SharkFest '17 Europe

20 QUIC Dissection

Using Wireshark to Understand QUIC Quickly

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ikeriri network service

ParkSuite Classroom
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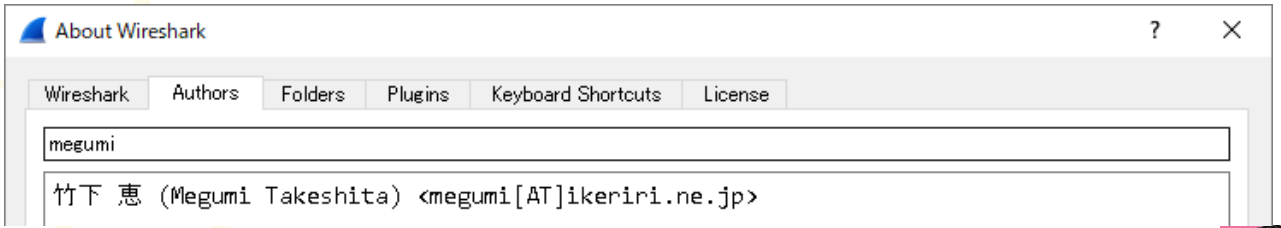
11:15am-12:30pm

supplemental files
http://www.ikeriri.ne.jp/sharkfest

Megumi Takeshita, ikeriri network service

- Founder, ikeriri network service co.,ltd
- Wrote 10+ books about Wireshark
- Reseller of Riverbed Technology (former CACE technologies) in Japan
- Attending all Sharkfest
- Translator of QT Wireshark into Japanese



20 QUIC: Using Wireshark to Understand QUIC Quickly

In this presentation, Megumi explains the details of QUIC, and shows you how to understand the protocol and mechanisms involved.
Using sample trace files, Megumi will show how to inspect and visualize QUIC traffic and explain the advantage of QUIC in comparison with other protocols too.

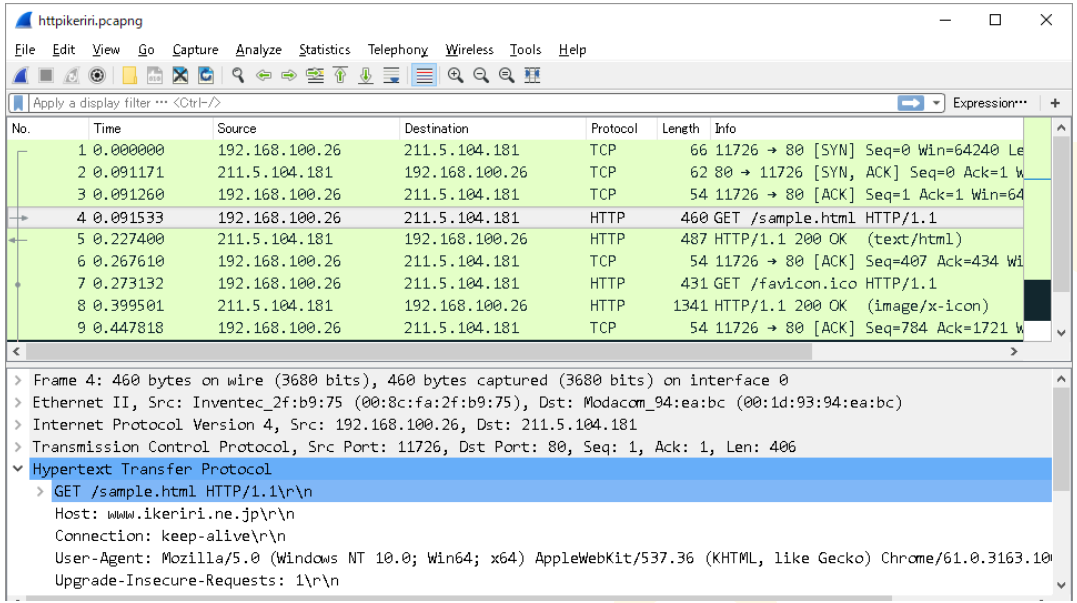
NOTE: IQUIC(IETF QUIC) is Internet-Draft and now standardizing, so some specification may be changed and the sample trace file is not adequate

Set up environment

- For QUIC dissection, we need nightly build version of Wireshark (this time I use 2.5.0-1547-gbe625b9b development version)
- All supplemental files of this presentation is below http://www.ikeriri.ne.jp/sharkfest (temporal)

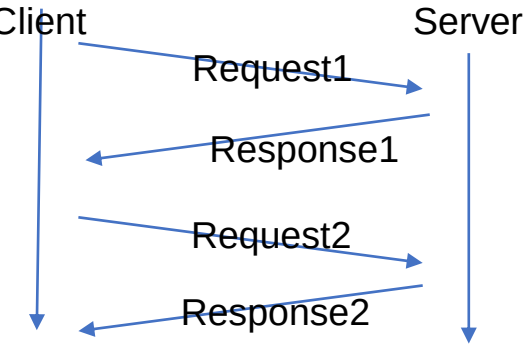
Open simple HTTP/1.1

- open httpikeriri.pcapng of simple HTTP/1.1 packet,

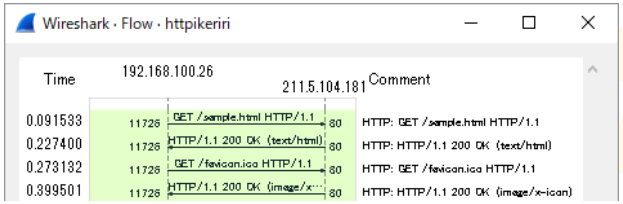


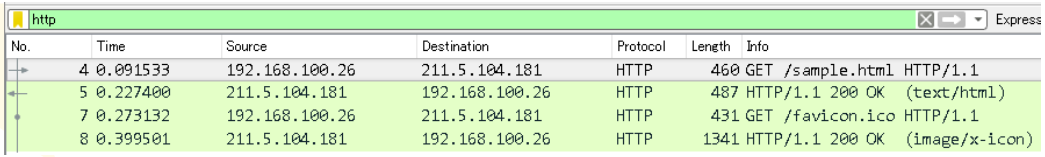
- HTTP/1.1 request response loop
- Head of Line blocking
- Rich application needs many TCP connection (AJAX)

HTTP/1.1 is difficult to speed up



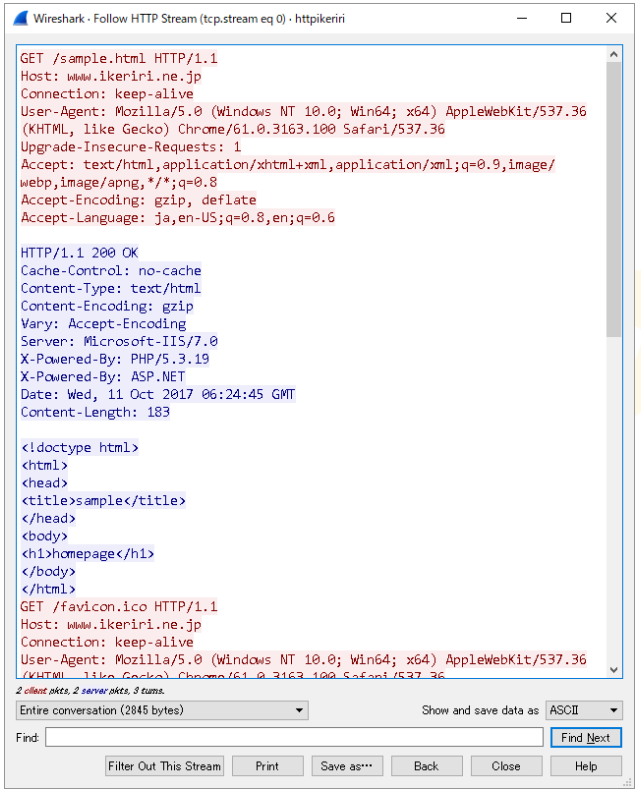
- HTTP request have to send after previous response has been received.
- Please input display filter in Wireshark “http.next_request_in” (Next request in frame in HTTP request)
- HTTP request is always waiting in one connection. (head line blocking)
- Display filter “http” and Statistics>Flow Graph





HTTP/1.1 is text based, not efficient protocol

- Right click HTTP header and “follow http stream”
- HTTP is text-based application protocol, easy to read,
  but not efficient, ambiguous, and redundant
- HTTP messages are clear texts so they uses more data and CPU power for dissection.
- Many connection is separated by each other TCP connection, they work their own TCP rules without HTTP.

