CS 305 Lab Tutorial
Lab 7 UDP&TCP&TLS

Dept. Computer Science and Engineering
Southern University of Science and Technology

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Thanks to Wei WANG & HHQ ZHANG

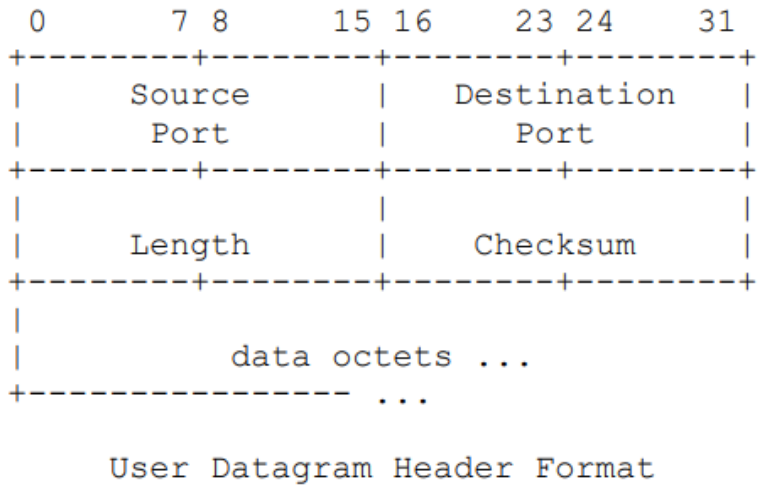
Part A. UDP

- UDP: User Datagram Protocol
- UDP is defined to make available a datagram mode of packet-switched computer communication in the environment of an interconnected set of computer networks.
- UDP assumes that the Internet Protocol (IP) is used as the underlying protocol.
- UDP is transaction oriented, and delivery and duplicate protection are NOT guaranteed.

https://tools.ietf.org/html/rfc768

UDP segment structure

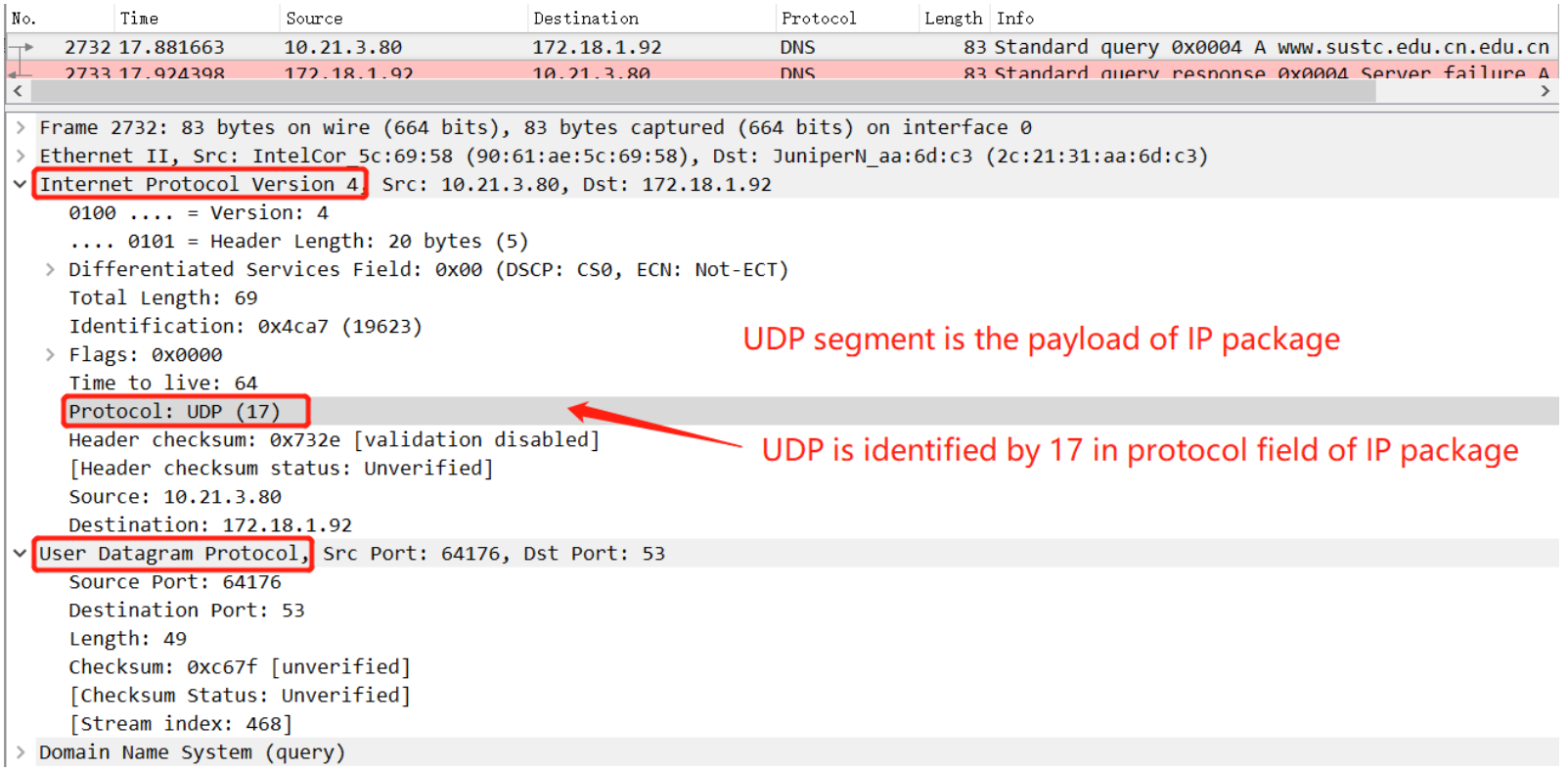
- Source port: may be zero or indicates the port of the sending process
- Destination port: an internet destination address
- Length: in octets of this user datagram including this header and the data. (This means the minimum value of the length is eight.)



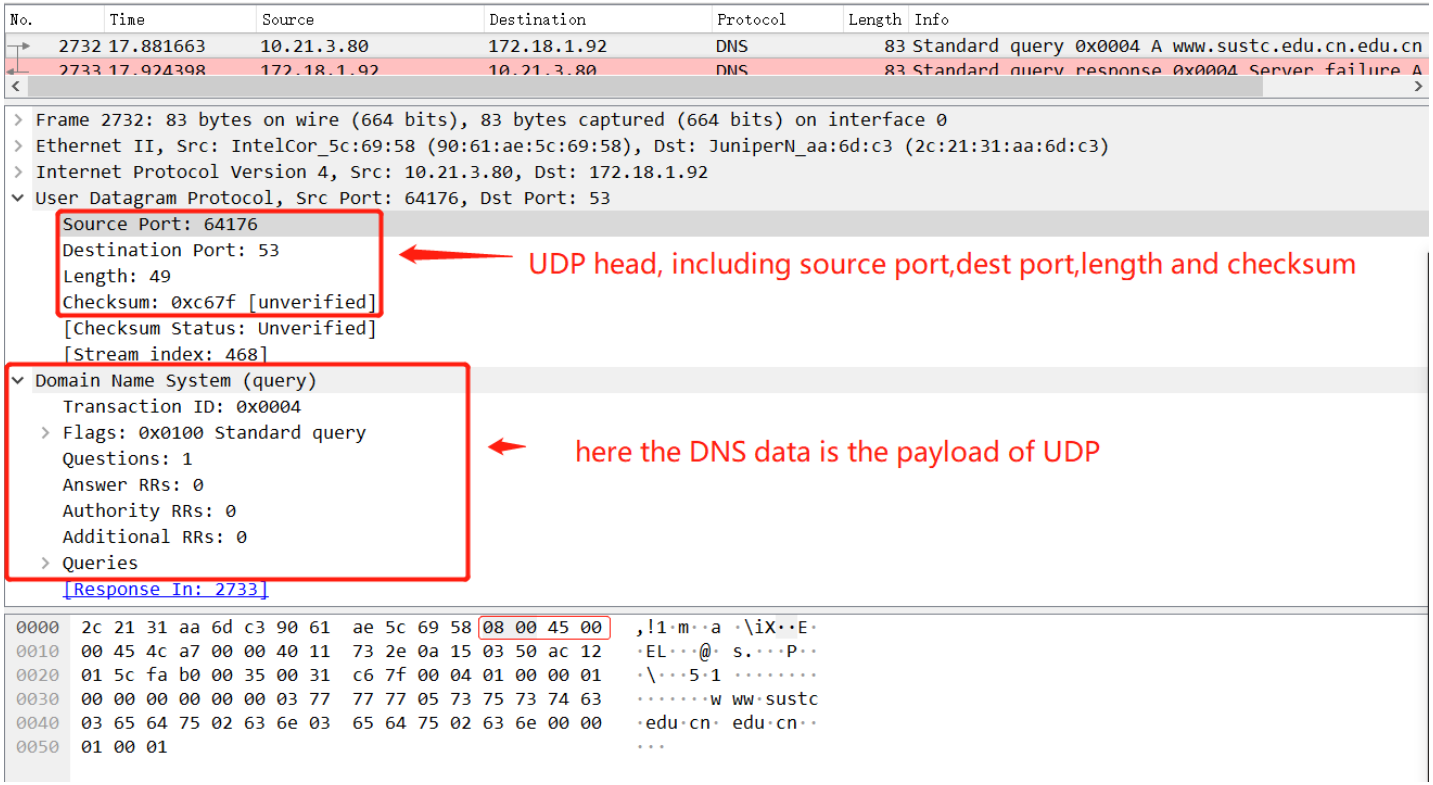
User Datagram Header Format

https://tools.ietf.org/html/rfc768

A UDP segment(1)



A UDP segment(2)



While invoke an DNS query, this session is using UDP as transport protocol

You can use ‘nslookup’ or ‘dig’ to invoke an DNS query

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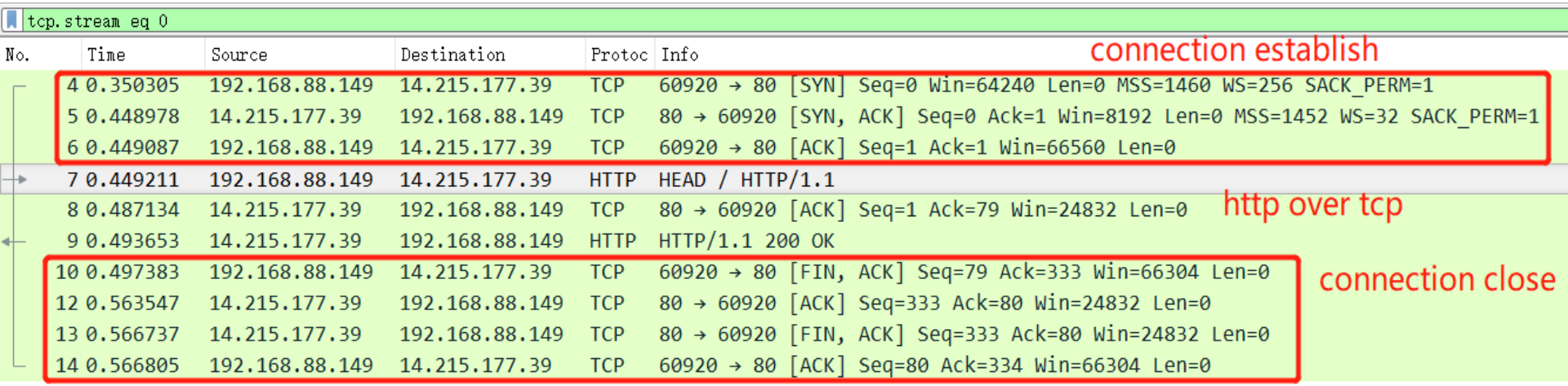
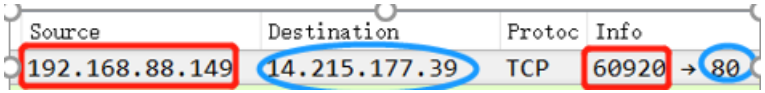
Part B. TCP

