Deciphering WhatsApp Web

CSEC380 – Computer Security Blogpost – Mehul Sen

Introduction

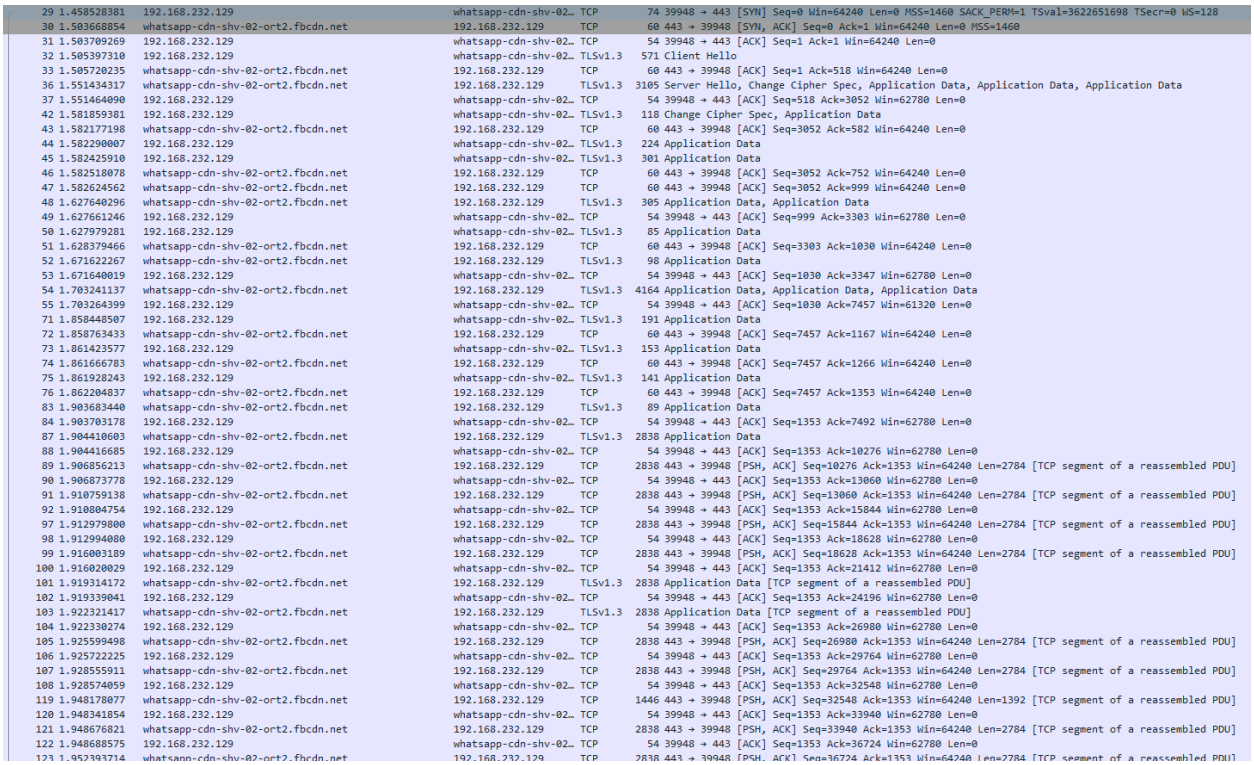
WhatsApp is an American freeware, cross-platform centralized messaging and voice-over-IP service owned by Facebook, Inc. It allows users to send text messages and voice messages, make voice and video calls, and share images, documents, user locations, and other content[0]. A feature of WhatsApp is the WhatsApp Web[1], using this WhatsApp's client application is also accessible from desktop computers as long as the user's mobile device remains connected to the Internet while they use the desktop app. This capability was introduced by WhatsApp in 2017 and the technology used behind this is fascinating since it syncs the phone application and uses the same WhatsApp account, retrieving all the messages and media. Unlike the mobile application, WhatsApp web works on web browsers, this means we can further investigate its infrastructure to better understand how it behaves.

Setup

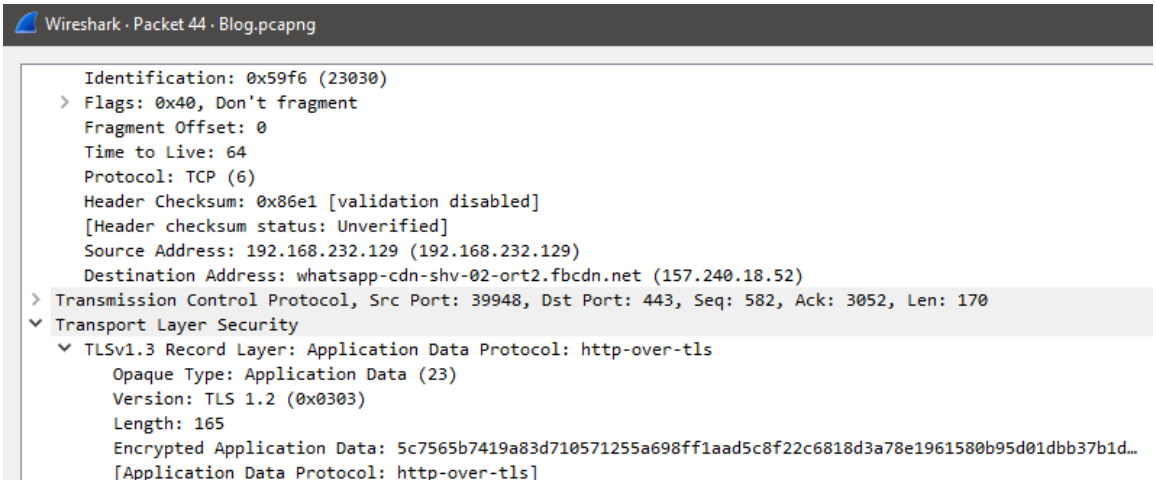
For my research, I had a ubuntu machine to log my SSL handshakes which had a Firefox web browser installed, and Wireshark, a working WhatsApp account and a stable internet connection.