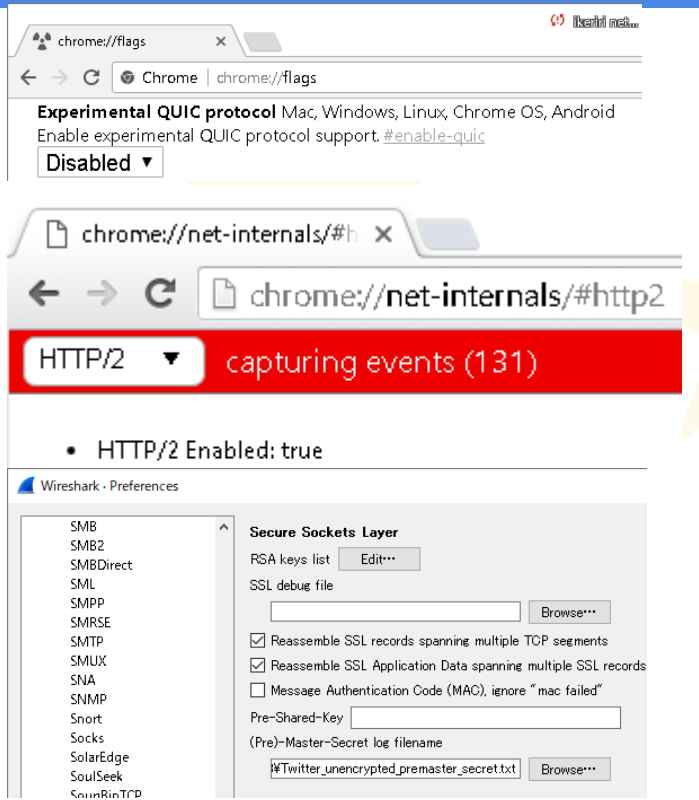


Accelerate Web service

- Wider bandwidth, Faster computing in todays internet, then what is the protocol ?
  HTTP/1.0 (RFC1945-,1996)
  HTTP/1.1 (RFC2068-,1997)
- New generation of web protocol comes
  HTTP/2.0 (RFC7540-,2015) former SPDY
  Google, Facebook, Twitter, Yahoo, and major website using Chrome, Edge, Safari and major browser

www.twitter.com with HTTP/2.0

- Set SSLKEYLOGFILE variable to decrypt SSL/TLS
- Open Chrome URL “chrome://flags/” and disable QUIC protocol in list box, now Chrome prefer to use HTTP2
- Start capture and open www.twitter.com, type chrome://net-internals/#http2 you can see the HTTP/2 sessions
- This time open twitter.pcapng and set (Pre)-Master-Secret log filename Twitter_unencrypted_premaster_secret.txt in SSL preference

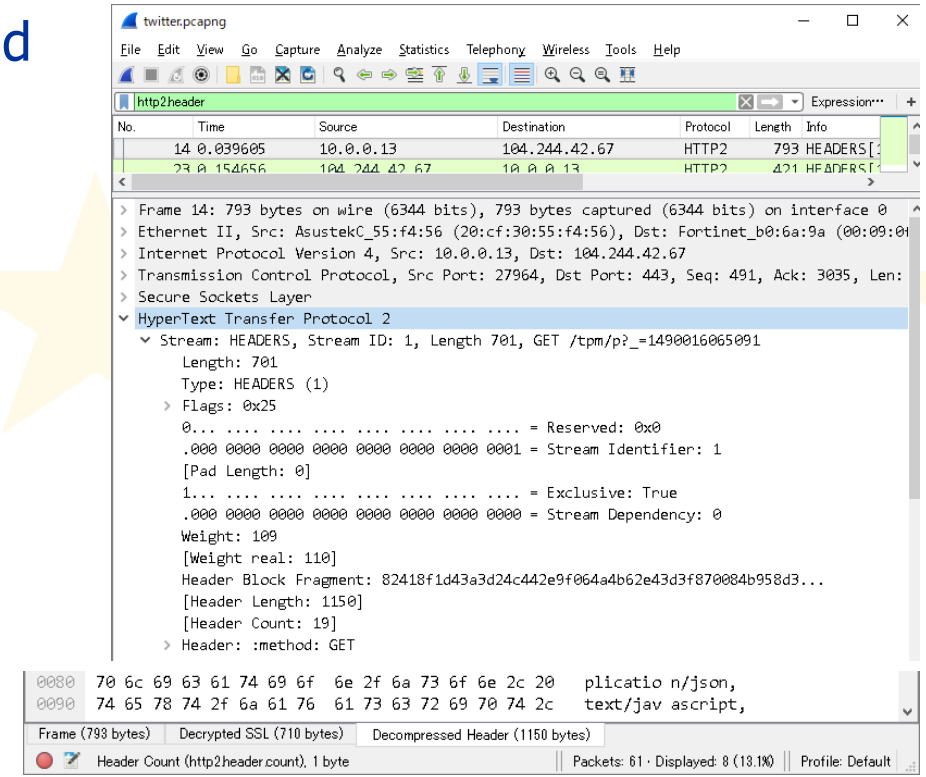


HTTP/2.0 uses binary frame with Huffman coding compression in a SSL/TLS connection

- Set “http2.header” in display filter and check the #14
- The packet contains EthernetII, IPv4, TCP, SSL, and HTTP2 header

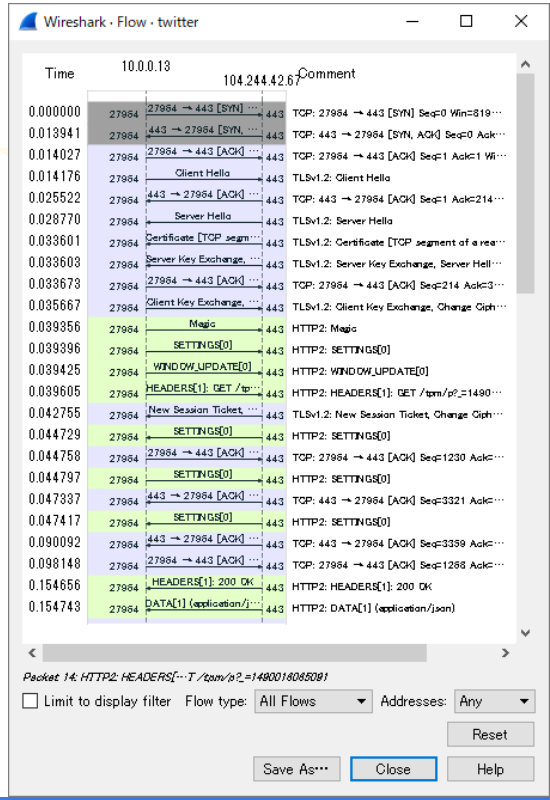
Application	HTTP/1.1 semantics
Session	HTTP/2.0
Session	SSL/TLS
Transport	TCP

- HTTP/2.0 uses binary frame with Huffman coding, check packet bytes pane



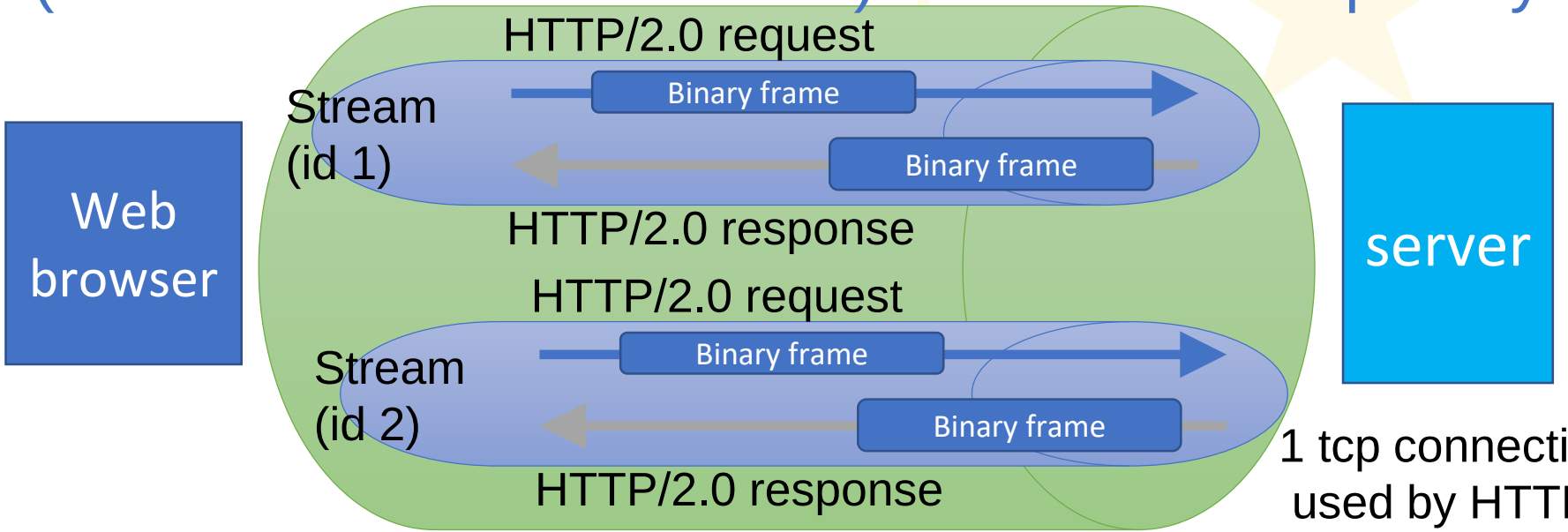
Connection process of HTTP/2.0

- Click Statistics > Flow Graph and check connection process of HTTP/2.0
- HTTP/2.0 needs TCP 3 way handshake that contains 1 RTT(round trip time) SYN-SYN/ACK-ACK from Client side
- HTTP/2.0 needs SSL/TLS connection that contains 2 RTT(round trip time) from Client side Client Hello/Server Hello-Certificate-Server Key Exchange-Server Hello Done/Client Key Exchange -New Session Ticket(TLS)-Change Cipher Spec-Finished at the first time
- We need TCP 1 and SSL/TLS 2 RTT at the first time

