In [ ]:
```
#InstallingPackages

# standard
import numpy as np
import pandas as pd
import time

# plots
import matplotlib.pyplot as plt
import plotly.express as px

# statistics
from statsmodels.graphics.mosaicplot import mosaic
```

In [ ]:
```
from google.colab import drive
drive.mount("/content/gdrive")
```

```
Drive already mounted at /content/gdrive; to attempt to forcibly re
mount, call drive.mount("/content/gdrive", force_remount=True).
```

In [ ]:
```
# read an file
df_example = pd.read_csv('/content/gdrive/My Drive/A_FINAL_YEAR_PROJE
# first glance
df_example.head()
```

Out[65]:

	avg_ipt	bytes_in	bytes_out	dest_ip	dest_port	entropy	num_pkts_out	num_pkts_in	p
0	0.0	0	14480	786	9200.0	2.116894	10	0	
1	0.0	0	7240	786	9200.0	3.748675	5	0	
2	0.0	0	14480	786	9200.0	2.079622	10	0	
3	0.0	0	14480	786	9200.0	2.033979	10	0	
4	0.0	0	14480	786	9200.0	1.955485	10	0	

In [ ]:
```
#DimensionsOfData
df_example.shape
```

Out[66]:
```
(1081952, 16)
```

In [ ]:
```
# imputation of missings and conversion to int
df_example.dest_port = df_example.dest_port.fillna(-1).astype('int64'
df_example.src_port = df_example.src_port.fillna(-1).astype('int64')
```

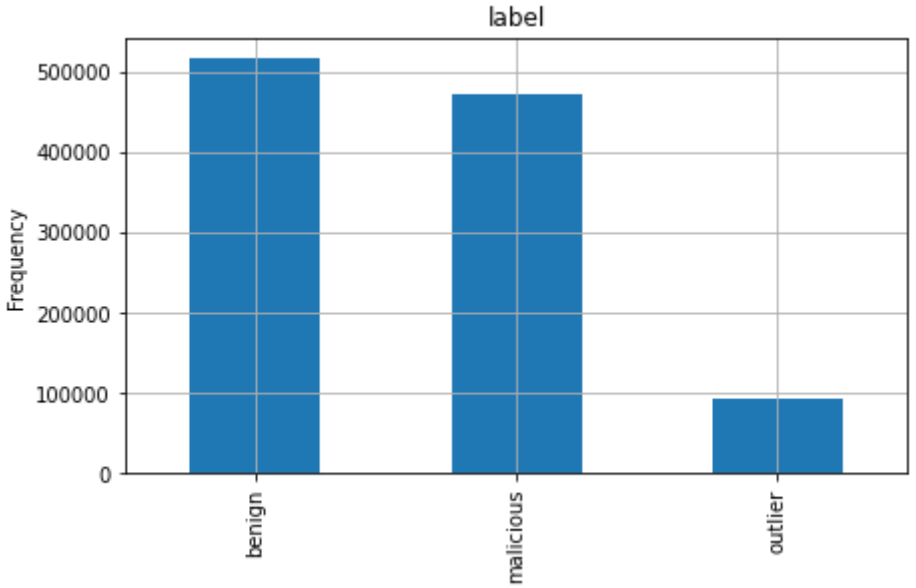
In [ ]:
```
# summary of numerical features
df_example.describe()
```

Out[68]:

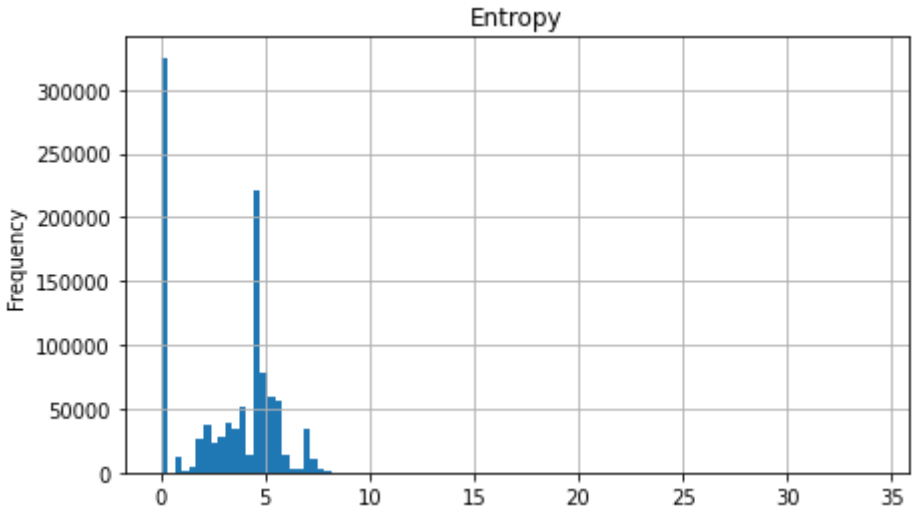
	avg_ipt	bytes_in	bytes_out	dest_ip	dest_port	entropy
count	1.081952e+06	1.081952e+06	1.081952e+06	1.081952e+06	1.081952e+06	1.081952e+06
mean	1.438714e+06	4.182185e+02	2.354654e+03	4.163730e+03	1.200858e+04	3.048347e+00
std	4.090331e+07	2.085036e+03	5.891802e+03	2.054663e+04	1.663640e+04	2.287969e+00
min	0.000000e+00	0.000000e+00	0.000000e+00	4.000000e+00	-1.000000e+00	0.000000e+00
25%	0.000000e+00	0.000000e+00	0.000000e+00	7.860000e+02	4.450000e+02	0.000000e+00
50%	0.000000e+00	0.000000e+00	1.910000e+02	7.860000e+02	9.200000e+03	3.762122e+00
75%	3.075000e+01	2.700000e+02	1.452000e+03	7.860000e+02	9.200000e+03	4.726709e+00
max	4.294967e+09	6.456800e+04	6.553200e+04	3.987220e+05	6.553500e+04	3.408484e+01

In [ ]:
```
#InitializingPlotSize
plt.rcParams['figure.figsize']=(7,4)
```

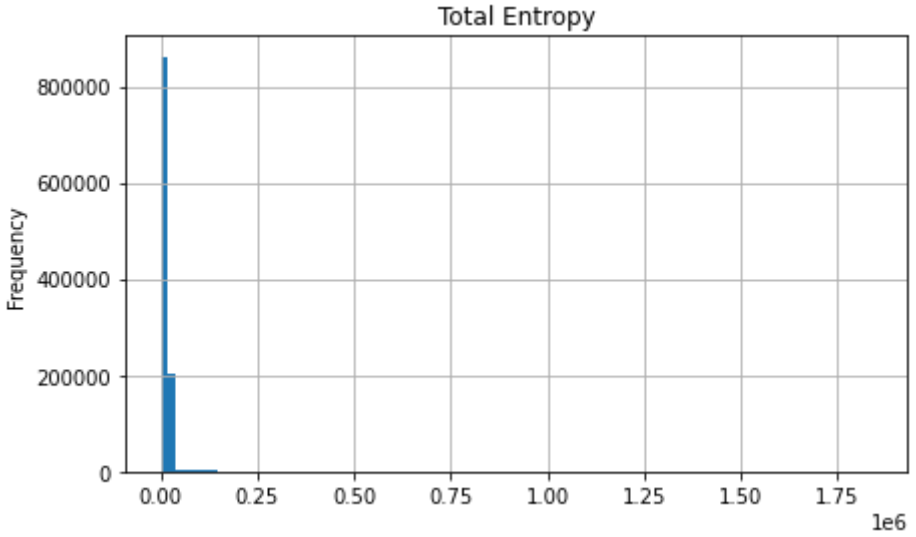
In [ ]:
```
#PrintingLabelDistribution
df_example.label.value_counts().plot(kind='bar')
plt.ylabel('Frequency')
plt.title('label')
plt.grid()
plt.show()
```



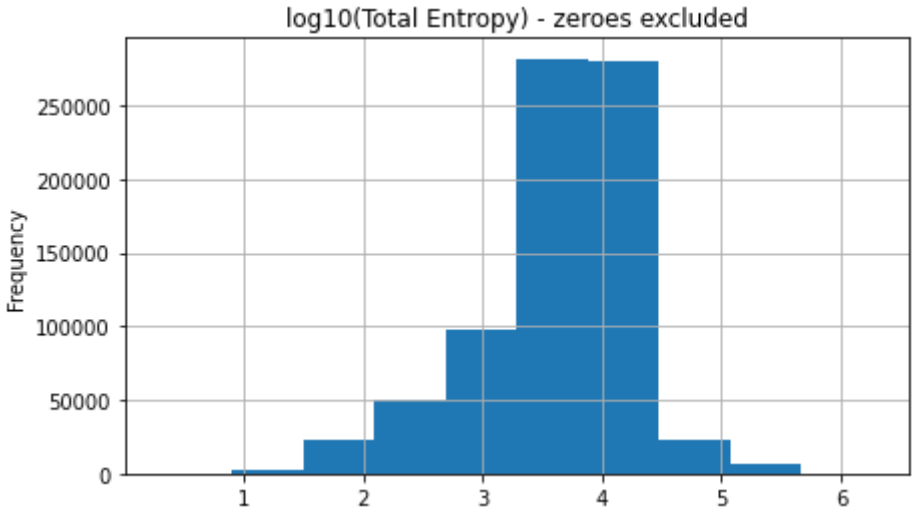
In [ ]:
```
# entropy in bits per byte of the data fields within the flow; ranges
df_example.entropy.plot(kind='hist', bins=100)
plt.title('Entropy')
plt.grid()
plt.show()
```