As with most messaging platforms, WhatsApp would be using SSL to encrypt their traffic, so our first step would be to figure out a way around the SSL encryption.

Taking a small Wireshark capture while using WhatsApp web confirms this, all the traffic that goes to the WhatsApp server from the web browser is encrypted using TLS, we are also able to see the TLS Client Hello and the change Cipher protocols in the Wireshark capture.



```
 29 1.458528381  192.168.232.129                 whatsapp-cdn-shv-02… TCP       74 39948 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1 TSval=3622651698 TSecr=0 WS=128
 30 1.503668854  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
 31 1.503709269  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
 32 1.505397310  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   571 Client Hello
 33 1.505720235  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=1 Ack=518 Win=64240 Len=0
 36 1.551434317  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3  3105 Server Hello, Change Cipher Spec, Application Data, Application Data, Application Data
 37 1.551464090  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=518 Ack=3052 Win=62780 Len=0
 42 1.581859381  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   118 Change Cipher Spec, Application Data
 43 1.582177198  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=3052 Ack=582 Win=64240 Len=0
 44 1.582290007  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   224 Application Data
 45 1.582425910  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   301 Application Data
 46 1.582518078  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=3052 Ack=752 Win=64240 Len=0
 47 1.582624562  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=3052 Ack=999 Win=64240 Len=0
 48 1.627640296  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3   305 Application Data, Application Data
 49 1.627661246  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=999 Ack=3303 Win=62780 Len=0
 50 1.627979281  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3    85 Application Data
 51 1.628379466  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=3303 Ack=1030 Win=64240 Len=0
 52 1.671622267  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3    98 Application Data
 53 1.671640019  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1030 Ack=3347 Win=62780 Len=0
 54 1.703241137  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3  4164 Application Data, Application Data, Application Data
 55 1.703264399  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1030 Ack=7457 Win=61320 Len=0
 71 1.858448507  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   191 Application Data
 72 1.858763433  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=7457 Ack=1167 Win=64240 Len=0
 73 1.861423577  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   153 Application Data
 74 1.861666783  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=7457 Ack=1266 Win=64240 Len=0
 75 1.861928243  192.168.232.129                 whatsapp-cdn-shv-02… TLSv1.3   141 Application Data
 76 1.862204837  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP       60 443 → 39948 [ACK] Seq=7457 Ack=1353 Win=64240 Len=0
 83 1.903683440  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3    89 Application Data
 84 1.903703178  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=7492 Win=62780 Len=0
 87 1.904410603  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3  2838 Application Data
 88 1.904416685  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=10276 Win=62780 Len=0
 89 1.906856213  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=10276 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
 90 1.906873778  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=13060 Win=62780 Len=0
 91 1.910759138  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=13060 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
 92 1.910804754  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=15844 Win=62780 Len=0
 97 1.912979800  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=15844 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
 98 1.912994080  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=18628 Win=62780 Len=0
 99 1.916003189  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=18628 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
100 1.916020029  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=21412 Win=62780 Len=0
101 1.919314172  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3  2838 Application Data [TCP segment of a reassembled PDU]
102 1.919339041  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=24196 Win=62780 Len=0
103 1.922321417  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TLSv1.3  2838 Application Data [TCP segment of a reassembled PDU]
104 1.922330274  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=26980 Win=62780 Len=0
105 1.925599498  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=26980 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
106 1.925722225  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=29764 Win=62780 Len=0
107 1.928555911  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=29764 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
108 1.928574059  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=32548 Win=62780 Len=0
119 1.948178077  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      1446 443 → 39948 [PSH, ACK] Seq=32548 Ack=1353 Win=64240 Len=1392 [TCP segment of a reassembled PDU]
120 1.948341854  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=33940 Win=62780 Len=0
121 1.948676821  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=33940 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
122 1.948688575  192.168.232.129                 whatsapp-cdn-shv-02… TCP       54 39948 → 443 [ACK] Seq=1353 Ack=36724 Win=62780 Len=0
123 1.952393714  whatsapp-cdn-shv-02-ort2.fbcdn.net 192.168.232.129      TCP      2838 443 → 39948 [PSH, ACK] Seq=36724 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
```