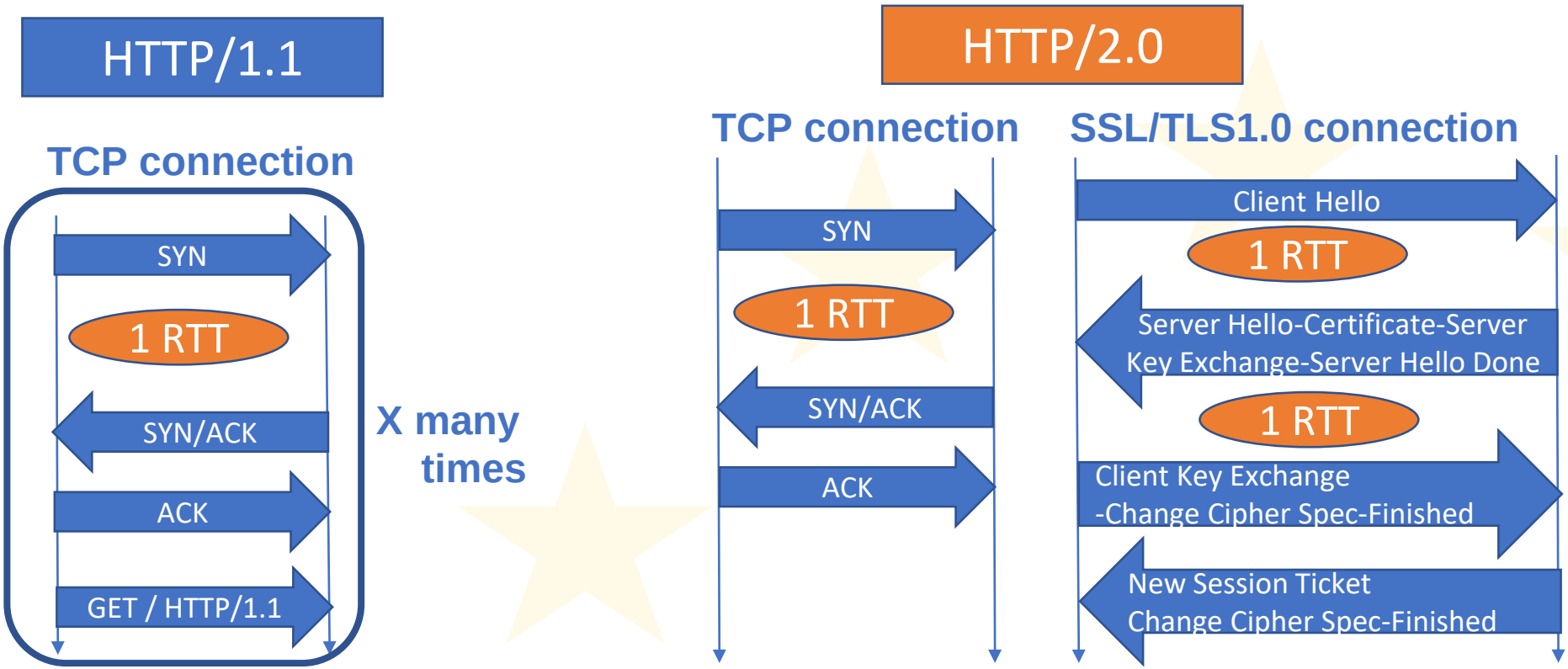


HTTP/2.0 Stream mechanism

HTTP/2.0 uses 1 tcp connection and many Stream (virtual connection channel) that has id and priority



Multiple HTTP connections (at the first time)

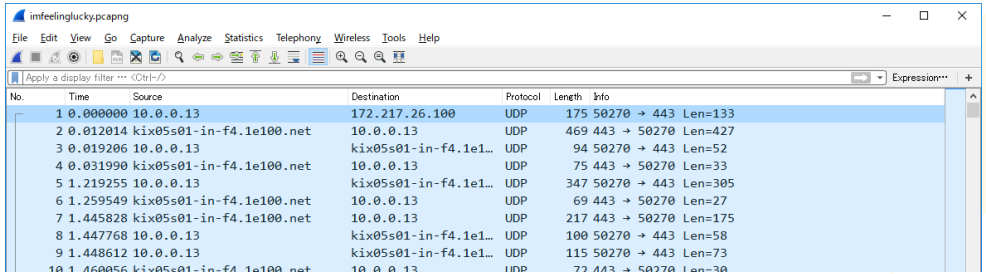


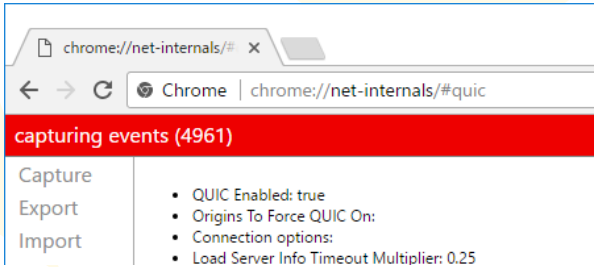
GQUIC

- Google creates proprietary protocol, QUIC (Quick UDP Internet Connection) (a.k.a. GQUIC)
- GQUIC omits TCP, SSL/TLS and HTTP/2.0 and provides a monolithic mechanism of TCP + SSL/TLS authentication and encryption + HTTP/2 multiplexing and compression in UDP stream
- Already used in Google service (Gmail, YouTube,…)
- QUIC needs just 1-RTT at the first time, and no RTT (0-RTT) when we connect again (if resumption successes)

imfeelinglucky.pcapng

- Open imfeelinglucky.pcapng, it is the packet that just I pushed I'm feeling lucky button at google using Chrome





- At this time we just see some UDP streams of QUIC
- Open the Chrome and type chrome://net-internals/#quic you can see current QUIC sessions

Host	Version	Peer address	Connection UID	Active stream count	Active streams	Total stream count	Packets Sent	Packets Lost	Packets Received	Connected
apis.google.com:443 ogs.google.com:443	QUIC_VERSION_35	216.58.197.142:443	8126651583460386461	0	None	1	7	0	7	true
clients4.google.com:443	QUIC_VERSION_35	172.217.26.46:443	7635153523791641412	0	None	1	8	0	7	true
clients5.google.com:443	QUIC_VERSION_35	172.217.26.46:443	3964807834205814218	0	None	0	3	0	3	true
fonts.gstatic.com:443 ssl.gstatic.com:443	QUIC_VERSION_35	172.217.26.35:443	3002020916089671232	0	None	0	3	0	3	true
lh3.googleusercontent.com:443	QUIC_VERSION_35	216.58.197.129:443	17881281563806618l0	0	None	0	4	0	4	true

Check GQUIC packets

- Check header encapsulation (Ethernet II, IP, UDP, and QUIC) and payloads are encrypted

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	10.0.0.13	172.217.26.100	QUIC	175	SH, Protected Payload (KP0), PKN: 205
2	0.012014	172.217.26.100	10.0.0.13	QUIC	469	SH, Protected Payload (KP0), PKN: 7
3	0.019206	10.0.0.13	172.217.26.100	QUIC	94	SH, Protected Payload (KP0), PKN: 205

```
> Frame 1: 175 bytes on wire (1400 bits), 175 bytes captured (1400 bits) on interface 0
> Ethernet II, Src: AsustekC_55:f4:56 (20:cf:30:55:f4:56), Dst: Fortinet_b0:6a:9a (00:09:0f:b0:6a:9
> Internet Protocol Version 4, Src: 10.0.0.13, Dst: 172.217.26.100
> User Datagram Protocol, Src Port: 50270, Dst Port: 443
v QUIC (Quick UDP Internet Connections) IETF
    0... .... = Header Form: Short Header (0)
    .0.. .... = Connection ID Flag: False
    ..0. .... = Key Phase Bit: False
    ...0 1100 = Packet Type: Unknown (12)
    Packet Number: 205
    Protected Payload: d7df8e5231d78606c86a83da1f6e65a50765b9f2cc2b8aca...
```

Packet Number	Info
205	SH, Protected Payload (KP0), PKN: 205
7	SH, Protected Payload (KP0), PKN: 7
205	SH, Protected Payload (KP0), PKN: 205
8	SH, Protected Payload (KP0), PKN: 8
205	SH, Protected Payload (KP0), PKN: 205
9	SH, Protected Payload (KP0), PKN: 9
10	SH, Protected Payload (KP0), PKN: 10
205	SH, Protected Payload (KP0), PKN: 205
205	SH, Protected Payload (KP0), PKN: 205
11	SH, Protected Payload (KP0), PKN: 11
12	SH, Protected Payload (KP0), PKN: 12

- This is not a first connection, so it immediately starts data transaction (0-RTT) because we can see SH(Short Header) at Header Form field.
- 64-bit packet number is used as a part of nonce. Each endpoint uses a separate packet number, that is increasing.

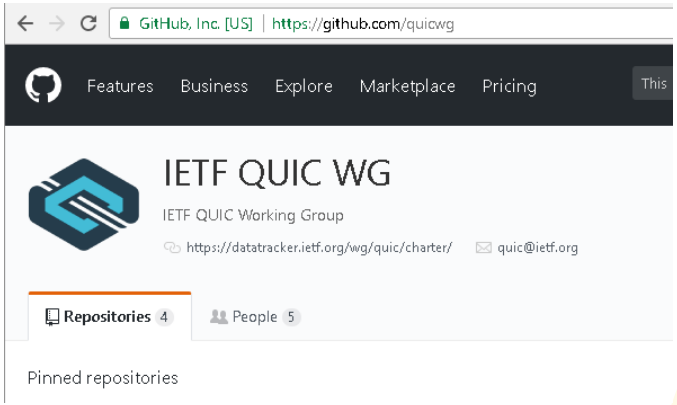
IQUIC (IETF Quick UDP Internet Connection)

