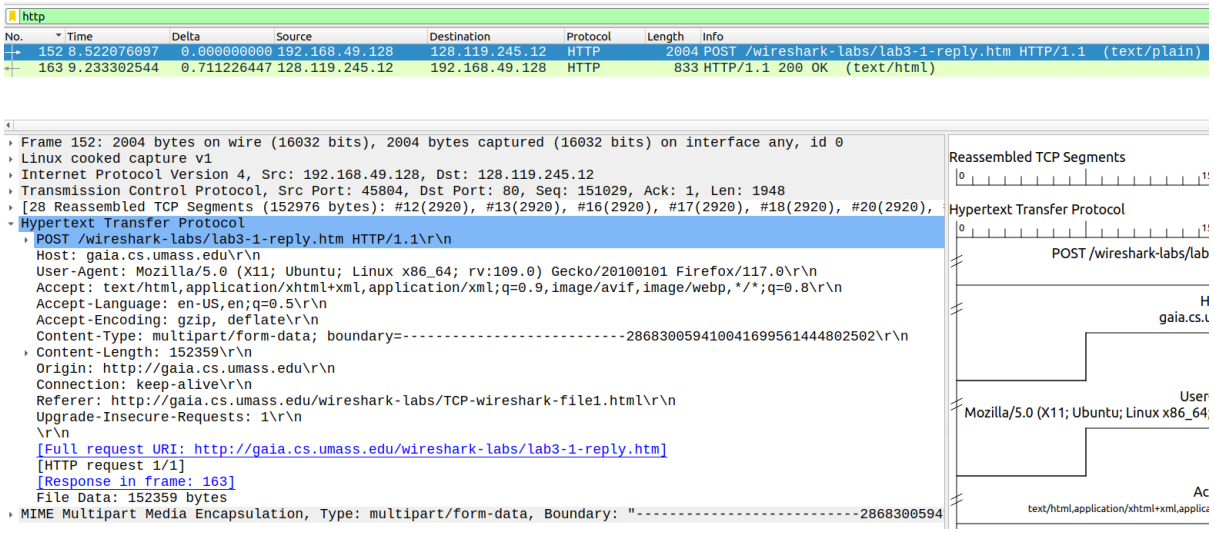
Assignment 3: Wireshark with TCP
PART - A

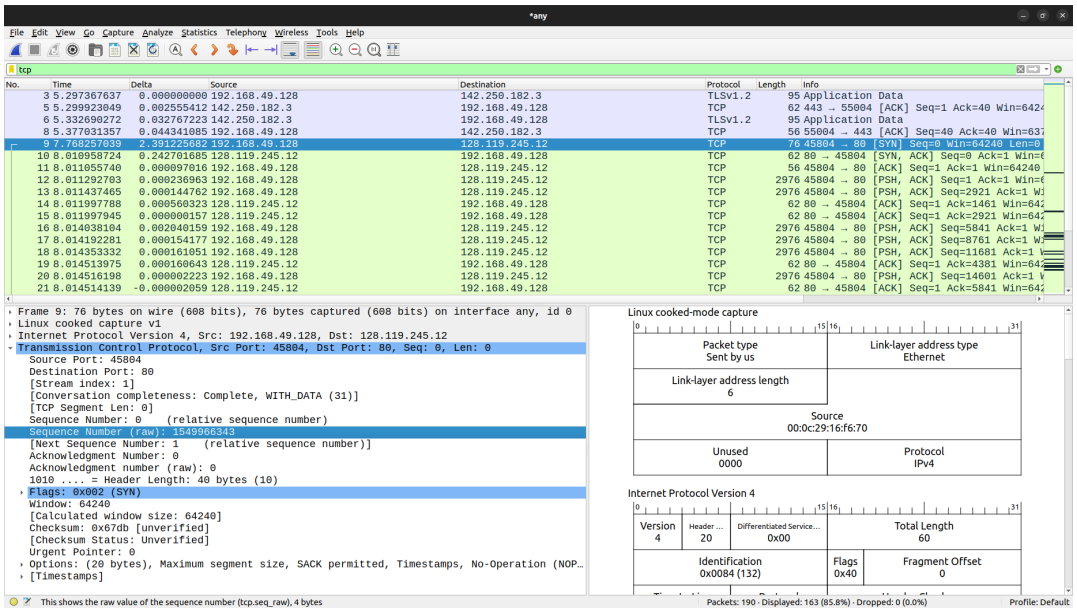
1. IP address - 192.168.49.128
TCP port number - 45804