Wireshark · Packet 44 · Blog.pcapng

```
    Identification: 0x59f6 (23030)
  > Flags: 0x40, Don't fragment
    Fragment Offset: 0
    Time to Live: 64
    Protocol: TCP (6)
    Header Checksum: 0x86e1 [validation disabled]
    [Header checksum status: Unverified]
    Source Address: 192.168.232.129 (192.168.232.129)
    Destination Address: whatsapp-cdn-shv-02-ort2.fbcdn.net (157.240.18.52)
> Transmission Control Protocol, Src Port: 39948, Dst Port: 443, Seq: 582, Ack: 3052, Len: 170
v Transport Layer Security
  v TLSv1.3 Record Layer: Application Data Protocol: http-over-tls
      Opaque Type: Application Data (23)
      Version: TLS 1.2 (0x0303)
      Length: 165
      Encrypted Application Data: 5c7565b7419a83d710571255a698ff1aad5c8f22c6818d3a78e1961580b95d01dbb37b1d…
      [Application Data Protocol: http-over-tls]
```

A bit of digging around provided me with an article on the AskF5 forum[2]. To get a better explanation of this method, I would suggest going over the link itself however the basic steps to go decipher the TLS packets are as follows.

- Create a Log file to store all the TLS handshakes.
  $ touch sslkey.log
- Modify the SSLKEYLOGFILE environment variable to store the handshakes within that log file.
  $ export SSLKEYLOGFILE=”/home/user/sslkey.log”
- Open Firefox within the same shell

$ firefox &

```
user@ubuntu:~$ touch sslkey.log
user@ubuntu:~$ export SSLKEYLOGFILE="/home/user/sslkey.log"
user@ubuntu:~$ firefox &
[2] 3759
user@ubuntu:~$
```

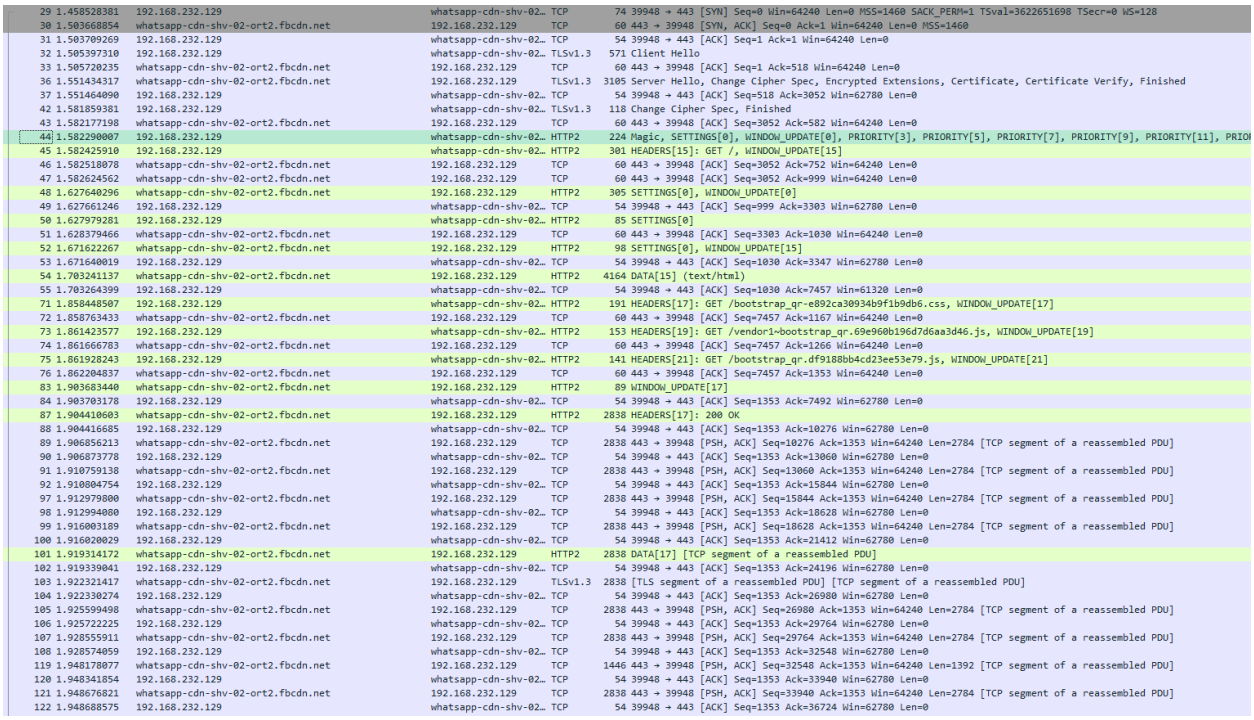
After using WhatsApp web using this web browser and capturing all this traffic through Wireshark we now have everything we need to see what is within the TLS packets.