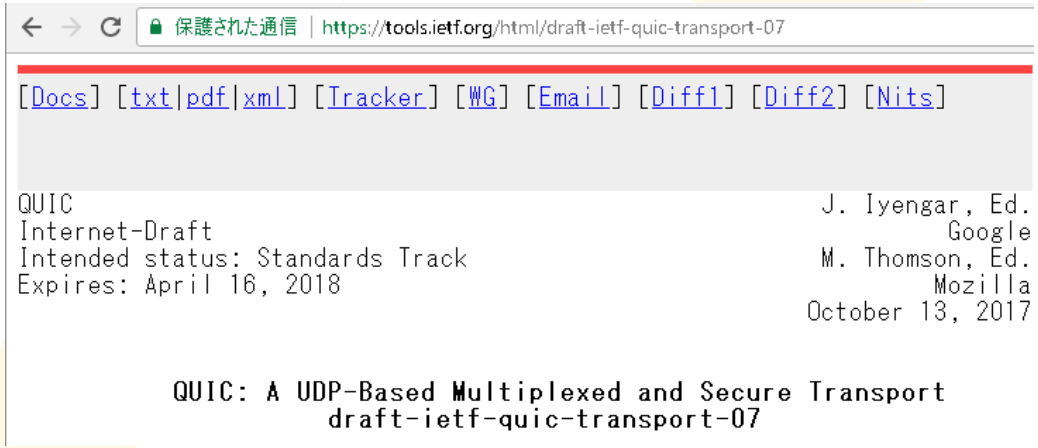
- Now IETF standardize IETF QUIC (a.k.a. IQUIC)
- IQUIC also provides a monolithic mechanism of TCP reliable transport + SSL/TLS1.3 authentication and encryption + HTTP/2 multiplexing and compression
- Now Internet-Draft (October13, 2017) https://tools.ietf.org/html/draft-ietf-quic-transport-07
- Data tracker (IETF) https://datatracker.ietf.org/wg/quic

TCP+SSL/TLS+HTTP/2.0=QUIC

IETF QUIC standards

- Working Group
  https://github.com/quicwg
- Internet-Draft (October, 2017)
  https://tools.ietf.org/html/draft-ietf-quic-transport-07

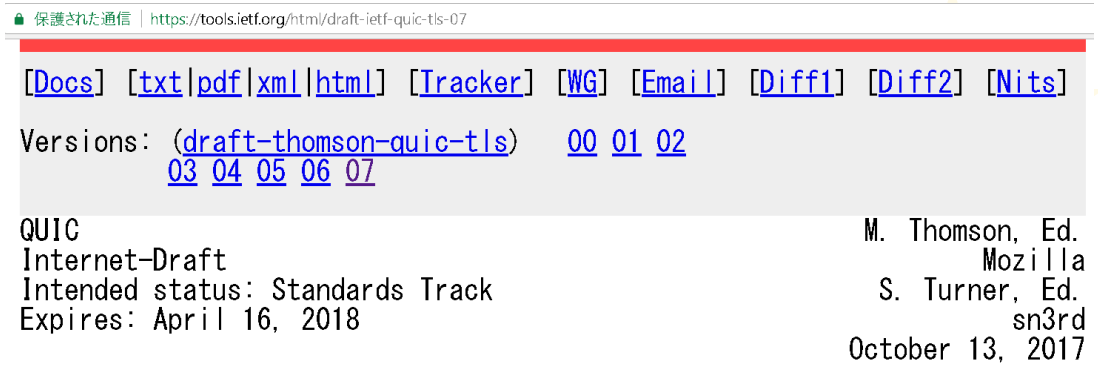




Core specification

IETF QUIC standards

- QUIC-TLS (October, 2017)
  https://tools.ietf.org/html/draft-ietf-quic-tls-07


保護された通信 | https://tools.ietf.org/html/draft-ietf-quic-tls-07

[Docs] [txt|pdf|xml|html] [Tracker] [WG] [Email] [Diff1] [Diff2] [Nits]

Versions: (draft-thomson-quic-tls) 00 01 02
03 04 05 06 07

QUIC
Internet-Draft
Intended status: Standards Track
Expires: April 16, 2018

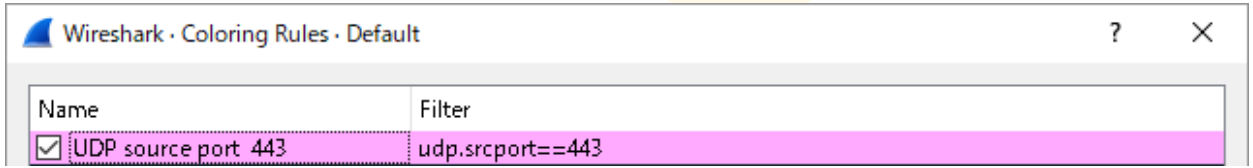
M. Thomson, Ed.
Mozilla
S. Turner, Ed.
sn3rd
October 13, 2017

Using Transport Layer Security (TLS) to Secure QUIC
draft-ietf-quic-tls-07

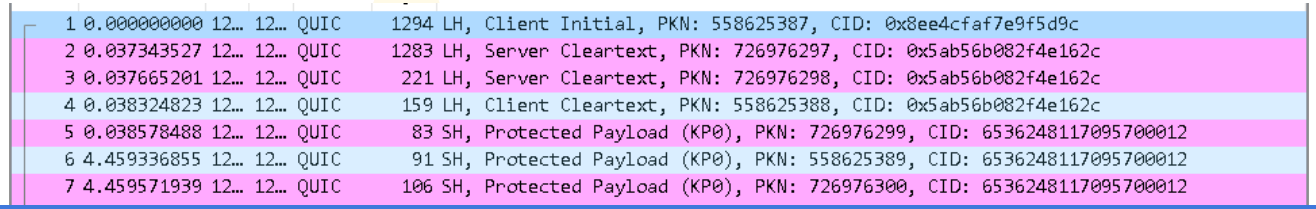
Using TLS in QUIC

Open sample packets of IETF QUIC

- Open quic_ietf_draft05_ngtcp2.pcapng using Wireshark
  (Thank you Alexis-san for dissector and sample pcap file)
- View> Coloring rules..., new rule name: UDP source port 443, set filter udp.srcport==443, and set pink color at background



- Blue color is from Client and Pink is from Server



Long header of QUIC

- Click #1 packet and check QUIC header format

```
User Datagram Protocol, Src Port: 39916, Dst Port: 443
QUIC (Quick UDP Internet Connections) IETF
   1... .... = Header Form: Long Header (1)
   .000 0010 = Packet Type: Client Initial (2)
   Connection ID: 0x8ee4cfaf7e9f5d9c
   Packet Number: 558625387
   Version: draft-05 (0xff000005)
 v STREAM Stream ID: 0
   v Frame Type: STREAM (0xc1)
       11.. .... = Stream: 0x3
       ..0. .... = Fin(F): False
       ...0 0... = Stream Length (SS): 1 Byte (0)
       .... .00. = Offset Length (OO): 0 Byte (0)
       .... ...1 = Data Length (D): 2 Bytes
     Stream ID: 0 (Cryptographic handshake)
     Data Length: 274
     Stream Data: 160301010d010001090303a29b79ac62f9
   > Secure Sockets Layer
 > PADDING Length: 948
   Hash: 4e8c7f5146059fb9
```

64-bit random connection ID from the client

Long headers are used for negotiation and establishment of 1-RTT keys
Once both conditions are met, a sender switches to send short header

Packet type indicates the frame type of QUIC

64-bit packet number is used as pa art of nonce. Each endpoint uses a separate packet number, that is increasing.

Stream is the same mechanism of HTTP/2.0 stream, and Stream ID 0 is reserved for cryptographic handshake (TLS1.3)

Packet Type (October, 2017)

type	Name	Explanation
0x01	Version Negotiation	Server sends this type packet for not supporting client's version (Long header)
0x02	Client Initial	Client sends this type packet for initializing handshake (Long Header)
0x03	Server Stateless Retry	Server sends this type packet as cryptographic handshake message and ACK for requiring a new Client Initial packet (Long Header)
0x04	Server Cleartext	Server sends this type packet as cryptographic handshake message and ACK that contains server chosen connection ID and randomized packet number with STREAM, PADDING, ACK. (Long Header)
0x05	Client Cleartext	Client sends this type packet as the receipt of Server Cleartext message, Client Cleartext contains Server selected connection ID and incremented packet number of Client Initial with STREAM, PADDING, ACK. (Long Header)
0x06	0-RTT Protected	Packets that are protected with 0-RTT keys are sent with Long Header; all packets protected with 1-RTT keys are sent with Short Header. Packets protected with 0−RTT keys use a type value of 0x06. The connection ID field for a 0−RTT packet is selected by the client.

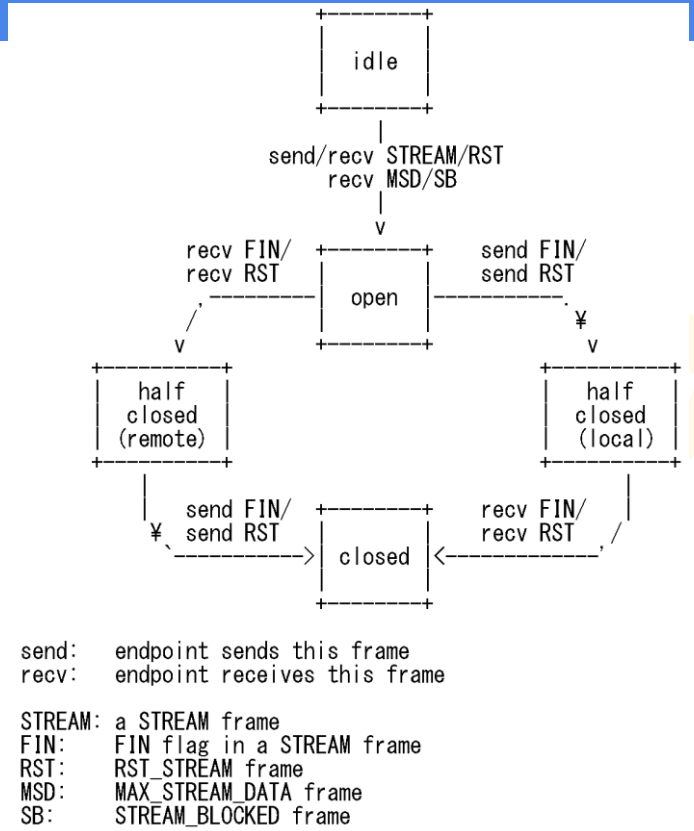
connection ID / packet number

- Click connection ID field, right click and “Apply as column” (same as packet number) in #1 packet, and check the changes of both
- Server set 64-bit the random connection ID in #2 packet, Client updates the connection ID as the same number
- Packet number is set randomly (0 and 2^31-1) and used as a part of nonce. Each endpoint uses a separate packet number, that is increasing