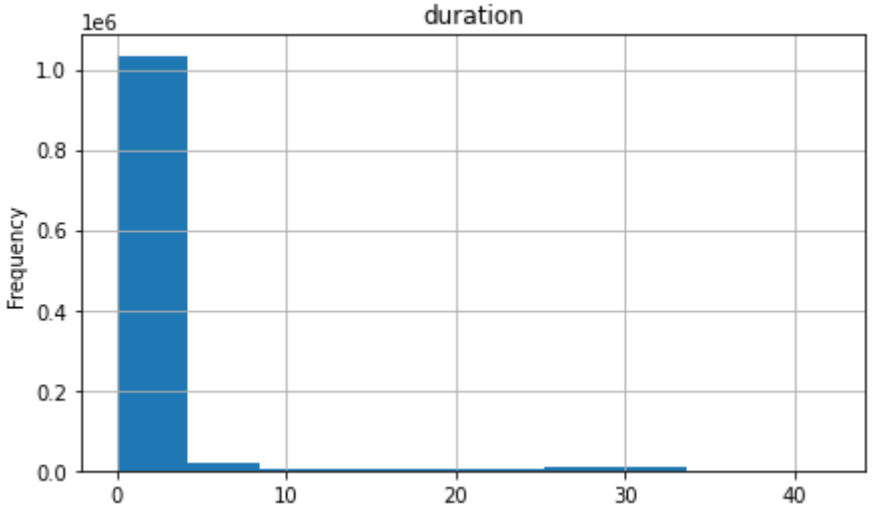
In [ ]:
```
# total entropy in bytes over all of the bytes in the data fields of
df_example.total_entropy.plot(kind='hist', bins=100)
plt.title('Total Entropy')
plt.grid()
plt.show()
```



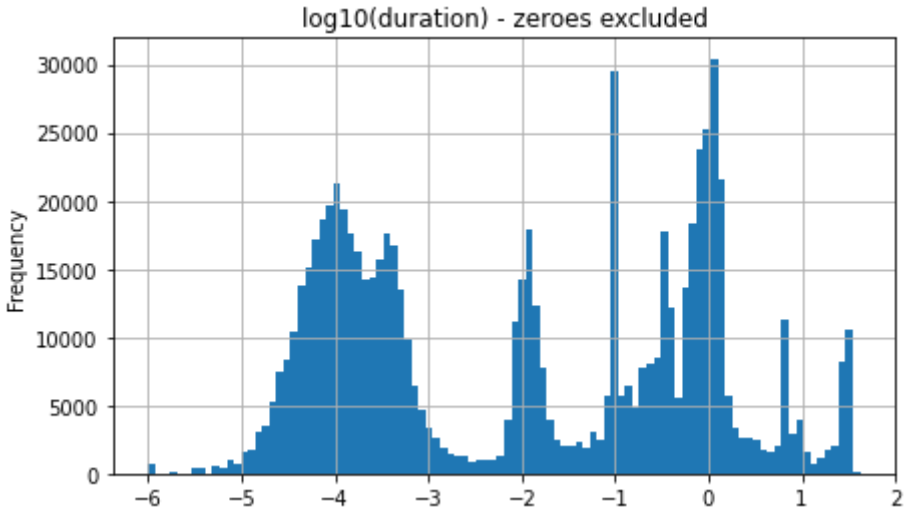
In [ ]:
```
# look at non-zeroes only
total_entropy_pos = df_example.total_entropy[df_example.total_entropy
# show log plot
plt.hist(np.log10(total_entropy_pos),10)
plt.ylabel('Frequency')
plt.title('log10(Total Entropy) - zeroes excluded')
plt.grid()
plt.show()
```



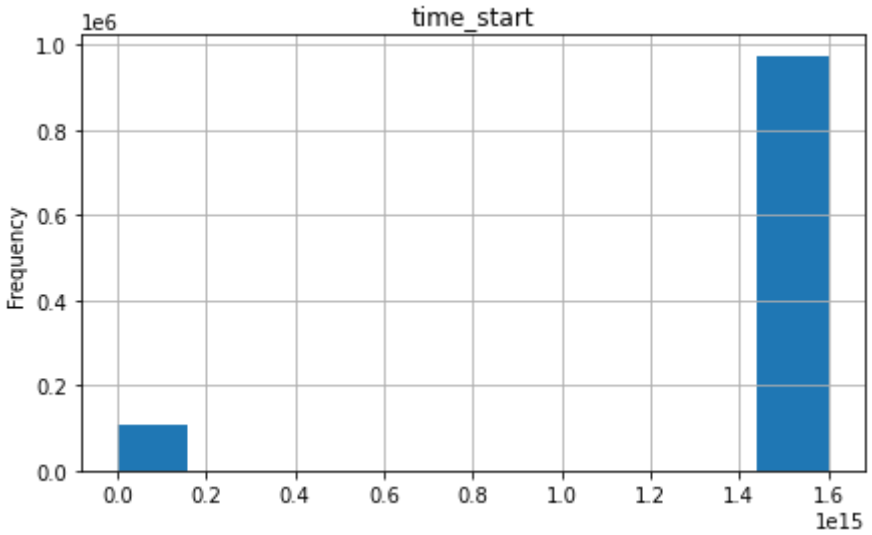
In [ ]:
```
# flow duration time, with microsecond precision
df_example.duration.plot(kind='hist', bins=10)
plt.title('duration')
plt.grid()
plt.show()
```



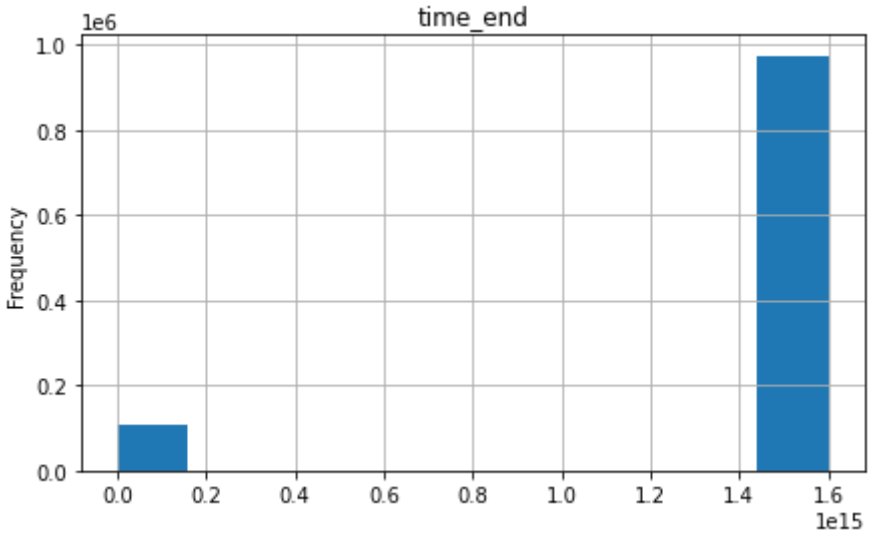
In [ ]:
```
# look at non-zeroes only
duration_pos = df_example.duration[df_example.duration>0]
# show log plot
plt.hist(np.log10(duration_pos),100)
plt.ylabel('Frequency')
plt.title('log10(duration) - zeroes excluded')
plt.grid()
plt.show()
```



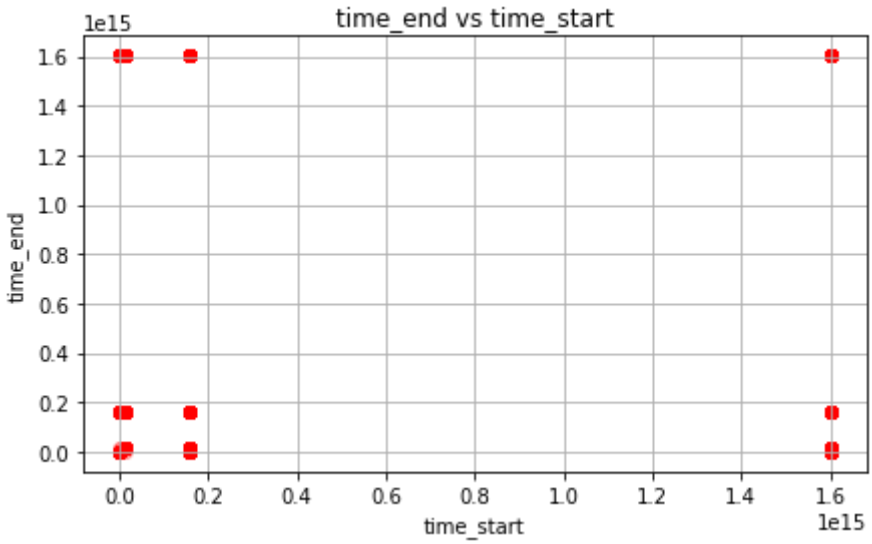
In [ ]:
```
# start time of the flow in seconds since the epoch
df_example.time_start.plot(kind='hist', bins=10)
plt.title('time_start')
plt.grid()
plt.show()
```