This is what the generated sslkey.log file looks like once it had logged all the handshakes.

```
1 # SSL/TLS secrets log file, generated by NSS
2 CLIENT_HANDSHAKE_TRAFFIC_SECRET
  6ebfc2fde2468ad973a16fe122f9701dd9dd78c1a6fbbd06aa72548b9437d618
  a7665028243be1c447920ead01b79810d70833aae3a509be589086dea285feb0
3 SERVER_HANDSHAKE_TRAFFIC_SECRET
  6ebfc2fde2468ad973a16fe122f9701dd9dd78c1a6fbbd06aa72548b9437d618
  db07376dd3c5344eafc8bcbc227e1e72ccb18e174be30cf879901bafb95b8b5d
4 CLIENT_TRAFFIC_SECRET_0 6ebfc2fde2468ad973a16fe122f9701dd9dd78c1a6fbbd06aa72548b9437d618
  cab81afadaad8e4b5b8e02f3c163cfd34cc10a8540d419dc5b84a5fba6127560
5 SERVER_TRAFFIC_SECRET_0 6ebfc2fde2468ad973a16fe122f9701dd9dd78c1a6fbbd06aa72548b9437d618
  157a0901d6077893e295f10679ed1319fd16466ee49fca195da375b15d9b7934
6 EXPORTER_SECRET 6ebfc2fde2468ad973a16fe122f9701dd9dd78c1a6fbbd06aa72548b9437d618
  2aa66430a6ab3d7d8dd313ef805d2f76a2b3bfd764af5f4ecea88d0bb7efef7b
7 CLIENT_HANDSHAKE_TRAFFIC_SECRET
  c3d9e137d1a7d9788bf94e9476d6efbcc8b81d1c89184bfab88d4f615a8a1492
  b670e59020c8b8b2e25bd6a9d9be97382ba4c9927802a1264902b1f59aae977c
8 SERVER_HANDSHAKE_TRAFFIC_SECRET
  c3d9e137d1a7d9788bf94e9476d6efbcc8b81d1c89184bfab88d4f615a8a1492
  94f907c4cf117375a70bb5b9204c9563d970a537d6f561be9680b90d86de9abc
9 CLIENT_TRAFFIC_SECRET_0 c3d9e137d1a7d9788bf94e9476d6efbcc8b81d1c89184bfab88d4f615a8a1492
  a6cfc1b8204380f6e74fa901edecbc278d749a06ca6ee420e630169aa649efa7
10 SERVER_TRAFFIC_SECRET_0 c3d9e137d1a7d9788bf94e9476d6efbcc8b81d1c89184bfab88d4f615a8a1492
   ab26f8fbc4ac24975032a50587f01da433090471cf93d21420220d2af3cbfc4e
11 EXPORTER_SECRET c3d9e137d1a7d9788bf94e9476d6efbcc8b81d1c89184bfab88d4f615a8a1492
   9083568740f633bb607cccb5f1cffedcadddd580c088761ef86b8fcb10bf2792
12 CLIENT_HANDSHAKE_TRAFFIC_SECRET
   2a3a9550f79ebe4f3e5e42506738c74411175a48b2767d0398f58828eede4d7c
   1d0c04fb5f65646b472193874a9283f90c8966cd57d7bb78db204bf34c91b32e
13 SERVER_HANDSHAKE_TRAFFIC_SECRET
   2a3a9550f79ebe4f3e5e42506738c74411175a48b2767d0398f58828eede4d7c
   92b53d3d40e051970da22428c14d34c8b4224642e09c5f57bca2d7804aefd3e0
14 CLIENT_TRAFFIC_SECRET_0 2a3a9550f79ebe4f3e5e42506738c74411175a48b2767d0398f58828eede4d7c
   78911d8aaaae00094dfe0f1442d1382dba3b4195a893603cad16d516fe7eed5a
15 SERVER_TRAFFIC_SECRET_0 2a3a9550f79ebe4f3e5e42506738c74411175a48b2767d0398f58828eede4d7c
   8caff8d2a050dd7574e9bf9976cf78b272839c8c10105305f4999a589460141b
16 EXPORTER_SECRET 2a3a9550f79ebe4f3e5e42506738c74411175a48b2767d0398f58828eede4d7c
   b70812ad73c40043eab9995efbe481722078e8ff843029a368c9a4b1949a684c
```

Wireshark has a built-in capability to read these logs and decrypt the .pcap traffic. This option is available under Edit > Preferences > Protocols > TLS > (Pre)-Master-Secret Log, selecting the generated sslkey.log, we are now able to look within all the encrypted TLS traffic.

By doing this, we are immediately able to see all the TLS traffic between the WhatsApp server and our web browser.