	Time	Source	Destina	Protocol	Length	Connection ID	Packet Number	Info
1	0.00…	127…	127…	QUIC	1294	0x8ee4cfaf7e9f5d9c	558625387	LH, Client Initial, PKN: 558625387, CID: 0x8ee4cfaf7e9f5d9c
2	0.03…	127…	127…	QUIC	1283	0x5ab56b082f4e162c	726976297	LH, Server Cleartext, PKN: 726976297, CID: 0x5ab56b082f4e162c
3	0.03…	127…	127…	QUIC	221	0x5ab56b082f4e162c	726976298	LH, Server Cleartext, PKN: 726976298, CID: 0x5ab56b082f4e162c
4	0.03…	127…	127…	QUIC	159	0x5ab56b082f4e162c	558625388	LH, Client Cleartext, PKN: 558625388, CID: 0x5ab56b082f4e162c
5	0.03…	127…	127…	QUIC	83	0x5ab56b082f4e162c	726976299	SH, Protected Payload (KP0), PKN: 726976299, CID: 6536248117095700012
6	4.45…	127…	127…	QUIC	91	0x5ab56b082f4e162c	558625389	SH, Protected Payload (KP0), PKN: 558625389, CID: 6536248117095700012
7	4.45…	127…	127…	QUIC	106	0x5ab56b082f4e162c	726976300	SH, Protected Payload (KP0), PKN: 726976300, CID: 6536248117095700012
8	4.45…	127…	127…	QUIC	83	0x5ab56b082f4e162c	726976301	SH, Protected Payload (KP0), PKN: 726976301, CID: 6536248117095700012
9	4.45…	127…	127…	QUIC	83	0x5ab56b082f4e162c	558625390	SH, Protected Payload (KP0), PKN: 558625390, CID: 6536248117095700012

Stream ID (encrypted in Short Header)

- IQUIC packet has a 32-bit STREAM id for multiplexing many data connections.
- Clients use odd-number, Server use even-number, 0 is reserved for cryptographic Handshake (usually TLS connection)
- IQUIC stream mechanism is almost the same as HTTP/2.0(also as TCP)
- Stream change the state, Many streams in a UDP connection



Short header of QUIC

- Click #5 packet and check QUIC IETF header

```
Frame 5: 83 bytes on wire (664 bits), 83 bytes captured (664 bits) on interface 0
Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
Internet Protocol Version 4, Src: 127.0.0.1, Dst: 127.0.0.1
User Datagram Protocol, Src Port: 443, Dst Port: 39916
QUIC (Quick UDP Internet Connections) IETF
   0... .... = Header Form: Short Header (0)
   .1.. .... = Connection ID Flag: True
   ..0. .... = Key Phase Bit: False
   ...0 0011 = Packet Type: 4 octet (3)
   Connection ID: 0x5ab56b082f4e162c
   Packet Number: 726976299
   Protected Payload: a48cd45b995a53917486448d31ac728254b21de8c7ad4c27
```

Set 0 : Connection ID field is omitted
Set 1 : Connection ID field is present

Every time that a new set of keys is used for protecting outbound packets, the KEY_PHASE bit in the public flags is toggled.

64-bit random Server chosen connection ID

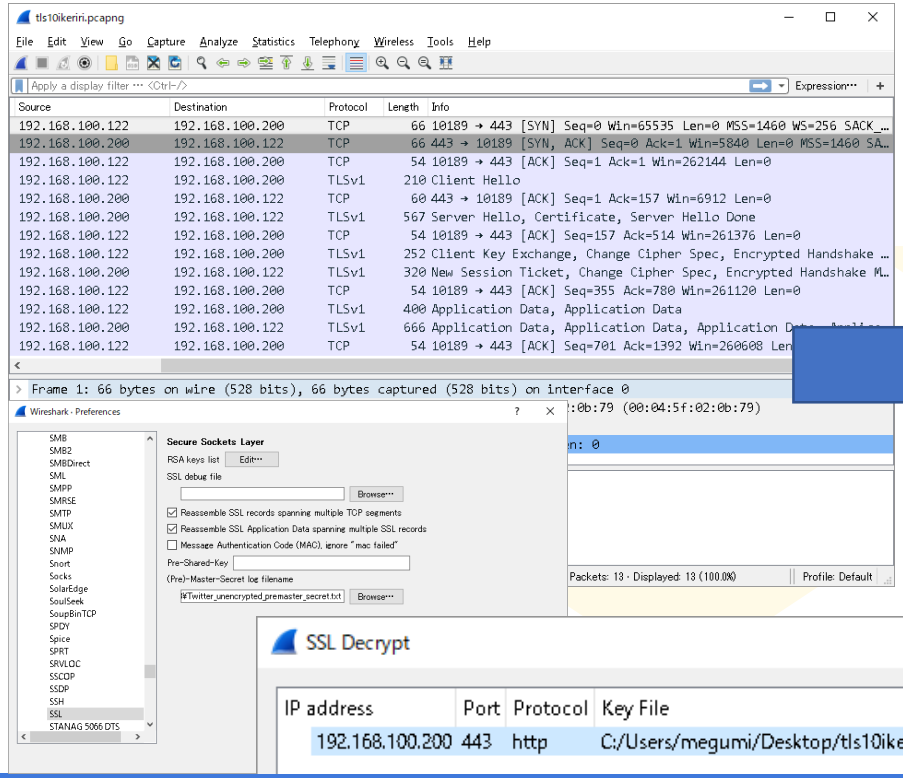
64-bit packet number is used as pa art of nonce. Each endpoint uses a separate packet number, that is increasing.

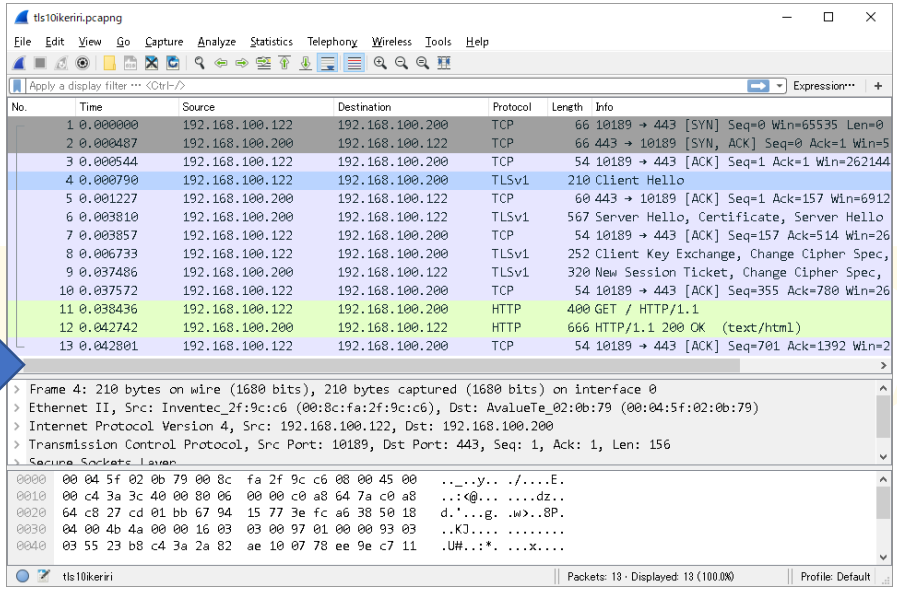
The short header can be used after the version and 1-RTT keys are negotiated.

How to negotiate and install session key in IQUIC

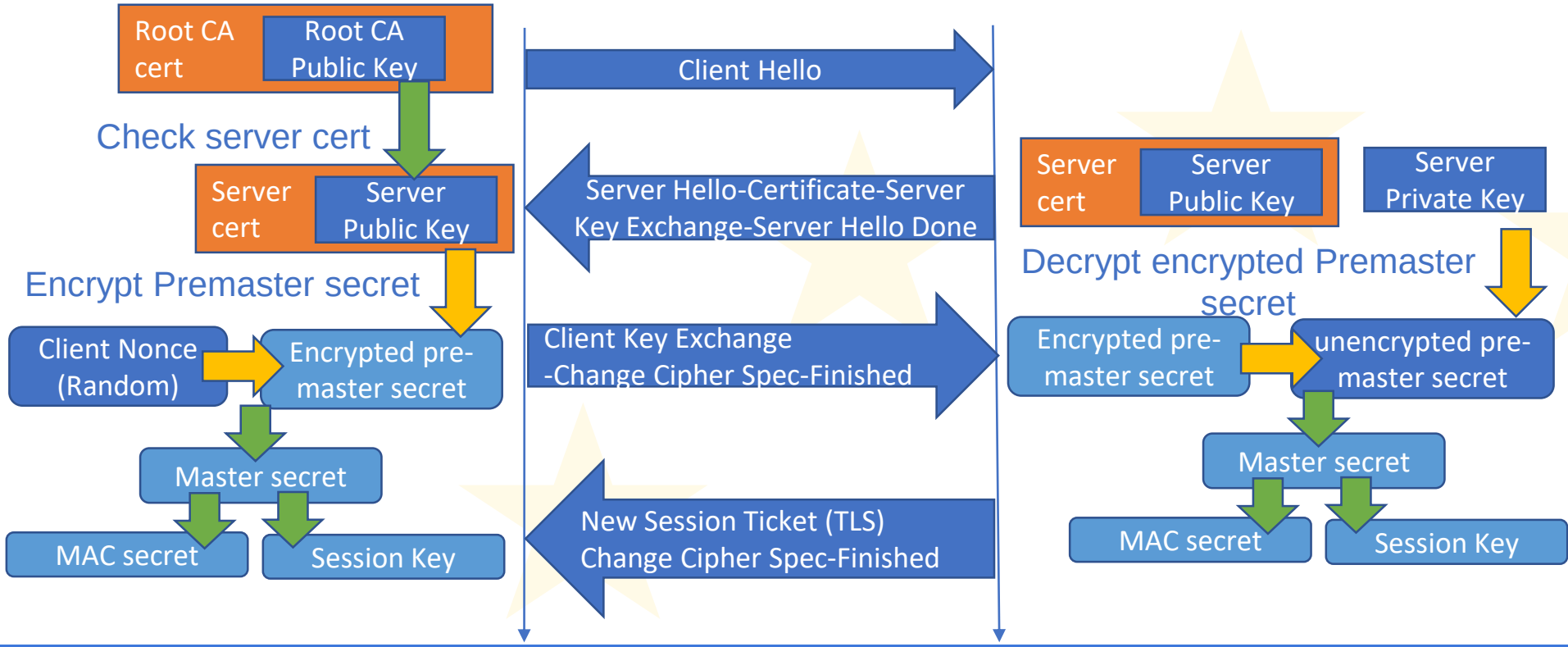
- IQUIC is learned from SSL/TLS to install session key, but how do QUIC install session key at the first time (1-RTT) and at resumption (0-RTT)
- Open tls10ikeriri.pcapng to remember how to negotiate and install session key in TLS1.0
- tls10ikeriri.txt is a PEM format certification file with server's private key
- Set RSA key list in SSL preference of Wireshark

