

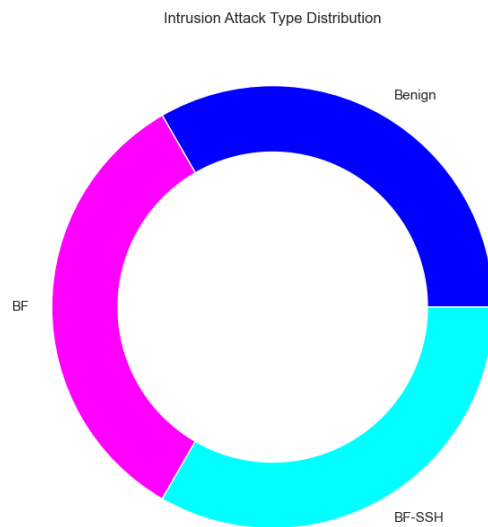
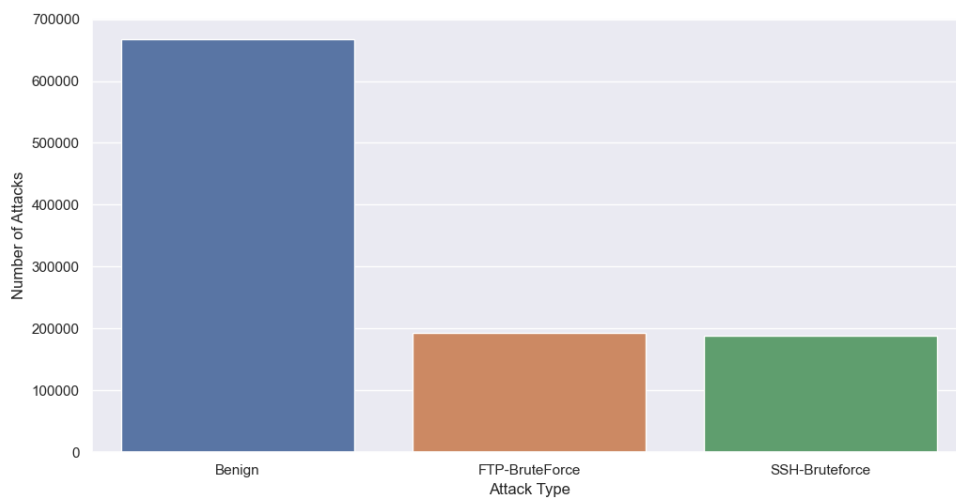
Transfer Learning preliminary results

Baseline CNN Model

```
Number of Rows (Samples): 1048575
Number of Columns (Features): 80
Total columns in our data: 80
```

```
Data columns (total 80 columns):
#   Column              Non-Null Count  Dtype
---  -
0   Dst Port             1048575 non-null int64
1   Protocol             1048575 non-null int64
2   Timestamp            1048575 non-null object
3   Flow Duration        1048575 non-null float64
4   Tot Fwd Pkts         1048575 non-null int64
5   Tot Bwd Pkts         1048575 non-null int64
6   TotLen Fwd Pkts      1048575 non-null int64
7   TotLen Bwd Pkts      1048575 non-null int64
8   Fwd Pkt Len Max      1048575 non-null int64
9   Fwd Pkt Len Min      1048575 non-null int64
10  Fwd Pkt Len Mean      1048575 non-null float64
11  Fwd Pkt Len Std       1048575 non-null float64
12  Bwd Pkt Len Max       1048575 non-null int64
13  Bwd Pkt Len Min       1048575 non-null int64
14  Bwd Pkt Len Mean      1048575 non-null float64
15  Bwd Pkt Len Std       1048575 non-null float64
16  Flow Byts/s           1046298 non-null float64
17  Flow Pkts/s           1048575 non-null float64
18  Flow IAT Mean         1048575 non-null float64
19  Flow IAT Std          1048575 non-null float64
20  Flow IAT Max          1048575 non-null float64
21  Flow IAT Min          1048575 non-null float64
22  Fwd IAT Tot           1048575 non-null float64
23  Fwd IAT Mean          1048575 non-null float64
24  Fwd IAT Std           1048575 non-null float64
25  Fwd IAT Max           1048575 non-null float64
26  Fwd IAT Min           1048575 non-null float64
27  Bwd IAT Tot           1048575 non-null int64
28  Bwd IAT Mean          1048575 non-null float64
29  Bwd IAT Std           1048575 non-null float64
30  Bwd IAT Max           1048575 non-null int64
31  Bwd IAT Min           1048575 non-null int64