2. IP address of gaia.cs.umass.edu - 128.119.245.12
port number used for sending and receiving the TCP segments for this connection - 80

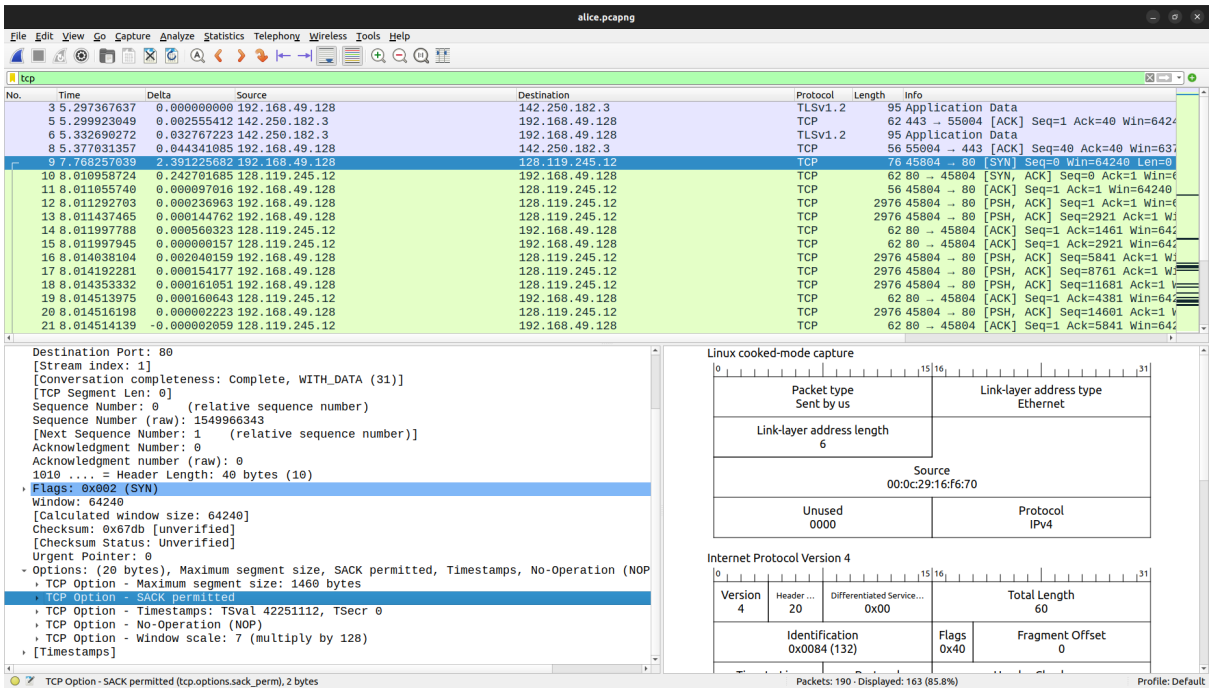


Reference image for question 1 and 2

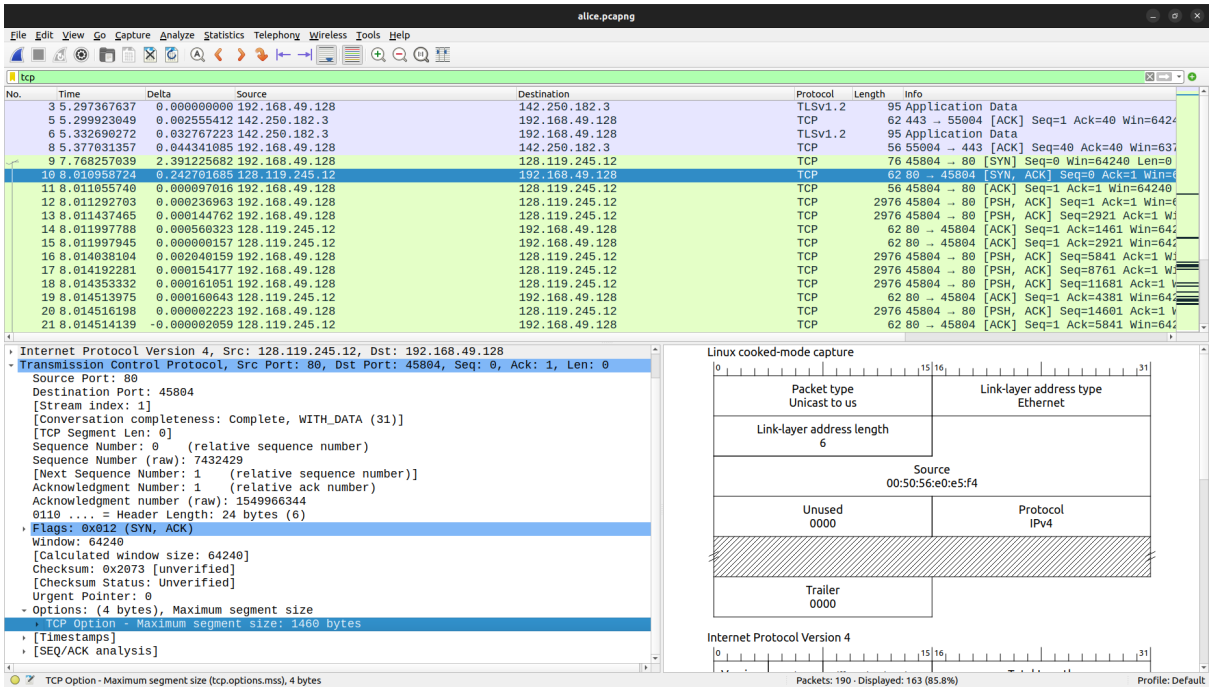
3. Sequence number of the TCP SYN segment that is used to initiate the TCP connection between the client computer and gaia.cs.umass.edu - 1549966343



- The SYN flag bit is set to 1 in the TCP segment which identifies the segment as a SYN segment