Open tls10ikeriri.pcapng and set RSA key list (tls10ikeriri.txt)





Key creation process of TLS1.0



Filter “ssl” and check the each TLS packet

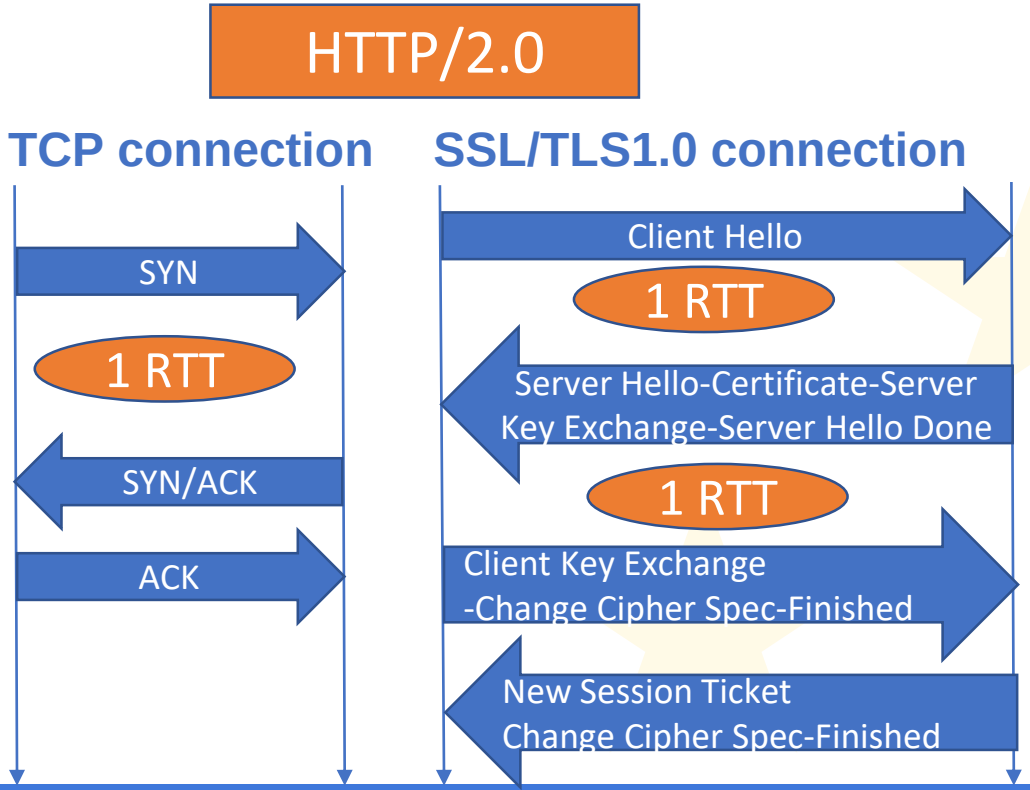
- Check packet #6 and expand Client Key Exchange

No.	Time	Source	Destination	Protocol	Length	Info
4	0.000790	192.168.100.122	192.168.100.200	TLSv1	210	Client Hello
6	0.003810	192.168.100.200	192.168.100.122	TLSv1	567	Server Hello, Certificate, Server Hello
8	0.006733	192.168.100.122	192.168.100.200	TLSv1	252	Client Key Exchange, Change Cipher Spec
9	0.037486	192.168.100.200	192.168.100.122	TLSv1	320	New Session Ticket, Change Cipher Spec,
11	0.038436	192.168.100.122	192.168.100.200	HTTP	400	GET / HTTP/1.1
12	0.042742	192.168.100.200	192.168.100.122	HTTP	666	HTTP/1.1 200 OK (text/html)

```
> Ethernet II, Src: Inventec_2f:9c:c6 (00:8c:fa:2f:9c:c6), Dst: AvalueTe_02:0b:79 (00:04:5f:02:0b:79)
> Internet Protocol Version 4, Src: 192.168.100.122, Dst: 192.168.100.200
> Transmission Control Protocol, Src Port: 10189, Dst Port: 443, Seq: 157, Ack: 514, Len: 198
v Secure Sockets Layer
  v TLSv1 Record Layer: Handshake Protocol: Client Key Exchange
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 134
    v Handshake Protocol: Client Key Exchange
        Handshake Type: Client Key Exchange (16)
        Length: 130
      > RSA Encrypted PreMaster Secret
  > TLSv1 Record Layer: Change Cipher Spec Protocol: Change Cipher Spec
  > TLSv1 Record Layer: Handshake Protocol: Finished
```

Client send Encrypted PreMaster Secret after negotiated with Server

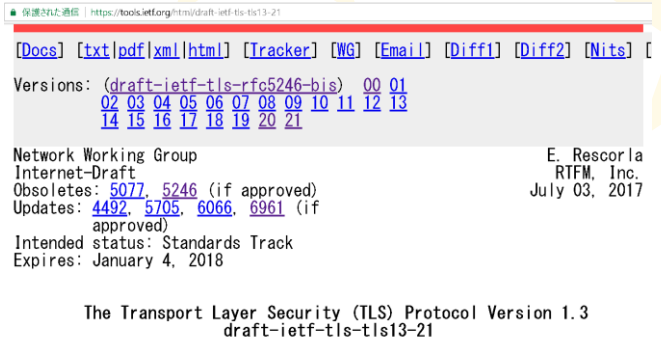
TLS1.0/1.2 needs 2 RTT at the first connection



- Old TLS needs 2 RTT at the fist connection
- It is not use for QUIC 1RTT connection
- Another way to negotiate and install session key....

TLS1.3 Internet Draft 21

- New TLS protocol since 2014 now Internet-Drafts
  https://tools.ietf.org/html/draft-ietf-tls-tls13-21
- Stronger (few cleartext) and Faster (few packet)
- New encryption / authentication
- No SessionID, No Ticket, use PSK
  No Change Cipher Spec,
  No Client Key Exchange,
- 1-RTT at first time, 0-RTT when we connect again



Sample trace of TLS1.3

- Open sample trace file sip.pcap from Wireshark Wiki sip-tls-1.3-and-rtcp.zip SIP call over TLS 1.3 transport with enabled RTCP. Used openssl 1.1.1 prerelease version (https://wiki.wireshark.org/SampleCaptures)
- Open sip.pcap and filter ssl in Display Filter
- Statistics > Flow Graph and set Displayed Packet to see the 1-RTT full handshake of TLS1.3

Open sip.pcapng and filter ssl and create Flow Graph

sip.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

ssl

No.	Time	Source	Destination	Protocol	Length	Info
4	0.000874	217.12.247.98	217.12.244.34	TLSv1.3	316	Client Hello
6	0.029061	217.12.244.34	217.12.247.98	TLSv1.3	2081	Server Hello, Application Data, Application Data, Appl
8	0.030460	217.12.247.98	217.12.244.34	TLSv1.3	142	Application Data
9	0.030627	217.12.247.98	217.12.244.34	TLSv1.3	928	Application Data

```
Frame 4: 316 bytes on wire (2528 bits), 316 bytes captured (2528 bits)
Linux cooked capture
Internet Protocol Version 4, Src: 217.12.247.98, Dst: 217.12.244.34
Transmission Control Protocol, Src Port: 59360, Dst Port: 5061, Seq: 1, Ack: 1, Len: 248
Secure Sockets Layer
  TLSv1.3 Record Layer: Handshake Protocol: Client Hello
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 243
    Handshake Protocol: Client Hello
        Handshake Type: Client Hello (1)
        Length: 239
        Version: TLS 1.2 (0x0303)
        Random: 254dc7519191161daafdd8ddbcef30dbe6f3c95a9fb4e140...
        Session ID Length: 0
```

```
0000  00 00 03 04 00 06 00 00  00 00 00 00 00 00 08 00   ........ ........
0010  45 00 01 2c e3 89 40 00  40 06 b8 a3 d9 0c f7 62   E..,..@. @......b
0020  d9 0c f4 22 e7 e0 13 c5  85 a5 5a da 90 aa 6c 41   ..."....  ..Z...lA
0030  80 18 01 56 9e bd 00 00  01 01 08 0a e3 ac b9 5f   ...V.... .......
```