- TCP: Transmission Control Protocol
- TCP is a highly reliable host-to-host protocol between hosts in packet-switched computer communication networks, and in interconnected systems of such networks.
- TCP must recover from data that is damaged, lost, duplicated, or delivered out of order by the Internet communication system.
  - Ports
  - connections
  - Flow control
  - Reliability

https://tools.ietf.org/html/rfc793

Part B.1 A TCP connection(1)

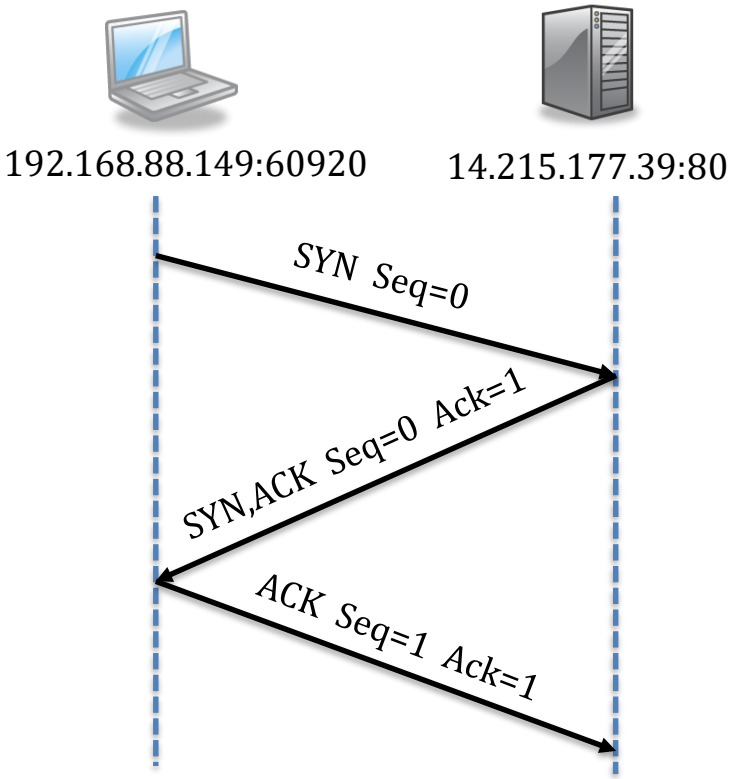




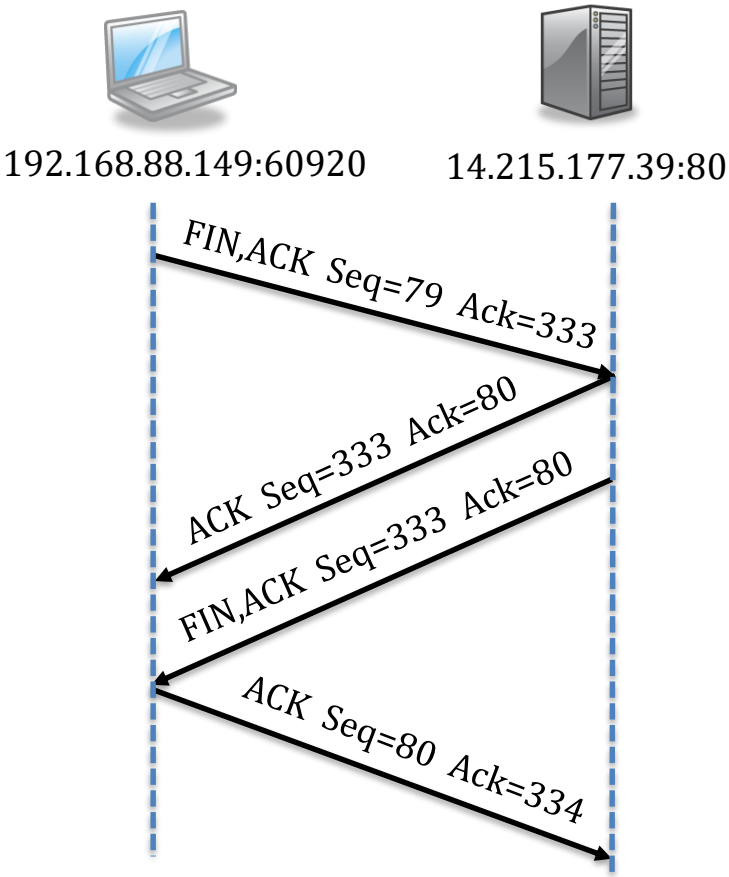
Source IP:192.168.88.149 port： 60920
Destination IP:14.215.177.39 port:80

Tips: Using command ‘curl’ to invoke a http request which using TCP for transport
For example: curl -i www.baidu.com

Part B.1 A TCP connection(2)

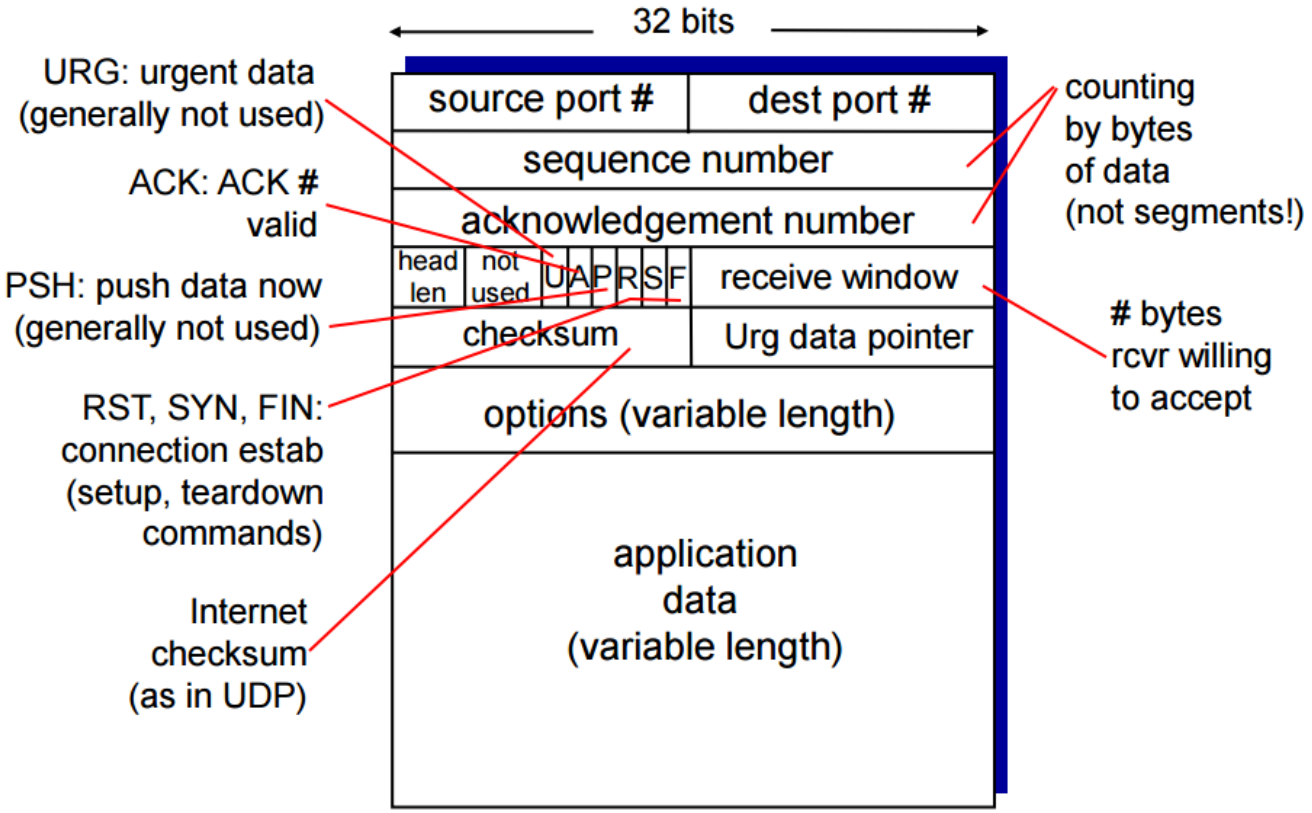


Establishing a TCP connection

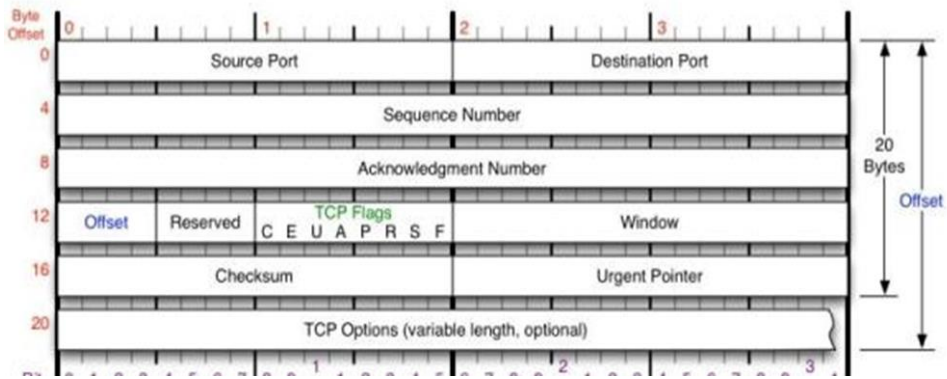


Closing a TCP connection

Part B.2 TCP segment structure



'Header len'/'offset' field in TCP header




```
Transmission Control Protocol, Src Port: 54861, Dst Port: 80, Seq: 1, Ack: 1, Len: 0
    Source Port: 54861
    Destination Port: 80
    [Stream index: 2]
    [TCP Segment Len: 0]
    Sequence number: 1    (relative sequence number)
    [Next sequence number: 1    (relative sequence number)]
    Acknowledgment number: 1    (relative ack number)
    0101 .... = Header Length: 20 bytes (5)
  > Flags: 0x010 (ACK)
    Window size value: 256
    [Calculated window size: 65536]
    [Window size scaling factor: 256]
    Checksum: 0x13ef [unverified]
    [Checksum Status: Unverified]
    Urgent pointer: 0
```

head length is 20 byte
while there's no options

Data Offset: 4 bits

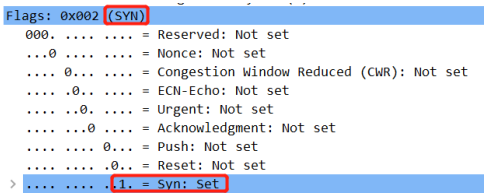
- The number of 32 bit words in the TCP Header. This indicates where the data begins.
- The TCP header (even one including options) is an integral number of 32 bits long.