32  Fwd PSH Flags         1048575 non-null int64
33  Bwd PSH Flags         1048575 non-null int64
34  Fwd URG Flags         1048575 non-null int64
35  Bwd URG Flags         1048575 non-null int64
36  Fwd Header Len        1048575 non-null int64
37  Bwd Header Len        1048575 non-null int64
38  Fwd Pkts/s            1048575 non-null float64
39  Bwd Pkts/s            1048575 non-null float64
40  Pkt Len Min           1048575 non-null int64
41  Pkt Len Max           1048575 non-null int64
42  Pkt Len Mean          1048575 non-null float64
43  Pkt Len Std           1048575 non-null float64
44  Pkt Len Var           1048575 non-null float64
45  FIN Flag Cnt          1048575 non-null int64
46  SYN Flag Cnt          1048575 non-null int64
47  RST Flag Cnt          1048575 non-null int64
48  PSH Flag Cnt          1048575 non-null int64
49  ACK Flag Cnt          1048575 non-null int64
50  URG Flag Cnt          1048575 non-null int64
51  CWE Flag Count        1048575 non-null int64
52  ECE Flag Cnt          1048575 non-null int64
53  Down/Up Ratio         1048575 non-null int64
54  Pkt Size Avg          1048575 non-null float64
55  Fwd Seg Size Avg      1048575 non-null float64
56  Bwd Seg Size Avg      1048575 non-null float64
57  Fwd Byts/b Avg        1048575 non-null int64
58  Fwd Pkts/b Avg        1048575 non-null int64
59  Fwd Blk Rate Avg      1048575 non-null int64
60  Bwd Byts/b Avg        1048575 non-null int64
61  Bwd Pkts/b Avg        1048575 non-null int64
62  Bwd Blk Rate Avg      1048575 non-null int64
63  Subflow Fwd Pkts      1048575 non-null int64
64  Subflow Fwd Byts      1048575 non-null int64
65  Subflow Bwd Pkts      1048575 non-null int64
66  Subflow Bwd Byts      1048575 non-null int64
67  Init Fwd Win Byts     1048575 non-null int64
68  Init Bwd Win Byts     1048575 non-null int64
69  Fwd Act Data Pkts     1048575 non-null int64