- No, the TCP receiver in this session will not be able to use Selective Acknowledgements (SACK) because it did not acknowledge support for the SACK option during the TCP handshake.



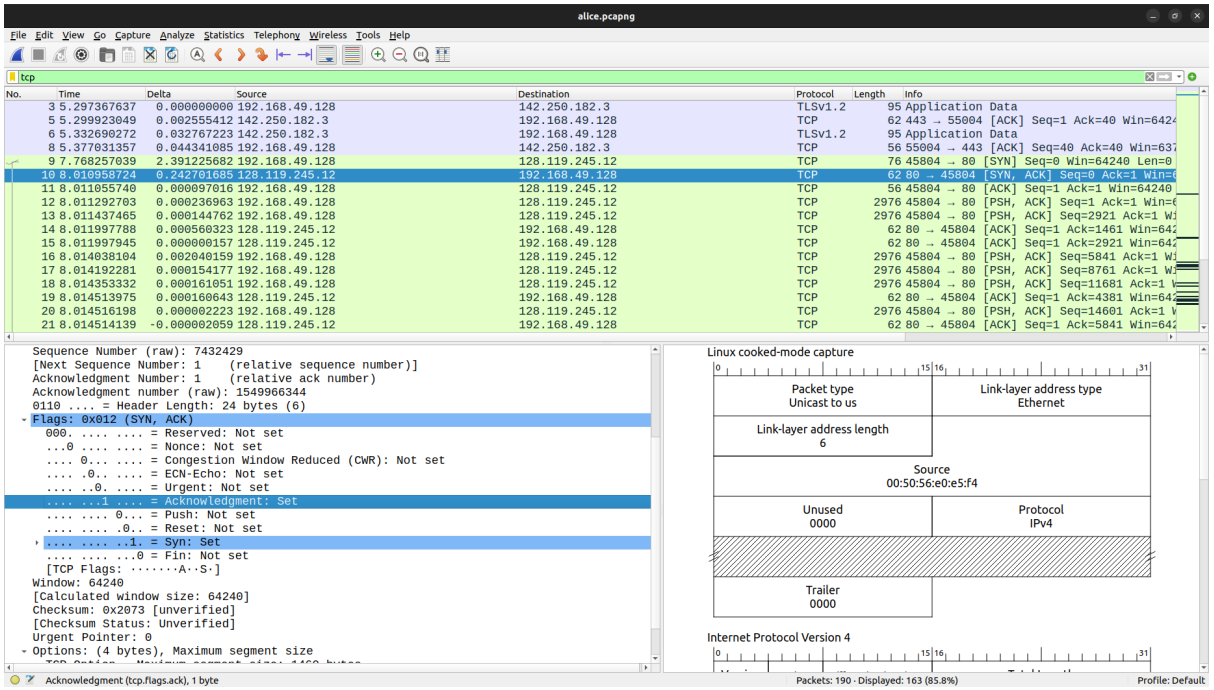
SACK permitted on sender side



SACK not permitted by the receiver

4. sequence number of the SYNACK segment sent by gaia.cs.umass.edu - 7432429

- The flag bits of SYN and ACK in the TCP segment identifies that this segment is SYNACK segment