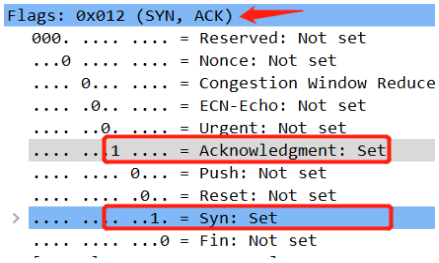
```
Transmission Control Protocol, Src Port: 54861, Dst Port: 80, Seq: 0, Len: 0
    Source Port: 54861
    Destination Port: 80
    [Stream index: 2]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    [Next sequence number: 0    (relative sequence number)]
    Acknowledgment number: 0
    1000 .... = Header Length: 32 bytes (8)
  > Flags: 0x002 (SYN)
    Window size value: 64240
    [Calculated window size: 64240]
    Checksum: 0x5335 [unverified]
    [Checksum Status: Unverified]
    Urgent pointer: 0
  > Options: (12 bytes), Maximum segment size, No-Operation (NOP), Window scale, N
```

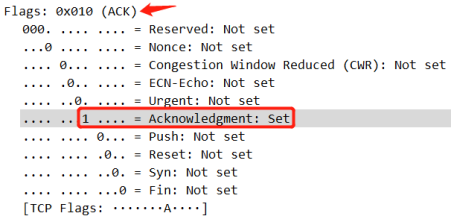
32 bytes= 8*4bytes

32bytes= 20(default length) +12 (options length)

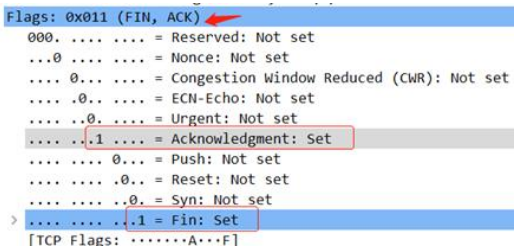
'Flags' in TCP header

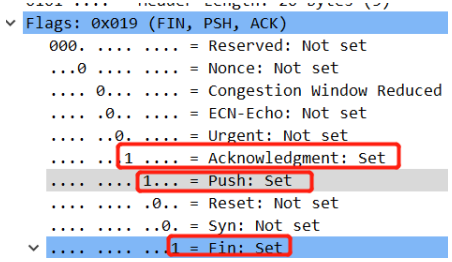






Control Bits:
URG: Urgent Pointer field significant
ACK: Acknowledgment field significant
PSH: Push Function
RST: Reset the connection
SYN: Synchronize sequence numbers
FIN: No more data from sender





Tips in Wireshark: Using ‘tcp.flags.xxx==1’ as filter to view the corresponding package
While xxx is the name of the flag, such as tcp.flags.syn==1

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'Sequence number' and 'Ack number'(1)

Transmission is made reliable via the use of **sequence numbers** and **acknowledgments**.

- The sequence number **of the first octet of data in a segment** is transmitted with that segment and is called the segment **sequence number**.
- Segments also carry an **acknowledgment number** which is the sequence number of the next expected data octet of transmissions in the reverse direction.

When the TCP transmits a segment containing data, it puts a copy on a retransmission queue and starts a timer;

- when the acknowledgment for that data is received, the segment is deleted from the queue.
- If the acknowledgment is not received before the timer runs out, the segment is retransmitted.

An acknowledgment by TCP does not guarantee that the data has been delivered to the end user, but only that the receiving TCP has taken the responsibility to do so.

https://tools.ietf.org/html/rfc793

'Sequence number' and 'Ack number'(2)

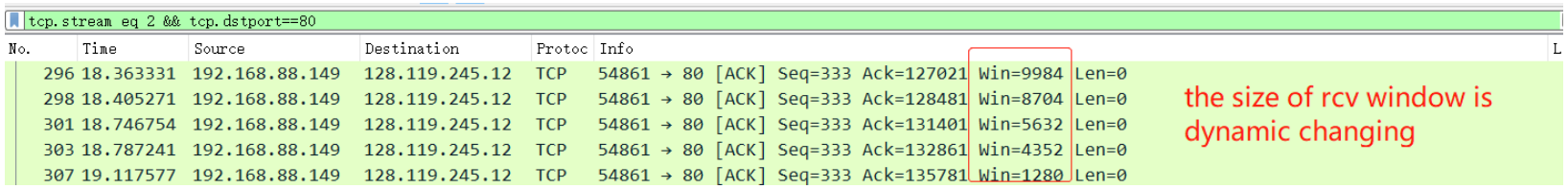
```
Transmission Control Protocol, Src Port: 80, Dst Port: 54861, Seq: 81761, Ack: 333, Len: 1460
   Source Port: 80
   Destination Port: 54861
   [Stream index: 2]
   [TCP Segment Len: 1460]
   Sequence number: 81761    (relative sequence number)
   [Next sequence number: 83221    (relative sequence number)]
   Acknowledgment number: 333    (relative ack number)
```

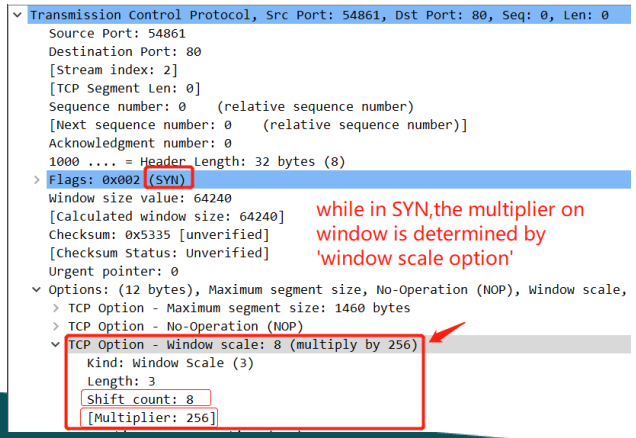
No.	Time	Source	Destination	Protoc	Info
234	10.752731	192.168.88.149	128.119.245.12	TCP	54861 → 80 [ACK] Seq=333 Ack=81761 Win=55296 Len=0
235	11.462632	128.119.245.12	192.168.88.149	TCP	80 → 54861 [ACK] Seq=81761 Ack=333 Win=30336 Len=1460 [TCP segment of a reassembled PDU]
236	11.463266	128.119.245.12	192.168.88.149	TCP	80 → 54861 [ACK] Seq=83221 Ack=333 Win=30336 Len=1460 [TCP segment of a reassembled PDU]
237	11.463358	192.168.88.149	128.119.245.12	TCP	54861 → 80 [ACK] Seq=333 Ack=84681 Win=52480 Len=0

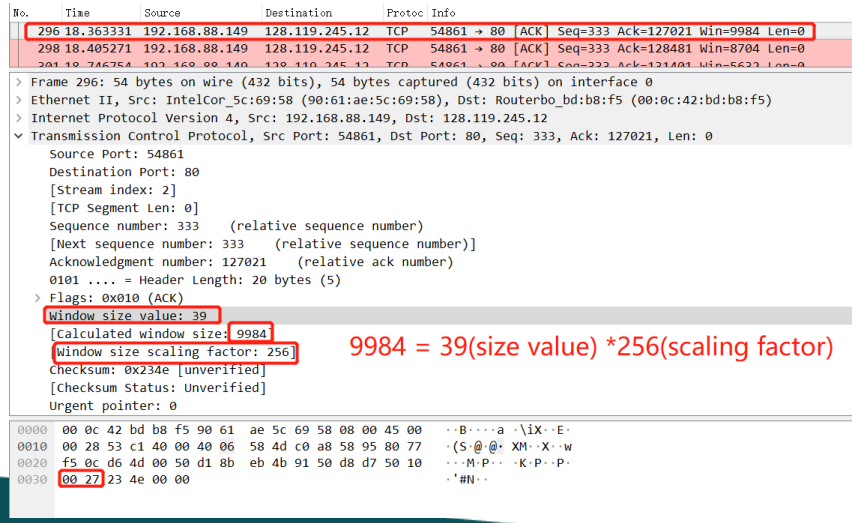
54861->80: seq = 333 len=0
80->54861: ack=333+0 seq = 81761 len=1460
80->54861: ack=333+0 seq = 83221(81761+1460) len=1460
54861->80: seq = 333(333+0) ack=84681(83221+1460) len=0

'Window' field in TCP header

- TCP provides a means for the receiver to govern the amount of data sent by the sender. This is achieved by returning a "window" with every ACK indicating a range of acceptable sequence numbers beyond the last segment successfully received.
- The window **indicates an allowed number of octets that the sender may transmit before receiving further permission**.







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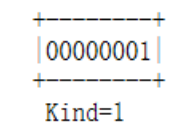
https://tools.ietf.org/html/rfc793

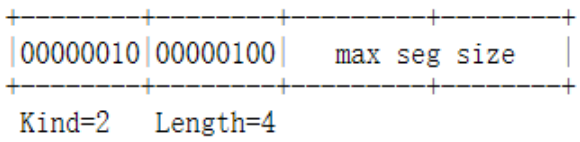
'Options'(variable) in TCP header

- May occupy **space at the end of the TCP header**
- **a multiple of 8 bits in length.**
- **No-operation** may be used between options, for example, to align the beginning of a subsequent option on a word boundary.

No-Operation



Maximum Segment Size




```
Options: (12 bytes), Maximum segment size, No-Operation (NOP), Window scale, No-Op
  TCP Option - Maximum segment size: 1460 bytes
    Kind: Maximum Segment Size (2)
    Length: 4
    MSS Value: 1460
  TCP Option - No-Operation (NOP)
  TCP Option - Window scale: 8 (multiply by 256)
    Kind: Window Scale (3)
    Length: 3
    Shift count: 8
    [Multiplier: 256]
  TCP Option - No-Operation (NOP)
  TCP Option - No-Operation (NOP)
  TCP Option - SACK permitted
    Kind: SACK Permitted (4)
    Length: 2
[Timestamps]
```

```
0000  00 0c 42 bd b8 f5 90 61  ae 5c 69 58 08 00 45 00   ··B····a ·\iX··E·
0010  00 34 53 6b 40 00 40 06  58 97 c0 a8 58 95 80 77   ·4Sk@·@· X···X··w
0020  f5 0c d6 4d 00 50 d1 8b  e9 fe 00 00 00 00 80 02   ···M·P·· ··------
0030  fa f0 53 35 00 00 02 04  05 b4 01 03 03 08 01 01   ··S5···· --------
0040  04 02
```

nop

mss

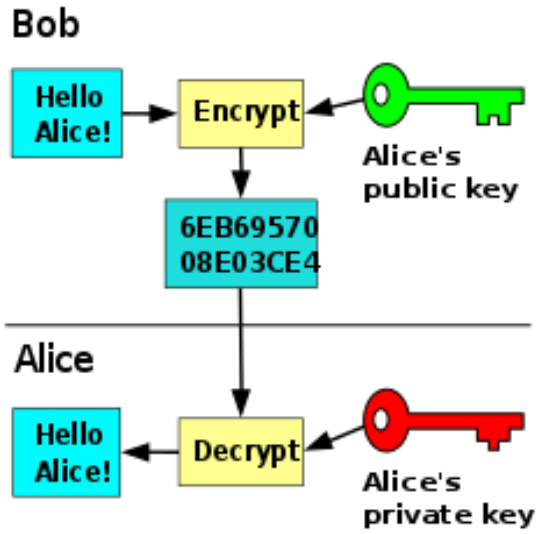
Part C. TLS

- TLS: Transport Layer Security
- TLS provides following features on TCP layer:
  - Encryption
  - Authentication of identity
  - Reliable transfer via integrity check (different from TCP reliable)

https://www.rfc-editor.org/rfc/rfc5246
https://www.rfc-editor.org/rfc/rfc8446

Part C. Public-key Cryptography

- Public-key cryptography, or asymmetric cryptography, is any cryptographic system that uses pairs of keys: public keys which may be disseminated widely, and private keys which are known only to the owner.