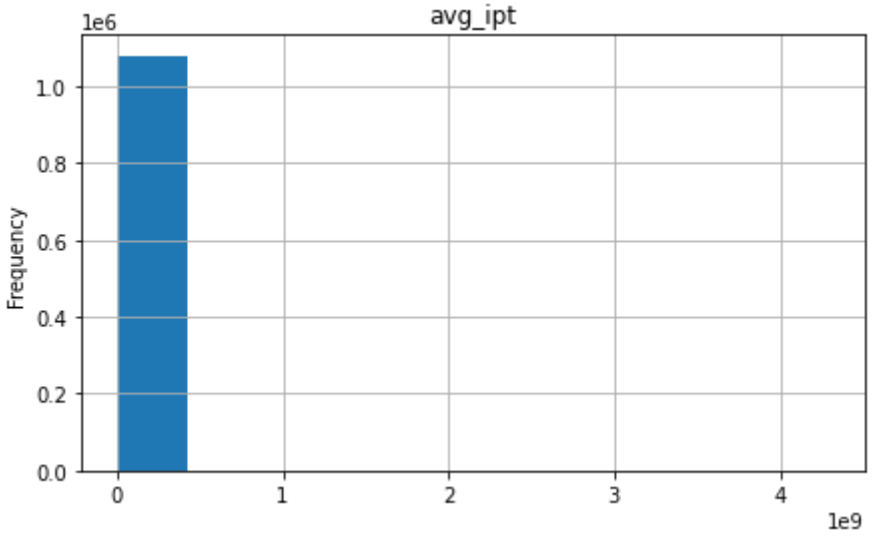
In [ ]:
```
# end time of the flow in seconds since the epoch
df_example.time_end.plot(kind='hist', bins=10)
plt.title('time_end')
plt.grid()
plt.show()
```



In [ ]:
```
# 2D plot of start and end time
plt.scatter(df_example.time_start, df_example.time_end, c='red' , alp
plt.xlabel('time_start')
plt.ylabel('time_end')
plt.title('time_end vs time_start')
plt.grid()
plt.show()
```

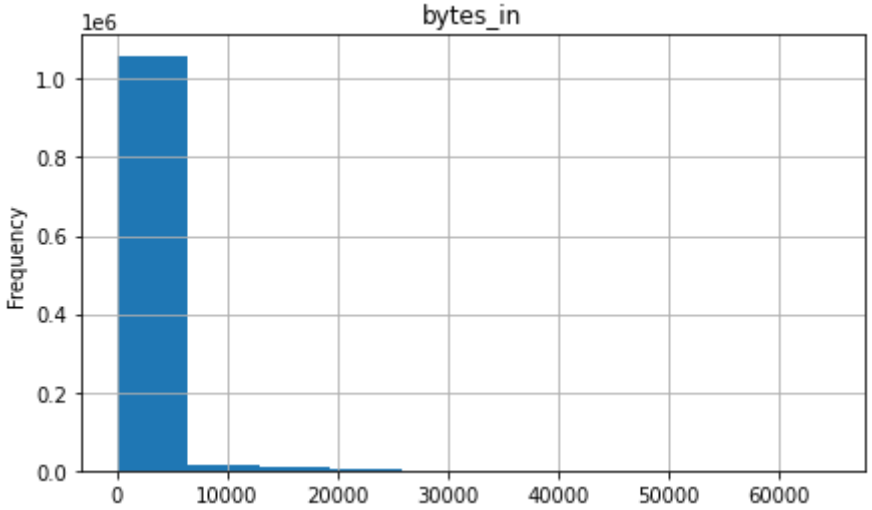


In [ ]:
```
# mean of the inter-packet arrival times of the flow (in description
df_example.avg_ipt.plot(kind='hist', bins=10)
plt.title('avg_ipt')
plt.grid()
plt.show()
```

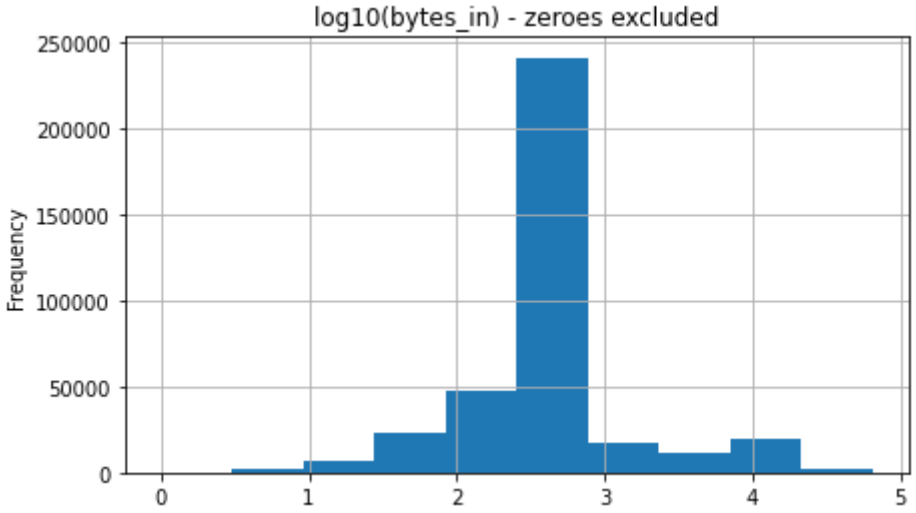


In [ ]:
```
# look at non-zeroes only
avg_ipt_pos = df_example.avg_ipt[df_example.avg_ipt>0]
# show log plot
plt.hist(np.log10(avg_ipt_pos),10)
plt.ylabel('Frequency')
plt.title('log10(avg_ipt) - zeroes excluded')
plt.grid()
plt.show()
```

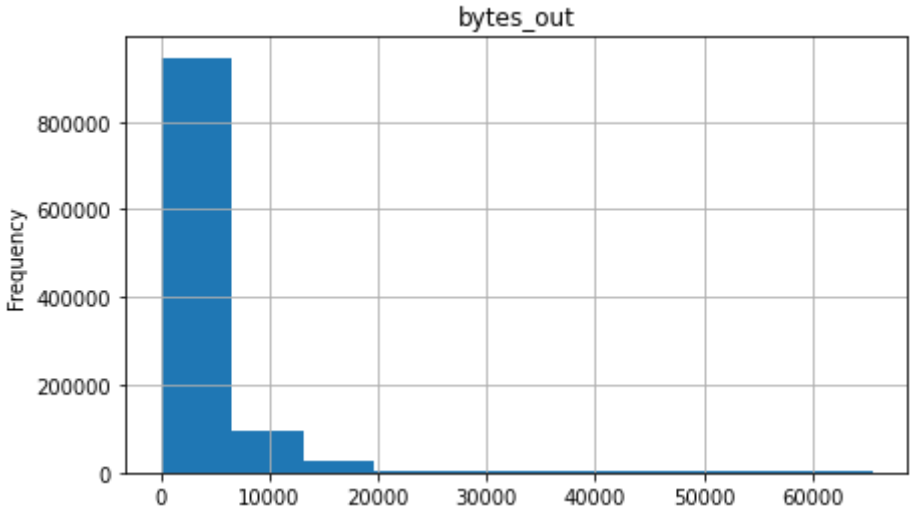
In [ ]:
```
# number of bytes transmitted from source to destination
df_example.bytes_in.plot(kind='hist', bins=10)
plt.title('bytes_in')
plt.grid()
plt.show()
```



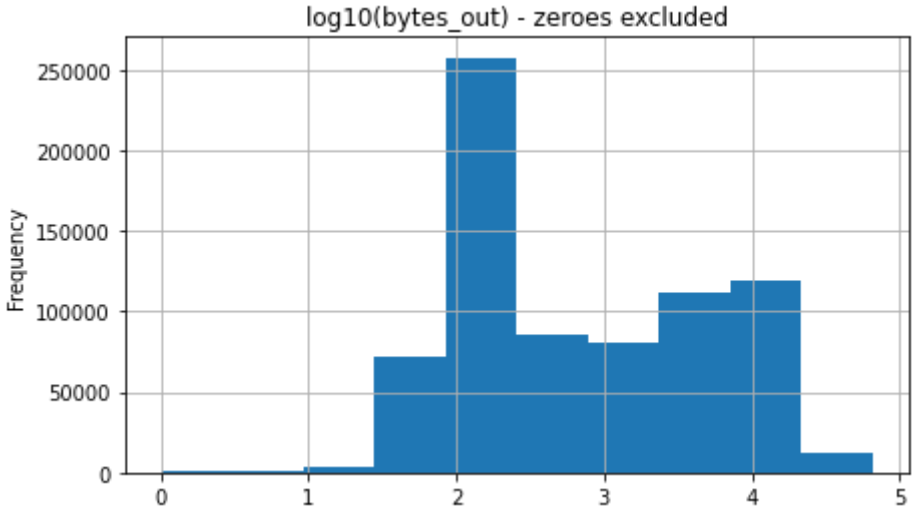
In [ ]:
```
# look at non-zeroes only
bytes_in_pos = df_example.bytes_in[df_example.bytes_in>0]
# show log plot
plt.hist(np.log10(bytes_in_pos),10)
plt.ylabel('Frequency')
plt.title('log10(bytes_in) - zeroes excluded')
plt.grid()
plt.show()
```