SYN and ACK flag bits set to 1

- Value of the Acknowledgement field in the SYNACK segment - 1549966344
- The gaia.cs.umass.edu determine that value as below

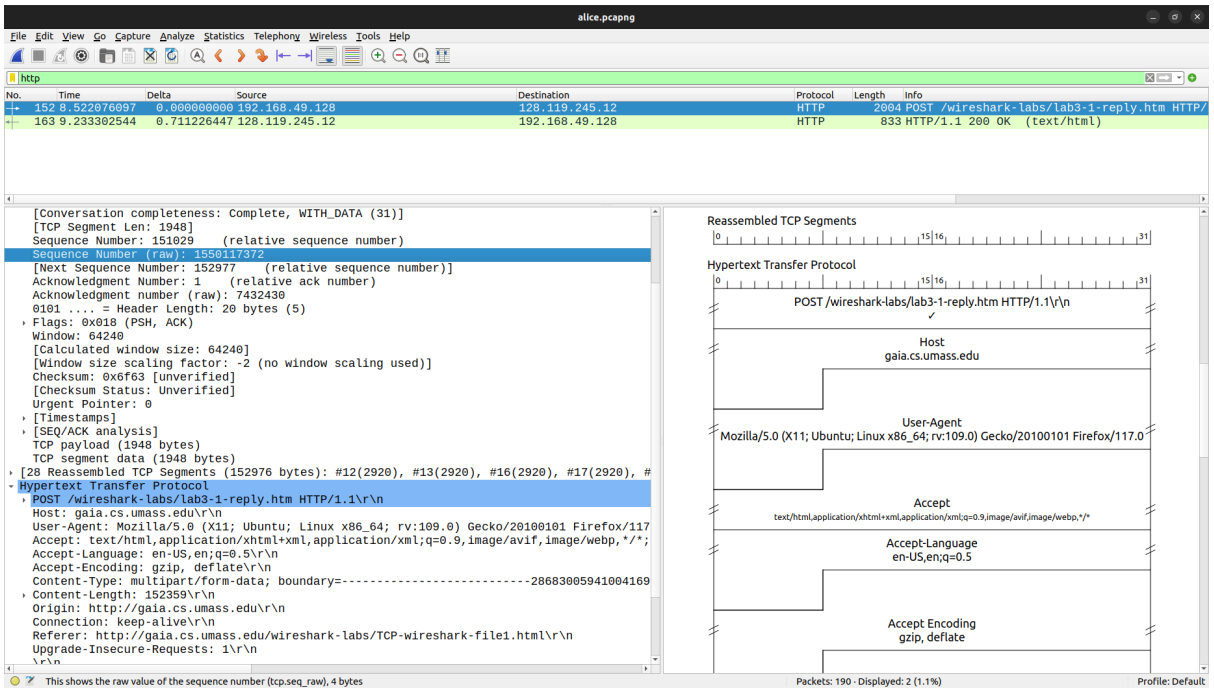
  Acknowledgment Number = Client's Initial Sequence Number + 1

  = 1549966343 + 1

  = 1549966344

  "+1" indicates that the gaia.cs.umass.edu is acknowledging the client's SYN segment and gaia.cs.umass.edu is expecting the next sequence number to be one greater than the client's initial sequence number.

5. The sequence number of the TCP segment containing the header of the HTTP POST command - 1550117372



- 1948 bytes of data are contained in the payload (data) field of this TCP segment.
- The data in the transferred file alice.txt does not fit into this single segment. It is getting segmented by the client computer (source) and then transmitted to the gaia.cs.umass.edu

6.