Hello! Let's start a encrypted conversation using TLS 1.2.

I want to talk to bank.com
I know the following cipher suites:
- ECDHE and RSA with 128bit AES in GCM mode and SHA256
- RSA with 128bit AES in GCM mode and SHA256
Here's a randomly chosen number:
3d86a5..04

Hi there, I think we can chat.

Let's use the cipher:
RSA with 128bit AES in GCM mode and SHA256
Here's my random number:
ca35f0..13
Here's my certificate chain:
[bank.com's certificate]

This certificate checks out: it was issued to bank.com and digitally signed by a certificate authority I trust.
Here's a secret encrypted with the RSA public key I took from your certificate:
[encrypted pre-master secret]
We can both derive the same key using this secret and the random numbers we exchanged.

I have decrypted the secret and derived the key.
From now on let's use the key to encrypt what we say.

[It's so great to speak privately]
[Can you get me the current balance of my checking account?]

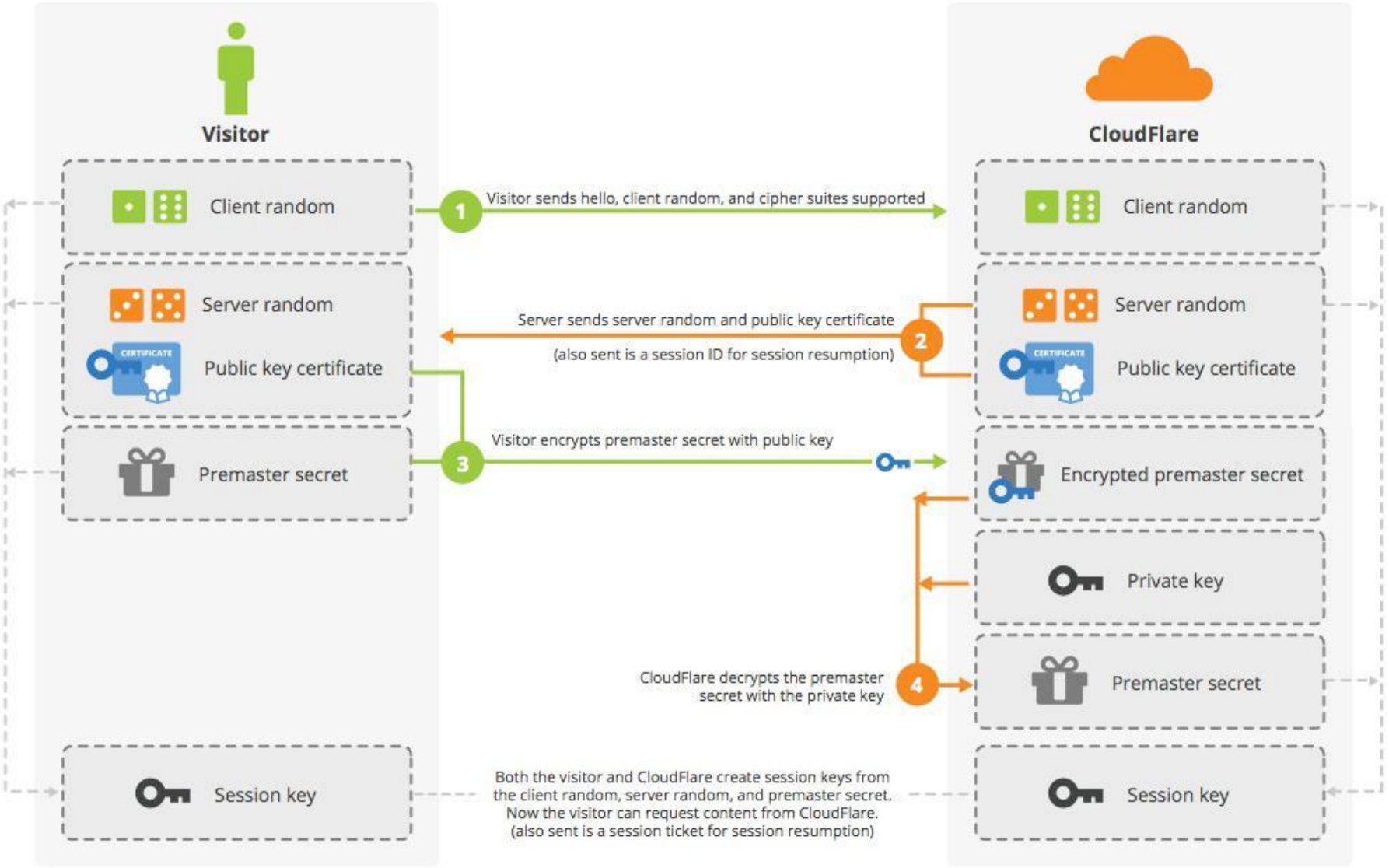
[Sure thing, you have $12.05 left in that account]

TLS Handshake (RSA without client cert)

- Client provide TLS version, a Client random and supported encryption method.
- Server check the TLS version and encryption method and provide server cert and Server random.
- Client validate the server cert and encrypt Premaster secret random using server public key.
- Server using private key to decrypt the Premaster secret.
- Server and Client using these three random numbers generate Session key standalone which will be used in the following session.

SSL Handshake (RSA) Without Keyless SSL

Handshake

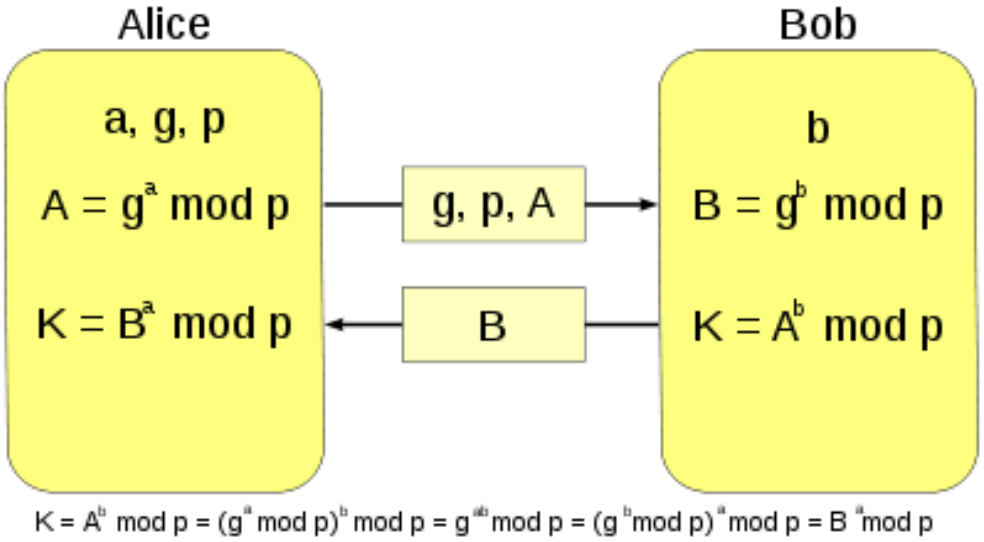


How could it be possible generate session key without encryption?

- If attacker is listening the TLS handshake, he will get the first two random numbers (client random, server random)
- The safety of session key depends on the premaster secret.
- If the RSA algorithm used is weak (using a 1024 bits cert example) can be cracked, the premaster secret can also be cracked. The entire session is not safe now.

Diffie-Hellman Key Exchange

- DH is a method of securely exchanging cryptographic keys over a public channel.



An DH Example

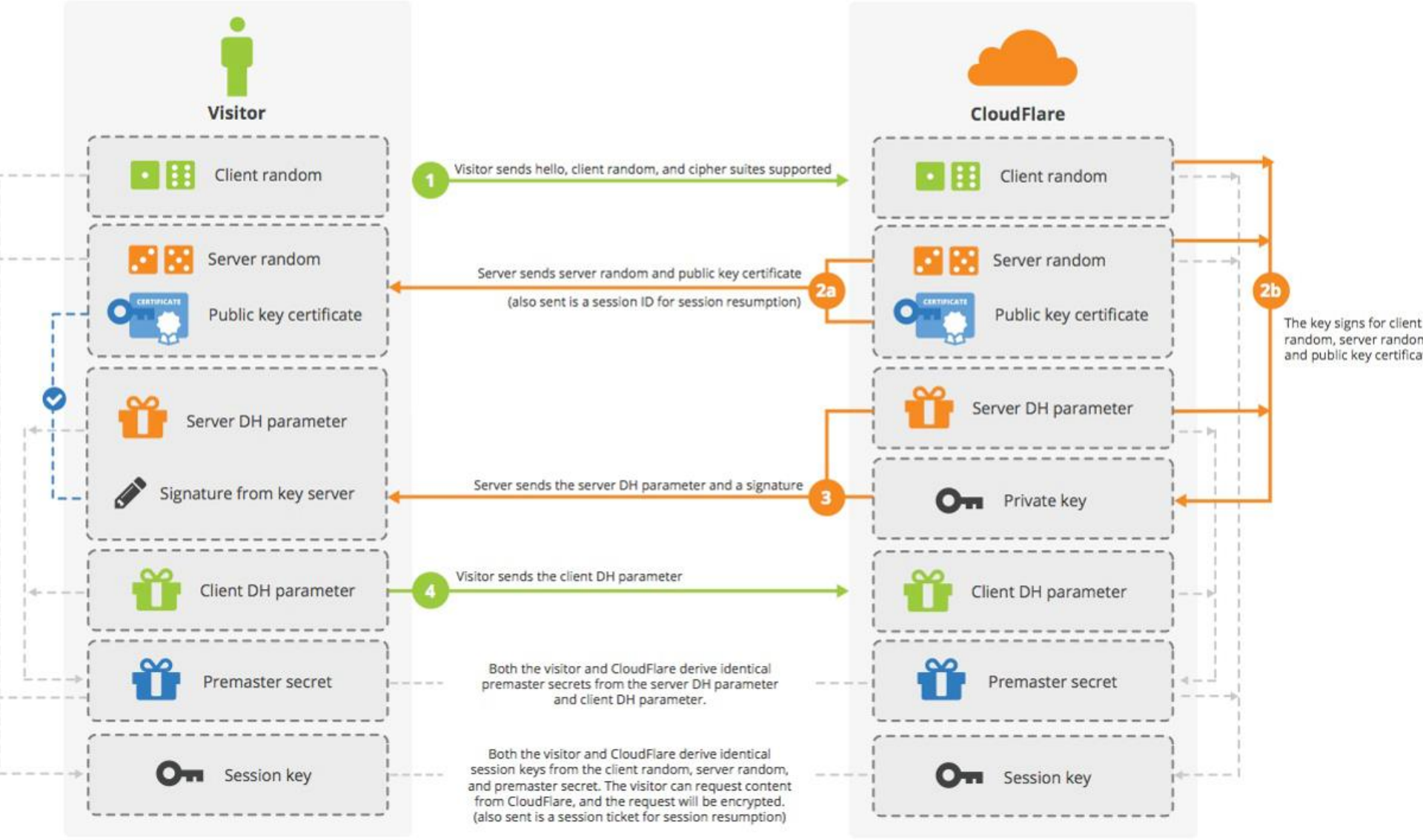
1. Alice and Bob agree to use a modulus $p = 23$ and base $g = 5$ (which is a primitive root modulo 23).
2. Alice chooses a secret integer $\boldsymbol{a} = 4$, then sends Bob $A = g^a \bmod p$
    1. $A = 5^4 \bmod 23 = 4$
3. Bob chooses a secret integer $\boldsymbol{b} = 3$, then sends Alice $B = g^b \bmod p$
    1. $B = 5^3 \bmod 23 = 10$
4. Alice computes $\boldsymbol{s} = B^a \bmod p$
    1. $\boldsymbol{s} = 10^4 \bmod 23 = 18$
5. Bob computes $\boldsymbol{s} = A^b \bmod p$
    1. $\boldsymbol{s} = 4^3 \bmod 23 = 18$
6. Alice and Bob now share a secret (the number 18).