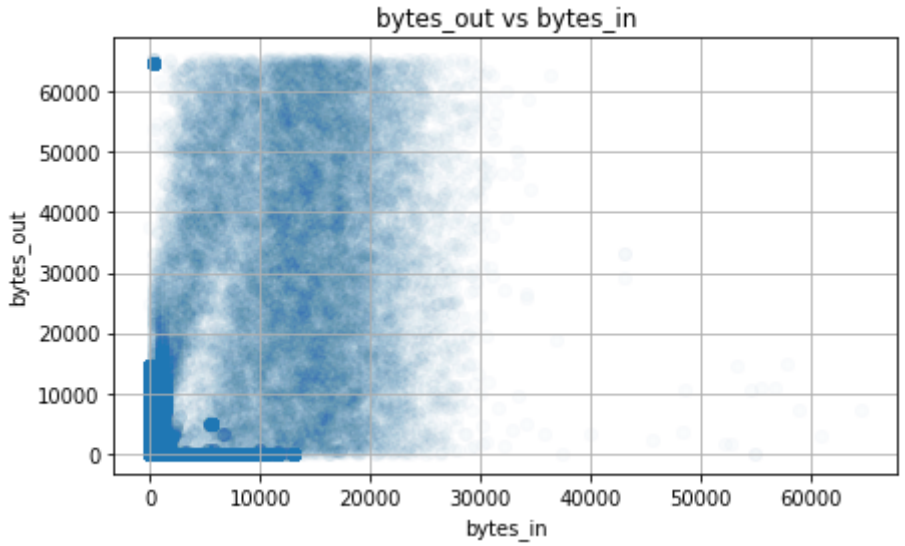
In [ ]:
```
# number of bytes transmitted from destination to source.
df_example.bytes_out.plot(kind='hist', bins=10)
plt.title('bytes_out')
plt.grid()
plt.show()
```



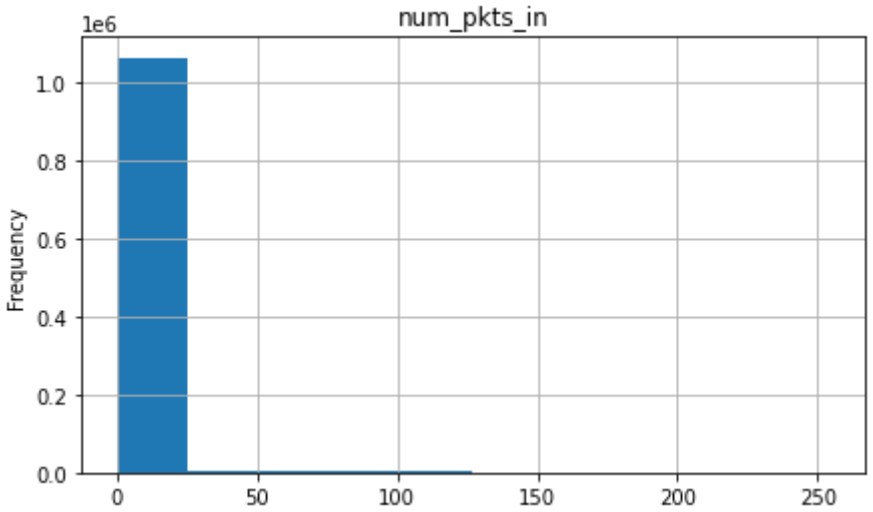
In [ ]:
```
# look at non-zeroes only
bytes_out_pos = df_example.bytes_out[df_example.bytes_out>0]
# show log plot
plt.hist(np.log10(bytes_out_pos),10)
plt.ylabel('Frequency')
plt.title('log10(bytes_out) - zeroes excluded')
plt.grid()
plt.show()
```



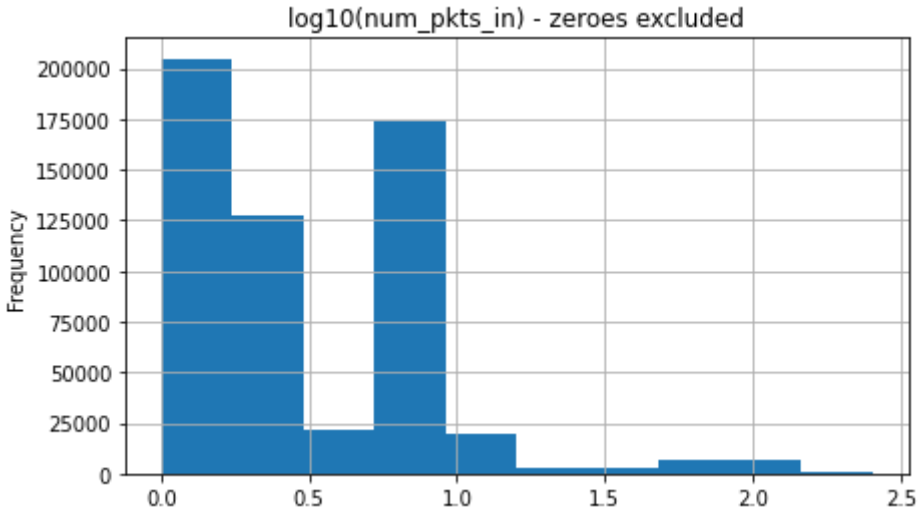
In [ ]:
```
# 2D plot of bytes in / out
plt.scatter(df_example.bytes_in, df_example.bytes_out, alpha=0.02)
plt.xlabel('bytes_in')
plt.ylabel('bytes_out')
plt.title('bytes_out vs bytes_in')
plt.grid()
plt.show()
```



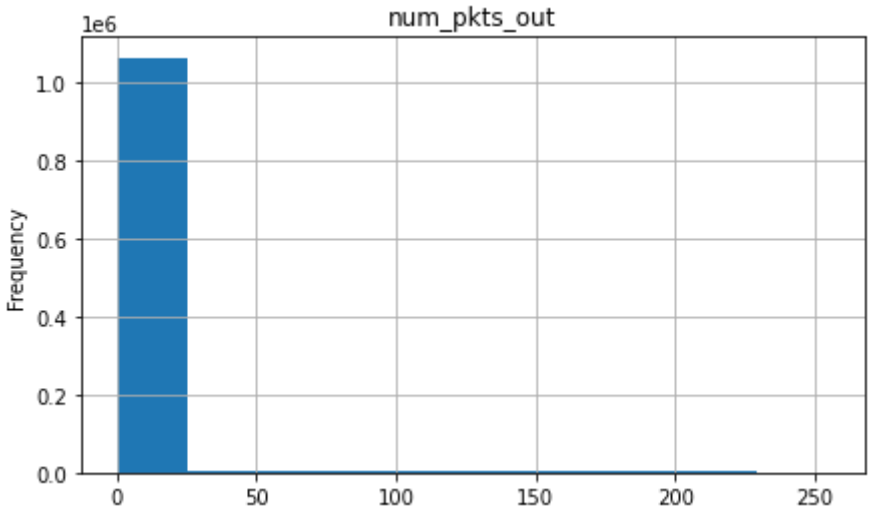
In [ ]:
```
# packet count from source to destination
df_example.num_pkts_in.plot(kind='hist', bins=10)
plt.title('num_pkts_in')
plt.grid()
plt.show()
```



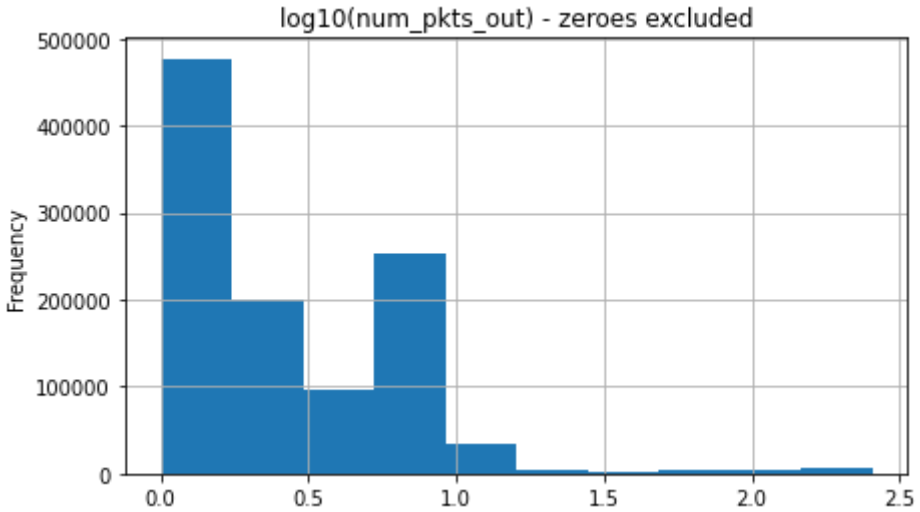
In [ ]:
```
# look at non-zeroes only
num_pkts_in_pos = df_example.num_pkts_in[df_example.num_pkts_in>0]
# show log plot
plt.hist(np.log10(num_pkts_in_pos),10)
plt.ylabel('Frequency')
plt.title('log10(num_pkts_in) - zeroes excluded')
plt.grid()
plt.show()
```