Handshake protocol message (sslhandshake), 243 bytes | Packets: 4558 · Displayed: 22 (0.5%) | Profile: Default

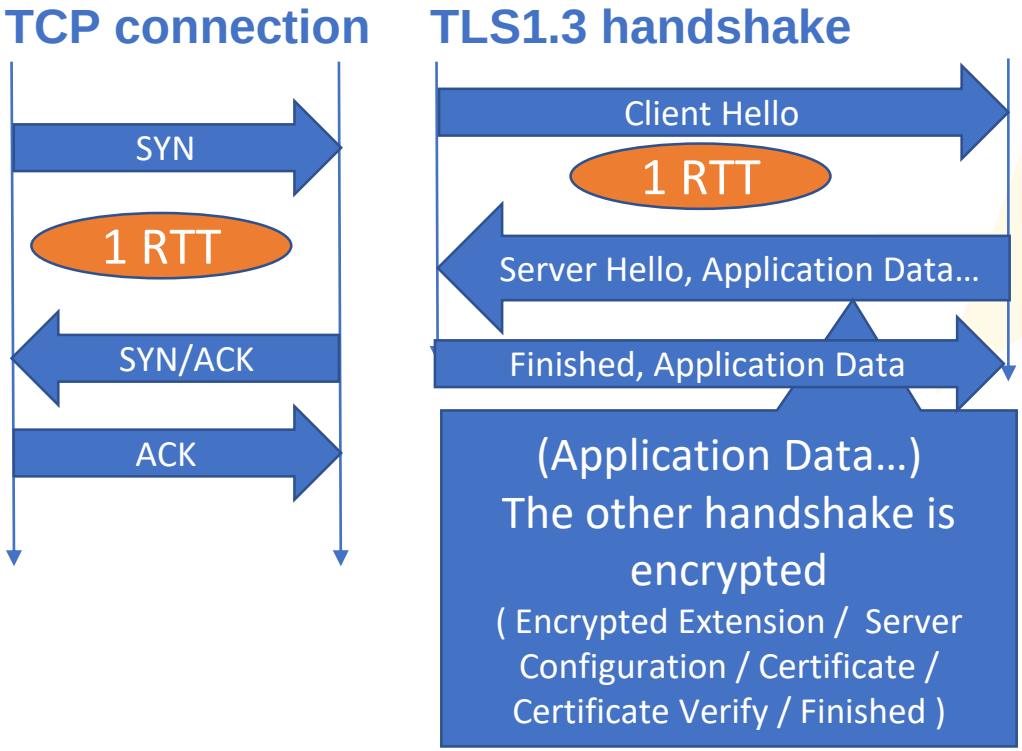
Wireshark · Flow · sip

Time	217.12.247.98	217.12.244.34	Comment
0.000874	59360	Client Hello → 5061	TLSv1.3: Client Hello
0.029061	59360	Server Hello, Application Data… ← 5061	TLSv1.3: Server Hello, Application Data, App…
0.030460	59360	Application Data → 5061	TLSv1.3: Application Data
0.030627	59360	Application Data → 5061	TLSv1.3: Application Data
0.030675	59360	Application Data → 5061	TLSv1.3: Application Data
0.030803	59360	Application Data → 5061	TLSv1.3: Application Data
0.033797	59360	Application Data → 5061	TLSv1.3: Application Data
0.034148	59360	Application Data → 5061	TLSv1.3: Application Data
0.034758	59360	Application Data → 5061	TLSv1.3: Application Data
0.034819	59360	Application Data → 5061	TLSv1.3: Application Data
0.034858	59360	Application Data → 5061	TLSv1.3: Application Data
0.058316	59360	Application Data → 5061	TLSv1.3: Application Data
0.073397	59360	Application Data → 5061	TLSv1.3: Application Data
0.073442	59360	Application Data → 5061	TLSv1.3: Application Data
0.073469	59360	Application Data → 5061	TLSv1.3: Application Data

Packet 15: TLSv1.3: Application Data

Limit to display filter | Flow type: All Flows | Addresses: Any | Reset | Save As… | Close | Help

TLS1.3 1-RTT handshake



There are no Client Key Exchange, no Change Cipher Spec packet, and the encryption starts after Server Hello

The other handshake is encrypted using PSK (Pre Shard Key).

Client send Application data after receiving Server packet

It needs just 1 Round trip time from Client side

Client Hello

(contains former Client Key Exchange, Change Cipher Spec)

Extension: psk_key_exchange_modes (len=2)

Type: psk_key_exchange_modes (45) Length: 2

PSK Key Exchange Modes Length: 1

PSK Key Exchange Mode: PSK with (EC)DHE key establishment (psk_dhe_ke) (1)

Set PSK Key Exchange Mode

Extension: key_share (len=71)

Type: key_share (40) Length: 71

Key Share extension

Client Key Share Length: 69

Key Share Entry: Group: secp256r1, Key Exchange length: 65

Set Key Share settings

Group: secp256r1 (23)

Key Exchange Length: 65

Key Exchange: 04f145e0e15072f4983d04be08c7886c598af98607204dd0...

Send Key Exchange Data

Extension: certificate_authorities (len=40)

Type: certificate_authorities (47) Length: 40

Distinguished Names Length: 38

Distinguished Names (38 bytes)

Send certificate authorities

```
Secure Sockets Layer
  TLSv1.3 Record Layer: Handshake Protocol: Client Hello
    Content Type: Handshake (22)
    Version: TLS 1.0 (0x0301)
    Length: 243
    Handshake Protocol: Client Hello
      Handshake Type: Client Hello (1)
      Length: 239
      Version: TLS 1.2 (0x0303)
      Random: 254dc7519191161daafdd8ddbcef30dbe6f3c95a9fb4e140...
      Session ID Length: 0
      Cipher Suites Length: 12
      Cipher Suites (6 suites)
      Compression Methods Length: 1
      Compression Methods (1 method)
        Compression Method: null (0)
      Extensions Length: 186
      Extension: ec_point_formats (len=4)
      Extension: supported_groups (len=4)
      Extension: SessionTicket TLS (len=0)
      Extension: signature_algorithms (len=22)
      Extension: encrypt_then_mac (len=0)
      Extension: extended_master_secret (len=0)
      Extension: supported_versions (len=3)
      Extension: psk_key_exchange_modes (len=2)
        Type: psk_key_exchange_modes (45)
        Length: 2
        PSK Key Exchange Modes Length: 1
        PSK Key Exchange Mode: PSK with (EC)DHE key establishment (psk_dhe_ke) (1)
      Extension: key_share (len=71)
        Type: key_share (40)
        Length: 71
        Key Share extension
          Client Key Share Length: 69
          Key Share Entry: Group: secp256r1, Key Exchange length: 65
            Group: secp256r1 (23)
            Key Exchange Length: 65
            Key Exchange: 04f145e0e15072f4983d04be08c7886c598af98607204dd0...
      Extension: certificate_authorities (len=40)
```

Send Client Nonce

Server Hello
(contains former Change Cipher Spec)

Handshake Protocol: Server Hello

Handshake Type: Server Hello (2)

Length: 111

Version: TLS 1.3 (draft 21) (0x7f15)

Random: 8f3a63a080b3c1ae2b3192c765[illegible]d4f28afdb1f123a68f81...

Cipher Suite: TLS_AES_256_GCM_SHA384 (0x1302)

Extensions Length: 73

Extension: key_share (len=69)

Type: key_share (40)

Length: 69

Key Share extension

Key Share Entry: Group: secp256r1, Key Exchange length: 65

Group: secp256r1 (23)

Key Exchange Length: 65

Key Exchange: 04110e96ae58d23b968ebb7fd9075d83348733a622013785...

TLSv1.3 Record Layer: Application Data Protocol: sip.tcp

Determined Auth/Encryption

Set Key Share settings

The others are encrypted

Send Key Exchange Data

```
▾ Secure Sockets Layer
  ▾ TLSv1.3 Record Layer: Handshake Protocol: Server Hello
      Content Type: Handshake (22)
      Version: TLS 1.0 (0x0301)
      Length: 115
    ▾ Handshake Protocol: Server Hello
        Handshake Type: Server Hello (2)
        Length: 111
        Version: TLS 1.3 (draft 21) (0x7f15)
        Random: 8f3a63a080b3c1ae2b3192c76574d4f28afdb1f123a68f81...
        Cipher Suite: TLS_AES_256_GCM_SHA384 (0x1302)
        Extensions Length: 73
      ▾ Extension: key_share (len=69)
          Type: key_share (40)
          Length: 69
        ▾ Key Share extension
          ▾ Key Share Entry: Group: secp256r1, Key Exchange length: 65
              Group: secp256r1 (23)
              Key Exchange Length: 65
              Key Exchange: 04110e96ae58d23b968ebb7fd9075d83348733a622
  › TLSv1.3 Record Layer: Application Data Protocol: sip.tcp
  › TLSv1.3 Record Layer: Application Data Protocol: sip.tcp
  › TLSv1.3 Record Layer: Application Data Protocol: sip.tcp
  › TLSv1.3 Record Layer: Application Data Protocol: sip.tcp
```