TLS Handshake (DH without client cert)

- Client provide TLS version, a Client random and supported encryption method.
- Server check the TLS version and encryption method and provide server cert, server random and server DH parameter with signature.
- Client validate the server cert and send client DH parameter.
- Server and Client using the DH parameters to generate premaster key which is used for session key generation.

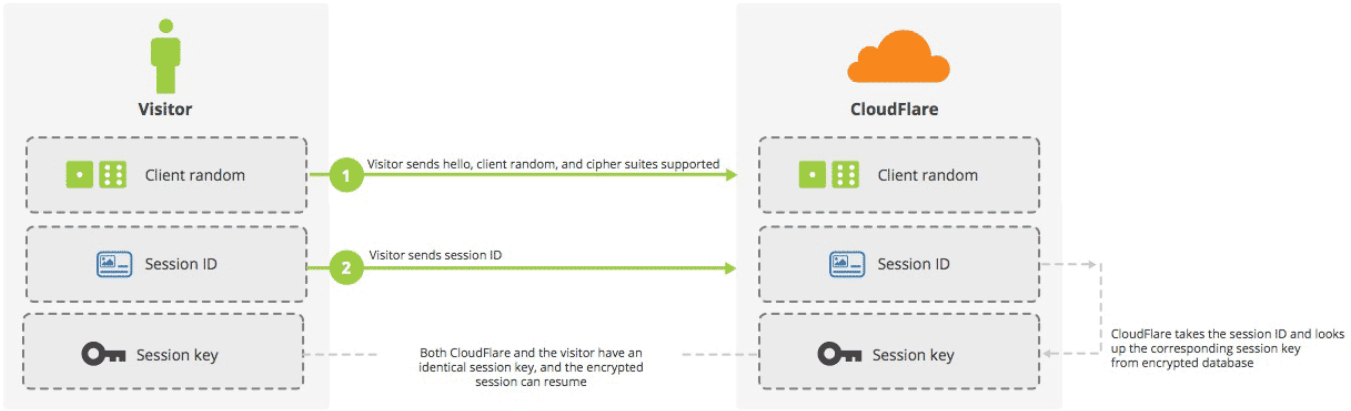
SSL Handshake (Diffie-Hellman) Without Keyless SSL

Handshake



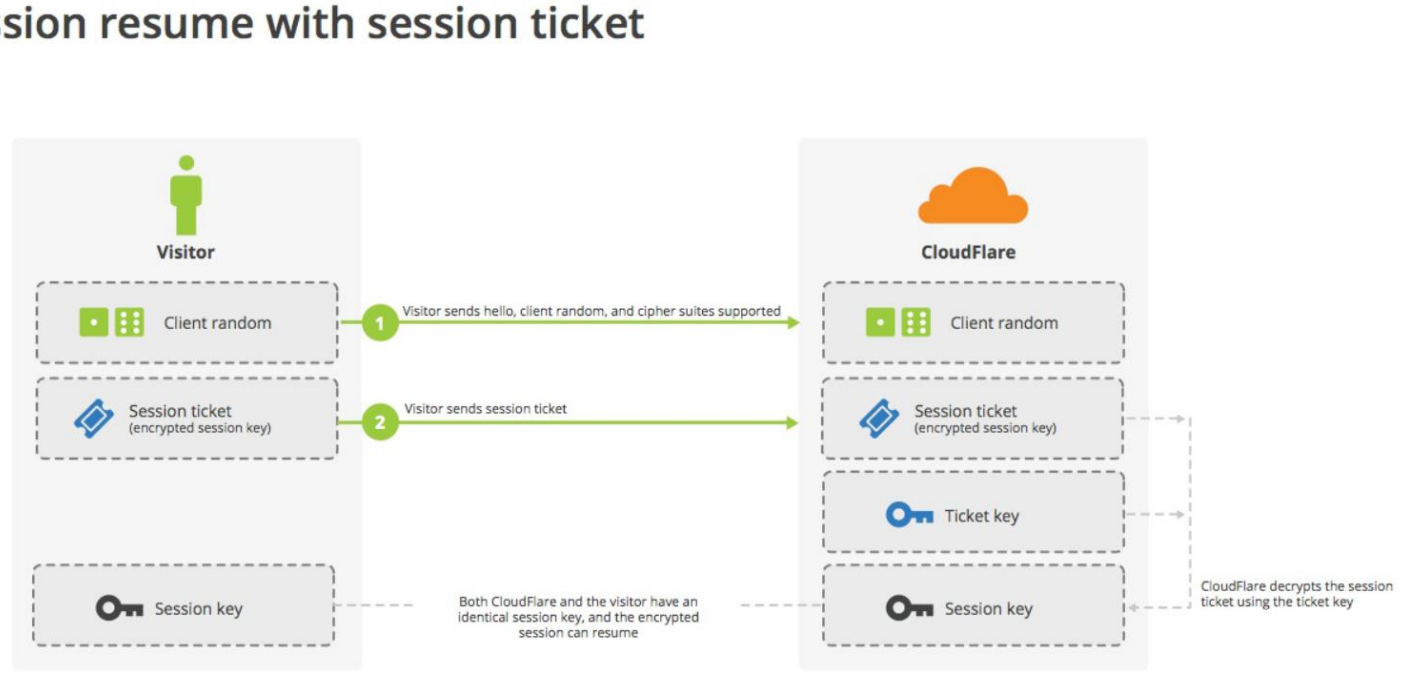
Session resume (1)

- If a TLS session is aborted, client can resume the session using session ID/session ticket.
  – No handshake needed (latency reduced)



Session resume (2)

- With session tickets, we can resume a session from any machine on our network.



TLS analysis using Wireshark

14801	26.204946	192.168.50.147	192.30.253.113	TLSv1.2	571 Client Hello
14815	26.709686	192.30.253.113	192.168.50.147	TLSv1.2	1514 Server Hello

14818	26.721227	192.30.253.113	192.168.50.147	TLSv1.2	1514 Certificate [TCP segment of a reassembled PDU]
14819	26.721368	192.30.253.113	192.168.50.147	TLSv1.2	100 Server Key Exchange, Server Hello Done
14821	26.726115	192.168.50.147	192.30.253.113	TLSv1.2	180 Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message

```
14801 26.204946     192.168.50.147     192.30.253.113     TLSv1.2    571 Client Hello
14815 26.709686     192.30.253.113     192.168.50.147     TLSv1.2   1514 Server Hello
14818 26.721227     192.30.253.113     192.168.50.147     TLSv1.2   1514 Certificate [TCP segment of a reassembled PDU]
```

```
Handshake Protocol: Client Hello
    Handshake Type: Client Hello (1)
    Length: 508
    Version: TLS 1.2 (0x0303)
    Random: 9d840af65ff38f4ed04151b2545f2895c690093511528 32d...
    Session ID Length: 32
    Session ID: f77b857bdacd5caa7abb0cbe1271992ef4848dc2d325a8d5...
    Cipher Suites Length: 36
    Cipher Suites (18 suites)
        Cipher Suite: TLS_AES_128_GCM_SHA256 (0x1301)
        Cipher Suite: TLS_CHACHA20_POLY1305_SHA256 (0x1303)
        Cipher Suite: TLS_AES_256_GCM_SHA384 (0x1302)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256 (0xc02b)
        Cipher Suite: TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (0xc02f)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_CHACHA20_POLY1305_SHA256 (0xcca9)
        Cipher Suite: TLS_ECDHE_RSA_WITH_CHACHA20_POLY1305_SHA256 (0xcca8)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384 (0xc02c)
        Cipher Suite: TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384 (0xc030)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_256_CBC_SHA (0xc00a)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_AES_128_CBC_SHA (0xc009)
        Cipher Suite: TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA (0xc013)
        Cipher Suite: TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA (0xc014)
        Cipher Suite: TLS_DHE_RSA_WITH_AES_128_CBC_SHA (0x0033)
        Cipher Suite: TLS_DHE_RSA_WITH_AES_256_CBC_SHA (0x0039)
        Cipher Suite: TLS_RSA_WITH_AES_128_CBC_SHA (0x002f)
        Cipher Suite: TLS_RSA_WITH_AES_256_CBC_SHA (0x0035)
        Cipher Suite: TLS_RSA_WITH_3DES_EDE_CBC_SHA (0x000a)
    Compression Methods Length: 1
    Compression Methods (1 method)
    Extensions Length: 399
    Extension: server_name (len=15)
        Type: server_name (0)
        Length: 15
        Server Name Indication extension
            Server Name list length: 13
            Server Name Type: host_name (0)
            Server Name length: 10
            Server Name: github.com
```