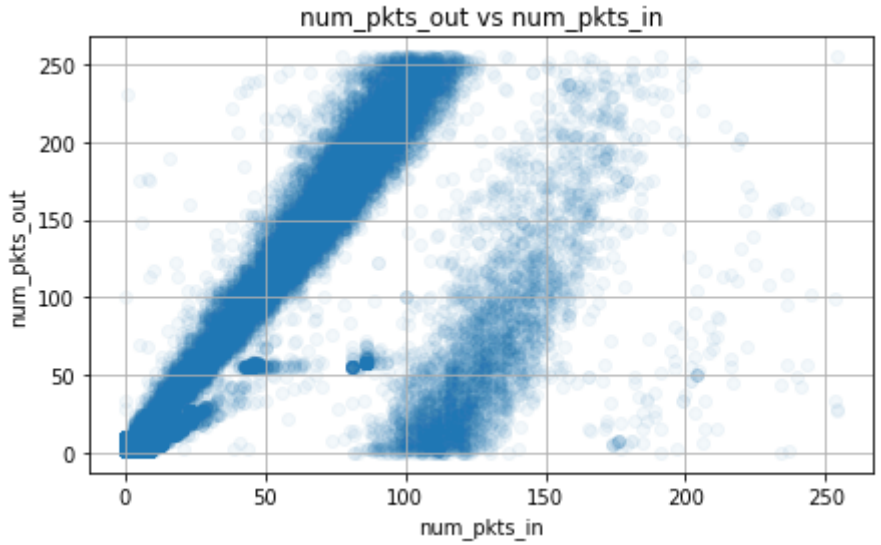
In [ ]:
```
# packet count from destination to source
df_example.num_pkts_out.plot(kind='hist', bins=10)
plt.title('num_pkts_out')
plt.grid()
plt.show()
```



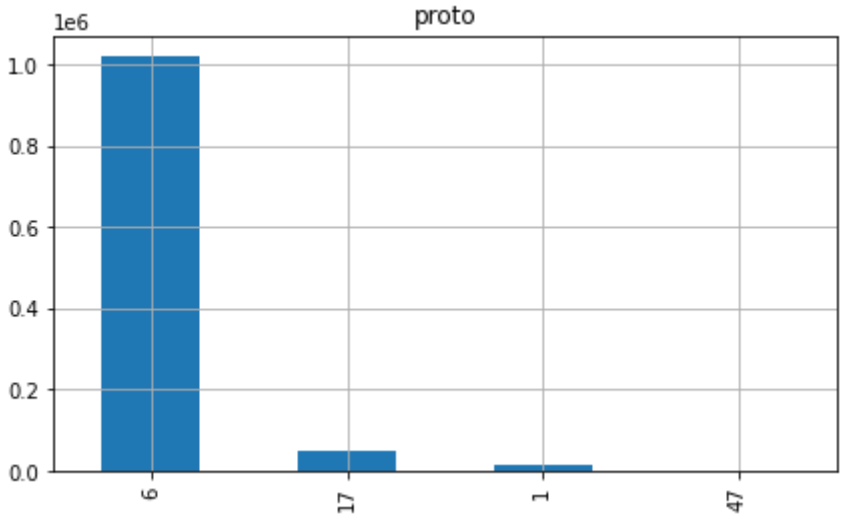
In [ ]:
```
# look at non-zeroes only
num_pkts_out_pos = df_example.num_pkts_out[df_example.num_pkts_out>0]
# show log plot
plt.hist(np.log10(num_pkts_out_pos),10)
plt.ylabel('Frequency')
plt.title('log10(num_pkts_out) - zeroes excluded')
plt.grid()
plt.show()
```



In [ ]:
```
# 2D plot of packets in / out
plt.scatter(df_example.num_pkts_in, df_example.num_pkts_out, alpha=0.
plt.xlabel('num_pkts_in')
plt.ylabel('num_pkts_out')
plt.title('num_pkts_out vs num_pkts_in')
plt.grid()
plt.show()
```



In [ ]:
```
# protocol number associated with the flow; e. g. TCP is 6
df_example.proto.value_counts().plot(kind='bar')
plt.title('proto')
plt.grid()
plt.show()
```

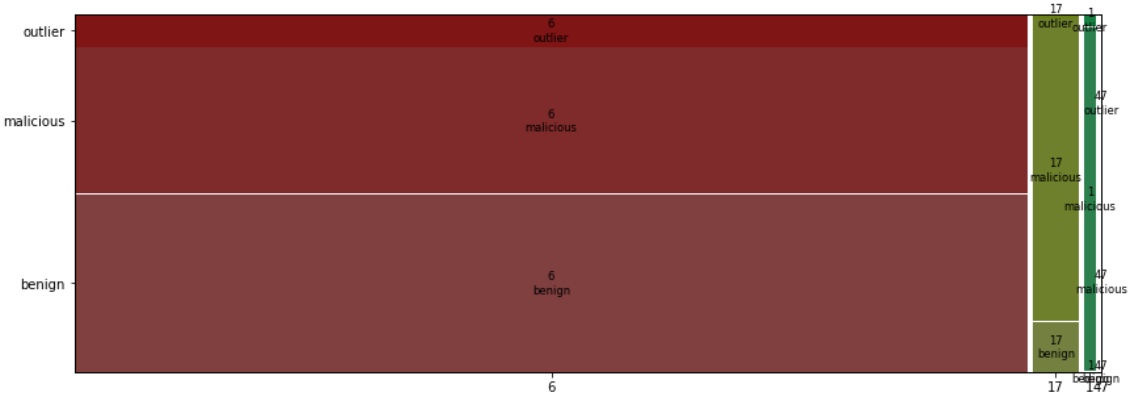


In [ ]:
```
# check impact of protocol on target
pd.crosstab(df_example.proto, df_example.label)
```

Out[92]:

label	benign	malicious	outlier
proto			
1	0	12831	431
6	510237	417293	92597
17	6756	41351	454
47	0	1	1

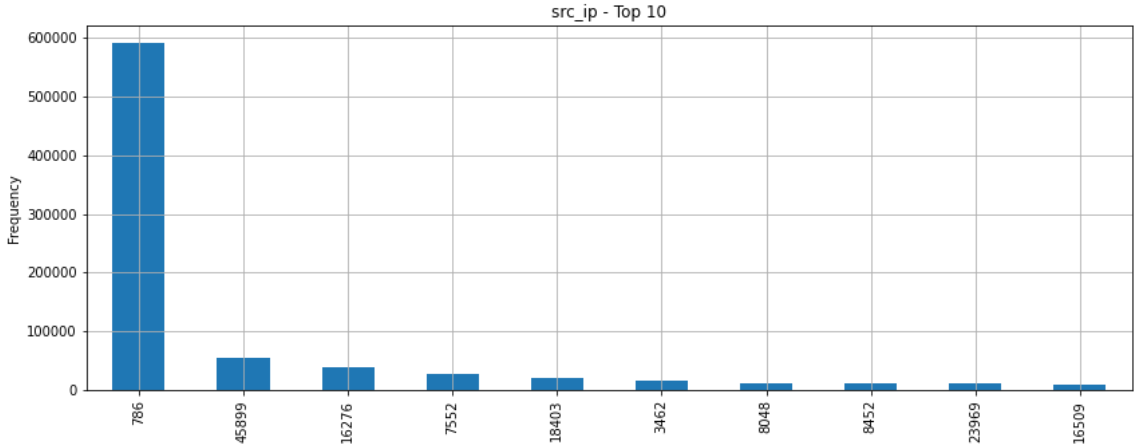
In [ ]:
```
# graphical version: mosaic plot
rcpar_save = plt.rcParams['figure.figsize']
plt.rcParams['figure.figsize']=(14,5)
mosaic(df_example, ['proto','label'])
plt.show()

#plt.rcParams['figure.figsize'] = rcpar_save # reset plot size to pre
```



In [ ]:
```
#Count of source IP (anonymized)
df_example.src_ip.value_counts()
```

Out[94]:
```
786       591446
45899      53877
16276      38551
7552       28109
18403      19854
           ...
62000          1
64050          1
134765         1
43205          1
39608          1
Name: src_ip, Length: 642, dtype: int64
```