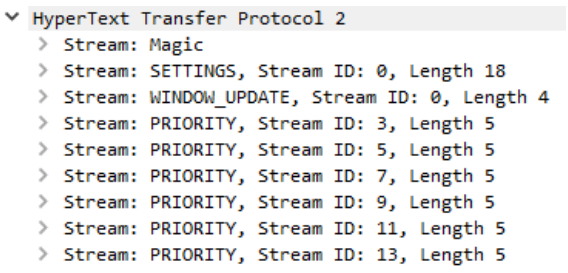
29	1.458528381	192.168.232.129	whatsapp-cdn-shv-02…	TCP	74 39948 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1 TSval=3622651698 TSecr=0 WS=128
30	1.503668854	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
31	1.503709269	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
32	1.505397310	192.168.232.129	whatsapp-cdn-shv-02…	TLSv1.3	571 Client Hello
33	1.505720235	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=1 Ack=518 Win=64240 Len=0
36	1.551434317	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TLSv1.3	3105 Server Hello, Change Cipher Spec, Encrypted Extensions, Certificate, Certificate Verify, Finished
37	1.551464090	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=518 Ack=3052 Win=62780 Len=0
42	1.581859381	192.168.232.129	whatsapp-cdn-shv-02…	TLSv1.3	118 Change Cipher Spec, Finished
43	1.582177198	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=3052 Ack=582 Win=64240 Len=0
44	1.582290007	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	224 Magic, SETTINGS[0], WINDOW_UPDATE[0], PRIORITY[3], PRIORITY[5], PRIORITY[7], PRIORITY[9], PRIORITY[11], PRIO
45	1.582425910	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	301 HEADERS[15]: GET /, WINDOW_UPDATE[15]
46	1.582518078	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=3052 Ack=752 Win=64240 Len=0
47	1.582624562	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=3052 Ack=999 Win=64240 Len=0
48	1.627640296	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	305 SETTINGS[0], WINDOW_UPDATE[0]
49	1.627661246	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=999 Ack=3303 Win=62780 Len=0
50	1.627979281	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	85 SETTINGS[0]
51	1.628379466	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=3303 Ack=1030 Win=64240 Len=0
52	1.671622267	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	98 SETTINGS[0], WINDOW_UPDATE[15]
53	1.671640019	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1030 Ack=3347 Win=62780 Len=0
54	1.703241137	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	4164 DATA[15] (text/html)
55	1.703264399	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1030 Ack=7457 Win=61320 Len=0
71	1.858448507	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	191 HEADERS[17]: GET /bootstrap_qr-e892ca30934b9f1b9db6.css, WINDOW_UPDATE[17]
72	1.858763433	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=7457 Ack=1167 Win=64240 Len=0
73	1.861423577	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	153 HEADERS[19]: GET /vendor1~bootstrap_qr.69e960b196d7d6aa3d46.js, WINDOW_UPDATE[19]
74	1.861666783	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=7457 Ack=1266 Win=64240 Len=0
75	1.861928243	192.168.232.129	whatsapp-cdn-shv-02…	HTTP2	141 HEADERS[21]: GET /bootstrap_qr.df9188bb4cd23ee53e79.js, WINDOW_UPDATE[21]
76	1.862204837	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	60 443 → 39948 [ACK] Seq=7457 Ack=1353 Win=64240 Len=0
83	1.903683440	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	89 WINDOW_UPDATE[17]
84	1.903703178	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=7492 Win=62780 Len=0
87	1.904410603	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	2838 HEADERS[17]: 200 OK
88	1.904416685	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=10276 Win=62780 Len=0
89	1.906856213	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=10276 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
90	1.906873778	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=13060 Win=62780 Len=0
91	1.910759138	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=13060 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
92	1.910804754	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=15844 Win=62780 Len=0
97	1.912979800	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=15844 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
98	1.912994080	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=18628 Win=62780 Len=0
99	1.916003189	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=18628 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
100	1.916020029	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=21412 Win=62780 Len=0
101	1.919314172	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	HTTP2	2838 DATA[17] [TCP segment of a reassembled PDU]
102	1.919339041	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=24196 Win=62780 Len=0
103	1.922321417	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TLSv1.3	2838 [TLS segment of a reassembled PDU] [TCP segment of a reassembled PDU]
104	1.922330274	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=26980 Win=62780 Len=0
105	1.925599498	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=26980 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
106	1.925722225	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=29764 Win=62780 Len=0
107	1.928555911	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=29764 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
108	1.928574059	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=32548 Win=62780 Len=0
119	1.948178077	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	1446 443 → 39948 [PSH, ACK] Seq=32548 Ack=1353 Win=64240 Len=1392 [TCP segment of a reassembled PDU]
120	1.948341854	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=33940 Win=62780 Len=0
121	1.948676821	whatsapp-cdn-shv-02-ort2.fbcdn.net	192.168.232.129	TCP	2838 443 → 39948 [PSH, ACK] Seq=33940 Ack=1353 Win=64240 Len=2784 [TCP segment of a reassembled PDU]
122	1.948688575	192.168.232.129	whatsapp-cdn-shv-02…	TCP	54 39948 → 443 [ACK] Seq=1353 Ack=36724 Win=62780 Len=0

We can now go further and analyze these packets to get a better clue of how WhatsApp works.

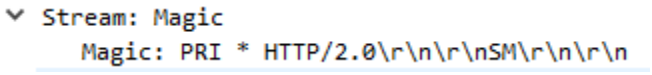
Analysis

After the TLS handshakes and the TCP connections, the first observation is that WhatsApp uses HTTP2 for most of its communication, the first packet sends out a Stream consisting of a couple of different headers.

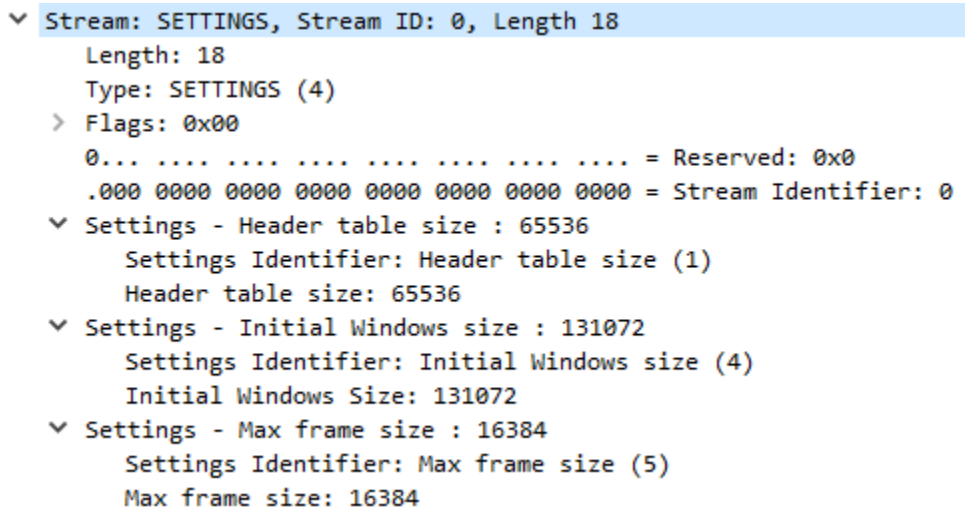
These are MAGIC, SETTINGS, WINDOW_UPDATE, and PRIORITY.