70  Fwd Seg Size Min      1048575 non-null int64
71  Active Mean           1048575 non-null float64
72  Active Std            1048575 non-null float64
73  Active Max            1048575 non-null int64
74  Active Min            1048575 non-null int64
75  Idle Mean             1048575 non-null float64
76  Idle Std              1048575 non-null float64
77  Idle Max              1048575 non-null float64
78  Idle Min              1048575 non-null int64
79  Label                 1048575 non-null object
dtypes: float64(31), int64(47), object(2)
memory usage: 640.0+ MB
Benign                667626
FTP-BruteForce         193360
SSH-Bruteforce         187589
Name: Label, dtype: int64
```

```
dtypes: float64(31), int64(47), object(2)
memory usage: 640.0+ MB
Benign          667626
FTP-BruteForce  193360
SSH-Bruteforce  187589
Name: Label, dtype: int64
```



```
(60000, 72)
(9000, 72)
(60000, 3)
(9000, 3)
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv1d (Conv1D)	(None, 72, 64)	448
batch_normalization (Batch Normalization)	(None, 72, 64)	256
max_pooling1d (MaxPooling1D)	(None, 36, 64)	0
conv1d_1 (Conv1D)	(None, 36, 64)	24640
batch_normalization_1 (Batch Normalization)	(None, 36, 64)	256
max_pooling1d_1 (MaxPooling1D)	(None, 18, 64)	0
conv1d_2 (Conv1D)	(None, 18, 64)	24640
batch_normalization_2 (Batch Normalization)	(None, 18, 64)	256
max_pooling1d_2 (MaxPooling1D)	(None, 9, 64)	0
flatten (Flatten)	(None, 576)	0
dense (Dense)	(None, 64)	36928
dense_1 (Dense)	(None, 64)	4160
dense_2 (Dense)	(None, 3)	195

Total params: 91,779

Trainable params: 91,395

Non-trainable params: 384

```
Epoch 1/10
100/100 [=====] - 21s 68ms/step - loss: 0.4288 - accuracy: 0.8214 - val_loss: 1.0584 - val_accuracy: 0.5010
Epoch 2/10
100/100 [=====] - 6s 63ms/step - loss: 0.1043 - accuracy: 0.9656 - val_loss: 0.5172 - val_accuracy: 0.9987
Epoch 3/10
100/100 [=====] - 6s 62ms/step - loss: 0.0728 - accuracy: 0.9775 - val_loss: 0.6905 - val_accuracy: 0.7143