- Timestamp for TCP SYN packet - 7.768257039
  Timestamp for 1st TCP segment as part of data transfer - 8.011292703
  Therefore the time taken to send the 1st TCP segment as part of data transfer is **0.243035664**

9	7.768257039	2.391225682	192.168.49.128	128.119.245.12	TCP	76	45804 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
10	8.010958724	0.242701685	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
11	8.011055740	0.000097016	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
12	8.011292703	0.000236963	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2920 [TCP se
13	8.011437465	0.000144762	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Len=2920 [TCP

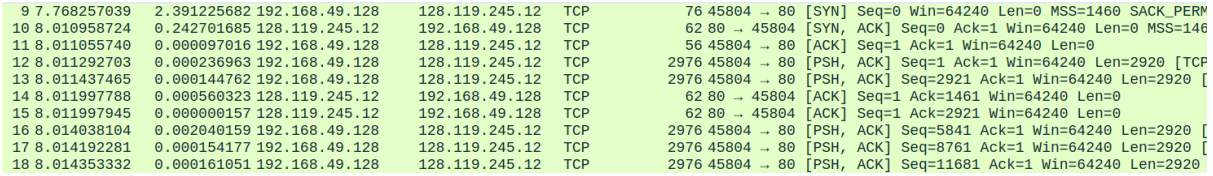
- The gaia.cs.umass.edu is sending ACK's in fragments like for 1st TCP segment the gaia.cs.umass.edu has sent 2 ACK's one for each half of the segment.
  Timestamp for 1st half ACK - 8.011997788
  Timestamp for 2nd half ACK - 8.011997945

11	8.011055740	0.000097016	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
12	8.011292703	0.000236963	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2920 [TC
13	8.011437465	0.000144762	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Len=2920
14	8.011997788	0.000560323	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=1461 Win=64240 Len=0
15	8.011997945	0.000000157	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=2921 Win=64240 Len=0

- RTT for this first data-containing segment is **0.000705242** seconds. RTT value of the second data-carrying TCP segment and its ACK is **0.003076674** seconds.

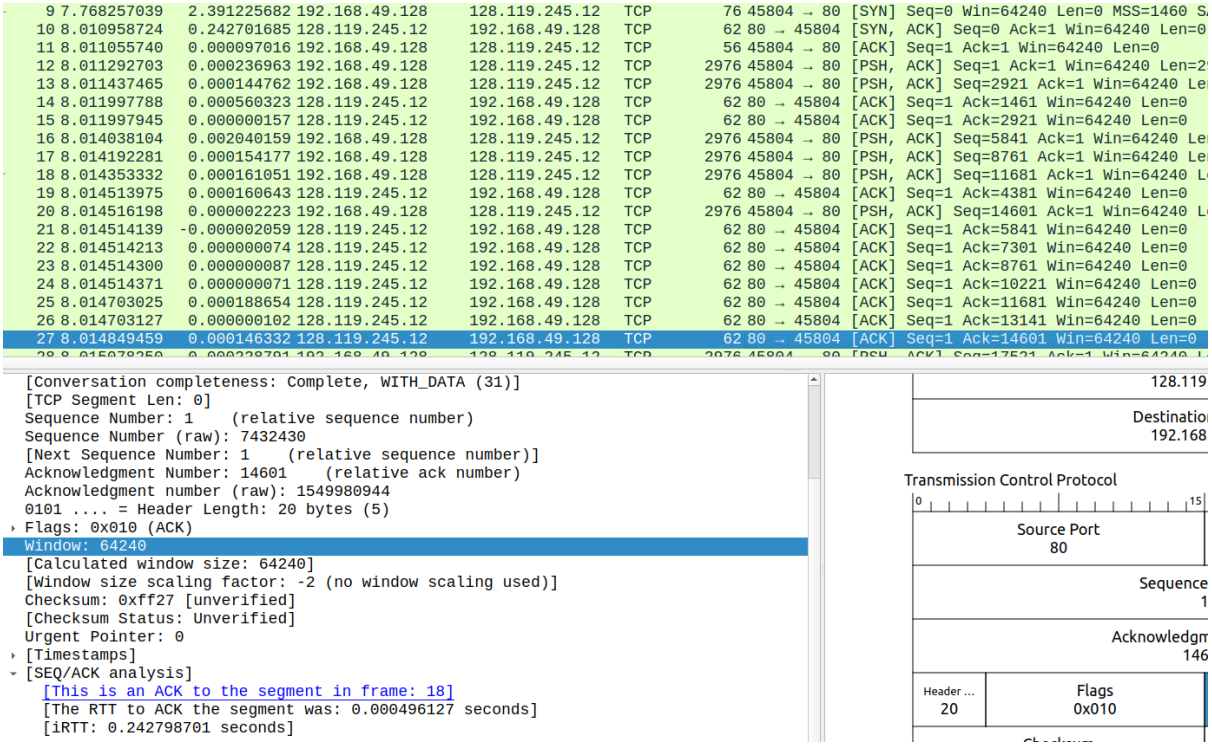
- Estimated RTT after the ACK for the second data-carrying segment is received is **0.001001671** seconds

7. length (header plus payload) of each of the first four data-carrying TCP segments are **2976, 2976, 2976, 2976** respectively.