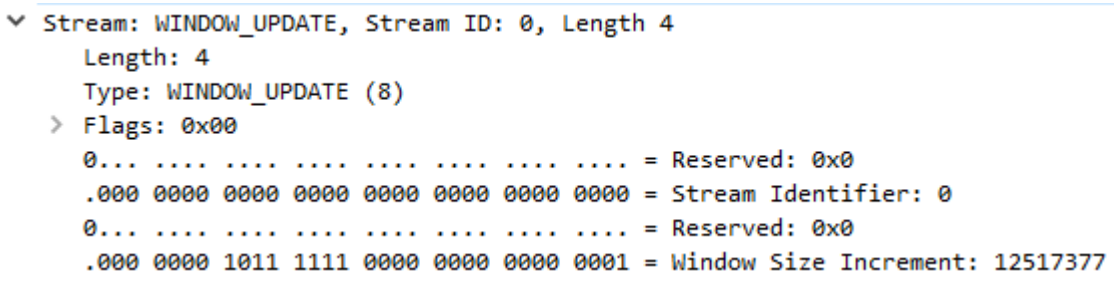
MAGIC – This contains the protocol and basic information about how data is being sent.



SETTINGS – Looking at the parameters which are Header Table Size, Initial Window Size, and Max Frame Size, This header would be used to set the initial browser window size, optimizing itself for the max size of frames it should receive based on the connection.



WINDOW_UPDATE – This header might provide any changes made to the window itself, updating the server using a parameter called "Window Size Increment".



PRIORITY – This header contains five parameters, Reserved, Stream Identifier, Exclusive, and Stream Dependency and Weight. Looking at multiple PRIORITY headers, we learn that the Stream Identifier is the ID pertaining to the Data that gets sent at a later stage, The Stream Dependency is the number on which that PRIORITY header is dependent on and it is always a value lower than its own Stream ID. The Weight ranges from 0 to 240, and this might signify how important any particular Stream ID is.

```
▼ Stream: PRIORITY, Stream ID: 3, Length 5
    Length: 5
    Type: PRIORITY (2)
  ▶ Flags: 0x00
    0... .... .... .... .... .... .... .... = Reserved: 0x0
    .000 0000 0000 0000 0000 0000 0000 0011 = Stream Identifier: 3
    0... .... .... .... .... .... .... .... = Exclusive: False
    .000 0000 0000 0000 0000 0000 0000 0000 = Stream Dependency: 0
    Weight: 200
    [Weight real: 201]
```

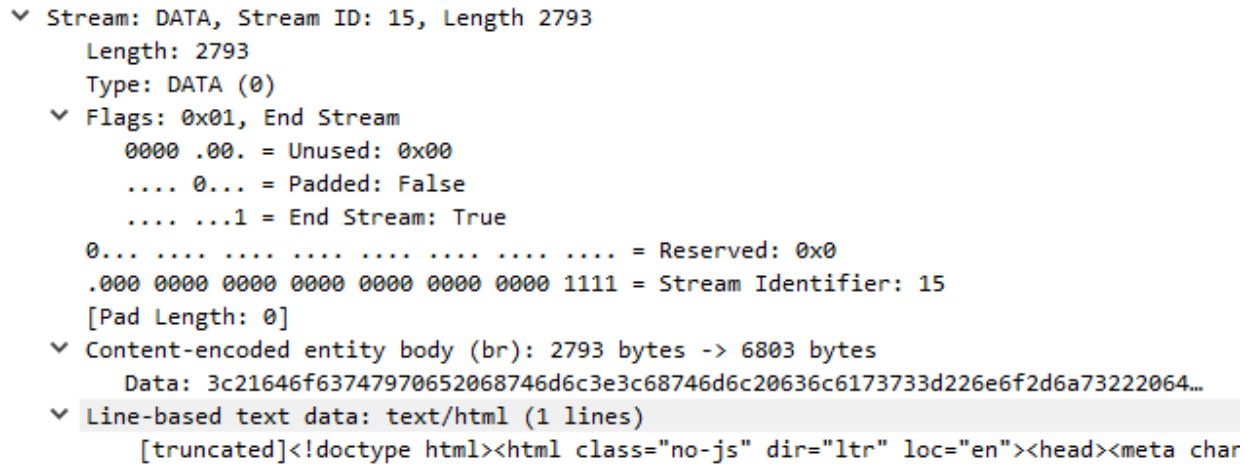
Although we can see HEADERS and WINDOW_UPDATE as well as SETTINGS throughout the packet capture, the MAGIC and PRIORITY headers are not sent again which might mean that they are used for only the initial setup for WhatsApp Web.