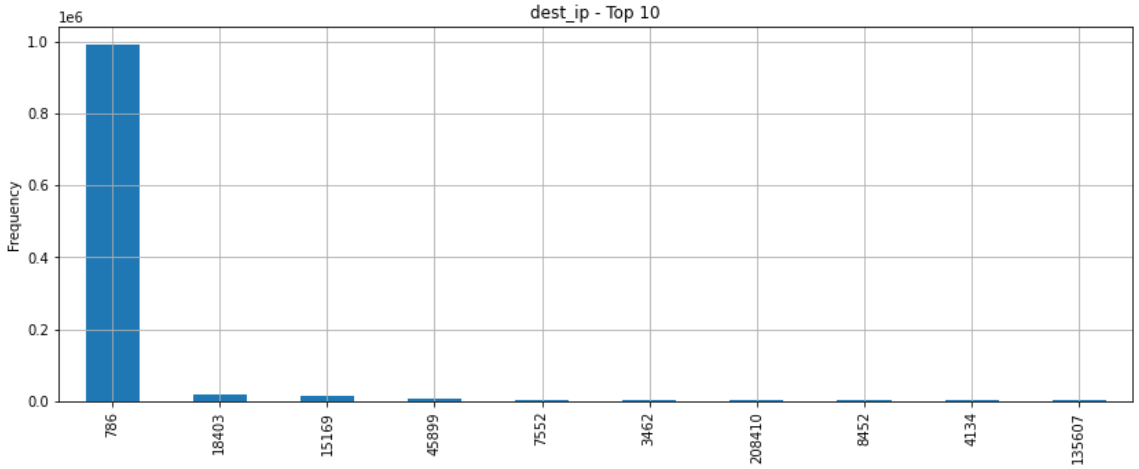
In [ ]:
```
df_example.src_ip.value_counts()[0:10].plot(kind='bar')
plt.ylabel('Frequency')
plt.title('src_ip - Top 10')
plt.grid()
plt.show()
```



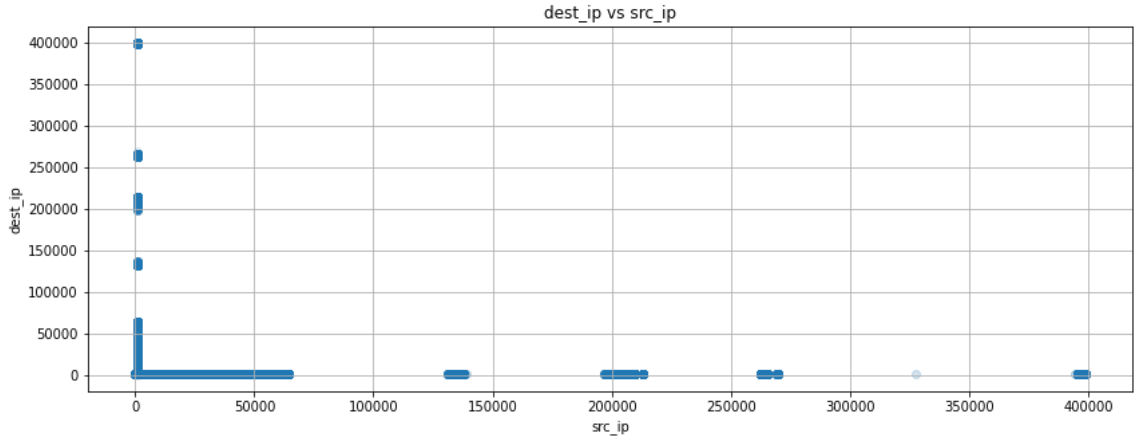
In [ ]:
```
#Count of destination IP (anonymized)
df_example.dest_ip.value_counts()
```

Out[96]:
```
786       992152
18403      18277
15169      15274
45899       8580
7552        3333
           ...
2500           1
262470         1
43513          1
47610          1
262272         1
Name: dest_ip, Length: 276, dtype: int64
```

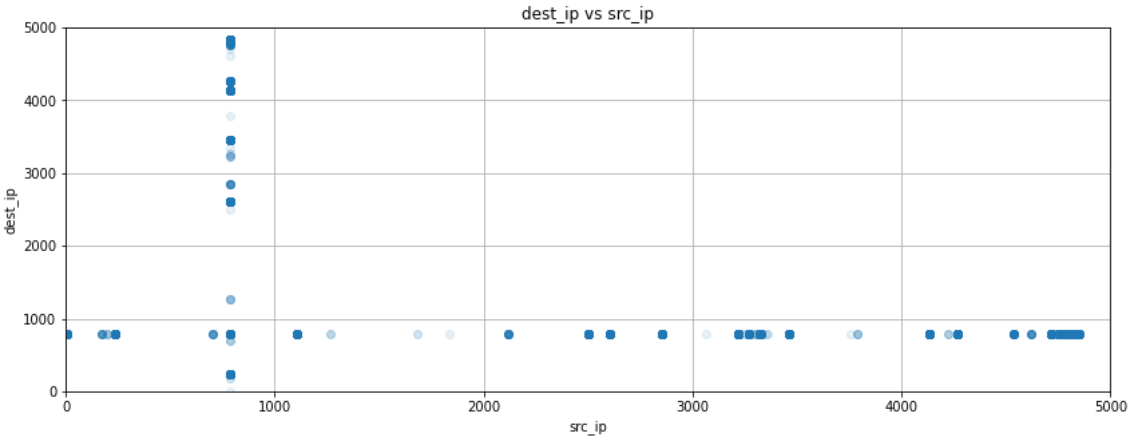
In [ ]:
```
# destination IP plot
df_example.dest_ip.value_counts()[0:10].plot(kind='bar')
plt.ylabel('Frequency')
plt.title('dest_ip - Top 10')
plt.grid()
plt.show()
```



In [ ]:
```
# destination IP vs source IP
plt.scatter(df_example.src_ip, df_example.dest_ip, alpha=0.1)
plt.xlabel('src_ip')
plt.ylabel('dest_ip')
plt.title('dest_ip vs src_ip')
plt.grid()
plt.show()
```



In [ ]:
```
# zoom in
plt.scatter(df_example.src_ip, df_example.dest_ip, alpha=0.1)
plt.xlim(0,5000)
plt.ylim(0,5000)
plt.xlabel('src_ip')
plt.ylabel('dest_ip')
plt.title('dest_ip vs src_ip')
plt.grid()
plt.show()
```



In [ ]:
```
# most frequent IP pairs
df_example['IP_pair'] = df_example.src_ip.astype(str) + ' >> ' + df_e
df_example.IP_pair.value_counts()[:20]
```

Out[100]:
```
786 >> 786       501646
45899 >> 786      53877
16276 >> 786      38551
7552 >> 786       28109
18403 >> 786      19854
786 >> 18403      18277
3462 >> 786       16361
786 >> 15169      15274
8048 >> 786       12313
8452 >> 786       10979
23969 >> 786      10682
16509 >> 786       9645
786 >> 45899       8580
137697 >> 786      7359
12389 >> 786       7311
4134 >> 786        6578
213371 >> 786      6194
17552 >> 786       5969
50010 >> 786       5919
9198 >> 786        5775
Name: IP_pair, dtype: int64
```

In [ ]:
```
pip install --upgrade plotly
```

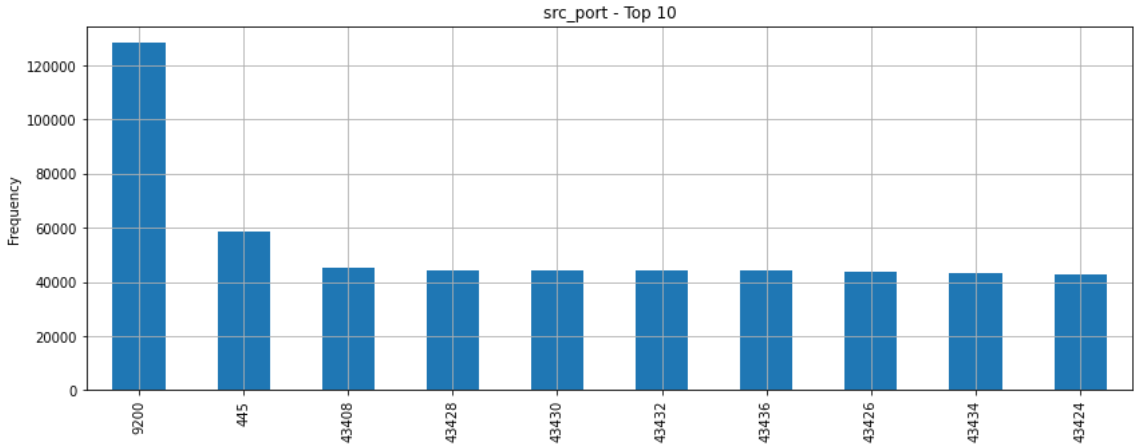
```
Requirement already up-to-date: plotly in /usr/local/lib/python3.7/
dist-packages (4.14.3)
Requirement already satisfied, skipping upgrade: retrying>=1.3.3 in
/usr/local/lib/python3.7/dist-packages (from plotly) (1.3.3)
Requirement already satisfied, skipping upgrade: six in /usr/local/
lib/python3.7/dist-packages (from plotly) (1.15.0)
```