Epoch 4/10
100/100 [=====] - 6s 62ms/step - loss: 0.0561 - accuracy: 0.9833 - val_loss: 0.1809 - val_accuracy: 0.9788
Epoch 5/10
100/100 [=====] - 6s 61ms/step - loss: 0.0561 - accuracy: 0.9822 - val_loss: 0.4231 - val_accuracy: 0.7853
Epoch 6/10
100/100 [=====] - 6s 63ms/step - loss: 0.0507 - accuracy: 0.9835 - val_loss: 0.1210 - val_accuracy: 0.9783
Epoch 7/10
100/100 [=====] - 6s 62ms/step - loss: 0.0499 - accuracy: 0.9841 - val_loss: 0.1309 - val_accuracy: 0.9789
Epoch 8/10
100/100 [=====] - 6s 64ms/step - loss: 0.0504 - accuracy: 0.9841 - val_loss: 0.2147 - val_accuracy: 0.9487
Epoch 9/10
100/100 [=====] - 6s 64ms/step - loss: 0.0497 - accuracy: 0.9839 - val_loss: 0.1081 - val_accuracy: 0.9692
Epoch 10/10
100/100 [=====] - 6s 63ms/step - loss: 0.0493 - accuracy: 0.9842 - val_loss: 0.0976 - val_accuracy: 0.9654
```



Evaluation Metrics

Accuracy = 98.17777872085571 %

Precision = 98.17866714009148 %

Recall = 98.16609374269646 %

F1 Score = 98.1685051851882 %

Transfer Learning Implementation

Number of Rows (Samples): 1048575

Number of Columns (Features): 80

dtypes: float64(24), int64(54), object(2)

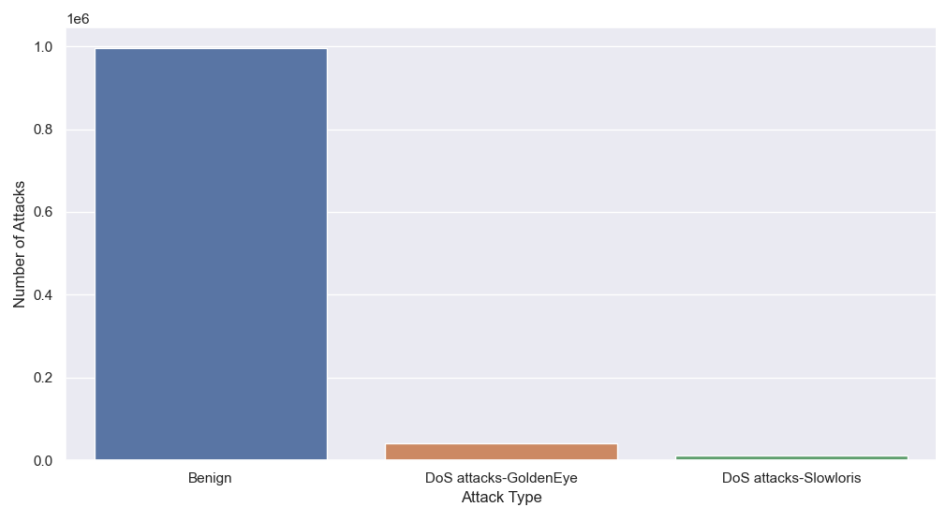
memory usage: 640.0+ MB

Benign	996077
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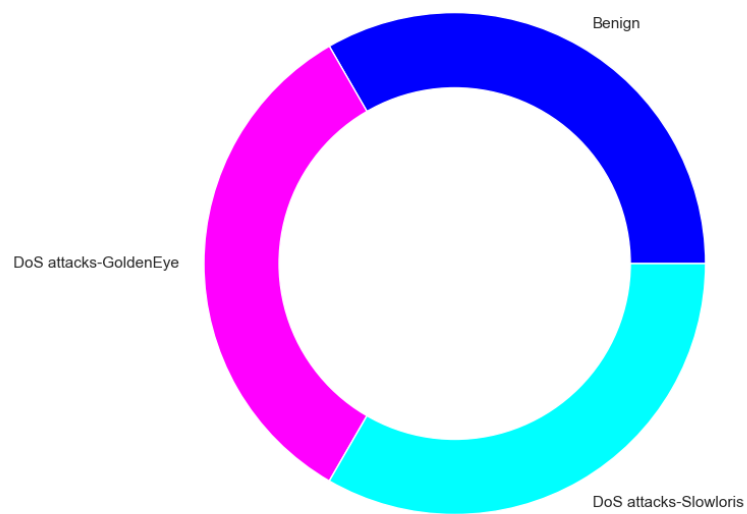
DoS attacks-GoldenEye	41508
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DoS attacks-Slowloris	10990
-----------------------	-------

Name: Label, dtype: int64



Intrusion Attack Type Distribution



```
(1043654, 80)
(1043654, 1)
(60000, 72)
(9000, 72)
(60000, 3)
(9000, 3)
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv1d (Conv1D)	(None, 72, 64)	448
batch_normalization (Batch Normalization)	(None, 72, 64)	256
max_pooling1d (MaxPooling1D)	(None, 36, 64)	0
conv1d_1 (Conv1D)	(None, 36, 64)	24640
batch_normalization_1 (Batch Normalization)	(None, 36, 64)	256
max_pooling1d_1 (MaxPooling1D)	(None, 18, 64)	0
conv1d_2 (Conv1D)	(None, 18, 64)	24640
batch_normalization_2 (Batch Normalization)	(None, 18, 64)	256
max_pooling1d_2 (MaxPooling1D)	(None, 9, 64)	0
flatten (Flatten)	(None, 576)	0
dense (Dense)	(None, 64)	36928
dense_1 (Dense)	(None, 64)	4160
dense_2 (Dense)	(None, 3)	195

Total params: 91,779
Trainable params: 91,395
Non-trainable params: 384

```
<keras.layers.convolutional.Conv1D object at 0x000001B82D5DF970> False
<keras.layers.normalization_v2.BatchNormalization object at 0x000001B82D668E80> False
<keras.layers.pooling.MaxPooling1D object at 0x000001B82D6680D0> False
<keras.layers.convolutional.Conv1D object at 0x000001B82D69F8E0> False
<keras.layers.normalization_v2.BatchNormalization object at 0x000001B82D69FBB0> False
<keras.layers.pooling.MaxPooling1D object at 0x000001B8585EC610> False
```

```
<keras.layers.convolutional.Conv1D object at 0x000001B82D6CD8E0> True
<keras.layers.normalization_v2.BatchNormalization object at 0x000001B82D69F3D0> True
<keras.layers.pooling.MaxPooling1D object at 0x000001B8585F66D0> True
<keras.layers.core.Flatten object at 0x000001B8585F65E0> True
<keras.layers.core.Dense object at 0x000001B82D69FD90> True
<keras.layers.core.Dense object at 0x000001B8585FBBB0> True
<keras.layers.core.Dense object at 0x000001B8585FB1F0> True
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv1d (Conv1D)	(None, 72, 64)	448
batch_normalization (Batch Normalization)	(None, 72, 64)	256
max_pooling1d (MaxPooling1D)	(None, 36, 64)	0
conv1d_1 (Conv1D)	(None, 36, 64)	24640
batch_normalization_1 (Batch Normalization)	(None, 36, 64)	256
max_pooling1d_1 (MaxPooling1D)	(None, 18, 64)	0

conv1d_2 (Conv1D)	(None, 18, 64)	24640
batch_normalization_2 (Batch Normalization)	(None, 18, 64)	256
max_pooling1d_2 (MaxPooling1D)	(None, 9, 64)	0
flatten (Flatten)	(None, 576)	0
dense (Dense)	(None, 64)	36928
dense_1 (Dense)	(None, 64)	4160