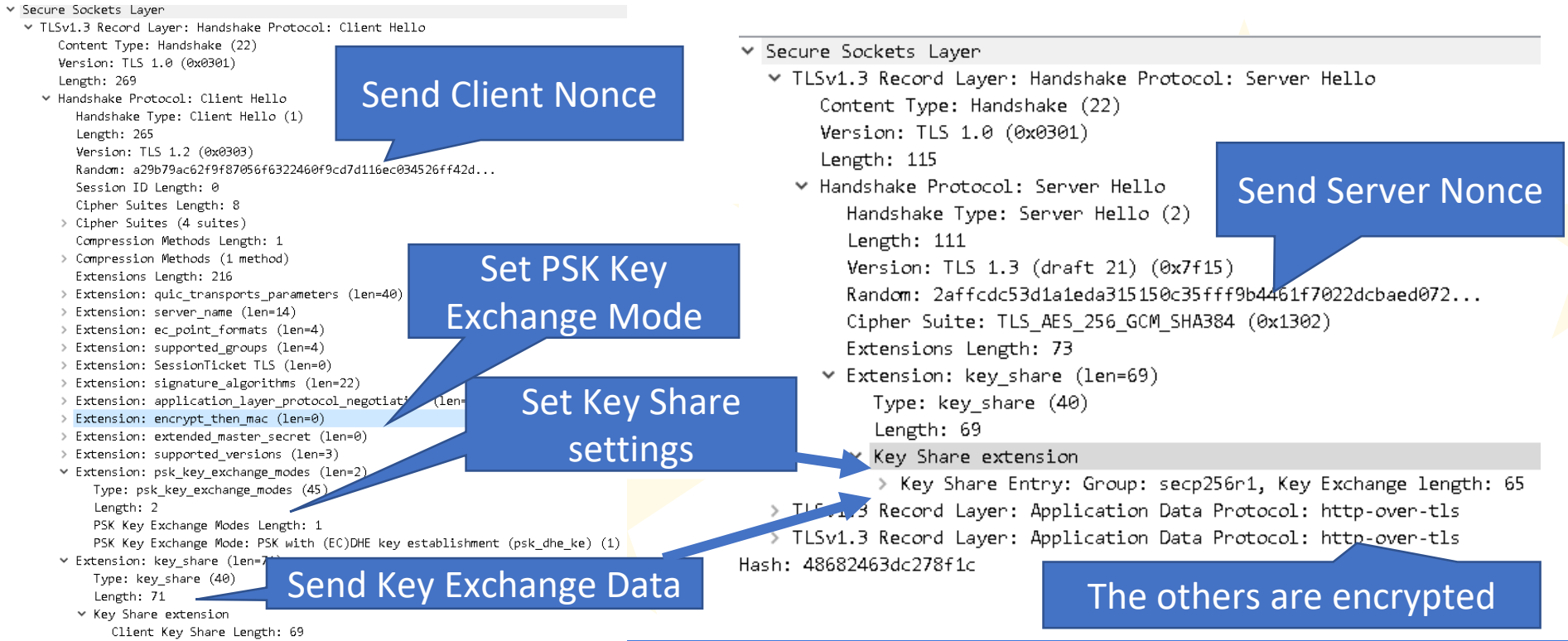
Send Server Nonce

TLS1.3 in IETF QUIC

- Let's go back to quic_ietf_draft05_ngtcp2.pcapng
- Check #1 packet of Client Initial (including Client Hello)
  Extension: quic_transport_parameters
  Extension: psk_key_exchange_modes
  Extension: key_share
- Check #2 packet of Server Cleartext (including Server Hello)
  Extension: key_share
- #3 (Server Cleartext) and #4(Client Cleartext) is encrypted with application data (http-over-tls)

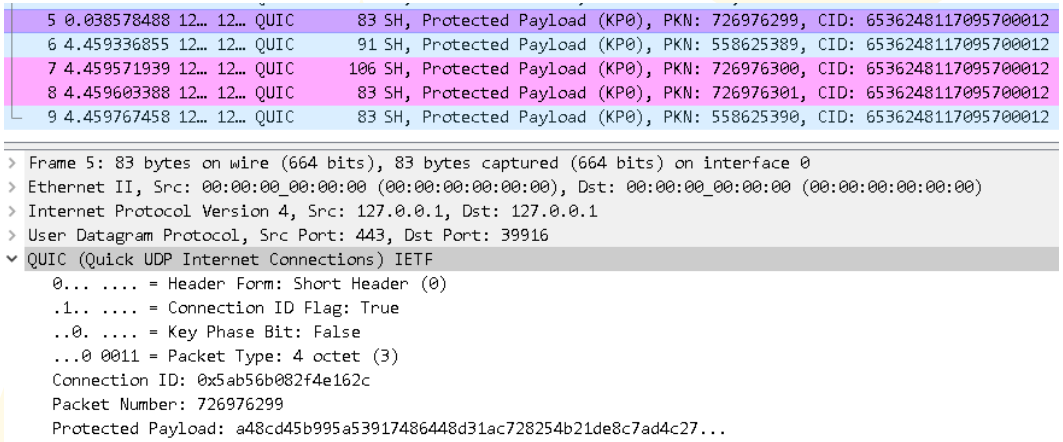
0x04	Server Cleartext	Server sends this type packet as cryptographic handshake message and ACK that contains server chosen connection ID and randomized packet number with with STREAM, PADDING, ACK. (Long Header)
0x05	Client Cleartext	Client sends this type packet as the receipt of Server Cleartext message, Client Cleartext contains Server selected connection ID and incremented packet number of Client Initial with STREAM, PADDING, ACK. (Long Header)

Client Hello/ Server Hello of IQUIC



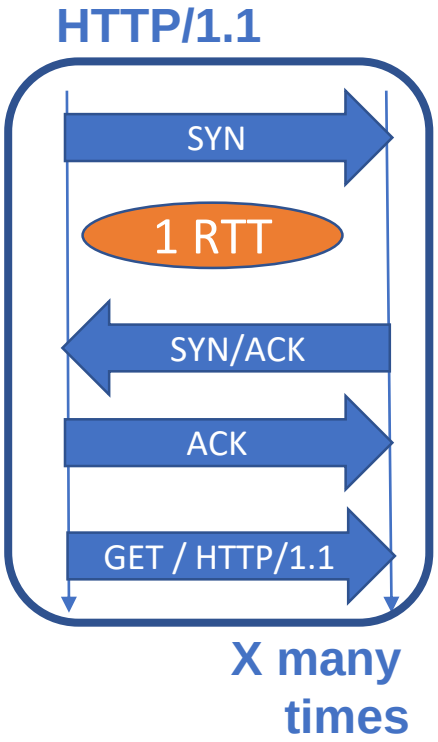
Short header transaction

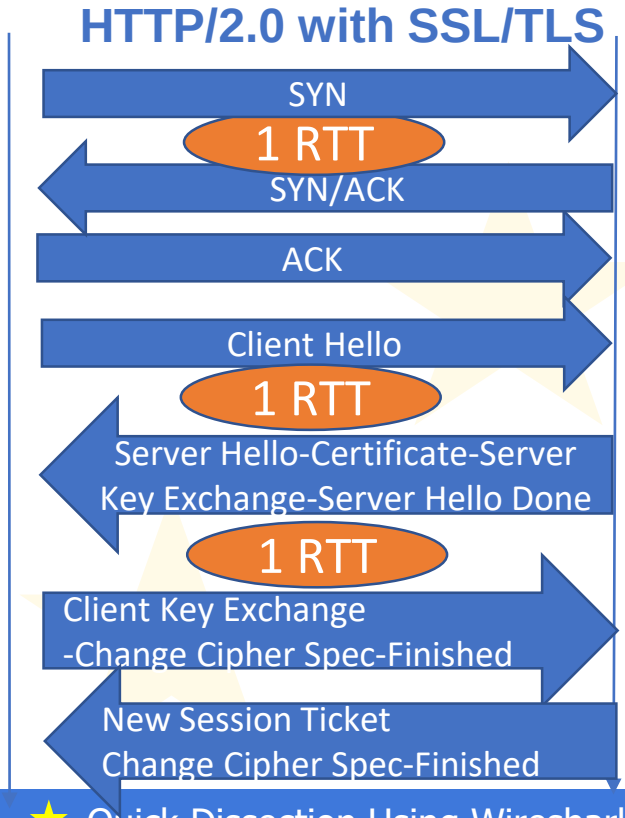
- Check #5- packets with Short Header of IQUIC
- The short header can be used after the version and 1-RTT keys are negotiated.

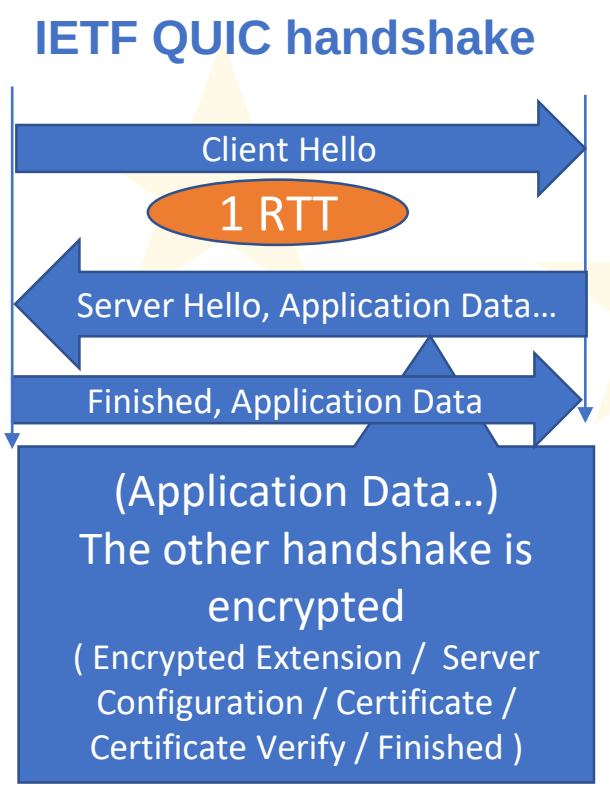


- Transactions are independent and based on IP/UDP
- Next time Client try to use 0-RTT way.

Comparizon between HTTP/1.1 HTTP/2.0 and IETF QUIC







Thank you very much !!

どうもありがとうございました！