In [ ]:
```
# interactive treemap visualization of source/destination IP
fig = px.treemap(df_example,path=['src_ip','dest_ip'], title='Source
fig.show()
```

In [ ]:
```
#Count of source port
df_example.src_port.value_counts()
```

Out[103]:
```
9200     128225
445       58489
43408     45329
43428     44302
43430     44155
          ...
45507         1
2516          1
25049         1
20959         1
2049          1
Name: src_port, Length: 51958, dtype: int64
```

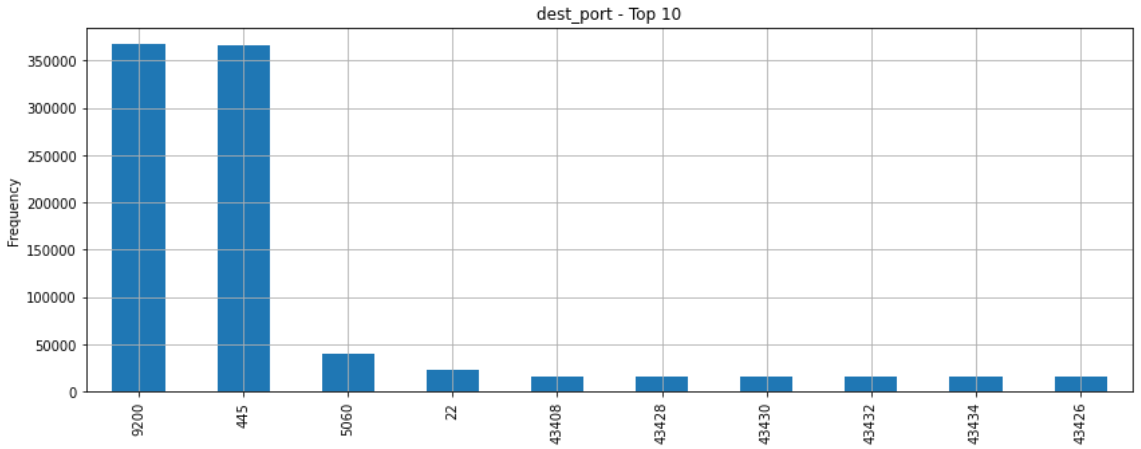
In [ ]:
```
#source port plot
df_example.src_port.value_counts().iloc[0:10].plot(kind='bar')
plt.ylabel('Frequency')
plt.title('src_port - Top 10')
plt.grid()
plt.show()
```



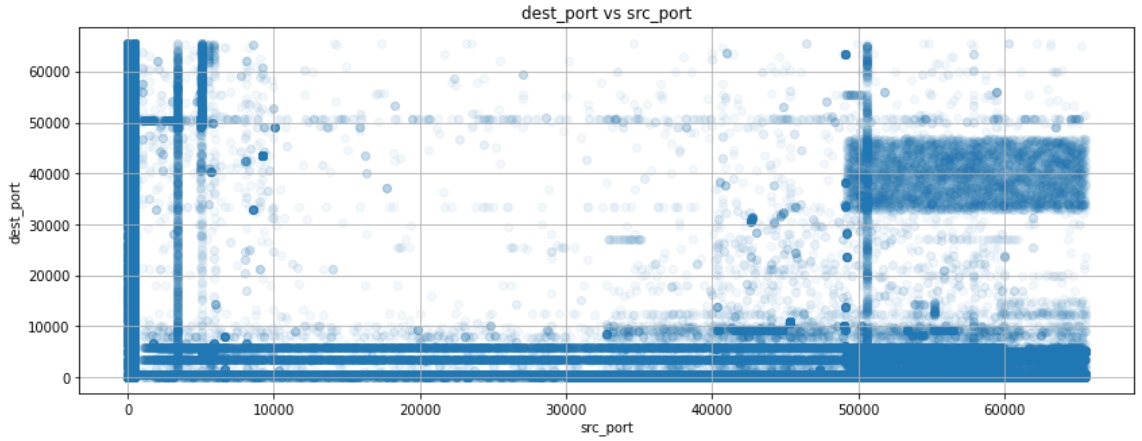
In [ ]:
```
#Count of destination port
df_example.dest_port.value_counts()
```

Out[105]:
```
9200     366702
445      366401
5060      40108
22        22747
43408     16354
          ...
35219         1
15145         1
10631         1
50585         1
8188          1
Name: dest_port, Length: 29660, dtype: int64
```

In [ ]:
```
# destination port plot
df_example.dest_port.value_counts().iloc[0:10].plot(kind='bar')
plt.ylabel('Frequency')
plt.title('dest_port - Top 10')
plt.grid()
plt.show()
```



In [ ]:
```
# destination port vs source port
plt.scatter(df_example.src_port, df_example.dest_port, alpha=0.05)
plt.xlabel('src_port')
plt.ylabel('dest_port')
plt.title('dest_port vs src_port')
plt.grid()
plt.show()
```



In [ ]:
```
# most frequent port pairs
df_example['port_pair'] = df_example.src_port.astype(str) + ' >> ' +
df_example.port_pair.value_counts()[0:20]
```

Out[108]:
```
43408 >> 9200    45323
43428 >> 9200    44296
43430 >> 9200    44153
43432 >> 9200    44038
43436 >> 9200    44019
43426 >> 9200    43901
43434 >> 9200    43476
43424 >> 9200    42964
9200 >> 43408    16354
9200 >> 43428    16237
9200 >> 43430    16120
9200 >> 43432    16051
9200 >> 43426    15960
9200 >> 43434    15957
9200 >> 43436    15860
9200 >> 43424    15676
-1 >> -1         13264
53318 >> 9200     3127
53314 >> 9200     3117
53316 >> 9200     3116
Name: port_pair, dtype: int64
```

In [ ]:
```
# select features
features = df_example.columns
features = features.drop(['label'])
features = list(features)
print(features)
```

```
['avg_ipt', 'bytes_in', 'bytes_out', 'dest_ip', 'dest_port', 'entro
py', 'num_pkts_out', 'num_pkts_in', 'proto', 'src_ip', 'src_port',
'time_end', 'time_start', 'total_entropy', 'duration', 'IP_pair', '
port_pair']
```

In [ ]:
```
! pip install h2o
```

```
Requirement already satisfied: h2o in /usr/local/lib/python3.7/dist
-packages (3.32.1.3)
Requirement already satisfied: tabulate in /usr/local/lib/python3.7
/dist-packages (from h2o) (0.8.9)
Requirement already satisfied: colorama>=0.3.8 in /usr/local/lib/py
thon3.7/dist-packages (from h2o) (0.4.4)
Requirement already satisfied: future in /usr/local/lib/python3.7/d
ist-packages (from h2o) (0.16.0)
Requirement already satisfied: requests in /usr/local/lib/python3.7
/dist-packages (from h2o) (2.23.0)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/
python3.7/dist-packages (from requests->h2o) (3.0.4)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/pytho
n3.7/dist-packages (from requests->h2o) (2.10)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.2
1.1 in /usr/local/lib/python3.7/dist-packages (from requests->h2o)
(1.24.3)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib
/python3.7/dist-packages (from requests->h2o) (2021.5.30)
```

In [ ]:
```
# start H2O
import h2o
from h2o.estimators import H2ORandomForestEstimator

h2o.init(max_mem_size='12G', nthreads=4)
```

```
Checking whether there is an H2O instance running at http://localho
st:54321 (http://localhost:54321) . connected.
```

H2O_cluster_uptime:	8 mins 27 secs
H2O_cluster_timezone:	Etc/UTC
H2O_data_parsing_timezone:	UTC
H2O_cluster_version:	3.32.1.3
H2O_cluster_version_age:	1 month
H2O_cluster_name:	H2O_from_python_unknownUser_rdj90z
H2O_cluster_total_nodes:	1
H2O_cluster_free_memory:	11.69 Gb
H2O_cluster_total_cores:	2
H2O_cluster_allowed_cores:	2
H2O_cluster_status:	locked, healthy
H2O_connection_url:	http://localhost:54321
H2O_connection_proxy:	{"http": null, "https": null}
H2O_internal_security:	False
H2O_API_Extensions:	Amazon S3, XGBoost, Algos, AutoML, Core V3, TargetEncoder, Core V4
Python_version:	3.7.10 final

In [ ]:
```
# upload data frame in H2O environment
t1 = time.time()
df_hex = h2o.H2OFrame(df_example)
t2 = time.time()
print('Elapsed time [s]: ', np.round(t2-t1,2))
```

```
Parse progress: |
| 100%
Elapsed time [s]:  21.88
```

In [ ]:
```
# define target
target = 'label'
# explicitly convert target to categorical => classification problem
df_hex[target] = df_hex[target].asfactor()
```