Client Random

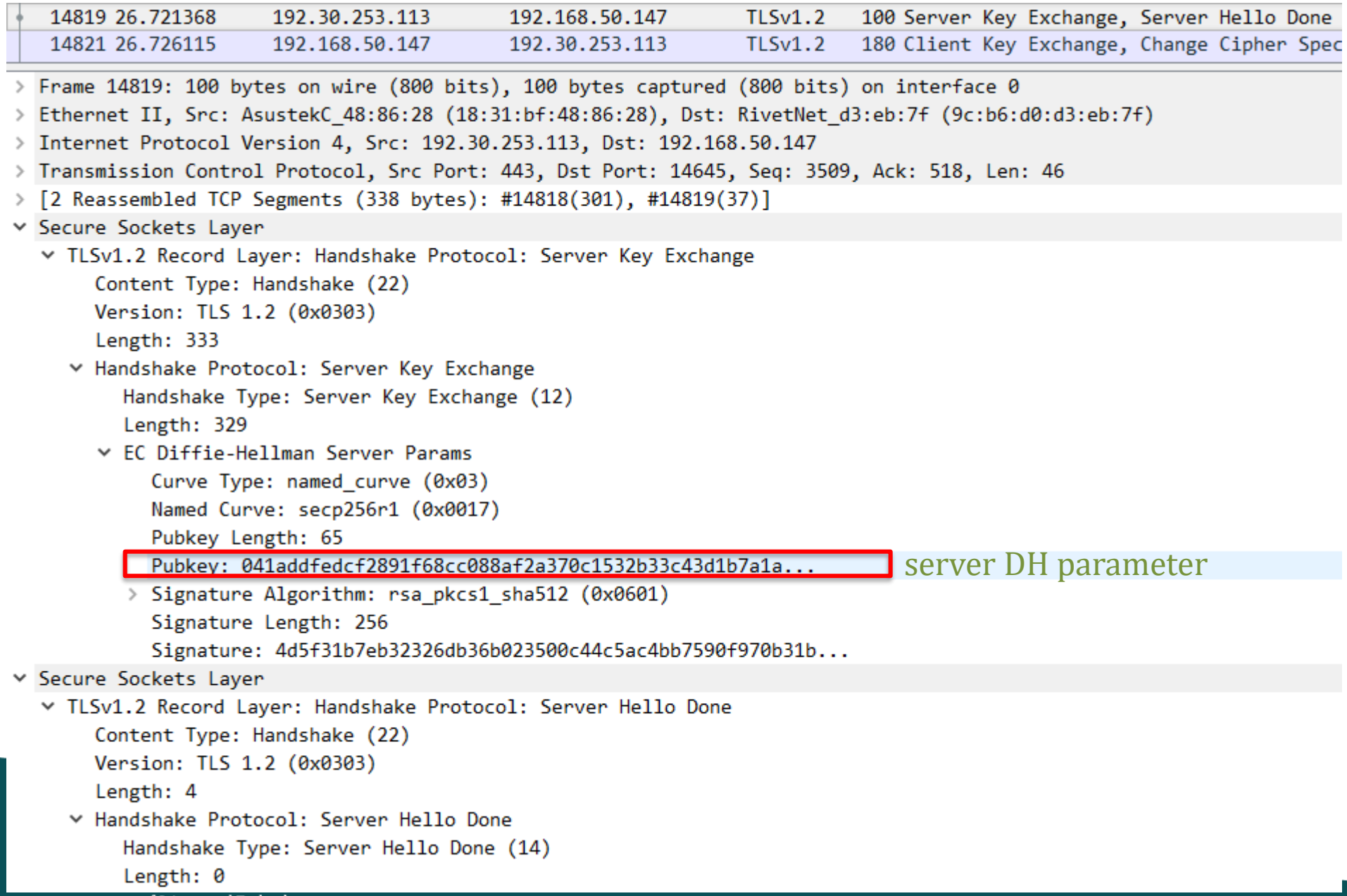
```
14815 26.709686    192.30.253.113    192.168.50.147    TLSv1.2   1514 Server Hello
14818 26.721227    192.30.253.113    192.168.50.147    TLSv1.2   1514 Certificate [TCP segment of a reassembled PDU]
```

```
> Frame 14815: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
> Ethernet II, Src: AsustekC_48:86:28 (18:31:bf:48:86:28), Dst: RivetNet_d3:eb:7f (9c:b6:d0:d3:eb:7f)
> Internet Protocol Version 4, Src: 192.30.253.113, Dst: 192.168.50.147
> Transmission Control Protocol, Src Port: 443, Dst Port: 14645, Seq: 1, Ack: 518, Len: 1460
v Secure Sockets Layer
  v TLSv1.2 Record Layer: Handshake Protocol: Server Hello
      Content Type: Handshake (22)
      Version: TLS 1.2 (0x0303)
      Length: 112
    v Handshake Protocol: Server Hello
        Handshake Type: Server Hello (2)
        Length: 108
        Version: TLS 1.2 (0x0303)
      > Random: 3ce162659fede832ec967eaee51df4904e922733980b0a2b...
        Session ID Length: 32
        Session ID: 66ed6a39d8a4fd9ada1769aac7a84376f7867fc6685fe48f...
        Cipher Suite: TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256 (0xc02f)
        Compression Method: null (0)
        Extensions Length: 36
      > Extension: renegotiation_info (len=1)
      > Extension: server_name (len=0)
      > Extension: ec_point_formats (len=4)
      > Extension: extended_master_secret (len=0)
      v Extension: application_layer_protocol_negotiation (len=11)
          Type: application_layer_protocol_negotiation (16)
          Length: 11
          ALPN Extension Length: 9
        v ALPN Protocol
            ALPN string length: 8
            ALPN Next Protocol: http/1.1
```

Server Random

```
14818 26.721227    192.30.253.113    192.168.50.147    TLSv1.2   1514 Certificate [TCP segment of a reassembled PDU]
14819 26.721368    192.30.253.113    192.168.50.147    TLSv1.2    100 Server Key Exchange, Server Hello Done
14821 26.726115    192.168.50.147    192.30.253.113    TLSv1.2    180 Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
```

```
> Frame 14818: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
> Ethernet II, Src: AsustekC_48:86:28 (18:31:bf:48:86:28), Dst: RivetNet_d3:eb:7f (9c:b6:d0:d3:eb:7f)
> Internet Protocol Version 4, Src: 192.30.253.113, Dst: 192.168.50.147
> Transmission Control Protocol, Src Port: 443, Dst Port: 14645, Seq: 2049, Ack: 518, Len: 1460
> [3 Reassembled TCP Segments (3090 bytes): #14815(1343), #14816(588), #14818(1159)]
v Secure Sockets Layer
  v TLSv1.2 Record Layer: Handshake Protocol: Certificate
      Content Type: Handshake (22)
      Version: TLS 1.2 (0x0303)
      Length: 3085
    v Handshake Protocol: Certificate
        Handshake Type: Certificate (11)
        Length: 3081
        Certificates Length: 3078
      v Certificates (3078 bytes)
          Certificate Length: 1862
        v Certificate: 308207423082062aa00302010202100a0630427f5bbced69... (id-at-commonName=github.com,id-at-organizationName=GitHub, Inc.,id-at-
          > signedCertificate
          > algorithmIdentifier (sha256WithRSAEncryption)
            Padding: 0
            encrypted: 700f5a96a758e5bf8a9da827982b007f26a907daba7b8254...
          Certificate Length: 1210
        v Certificate: 308204b63082039ea00302010202100c79a944b08c119520... (id-at-commonName=DigiCert SHA2 Extended Validation Server CA,id-at-org
          > signedCertificate
          > algorithmIdentifier (sha256WithRSAEncryption)
            Padding: 0
            encrypted: 9db6d09086e18602edc5a0f0341c74c18d76cc860aa8f04a...
```


14819 26.721368 192.30.253.113 192.168.50.147 TLSv1.2 100 Server Key Exchange, Server Hello Done
14821 26.726115 192.168.50.147 192.30.253.113 TLSv1.2 180 Client Key Exchange, Change Cipher Spec
Frame 14819: 100 bytes on wire (800 bits), 100 bytes captured (800 bits) on interface 0
Ethernet II, Src: AsustekC_48:86:28 (18:31:bf:48:86:28), Dst: RivetNet_d3:eb:7f (9c:b6:d0:d3:eb:7f)
Internet Protocol Version 4, Src: 192.30.253.113, Dst: 192.168.50.147
Transmission Control Protocol, Src Port: 443, Dst Port: 14645, Seq: 3509, Ack: 518, Len: 46
[2 Reassembled TCP Segments (338 bytes): #14818(301), #14819(37)]
Secure Sockets Layer
TLSv1.2 Record Layer: Handshake Protocol: Server Key Exchange
Content Type: Handshake (22)
Version: TLS 1.2 (0x0303)
Length: 333
Handshake Protocol: Server Key Exchange
Handshake Type: Server Key Exchange (12)
Length: 329
EC Diffie-Hellman Server Params
Curve Type: named_curve (0x03)
Named Curve: secp256r1 (0x0017)
Pubkey Length: 65
Pubkey: 041addfedcf2891f68cc088af2a370c1532b33c43d1b7a1a...
server DH parameter
Signature Algorithm: rsa_pkcs1_sha512 (0x0601)
Signature Length: 256
Signature: 4d5f31b7eb32326db36b023500c44c5ac4bb7590f970b31b...
Secure Sockets Layer
TLSv1.2 Record Layer: Handshake Protocol: Server Hello Done
Content Type: Handshake (22)
Version: TLS 1.2 (0x0303)
Length: 4
Handshake Protocol: Server Hello Done
Handshake Type: Server Hello Done (14)
Length: 0

```
14821 26.726115    192.168.50.147    192.30.253.113    TLSv1.2   180 Client Key Exchange, Change Cipher Spec, Encrypted Handshake Message
14829 26.821420    192.168.50.147    192.30.253.113    TLSv1.2   407 Application Data
14832 26.976118    192.30.253.113    192.168.50.147    TLSv1.2   105 Change Cipher Spec, Encrypted Handshake Message
14837 27.277675    192.30.253.113    192.168.50.147    TLSv1.2  1514 Application Data
```

```
> Frame 14821: 180 bytes on wire (1440 bits), 180 bytes captured (1440 bits) on interface 0
> Ethernet II, Src: RivetNet_d3:eb:7f (9c:b6:d0:d3:eb:7f), Dst: AsustekC_48:86:28 (18:31:bf:48:86:28)
> Internet Protocol Version 4, Src: 192.168.50.147, Dst: 192.30.253.113
> Transmission Control Protocol, Src Port: 14645, Dst Port: 443, Seq: 518, Ack: 3555, Len: 126
v Secure Sockets Layer
  v TLSv1.2 Record Layer: Handshake Protocol: Client Key Exchange
      Content Type: Handshake (22)
      Version: TLS 1.2 (0x0303)
      Length: 70
    v Handshake Protocol: Client Key Exchange
        Handshake Type: Client Key Exchange (16)
        Length: 66
      v EC Diffie-Hellman Client Params
          Pubkey Length: 65
          Pubkey: 042049f1720a9a9f5a2e357925528e547f75c1b9aa52af42...
  v TLSv1.2 Record Layer: Change Cipher Spec Protocol: Change Cipher Spec
      Content Type: Change Cipher Spec (20)
      Version: TLS 1.2 (0x0303)
      Length: 1
      Change Cipher Spec Message
  v TLSv1.2 Record Layer: Handshake Protocol: Encrypted Handshake Message
      Content Type: Handshake (22)
      Version: TLS 1.2 (0x0303)
      Length: 40
      Handshake Protocol: Encrypted Handshake Message
```

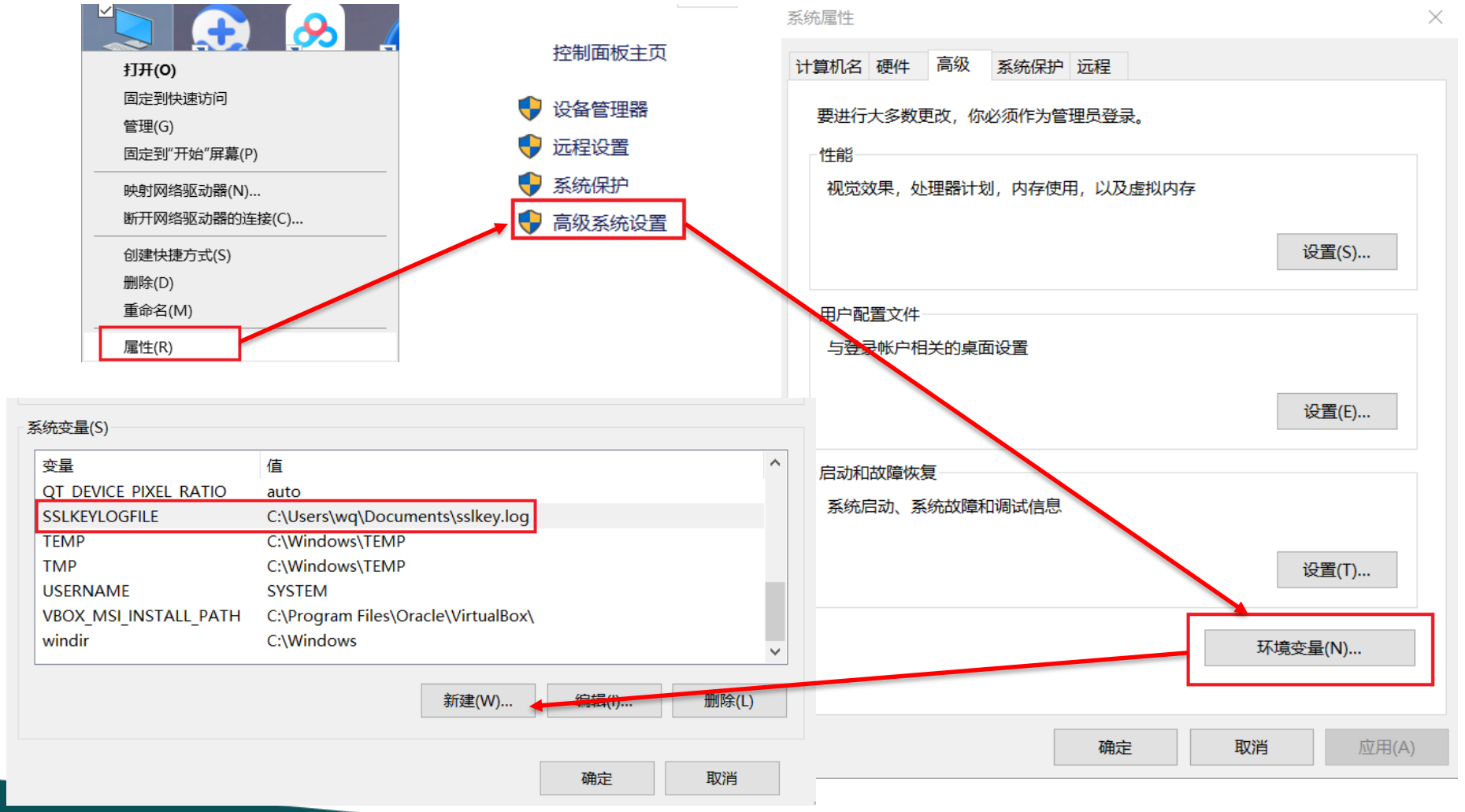
client DH parameter

```
0000  18 31 bf 48 86 28 9c b6  d0 d3 eb 7f 08 00 45 00   ·1·H·(·· ·····E·
0010  00 a6 32 97 40 00 80 06  16 ef c0 a8 32 93 c0 1e   ··2·@··· ····2···
0020  fd 71 39 35 01 bb c1 af  91 96 ce ef 49 b8 50 18   ·q95···· ····I·P·
0030  01 00 0d b2 00 00 16 03  03 00 46 10 00 00 42 41   ········ ··F···BA
0040  04 20 49 f1 72 0a 9a 9f  5a 2e 35 79 25 52 8e 54   · I·r··· Z.5y%R·T
0050  7f 75 c1 b9 aa 52 af 42  68 46 e2 b2 63 91 98 57   ·u···R·B hF··c··W
0060  a2 6d 18 d2 7b af f1 a1  92 bf 36 df ad 4b 2c 75   ·m··{··· ··6··K,u
0070  a2 53 22 63 96 db a9 b2  4a 42 fb e3 84 e2 6b 18   ·S"c···· JB····k·
0080  ff 14 03 03 00 01 01 16  03 03 00 28 00 00 00 00   ······ ··· ···(····
0090  00 00 00 00 3b 93 f4 27  ae 57 96 5f c2 be c2 0d   ····;·· ·W·_····
00a0  8e 82 11 74 e2 3d df 45  62 93 07 69 35 bb a0 6f   ···t·=·E b··i5··o
00b0  af ff cf 5b                                       ···[
```

Viewing Https plaintext using Wireshark (1)

- Using SSL log of browsers.
- Suitable for Chrome and Firefox browser.
- Configuration steps
  - 1. Set system environment variable on Windows
  - 2. Set Pre-master-secret log file on Wireshark

Set system environment variable on Windows



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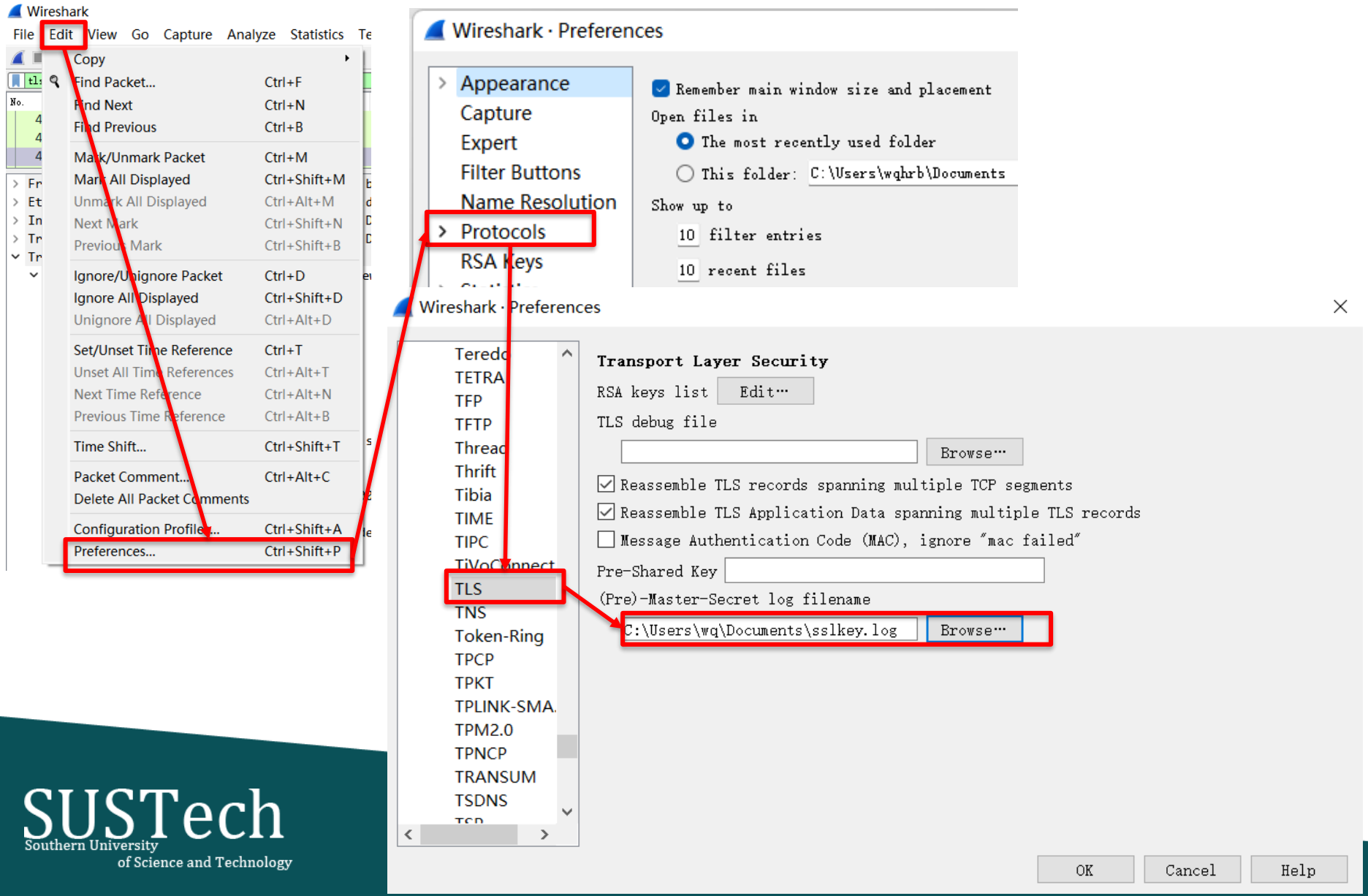
Set Pre-master-secret log file on Wireshark



Viewing Https plaintext using Wireshark (2)

tls && ip.addr == 172.18.1.3

No.	Time	Source	Destination	Protocol	Length	Info
454	5.820919	10.16.94.83	172.18.1.3	TLSv1.3	673	Client Hello
456	5.823842	172.18.1.3	10.16.94.83	TLSv1.3	308	Server Hello, Change Cipher Spec, Application Data, Application Data
457	5.824314	10.16.94.83	172.18.1.3	TLSv1.3	134	Change Cipher Spec, Application Data
458	5.824383	10.16.94.83	172.18.1.3	TLSv1.3	146	Application Data
459	5.824508	10.16.94.83	172.18.1.3	TLSv1.3	600	Application Data
461	5.827800	172.18.1.3	10.16.94.83	TLSv1.3	341	Application Data
462	5.827800	172.18.1.3	10.16.94.83	TLSv1.3	125	Application Data
464	5.827947	10.16.94.83	172.18.1.3	TLSv1.3	85	Application Data
465	5.841053	172.18.1.3	10.16.94.83	TLSv1.3	193	Application Data
496	6.074384	10.16.94.83	172.18.1.3	TLSv1.3	673	Client Hello
500	6.083003	172.18.1.3	10.16.94.83	TLSv1.3	308	Server Hello, Change Cipher Spec, Application Data, Application Data
501	6.083561	10.16.94.83	172.18.1.3	TLSv1.3	134	Change Cipher Spec, Application Data
502	6.089085	172.18.1.3	10.16.94.83	TLSv1.3	341	Application Data
503	6.089085	172.18.1.3	10.16.94.83	TLSv1.3	116	Application Data

tls && ip.addr == 172.18.1.3

No.	Time	Source	Destination	Protocol	Length	Info
454	5.820919	10.16.94.83	172.18.1.3	TLSv1.3	673	Client Hello
456	5.823842	172.18.1.3	10.16.94.83	TLSv1.3	308	Server Hello, Change Cipher Spec, Encrypted Extensions, Finished
457	5.824314	10.16.94.83	172.18.1.3	TLSv1.3	134	Change Cipher Spec, Finished
458	5.824383	10.16.94.83	172.18.1.3	HTTP2	146	Magic, SETTINGS[0], WINDOW_UPDATE[0]
459	5.824508	10.16.94.83	172.18.1.3	HTTP2	600	HEADERS[1]: GET //
461	5.827800	172.18.1.3	10.16.94.83	TLSv1.3	341	New Session Ticket
462	5.827800	172.18.1.3	10.16.94.83	HTTP2	125	SETTINGS[0], WINDOW_UPDATE[0], SETTINGS[0]
464	5.827947	10.16.94.83	172.18.1.3	HTTP2	85	SETTINGS[0]
465	5.841053	172.18.1.3	10.16.94.83	HTTP2	193	HEADERS[1]: 304 Not Modified
496	6.074384	10.16.94.83	172.18.1.3	TLSv1.3	673	Client Hello
500	6.083003	172.18.1.3	10.16.94.83	TLSv1.3	308	Server Hello, Change Cipher Spec, Encrypted Extensions, Finished
501	6.083561	10.16.94.83	172.18.1.3	TLSv1.3	134	Change Cipher Spec, Finished
502	6.089085	172.18.1.3	10.16.94.83	TLSv1.3	341	New Session Ticket
503	6.089085	172.18.1.3	10.16.94.83	HTTP2	116	SETTINGS[0], WINDOW_UPDATE[0]

```
458 5.824383    10.16.94.83    172.18.1.3    TLSv1.3    146 Application Data

> Frame 458: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface \Device\NPF_{6E621CDA-
> Ethernet II, Src: Dell_ab:05:ee (e4:54:e8:ab:05:ee), Dst: JuniperN_d0:93:c2 (3c:8c:93:d0:93:c2)
> Internet Protocol Version 4, Src: 10.16.94.83, Dst: 172.18.1.3
> Transmission Control Protocol, Src Port: 5864, Dst Port: 443, Seq: 700, Ack: 255, Len: 92
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: 87
      Encrypted Application Data: 6009fb231eaf33247375cda4746e3a6d0e36e88f36e2d4ba3050562318199b319f123d04…
      [Application Data Protocol: http-over-tls]
```

```
458 5.824383    10.16.94.83    172.18.1.3    HTTP2    146 Magic, SETTINGS[0], WINDOW_UP

> Frame 458: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface \Dev
> Ethernet II, Src: Dell_ab:05:ee (e4:54:e8:ab:05:ee), Dst: JuniperN_d0:93:c2 (3c:8c:93:d0:9
> Internet Protocol Version 4, Src: 10.16.94.83, Dst: 172.18.1.3
> Transmission Control Protocol, Src Port: 5864, Dst Port: 443, Seq: 700, Ack: 255, Len: 92
v Transport Layer Security
  v TLSv1.3 Record Layer: Application Data Protocol: http2
      Opaque Type: Application Data (23)
      Version: TLS 1.2 (0x0303)
      Length: 87
      [Content Type: Application Data (23)]
      Encrypted Application Data: 6009fb231eaf33247375cda4746e3a6d0e36e88f36e2d4ba305056231
      [Application Data Protocol: http2]
v HyperText Transfer Protocol 2
  v Stream: Magic
      Magic: PRI * HTTP/2.0\r\n\r\nSM\r\n\r\n
  v Stream: SETTINGS, Stream ID: 0, Length 24
      Length: 24
      Type: SETTINGS (4)
    > Flags: 0x00
      0... .... .... .... .... .... .... .... = Reserved: 0x0
      .000 0000 0000 0000 0000 0000 0000 0000 = Stream Identifier: 0
    > Settings - Header table size : 65536
    > Settings - Max concurrent streams : 1000
    > Settings - Initial Windows size : 6291456
    > Settings - Max header list size : 262144
  v Stream: WINDOW_UPDATE, Stream ID: 0, Length 4
      Length: 4
      Type: WINDOW_UPDATE (8)
    > Flags: 0x00
      0... .... .... .... .... .... .... .... = Reserved: 0x0
      .000 0000 0000 0000 0000 0000 0000 0000 = Stream Identifier: 0
      0... .... .... .... .... .... .... .... = Reserved: 0x0
      .000 0000 1110 1111 0000 0000 0000 0001 = Window Size Increment: 15663105
```

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```
459 5.824508    10.16.94.83    172.18.1.3      TLSv1.3    600 Application Data
```

```
> Frame 459: 600 bytes on wire (4800 bits), 600 bytes captured (4800 bits) on interface \Device\NPF_{6E621CDA-
> Ethernet II, Src: Dell_ab:05:ee (e4:54:e8:ab:05:ee), Dst: JuniperN_d0:93:c2 (3c:8c:93:d0:93:c2)
> Internet Protocol Version 4, Src: 10.16.94.83, Dst: 172.18.1.3
> Transmission Control Protocol, Src Port: 5864, Dst Port: 443, Seq: 792, Ack: 255, Len: 546
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: 541
      Encrypted Application Data: bdea1bfd80f323d8928e9ab971c170bcab88dfac7307785927789a602a93b2a237bf724c…
      [Application Data Protocol: http-over-tls]
```

```
459 5.824508    10.16.94.83    172.18.1.3      HTTP2      600 HEADERS[1]: GET //
```

```
> Transmission Control Protocol, Src Port: 5864, Dst Port: 443, Seq: 792, Ack: 255, Len: 546
v Transport Layer Security
  v TLSv1.3 Record Layer: Application Data Protocol: http2
      Opaque Type: Application Data (23)
      Version: TLS 1.2 (0x0303)
      Length: 541
      [Content Type: Application Data (23)]
      Encrypted Application Data: bdea1bfd80f323d8928e9ab971c170bcab88dfac7307785927789a602a93b2a237bf724c…
      [Application Data Protocol: http2]
v HyperText Transfer Protocol 2
  v Stream: HEADERS, Stream ID: 1, Length 515, GET //
      Length: 515
      Type: HEADERS (1)
    > Flags: 0x25, Priority, End Headers, End Stream
      0... .... .... .... .... .... .... .... = Reserved: 0x0
      .000 0000 0000 0000 0000 0000 0000 0001 = Stream Identifier: 1
      [Pad Length: 0]
      1... .... .... .... .... .... .... .... = Exclusive: True
      .000 0000 0000 0000 0000 0000 0000 0000 = Stream Dependency: 0
      Weight: 255
      [Weight real: 256]
      Header Block Fragment: 82418df1e3c2e8b50929275cb25ab92a8704022f2f40874148b1275ad1ffb8fe54d274a9…
      [Header Length: 876]
      [Header Count: 19]
    > Header: :method: GET
    > Header: :authority: www.sustech.edu.cn
    > Header: :scheme: https
    > Header: :path: //
    > Header: sec-ch-ua: " Not A;Brand";v="99", "Chromium";v="98", "Google Chrome";v="98"
    > Header: sec-ch-ua-mobile: ?0
    > Header: sec-ch-ua-platform: "Windows"
    > Header: upgrade-insecure-requests: 1
    > Header: user-agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chr
    > Header: accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*
    > Header: sec-fetch-site: none
    > Header: sec-fetch-mode: navigate
    > Header: sec-fetch-user: ?1
    > Header: sec-fetch-dest: document
    > Header: accept-encoding: gzip, deflate, br
```

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```
461 5.827800    172.18.1.3     10.16.94.83     TLSv1.3    341 New Session Ticket
```

```
> Frame 461: 341 bytes on wire (2728 bits), 341 bytes captured (2728 bits) on interface \Device\NPF_{6E621
> Ethernet II, Src: JuniperN_d0:93:c2 (3c:8c:93:d0:93:c2), Dst: Dell_ab:05:ee (e4:54:e8:ab:05:ee)
> Internet Protocol Version 4, Src: 172.18.1.3, Dst: 10.16.94.83
> Transmission Control Protocol, Src Port: 443, Dst Port: 5864, Seq: 255, Ack: 1338, Len: 287
v Transport Layer Security
  v TLSv1.3 Record Layer: Handshake Protocol: New Session Ticket
      Opaque Type: Application Data (23)
      Version: TLS 1.2 (0x0303)
      Length: 282
      [Content Type: Handshake (22)]
    v Handshake Protocol: New Session Ticket
        Handshake Type: New Session Ticket (4)
        Length: 261
      v TLS Session Ticket
          Session Ticket Lifetime Hint: 86400 seconds (1 day)
          Session Ticket Age Add: 1504948360
          Session Ticket Nonce Length: 8
          Session Ticket Nonce: 0000000000000000
          Session Ticket Length: 240
          Session Ticket: 74047c64162dba6ed1fded9e6cd540eef39e8495ec3dbdccfabee2cea22517e7de46318f…
          Extensions Length: 0
```

```
461 5.827800    172.18.1.3     10.16.94.83     TLSv1.3    341 Application Data
```

```
> Frame 461: 341 bytes on wire (2728 bits), 341 bytes captured (2728 bits) on interface \Device\NPF_{6E621CDA-9
> Ethernet II, Src: JuniperN_d0:93:c2 (3c:8c:93:d0:93:c2), Dst: Dell_ab:05:ee (e4:54:e8:ab:05:ee)
> Internet Protocol Version 4, Src: 172.18.1.3, Dst: 10.16.94.83
> Transmission Control Protocol, Src Port: 443, Dst Port: 5864, Seq: 255, Ack: 1338, Len: 287
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: 282
      Encrypted Application Data: d9033c1acd2aea6fd9fa83eaaafe86ffb6fb281091489d17fc3ac1e56d089173bb64c805…
      [Application Data Protocol: http-over-tls]
```

Practice 7.1

7.1 Select one UDP packet from your trace. From this packet,

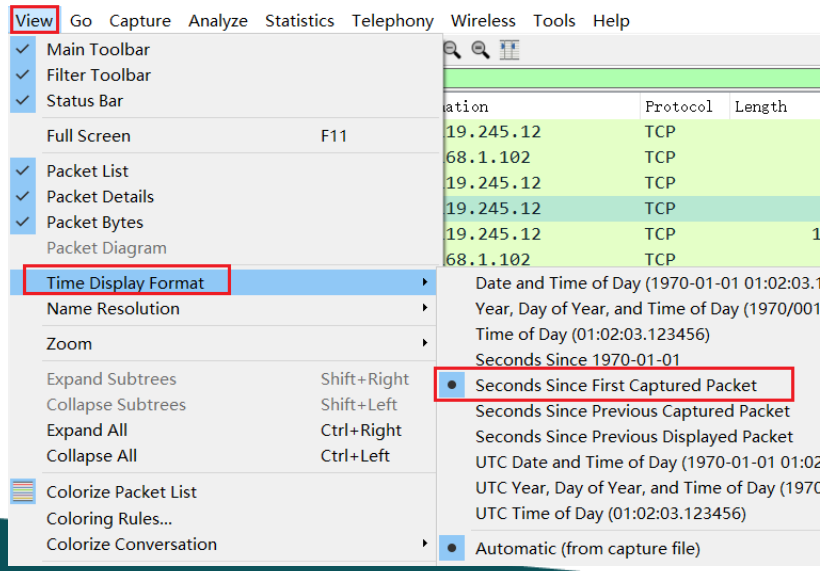
- determine
  - Q1) how many fields are there in the UDP header.
  - Q2) what are the name and value of each field in the UDP header.
  - Q3) the length (in bytes) of each fields in the UDP header.
  - Q4) What is the maximum number of bytes of a UDP packet ? (Hint: the answer can be determined by your answer to Q3 above)
  - Q5) What is the largest possible destination port number? (Hint: same as the hint in Q4 above.)
  - Q6) What is the protocol ID for UDP in IP protocol?(Give your answer in both hexadecimal and decimal notation.)

Practice 7.2

- Finish the question 4, 5, 6, 7, 9, 10, 12 of Wireshark_TCP_v8.0.pdf
- Tips: To calculate the throughput for the TCP connection, we can use following formula:

  Throughput (Bytes/s) = Total data(Bytes) / Total time(s)

- Tips: It's convenient to use "seconds since first captured packet" time format.



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