After the initial packet, the next packet contains a new header called HEADERS. This contains information like the method used, the path, the authority, scheme, user-agent, data accepted, the language accepted, encoding accepted, upgrade-insecure-requests, and the trailers.

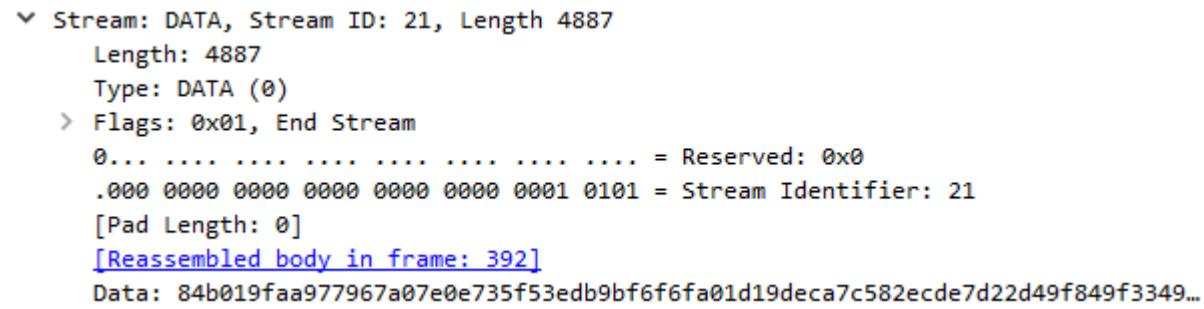
```
▼ Stream: HEADERS, Stream ID: 15, Length 203, GET /
    Length: 203
    Type: HEADERS (1)
  ▼ Flags: 0x25, Priority, End Headers, End Stream
      00.0 ..0. = Unused: 0x00
      ..1. .... = Priority: True
      .... 0... = Padded: False
      .... .1.. = End Headers: True
      .... ...1 = End Stream: True
    0... .... .... .... .... .... .... .... = Reserved: 0x0
    .000 0000 0000 0000 0000 0000 0000 1111 = Stream Identifier: 15
    [Pad Length: 0]
    0... .... .... .... .... .... .... .... = Exclusive: False
    .000 0000 0000 0000 0000 0000 0000 0111 = Stream Dependency: 7
    Weight: 41
    [Weight real: 42]
    Header Block Fragment: 82048163418cf058d7f138d281d75ae43d3f877abad07f66a281b0dae053fafc087ed4e1…
    [Header Length: 397]
    [Header Count: 10]
  ▶ Header: :method: GET
  ▶ Header: :path: /
  ▶ Header: :authority: web.whatsapp.com
  ▶ Header: :scheme: https
  ▶ Header: user-agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:88.0) Gecko/20100101 Firefox/88.0
  ▶ Header: accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
  ▶ Header: accept-language: en-US,en;q=0.5
  ▶ Header: accept-encoding: gzip, deflate, br
  ▶ Header: upgrade-insecure-requests: 1
  ▶ Header: te: trailers
```

The next couple of HEADERS send GET requests to “/bootstrap_qr-e892ca30934b9f1b9db6.css” for CSS, and “/vendor1~bootstrap_qr.69e960b196d7d6aa3d46.js”, “/bootstrap_qr.df9188bb4cd23ee53e79.js” for JavaScript.

As a reply, the server sends back a packet containing a DATA header. The first couple of DATA headers contain HTML, CSS and JavaScript requested by the Web Browser.



The DATA header is much simpler than its counterparts, it has a Stream Identifier parameter and a Data parameter that contain that data. It also has flags like Unused, Padded, and End-Stream. Padded is set to 1 when data is being sent, after the data has been completed, it gets set to 0 and the End Stream Flag is set to 1.



Observing all this data, we can see that it is all encrypted as well, this would be because of the implemented end-to-end encryption by WhatsApp, where each chat is individually encrypted among the recipients. WhatsApp provides its white pages which have a good explanation of how its Encryption and various features work[3].

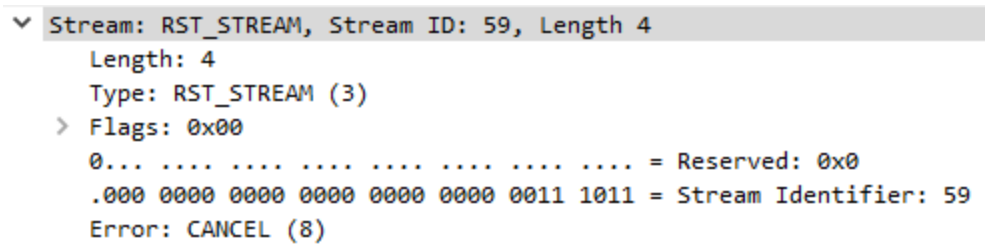
Although the chat itself is encrypted, we are still able to catch some data types that come from the server. One example of this is when a picture is shared, we can get the PNG signature, the image header, palette, image data chunk, and the image trailer.

```
Stream: DATA, Stream ID: 37, Length 711
    Length: 711
    Type: DATA (0)
  > Flags: 0x01, End Stream
    0... .... .... .... .... .... .... .... = Reserved: 0x0
    .000 0000 0000 0000 0000 0000 0010 0101 = Stream Identifier: 37
    [Pad Length: 0]
  > [2 Body fragments (4807 bytes): #540(4096), #540(711)]
  > Content-encoded entity body (br): 4807 bytes -> 4803 bytes
  v Portable Network Graphics
      PNG Signature: 89504e470d0a1a0a
    > Image Header (IHDR)
    > Palette (PLTE)
    > Image data chunk (IDAT)
    > Image Trailer (IEND)
```

