc activity

[18430 rows x 5 columns]
```

In [266]:

```
df["label"] = df.classification
df = df.drop(["classification"], axis=1)
print(df.head())
```

```
     sourceIP           destIP  SourceLabel  DestinationLabel
label
0  10.32.5.58  172.23.232.154            1                 1
Misc activity
1  10.32.5.56   172.23.232.56            4                 1
Misc activity
2  10.32.5.54    172.23.232.1            4                 1
Misc activity
3  10.32.5.57   172.23.233.52            3                 1
Misc activity
4  10.32.5.54   172.23.233.56            4                 1
Misc activity
```

In [267]:

```
import random
from pprint import pprint

random.seed(0)

train_df, test_df = train_test_split(df, 0.2)
tree = decision_tree_algorithm(train_df, max_depth=3)
accuracy = calculate_accuracy(test_df, tree)

pprint(tree, width=50)
accuracy
```

```
{'DestinationLabel = 4': [{'SourceLabel = 4': [' '
                                               'Generic '
                                               'Protocol '
                                               'Command '
                                               'Decode',
                                               {'sourceIP = 17
2.23.0.111': [' '

'Generic '

'Protocol '

'Command '

'Decode',

' '

'Generic '

'Protocol '

'Command '

'Decode']}]},
                          ' Misc activity']}
```

Out[267]:

```
0.9829083016820401
```

Relation to Dataset_2

In [268]:

```
# Dataframe with second dataset.

dataFrame_2 = pds.read_csv('Dataset_2.csv')

sIP_dict_2 = dataFrame_2.groupby('sourceIP').groups
dIP_dict_2 = dataFrame_2.groupby('destIP').groups

distict_sIPs_keys_2 = list(sIP_dict_2.keys()) # Distinct Source IPs list
distict_dIPs_keys_2 = list(dIP_dict_2.keys()) # Distinct Destination IPs l
ist


distict_sIPs_values_2 = list(map(lambda x: x.size, sIP_dict_2.values()))
# Distinct Source IPs Frequency of appearance
distict_dIPs_values_2 = list(map(lambda x: x.size, dIP_dict_2.values()))
# Distinct Destination IPs Frequency of appearance

sIPs_df_2 = pd.DataFrame(list(zip(distict_sIPs_keys_2, distict_sIPs_values
_2)),
               columns =['SourceIPs', 'Frequency'])

dIPs_df_2 = pd.DataFrame(list(zip(distict_dIPs_keys_2, distict_dIPs_values
_2)),
             columns =['DestinationIPs', 'Frequency'])

sIPs_df_2['IndexColumn'] = sIPs_df_2.index
dIPs_df_2['IndexColumn'] = dIPs_df_2.index

sIPs_df_2['ClusterLabel'] = sIPs_df_2.apply(clusterSourceIPs, axis=1)
dIPs_df_2['ClusterLabel'] = dIPs_df_2.apply(clusterDestinationIPs, axis=1)
```

In [269]:

```
def createLabelForSource_2(row):
    ip = row['sourceIP']
    indexVal = sIPs_df_2[sIPs_df_2.SourceIPs == ip].index.item();
    return sIPs_df_2.at[indexVal,'ClusterLabel']

def createLabelForDestination_2(row):
    ip = row['destIP']
    indexVal = dIPs_df_2[dIPs_df_2.DestinationIPs == ip].index.item();
    return dIPs_df_2.at[indexVal,'ClusterLabel']


newDF_2 = dataFrame_2[['sourceIP', 'destIP', 'classification']]
newDF_2['SourceLabel'] = newDF_2.apply(createLabelForSource_2, axis=1)
newDF_2['DestinationLabel'] = newDF_2.apply(createLabelForDestination_2, a
xis=1)
print(newDF_2)
```

```
<ipython-input-269-9f92f4ae7edc>:13: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFr
ame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.or
g/pandas-docs/stable/user_guide/indexing.html#returning-a-view
-versus-a-copy
  newDF_2['SourceLabel'] = newDF_2.apply(createLabelForSource_
2, axis=1)

           sourceIP          destIP                     classif
ication  \
0      172.23.1.101     172.23.0.10   Generic Protocol Command
Decode
1      172.23.1.101     172.23.0.10   Generic Protocol Command
Decode
2      172.23.1.101     172.23.0.10   Generic Protocol Command
Decode
3      172.23.1.101     172.23.0.10   Generic Protocol Command
Decode
4      172.23.0.212     172.23.0.10   Generic Protocol Command
Decode
...             ...             ...
...
32638    10.32.5.56   172.23.231.64                      Misc a
ctivity
32639    10.32.5.54   172.23.231.60                      Misc a
ctivity
32640    10.32.5.54  172.23.232.155                      Misc a
ctivity
32641    10.32.5.51   172.23.232.56                      Misc a
ctivity
32642    10.32.5.56    172.23.233.2                      Misc a
ctivity

       SourceLabel  DestinationLabel
0                3                 4
1                3                 4
2                3                 4
3                3                 4
4                3                 4
...            ...               ...
32638            4                 1
32639            4                 1
32640            4                 1
32641            4                 1
32642            4                 1

[32643 rows x 5 columns]
```

```
<ipython-input-269-9f92f4ae7edc>:14: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFr
ame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.or
g/pandas-docs/stable/user_guide/indexing.html#returning-a-view
-versus-a-copy
  newDF_2['DestinationLabel'] = newDF_2.apply(createLabelForDe
stination_2, axis=1)
```

In [270]:

```
df_2 = newDF_2.copy()
'''print (df_2)'''
df_2 = df_2[['sourceIP', 'destIP', 'SourceLabel', 'DestinationLabel', 'cla
ssification']]
'''print(df)'''
df_2["label"] = df_2.classification
df_2 = df_2.drop(["classification"], axis=1)
print(df_2.head())
```

```
       sourceIP       destIP  SourceLabel  DestinationLabel  \
0  172.23.1.101  172.23.0.10            3                 4
1  172.23.1.101  172.23.0.10            3                 4
2  172.23.1.101  172.23.0.10            3                 4
3  172.23.1.101  172.23.0.10            3                 4
4  172.23.0.212  172.23.0.10            3                 4

                             label
0   Generic Protocol Command Decode
1   Generic Protocol Command Decode
2   Generic Protocol Command Decode
3   Generic Protocol Command Decode
4   Generic Protocol Command Decode
```

In [205]:

```
train_df_2, test_df_2 = train_test_split(df_2, 0.2)
tree_2 = decision_tree_algorithm(train_df_2, max_depth=3)
accuracy_2 = calculate_accuracy(test_df_2, tree)

pprint(tree_2, width=50)
accuracy_2
```

```
{'destIP = 172.23.0.10': [{'sourceIP = 172.23.1.104': [' '
                                                        'Generi
c '
                                                        'Protoc
ol '
                                                        'Comman
d '
                                                        'Decod
e',
                                                        {'sourc
eIP = 172.23.5.115': [' '

'Generic '

'Protocol '

'Command '

'Decode',

' '

'Generic '

'Protocol '

'Command '

'Decode']}]},
                          {'DestinationLabel = 4': [{'sourceIP
= 172.23.231.69': [' '

'Attempted '

'Information '

'Leak',

' '

'Attempted '

'Information '

'Leak']},
                                                     {'destIP =
172.23.0.101': [' '

'Generic '

'Protocol '

'Command '

'Decode',
```

```
' '

'Misc '

'activity']}]}]}
```

Out[205]:

```
0.9814672997396232
```

In [ ]: