

Is Encrypted Client Hello (ECH) a Challenge for Traffic Classification?

Presented by - Devendra Pratap Singh (2101AI13)

TLS Handshake Phases

- **Key Exchange**
 - Client sends ClientHello (CH) with TLS parameters.
 - Server responds with ServerHello (SH) to compute shared encryption secrets
 - **Server Parameters**
 - Server sends remaining parameters in an EncryptedExtensions (EE) message
 - **Authentication**
 - Parties authenticate via Certificate exchange and complete the handshake.

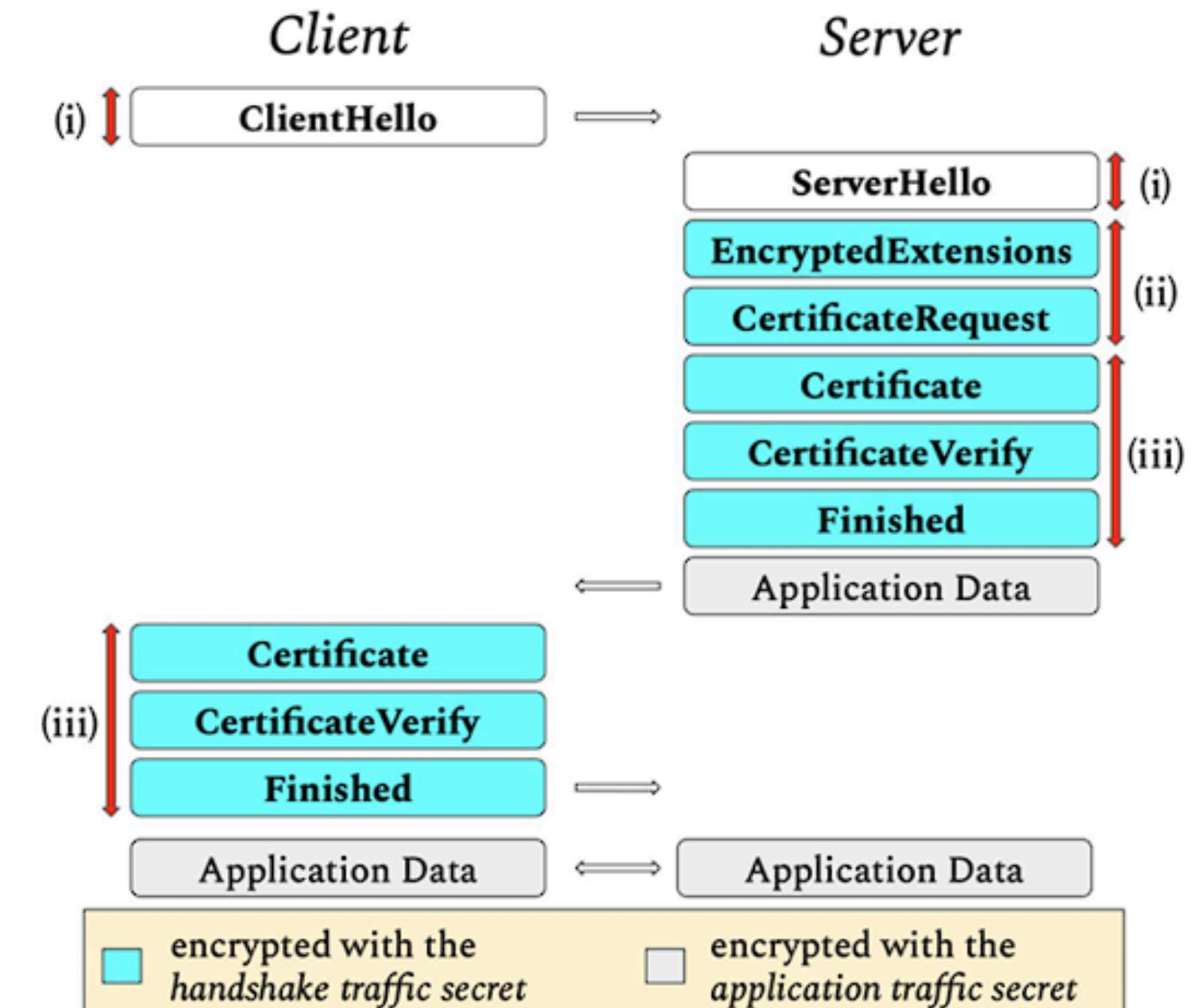


FIGURE 1. Three phases of the TLS 1.3 handshake protocol: (i) Key exchange, (ii) Server parameters and (iii) Authentication.

Record Type	Record Version	Record Len	Handshake Type	Message Len	Message Version
1 byte	2 bytes	2 bytes	1 byte	3 bytes	2 bytes
Random		Session ID Len	Session ID		Cipher Suites Len
32 bytes		1 byte	SID len bytes		CS len bytes
Compression Methods Len		Compression Methods		Extensions Len	Ext 1 Type
1 byte		CM len bytes		2 bytes	Ext 1 Len
Ext 1 Data	Ext 2 Type	Ext 2 Len	Ext 2 Data	...	Ext n Type
ext 1 len bytes	2 bytes	2 bytes	ext 2 len bytes	...	Ext n Len
ext 1 len bytes	2 bytes	2 bytes	ext 2 len bytes	...	Ext n Data

(a)

Record Type	Record Version	Record Len	Handshake Type	Message Len	Message Version
1 byte	2 bytes	2 bytes	1 byte	3 bytes	2 bytes
Random		Session ID Len	Session ID		Compression Method
32 bytes		1 byte	SID len bytes		1 byte
Extensions Len		Ext 1 Type	Ext 1 Len	Ext 1 Data	Ext n Type
2 bytes		2 bytes	2 bytes	ext 1 len bytes	Ext n Len
2 bytes		2 bytes	2 bytes	...	Ext n Data

(b)

FIGURE 2. (a) ClientHello and (b) ServerHello message structure.

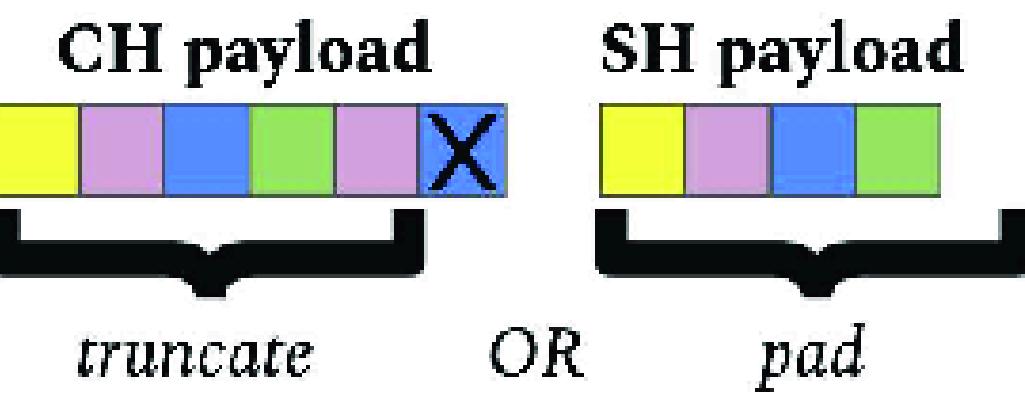
Aligned Bytes Random Forest (AB-RF)

Payload Alignment: Extracts exactly B bytes from the payload of each message (CH and SH), truncating or padding with zeros, and concatenates them into a single vector.

Random Forest: Uses the aligned bytes as a feature vector, builds D decision trees during training, and predicts traffic class based on decisions across all trees.

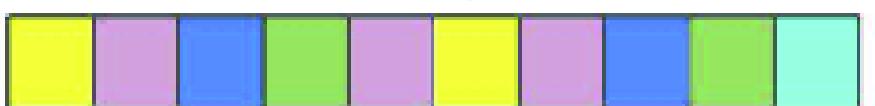
- Number of decision trees is varied.
- Number of features is set to 35.
- Evaluated with an aligned payload length of 185 bytes, which offers the lowest error rate.

1. Payload Alignment

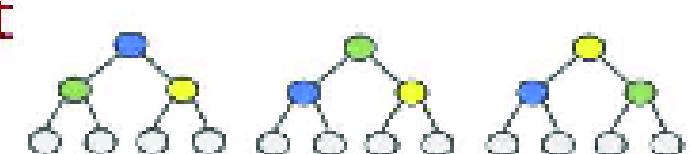


concatenate

fixed-size byte vector



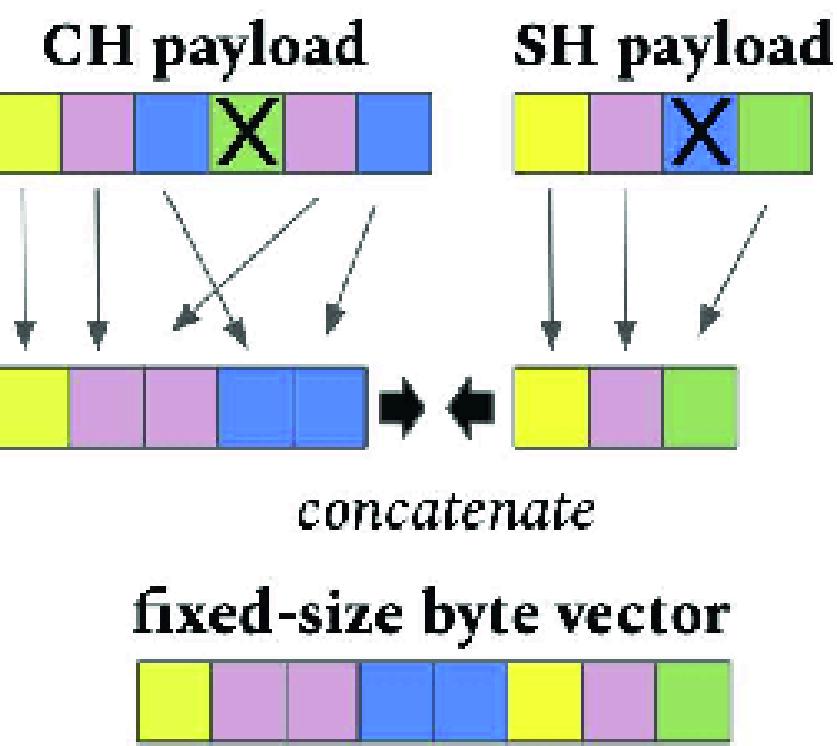
2. Random Forest



a) AB-RF

Recomposed-Bytes Random Forest (RB-RF)

1. Payload Recomposition



It improves classification by rearranging payload parameters, assigning fixed positions and lengths to them.

Decomposition:

Breaks down CH and SH messages into fields, extension types, lengths, and data.

New Composition

Parameters are selected and assigned fixed-length representations in a specific order. The recomposed payload contains four blocks: **field values, extension types, extension lengths, and selected extension contents.**



b) RB-RF

Record Version	Record Len	Message Len	Message Version	SID Len	Cipher Suites Len	Cipher Suites	Extensions Len
2 bytes	2 bytes	3 bytes	2 bytes	1 byte	2 bytes	70 bytes	2 bytes
Ext 1 Type	Ext 2 Type	...	Ext 20 Type	Padding (21) Len	Session Ticket (35) Len	PSK (41) Len	Cookie (44) Len SNI (0) Len
2 bytes	2 bytes	34 bytes	2 bytes	2 bytes	2 bytes	2 bytes	2 bytes
Cached info (25) Len	Key Share (51) Len	ALPN (16) Len	Trusted CA keys (3) Data	Heartbeat (15) Data	PSK KE modes (45) Data		
2 bytes	2 bytes	2 bytes	2 bytes	2 bytes	2 bytes	2 bytes	
Compress Certificate (27) Data	Record size limit (28) Data	user mapping (6) Data	EC point formats (11) Data	Client Cert type (19) Data			
4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	4 bytes	
Server Cert type (20) Data	Ticket Request (58) Data	Supported Versions (43) Data	Supported Groups (10) Data	SA (13) Data	ALPN (16) Data		
4 bytes	4 bytes	12 bytes	26 bytes	26 bytes	4 bytes		

(a)

Record Version	Record Len	Message Len	Message Version	SID Len	Cipher Suite	Extensions Len
2 bytes	2 bytes	3 bytes	2 bytes	1 byte	2 bytes	2 bytes
Ext 1 Type	...	Ext 10 Type	PSK (41) Len	Key Share (51) Len	Key Share (51) Data	Supported Versions (43) Data
2 bytes	16 bytes	2 bytes	2 bytes	2 bytes	2 bytes	2 bytes

(b)

FIGURE 7. (a) ClientHello and (b) ServerHello recomposed payload structure.

Data Preprocessing for TC Protocols

- **TLS Handshake Data Extraction**

- Scapy is used to extract L4 (transport layer) payloads from packets carrying Client Hello (CH) and Server Hello (SH) messages.
- Only CH and SH packets are considered, as packets beyond TLS 1.3 are encrypted and do not improve classification quality.
- Server Certificate message (third packet) is used only for baseline classifier validation on Open HTTPS datasets.
- QUIC flows and L3/lower-layer headers are excluded due to potential dataset biases.

- **Random Field Modification:**

- The first 4 bytes of the random fields in CH and SH are replaced with zeros to avoid time/date biases in the dataset.

Data Preprocessing for TC Protocols

- **TLS Handshake Data Extraction**

- Scapy is used to extract L4 (transport layer) payloads from packets carrying Client Hello (CH) and Server Hello (SH) messages.

- **Random Field Modification:**

- The first 4 bytes of the random fields in CH and SH are replaced with zeros to avoid time/date biases in the dataset.

Models of Encryption Scenarios

- **ESNI (Encrypted SNI)**

- Conceals only the SNI value, not its length.
- CH payload is extracted from the first packet, and SNI is hidden by replacing it with zeros.

- **ECH (Encrypted ClientHello)**

- Represents the strongest encryption where all CH extensions (except key share, pre-shared key, supported versions) are removed.
- CH fields like Extensions Length, Record Length, and Message Length are updated based on removed extensions.

- **Common**

- SH payload is extracted from the second packet.

WNL TLS Dataset

The dataset contains download traces of TLS-encrypted flows of four traffic types: buffered video, buffered audio, uplink live video streaming, and web.

WW	1018
Netflix	427
YandexMusic	375
AppleMusic	289
SoundCloud	280
Kinopoisk	267
Spotify	251
YouTube_PC	249
PrimeVideo	188
Live_Youtube	108
Live_Facebook	106
Vimeo	94
Name:	count, dtype: int64

ESNI

Extracted the payload from first packet of the flow and hide the SNI extension with zeroes

ECH

Extracted the CH payload and remove bytes corresponding to all CH extensions registered by IANA except for the ones that cannot be encrypted: key share, pre-shared key, and supported versions. Also, updated the Extensions Length, Record Length, Message Length fields of the CH

Result of AB-RF on ESNI Dataset

Training Time: 4.4664 seconds

Class-wise Performance Table:

	Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	AppleMusic	100.000000	0.000000	100.000000	100.000000
1	Kinopoisk	100.000000	0.000000	98.148148	100.000000
2	Live_Facebook	100.000000	0.000000	100.000000	100.000000
3	Live_Youtube	100.000000	0.000000	100.000000	100.000000
4	Netflix	100.000000	0.000000	100.000000	100.000000
5	PrimeVideo	100.000000	0.000000	100.000000	100.000000
6	SoundCloud	100.000000	0.000000	100.000000	100.000000
7	Spotify	100.000000	0.000000	100.000000	100.000000
8	Vimeo	100.000000	0.000000	95.000000	100.000000
9	YandexMusic	100.000000	0.000000	97.402597	100.000000
10	YouTube_PC	100.000000	0.000000	100.000000	100.000000
11	ww	98.039216	1.960784	100.000000	98.039216

Overall Accuracy: 0.9945

F1 Score: 0.9945

Result of AB-RF on ECH Dataset

Training Time: 6.1302 seconds

Class-wise Performance Table:

	Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	AppleMusic	100.000000	0.000000	98.305085	100.000000
1	Kinopoisk	62.264151	37.735849	89.189189	62.264151
2	Live_Facebook	100.000000	0.000000	100.000000	100.000000
3	Live_Youtube	100.000000	0.000000	100.000000	100.000000
4	Netflix	100.000000	0.000000	78.703704	100.000000
5	PrimeVideo	86.842105	13.157895	89.189189	86.842105
6	SoundCloud	100.000000	0.000000	98.245614	100.000000
7	Spotify	98.000000	2.000000	87.500000	98.000000
8	Vimeo	73.684211	26.315789	87.500000	73.684211
9	YandexMusic	96.000000	4.000000	67.924528	96.000000
10	YouTube_PC	100.000000	0.000000	100.000000	100.000000
11	ww	76.960784	23.039216	96.913580	76.960784

Overall Accuracy: 0.8892

F1 Score: 0.8882

Result of RB-RF on ESNI Dataset

Training Time: 1.1261 seconds

Class-wise Performance Table:

	Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	AppleMusic	100.000000	0.000000	100.000000	100.000000
1	Kinopoisk	98.148148	1.851852	100.000000	98.148148
2	Live_Facebook	100.000000	0.000000	100.000000	100.000000
3	Netflix	100.000000	0.000000	100.000000	100.000000
4	PrimeVideo	100.000000	0.000000	100.000000	100.000000
5	SoundCloud	98.214286	1.785714	100.000000	98.214286
6	Spotify	100.000000	0.000000	98.076923	100.000000
7	Vimeo	100.000000	0.000000	100.000000	100.000000
8	YandexMusic	98.666667	1.333333	98.666667	98.666667
9	YouTube_PC	98.000000	2.000000	100.000000	98.000000
10	WW	99.521531	0.478469	98.578199	99.521531

Overall Accuracy: 0.9931

F1 Score: 0.9931

Result of RB-RF on ECH Dataset

Training Time: 1.1015 seconds

Class-wise Performance Table:

	Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	AppleMusic	100.000000	0.000000	95.161290	100.000000
1	Kinopoisk	66.666667	33.333333	73.469388	66.666667
2	Live_Facebook	100.000000	0.000000	100.000000	100.000000
3	Netflix	91.954023	8.045977	81.632653	91.954023
4	PrimeVideo	86.842105	13.157895	100.000000	86.842105
5	SoundCloud	100.000000	0.000000	96.551724	100.000000
6	Spotify	100.000000	0.000000	82.258065	100.000000
7	Vimeo	57.142857	42.857143	100.000000	57.142857
8	YandexMusic	86.666667	13.333333	72.222222	86.666667
9	YouTube_PC	98.000000	2.000000	100.000000	98.000000
10	WW	83.253589	16.746411	93.048128	83.253589

Overall Accuracy: 0.8821

F1 Score: 0.8813

Next Steps



Comparison with
Baseline Models
(BGRUA and MATEC)



VNAT Dataset
(provided by Samsung)



ISCXVPN2016 Dataset
(provided by Samsung)



Comparisons

Next Steps

Comparison with
Baseline Models
(BGRUA and MATEC)

BGRUA

DataSet - Open HTTPS

- ◆ Two bidirectional GRU layers with a hidden state size of 256, along with Self-attention layer.
- ◆ Fully connected layer with a softmax activation function for class probability output.
- ◆ Packet lengths are aligned to 900 bytes and reshaped into six vectors of 150 bytes each.
- ◆ Each vector is normalized to [0, 1] by dividing by 255.

MATEC

DataSet - Open HTTPS

- ◆ Input packets are normalized to [0, 1] before processing.
- ◆ Combines embeddings and high-level features through attention and CNN layers.
- ◆ Embedding size = 432, extracts low-level features.
Hyperparameter - Embedding size = 256
- ◆ T multi-head attention layers: $T \geq 2$, with 3 attention heads.
- ◆ Number of kernels = 432.
Kernel size = 1.
- ◆ Dense layer with softmax activation function for class probabilities.

Result of MATEC

```
Epoch 40/40
80/80 ————— 40s 249ms/step - accuracy: 0.9679 - loss: 0.1279 - val_accuracy: 0.9718 - val_loss: 0.1275
23/23 ————— 1s 32ms/step - accuracy: 0.9445 - loss: 0.3126
Test Loss: 0.3161
Test Accuracy: 0.9451
Total Evaluation Time: 0.82 seconds
23/23 ————— 1s 45ms/step
```

Class-wise Error Rate Table:

	Class	Error Rate (%)
0	AppleMusic	5.882353
1	Kinopoisk	2.469136
2	Live_Facebook	0.000000
3	Live_Youtube	0.000000
4	Netflix	2.127660
5	PrimeVideo	14.285714
6	SoundCloud	7.547170
7	Spotify	7.692308
8	Vimeo	16.666667
9	YandexMusic	11.111111
10	YouTube_PC	0.000000
11	WW	3.649635

Result of BGRUA

```
94/94 18s 175ms/step - accuracy: 0.9849 - loss: 0.0410 - val_accuracy: 0.9692 - val_loss: 0.1646
Epoch 40/40
94/94 21s 176ms/step - accuracy: 0.9909 - loss: 0.0300 - val_accuracy: 0.9678 - val_loss: 0.1502
24/24 1s 56ms/step - accuracy: 0.9631 - loss: 0.1299
Test Loss: 0.15020278096199036, Test Accuracy: 0.9678283929824829
Total Evaluation Time: 1.50 seconds
```

Classification Report:

	precision	recall	f1-score	support
Class 0	0.98	1.00	0.99	41
Class 1	1.00	0.92	0.96	65
Class 2	1.00	1.00	1.00	21
Class 3	0.96	1.00	0.98	22
Class 4	1.00	1.00	1.00	88
Class 5	1.00	1.00	1.00	55
Class 6	0.84	0.95	0.89	64
Class 7	0.90	0.94	0.92	69
Class 8	0.90	0.90	0.90	21
Class 9	1.00	0.95	0.98	108
Class 10	0.98	1.00	0.99	57
Class 11	1.00	0.96	0.98	135
accuracy			0.97	746
macro avg	0.96	0.97	0.97	746
weighted avg	0.97	0.97	0.97	746

VNAT Dataset

```
# SNI substring mappings
sni_mapping = {
    "googlemail": "Gmail",
    "ftps": "FileTransfer",
    "player.vimeo.com": "Vimeo",
    "vimeocdn": "Vimeo",
    "conviva": "Vimeo",
    "vimeo.com": "Vimeo",
    "googlevideo": "Youtube",
    "ssl.gstatic.com": "ssl.gstatic",
    "play.google.com": "Hangout",
    "nflxvideo": "Netflix",
    "client": "ThirdParty(Google Services)"
}
```

8 classes

FileTransfer
Gmail
Google Services
Hangout
Netflix
Vimeo
Youtube
ssl.gstatic

VNAT Dataset

tls.handshake.type == 1						
No.	Time	Source	Destination	Protocol	Length	Info
65888	98.496183	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
65872	98.493767	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
55017	87.677389	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
52971	81.284951	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
39522	73.524451	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
37500	65.913827	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
1019	5.448302	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
999	5.356737	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
82	2.645554	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
80	2.645292	10.122.1.103	10.124.1.194	TLSv1.2	569	Client Hello (SNI=www.netflix.com)
76	2.638597	10.122.1.103	10.124.1.194	TLSv1.3	629	Client Hello (SNI=www.gstatic.com)
39553	73.615148	10.122.1.103	10.124.1.194	TLSv1.3	638	Client Hello (SNI=www.googleapis.com)
10	0.009386	10.122.1.103	10.124.1.194	TLSv1.3	628	Client Hello (SNI=www.google.com)

VNAT Dataset

tls.handshake.type == 2

No.	Time	Source	Destination	Protocol	Length	Info
2373...	1746.463574	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
2323...	1682.342975	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
2280...	1634.246305	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
2177...	1473.972594	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1802...	1090.746832	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1778...	1058.550835	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1702...	914.279657	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1666...	834.098001	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1641...	785.554898	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1628...	769.269670	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1622...	753.473467	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1457...	529.585447	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1341...	401.489835	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
1008...	150.397602	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
86833	137.171950	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
85601	137.055109	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
77602	119.235129	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
75509	118.212867	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message
75213	117.811411	10.124.1.194	10.122.1.103	TLSv1.2	208	Server Hello, Change Cipher Spec, Encrypted Handshake Message

VNAT Dataset

```
tcp_streams_cmd = [
    "tshark", "-r", input_pcap_path,
    "-Y", "tls.handshake.type == 1",
    "-T", "fields", "-e", "tcp.stream", "-e", "tls.handshake.extensions_server_name"
]
```

- We used a script for extracting CH and SH pairs from the dataset , Using TSHARK, to pcap files.

```
extract_cmd = [
    "tshark", "-r", input_pcap_path,
    "-Y", f"tcp.stream == {stream_id} && (tls.handshake.type == 1 || tls.handshake.type == 2)",
    "-w", output_file
]
```

VNAT Dataset

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.8.8.138	74.125.226.32	TLSv1.2	259	Client Hello (SNI=clients4.google.com)
2	0.206331	74.125.226.32	10.8.8.138	TLSv1.2	1360	Server Hello

No.	Time	Source	Destination	Protocol	Leng	Info
1	0.000000	10.8.0.6	173.194.12...	TLSv1.2	569	Client Hello (SNI=clients4.google.com)
2	0.027427	173.194.1...	10.8.0.6	TLSv1.2	205	Server Hello, Change Cipher Spec, Encrypted Handshake Message

- Like this we got our CH and SH pairs. Now we extract these pairs in a CSV format so that we can apply ABRF and RBRF on that. For that, again we made a script.

ISCXVPN2016 Dataset

- Since ISCXVPN2016 Dataset had 5 classes, and all of them were similar to VNAT.
- Similar Preprocessing for this too, but the value counts for both the VNAT dataset and ISCXVPN 2016 Dataset was low.
- This would give us baised Data.
- To solve this, we Merged both the Datasets, i.e. VNAT + ISCXVPN2016 Dataset

Merged Dataset

- Classes = 8

```
value_counts = target.value_counts()

# Print the result
print(value_counts)

→ target
    Vimeo          200
    Gmail           180
    Youtube         169
    Google Services   73
    Netflix           67
    FileTransfer       52
    ssl.gstatic        45
    Hangout            22
Name: count, dtype: int64
```

Merged Dataset Results - ABRF ESNI

Training Time: 1.4429 seconds

Prediction Time: 0.0220 seconds

Class-wise Performance Table:

Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	0	100.000000	100.0	100.000000
1	1	100.000000	100.0	100.000000
2	2	100.000000	100.0	100.000000
3	3	100.000000	80.0	100.000000
4	4	100.000000	100.0	100.000000
5	5	100.000000	100.0	100.000000
6	6	100.000000	100.0	100.000000
7	7	88.888889	11.111111	100.0

Overall Accuracy: 0.9938

F1 Score: 0.9940

Merged Dataset Results - ABRF-ECH

Training Time: 3.5634 seconds

Class-wise Performance Table:

class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	0	100.000000	0.000000	100.000000
1	1	100.000000	0.000000	100.000000
2	2	80.000000	20.000000	60.000000
3	3	0.000000	100.000000	0.000000
4	4	100.000000	0.000000	100.000000
5	5	100.000000	0.000000	100.000000
6	6	100.000000	0.000000	97.142857
7	7	55.555556	44.444444	71.428571

Overall Accuracy: 0.9321

F1 Score: 0.9223

Confusion Matrix:

10	0	0	0	0	0	0	0
0	36	0	0	0	0	0	0
0	0	12	0	0	0	1	2
0	0	4	0	0	0	0	0
0	0	0	0	14	0	0	0
0	0	0	0	0	40	0	0
0	0	0	0	0	0	34	0
0	0	4	0	0	0	0	5

Prediction Time: 0.0992 seconds

Merged Dataset Results - RBRF-ESNI

→ Training Time: 0.5956 seconds

Class-wise Performance Table:

Class	Accuracy (%)	Error Rate (%)	Precision (%)	Recall (%)
0	0	100.000000	0.000000	100.0 100.000000
1	1	100.000000	0.000000	100.0 100.000000
2	2	100.000000	0.000000	100.0 100.000000
3	3	100.000000	0.000000	80.0 100.000000
4	4	100.000000	0.000000	100.0 100.000000
5	5	100.000000	0.000000	100.0 100.000000
6	6	100.000000	0.000000	100.0 100.000000
7	7	88.888889	11.111111	100.0 88.888889

Overall Accuracy: 0.9938

F1 Score: 0.9940

Confusion Matrix:

```
[[11  0  0  0  0  0  0  0]
 [ 0 36  0  0  0  0  0  0]
 [ 0  0 14  0  0  0  0  0]
 [ 0  0  0  4  0  0  0  0]
 [ 0  0  0  0 14  0  0  0]
 [ 0  0  0  0  0 40  0  0]
 [ 0  0  0  0  0  0 34  0]
 [ 0  0  0  1  0  0  0  8]]
```

Prediction Time: 0.0511 seconds

Merged Dataset Results - RBRF-ECH

```
Σ Training Time: 0.6885 seconds
Class-wise Performance Table:
  Class Accuracy (%) Error Rate (%) Precision (%) Recall (%)
  0      0 100.000000 0.000000 100.000000 100.000000
  1      1 100.000000 0.000000 100.000000 100.000000
  2      2 42.857143 57.142857 66.666667 42.857143
  3      3 100.000000 0.000000 57.142857 100.000000
  4      4 100.000000 0.000000 100.000000 100.000000
  5      5 100.000000 0.000000 100.000000 100.000000
  6      6 100.000000 0.000000 100.000000 100.000000
  7      7 55.555556 44.444444 45.454545 55.555556

Overall Accuracy: 0.9259
F1 Score: 0.9242
```

```
Confusion Matrix:
[[11  0  0  0  0  0  0  0]
 [ 0 36  0  0  0  0  0  0]
 [ 0  0  6  2  0  0  0  6]
 [ 0  0  0  4  0  0  0  0]
 [ 0  0  0  0 14  0  0  0]
 [ 0  0  0  0  0 40  0  0]
 [ 0  0  0  0  0  0 34  0]
 [ 0  0  3  1  0  0  0  5]]
```

Prediction Time: 0.0663 seconds

Thank You