The emojis shared can also be seen when the web browser uses a HEADERS header to send a GET request for those resources, which goes as follows GET /img/[emoji-name].webp

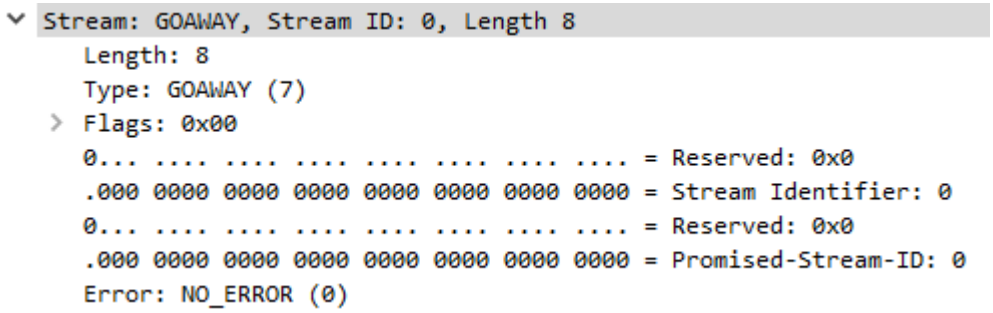
```
Stream: HEADERS, Stream ID: 65, Length 37, GET /img/emoji-3-40_0b9fe45.webp
    Length: 37
    Type: HEADERS (1)
  > Flags: 0x25, Priority, End Headers, End Stream
    0... .... .... .... .... .... .... .... = Reserved: 0x0
    .000 0000 0000 0000 0000 0000 0100 0001 = Stream Identifier: 65
    [Pad Length: 0]
    0... .... .... .... .... .... .... .... = Exclusive: False
    .000 0000 0000 0000 0000 0000 0000 0111 = Stream Dependency: 7
    Weight: 21
    [Weight real: 22]
    Header Block Fragment: 82059560d4ccc1693f432ccacd022046fca569b5fc163affd587d4ccd2d1cdcf
    [Header Length: 375]
    [Header Count: 10]
  > Header: :method: GET
  > Header: :path: /img/emoji-3-40_0b9fe45.webp
  > Header: :authority: web.whatsapp.com
  > Header: :scheme: https
  > Header: user-agent: Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:88.0) Gecko/20100101 Firefox/88.0
  > Header: accept: */*
  > Header: accept-language: en-US,en;q=0.5
  > Header: accept-encoding: gzip, deflate, br
  > Header: referer: https://web.whatsapp.com/serviceworker.js
  > Header: te: trailers
```

Another interesting header that occasionally comes up is the RST_STREAM header which contains a Stream Identifier parameter and an Error parameter.



This is being used by the web browser to tell the server to stop processing certain streams or convey any other such errors.

The last header that gets sent to close the connections is the GOAWAY header, this is first sent by the web browser to the server and then the server echoes it back to the web browser, this contains a Stream Identifier, a reserved parameter, a Promised-Stream-ID parameter, and an Error parameter. A Successful closing takes place with the Error parameter set to 0 which is the NO_ERROR condition.



Future Research Possibilities

Further research can be conducted on the protocol, traffic can be captured while performing various actions such as sending different media through chat, adding new users, deleting messages, creating group chats, etc. This will provide us with an even clearer understanding of the headers and protocols used by WhatsApp. We can even use the technical white pages [3] provided by WhatsApp to further decrypt the end-to-end encrypted data, finding out exactly how each text message is sent.

Conclusion

WhatsApp Messenger is a very sophisticated environment with its own set of protocols and headers, WhatsApp Web allows us to monitor this traffic through HTTP and get a better understanding of how it behaves. We can

bypass the SSL encryption and get a clearer view of the interactions taking place between WhatsApp servers and the Web browser.

Disclaimer

Since WhatsApp web is a private organization, it does not disclose its exact source code. We cannot know exactly how it behaves in the backend, the most we can do is observe the traffic and make educated guesses on how it might work. I analyzed the web traffic captured and tried making the best estimates as to how I believe these headers might be used. This information may not be completely accurate.

References:

[0] WhatsApp General Information and Organizational Details :

https://en.wikipedia.org/wiki/WhatsApp

[1] WhatsApp Web :

https://web.whatsapp.com/

[2] AskF5 Forum Decrypting SSL Traffic :

https://support.f5.com/csp/article/K50557518

[3] WhatsApp Encryption Overview Technical White Paper :

https://scontent.whatsapp.net/v/t39.8562-34/122249142_469857720642275_2152527586907531259_n.pdf/WA_Security_WhitePaper.pdf?ccb=1-3&_nc_sid=2fbf2a&_nc_ohc=Uz1ThVZZLqUAX_10j-p&_nc_ht=scontent.whatsapp.net&oh=29e00608fc684abe813d602a491f5757&oe=60B54C19