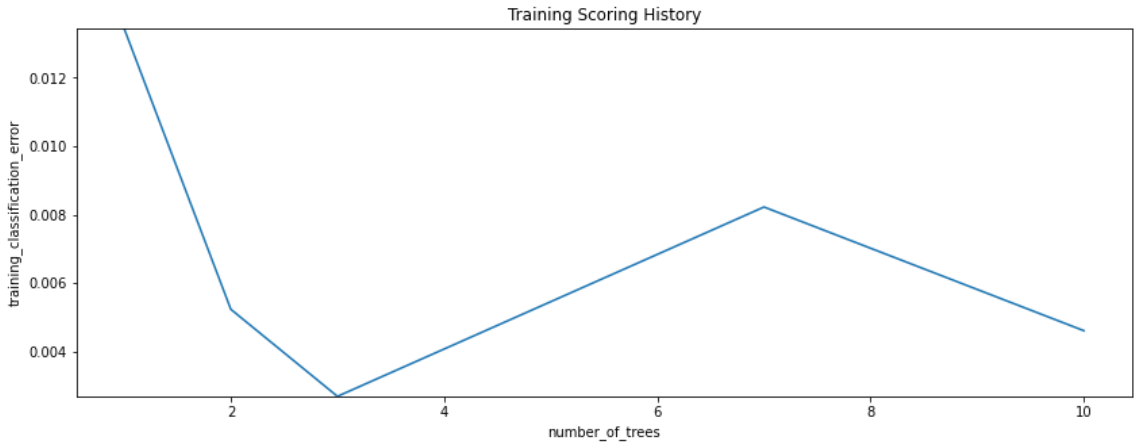
In [ ]:
```
# train / test split (80/20)
train_hex, test_hex = df_hex.split_frame(ratios=[0.8], seed=999)
```

In [ ]:
```
# define (distributed) random forest model
fit_DRF = H2ORandomForestEstimator(ntrees=10,
                                   max_depth=5,
                                   min_rows=10,
                                   nfolds=5,
                                   seed=999)
```

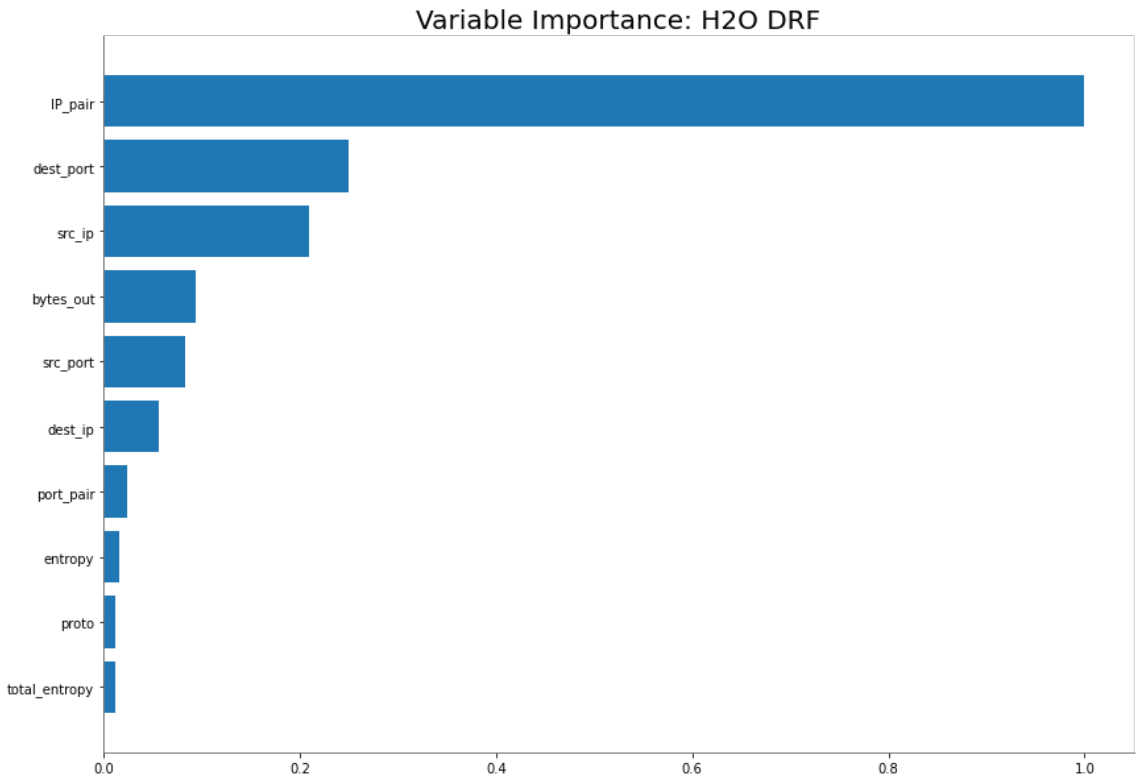
In [ ]:
```
# train model
t1 = time.time()
fit_DRF.train(x=features,
              y=target,
              training_frame=train_hex)
t2 = time.time()
print('Elapsed time [s]: ', np.round(t2-t1,2))
```

```
drf Model Build progress: |
| 100%
Elapsed time [s]:  89.4
```

In [ ]:
```
# show training scoring history
fit_DRF.plot()
```



In [ ]:
```
# variable importance
fit_DRF.varimp_plot()
```



In [ ]:
```
# performance on training
perf_train = fit_DRF.model_performance(train=True)
perf_train
```

```
WARNING: The `auc_type` parameter is set but it is not used because
the `test_data` parameter is None.

ModelMetricsMultinomial: drf
** Reported on train data. **

MSE: 0.008289002220517415
RMSE: 0.09104395762771637
LogLoss: 0.044904258054713125
Mean Per-Class Error: 0.016687015945657104
AUC: NaN
AUCPR: NaN
Multinomial auc values: Table is not computed because it is disable
d (model parameter 'auc_type' is set to AUTO or NONE) or due to dom
ain size (maximum is 50 domains).
Multinomial auc_pr values: Table is not computed because it is disa
bled (model parameter 'auc_type' is set to AUTO or NONE) or due to
domain size (maximum is 50 domains).

Confusion Matrix: Row labels: Actual class; Column labels: Predicte
d class
```

	benign	malicious	outlier	Error	Rate
0	409166.0	101.0	5.0	0.000259	106 / 409,272
1	133.0	372884.0	59.0	0.000515	192 / 373,076
2	18.0	3634.0	70444.0	0.049287	3,652 / 74,096
3	409317.0	376619.0	70508.0	0.004612	3,950 / 856,444

```
Top-3 Hit Ratios:
```

	k	hit_ratio
0	1	0.995388
1	2	0.999919
2	3	1.000000

Out[119]:

In [ ]:
```
# cross validation metrics
fit_DRF.cross_validation_metrics_summary()
```

Cross-Validation Metrics Summary:

		mean	sd	cv_1_valid	cv_2_valid	cv_
0	accuracy	0.9996199	1.4934083E-4	0.9995547	0.99950355	0.9
1	auc	NaN	0.0	NaN	NaN	
2	err	3.801214E-4	1.4934083E-4	4.4527717E-4	4.9642974E-4	2.2528
3	err_count	65.8	25.820534	77.0	86.0	
4	logloss	0.044420037	0.0015460032	0.044766143	0.04458454	0.04
5	max_per_class_error	0.0034458057	0.0017701992	0.0038474295	0.005235255	0.0013
6	mean_per_class_accuracy	0.99879354	5.854098E-4	0.9986401	0.99822634	0.99
7	mean_per_class_error	0.001206447	5.854098E-4	0.0013598939	0.0017736652	5.2223
8	mse	0.0061502084	4.0287487E-4	0.0063612675	0.006169839	0.006
9	pr_auc	NaN	0.0	NaN	NaN	
10	r2	0.98504645	9.4168045E-4	0.98457646	0.9850352	0.9
11	rmse	0.0783892	0.0025840965	0.07975756	0.07854832	0.081

Out[120]:

In [ ]:
```
pred_test = fit_DRF.predict(test_hex)
```

```
drf prediction progress: |████████████████████████████████████████
███████| 100%
```

In [ ]:
```
# add actual target
pred_test['target'] = test_hex['label']
# and convert to pandas data frame
pred_test = pred_test.as_data_frame()
```

In [ ]:
```
# show a few examples, the 3 numeric values are the predicted probabi
pred_test.tail(10)
```

Out[123]:

	predict	benign	malicious	outlier	target
216244	malicious	2.811451e-05	0.960361	0.039610	malicious
216245	malicious	0.000000e+00	0.999817	0.000183	malicious
216246	malicious	4.188829e-07	0.999996	0.000003	malicious
216247	malicious	2.855797e-05	0.907556	0.092415	malicious
216248	malicious	4.188829e-07	0.999996	0.000003	malicious
216249	malicious	4.953982e-07	0.976200	0.023799	malicious
216250	malicious	4.188829e-07	0.999996	0.000003	malicious
216251	benign	9.499847e-01	0.050012	0.000003	benign
216252	malicious	2.815577e-05	0.992288	0.007684	malicious
216253	malicious	4.188829e-07	0.999996	0.000003	malicious

In [ ]:
```
# evaluate confusion matrix
pd.crosstab(pred_test.predict, pred_test.target)
```

Out[124]:

target	benign	malicious	outlier
predict			
benign	103231	0	4
malicious	14	94416	81
outlier	0	2	18506