dense_2 (Dense)	(None, 3)	195

Total params: 91,779

Trainable params: 66,051

Non-trainable params: 25,728

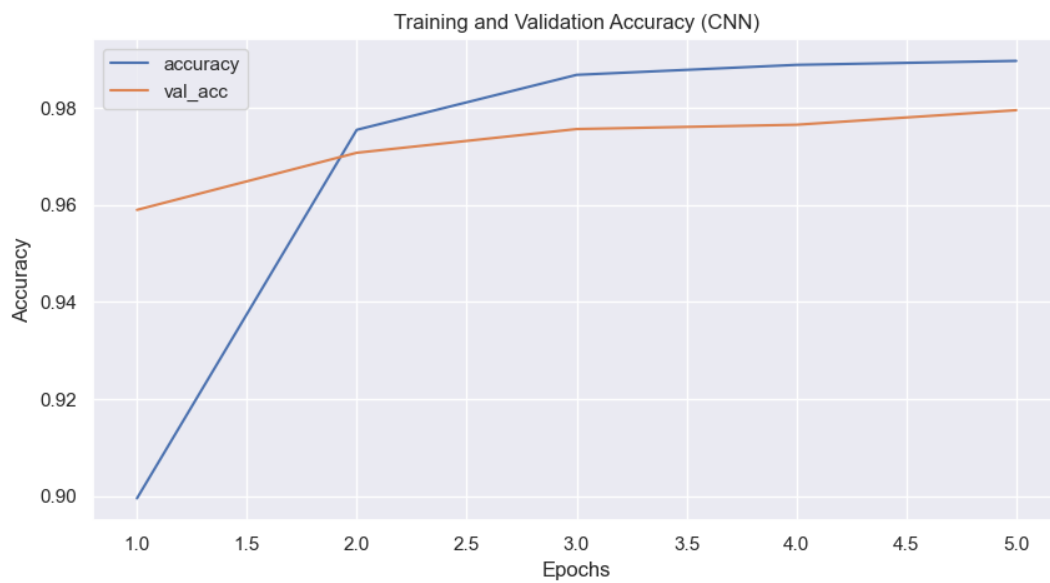
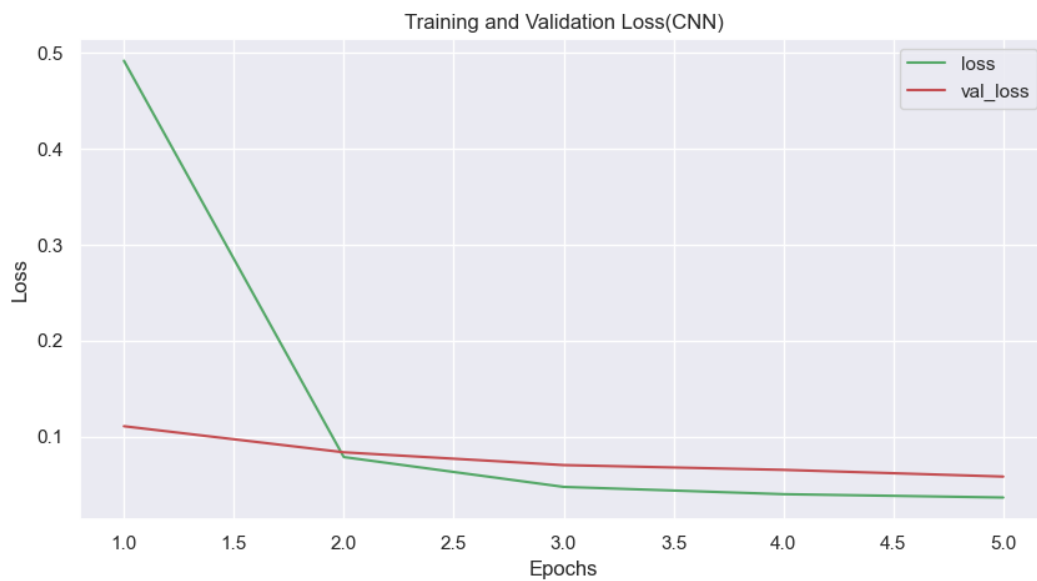
Before

Total params: 91,779
Trainable params: 91,395
Non-trainable params: 384

After

Total params: 91,779
Trainable params: 66,051
Non-trainable params: 25,728

```
Epoch 1/5
2022-03-15 01:48:40.060484: I tensorflow/stream_executor/platform/default/dso_loader.cc:53] Successfully opened dynamic library cudnn64_8.dll
2022-03-15 01:48:40.814085: I tensorflow/stream_executor/cuda/cuda_dnn.cc:359] Loaded cuDNN version 8200
2022-03-15 01:48:42.415557: I tensorflow/stream_executor/platform/default/dso_loader.cc:53] Successfully opened dynamic library cublas64_11.dll
2022-03-15 01:48:44.057401: I tensorflow/stream_executor/platform/default/dso_loader.cc:53] Successfully opened dynamic library cublasLt64_11.dll
2022-03-15 01:48:44.355555: I tensorflow/stream_executor/cuda/cuda_blas.cc:1838] TensorFlow-32 will be used for the matrix multiplication. This will only be logged once.
100/100 [=====] - 21s 12ms/step - loss: 1.3862 - accuracy: 0.8065 - val_loss: 0.1109 - val_accuracy: 0.9590
Epoch 2/5
100/100 [=====] - 0s 4ms/step - loss: 0.0935 - accuracy: 0.9691 - val_loss: 0.0838 - val_accuracy: 0.9708
Epoch 3/5
100/100 [=====] - 0s 4ms/step - loss: 0.0507 - accuracy: 0.9863 - val_loss: 0.0704 - val_accuracy: 0.9757
Epoch 4/5
100/100 [=====] - 0s 4ms/step - loss: 0.0392 - accuracy: 0.9889 - val_loss: 0.0654 - val_accuracy: 0.9766
Epoch 5/5
100/100 [=====] - 0s 4ms/step - loss: 0.0368 - accuracy: 0.9896 - val_loss: 0.0584 - val_accuracy: 0.9796
282/282 [=====] - 1s 2ms/step - loss: 0.0397 - accuracy: 0.9870
```



Evaluation Metrics

Accuracy = 98.69999885559082 %

Precision = 98.71092123511195 %

Recall = 98.69178602401635 %

F1 Score = 98.6970213131052 %

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