9	7.768257039	2.391225682	192.168.49.128	128.119.245.12	TCP	76	45804 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM
10	8.010958724	0.242701685	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=146
11	8.011055740	0.000097016	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
12	8.011292703	0.000236963	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2920 [TCP
13	8.011437465	0.000144762	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Len=2920 [
14	8.011997788	0.000560323	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=1461 Win=64240 Len=0
15	8.011997945	0.000000157	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=2921 Win=64240 Len=0
16	8.014038104	0.002040159	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=5841 Ack=1 Win=64240 Len=2920 [
17	8.014192281	0.000154177	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=8761 Ack=1 Win=64240 Len=2920 [
18	8.014353332	0.000161051	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=11681 Ack=1 Win=64240 Len=2920

8. The minimum amount of available buffer space advertised to the client by gaia.cs.umass.edu among these first five data-carrying TCP segments is **64240 bytes.**



9	7.768257039	2.391225682	192.168.49.128	128.119.245.12	TCP	76	45804 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 S
10	8.010958724	0.242701685	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
11	8.011055740	0.000097016	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
12	8.011292703	0.000236963	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2
13	8.011437465	0.000144762	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Le
14	8.011997788	0.000560323	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=1461 Win=64240 Len=0
15	8.011997945	0.000000157	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=2921 Win=64240 Len=0
16	8.014038104	0.002040159	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=5841 Ack=1 Win=64240 Le
17	8.014192281	0.000154177	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=8761 Ack=1 Win=64240 Le
18	8.014353332	0.000161051	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=11681 Ack=1 Win=64240 L
19	8.014513975	0.000160643	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=4381 Win=64240 Len=0
20	8.014516198	0.000002223	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=14601 Ack=1 Win=64240 L
21	8.014514139	-0.000002059	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=5841 Win=64240 Len=0
22	8.014514213	0.000000074	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=7301 Win=64240 Len=0
23	8.014514300	0.000000087	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=8761 Win=64240 Len=0
24	8.014514371	0.000000071	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=10221 Win=64240 Len=0
25	8.014703025	0.000188654	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=11681 Win=64240 Len=0
26	8.014703127	0.000000102	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=13141 Win=64240 Len=0
27	8.014849459	0.000146332	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=14601 Win=64240 Len=0

```
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 0]
Sequence Number: 1    (relative sequence number)
Sequence Number (raw): 7432430
[Next Sequence Number: 1    (relative sequence number)]
Acknowledgment Number: 14601    (relative ack number)
Acknowledgment number (raw): 1549980944
0101 .... = Header Length: 20 bytes (5)
▸ Flags: 0x010 (ACK)
  Window: 64240
[Calculated window size: 64240]
[Window size scaling factor: -2 (no window scaling used)]
Checksum: 0xff27 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
▸ [Timestamps]
▾ [SEQ/ACK analysis]
    [This is an ACK to the segment in frame: 18]
    [The RTT to ACK the segment was: 0.000496127 seconds]
    [iRTT: 0.242798701 seconds]
```

```
128.119
Destinatio
192.168
Transmission Control Protocol
0 ... 15
Source Port
80
Sequence
1
Acknowledgm
146
Header ...
20
Flags
0x010
```

- No, for the first five segments the window size did not throttle the sender. But further looking this session the window size is throttling the sender as the sender is sending more and more segments (may be some of the segments are of different size)

```
119 8.018003937   0.000000074 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=126209 Win=4380 Len=0
120 8.018003999   0.000000062 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=127669 Win=2920 Len=0
121 8.018171466   0.000167467 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=129129 Win=1460 Len=0
122 8.018171567   0.000000101 128.119.245.12   192.168.49.128   TCP      62 [TCP ZeroWindow] 80 → 45804 [ACK] Seq=1 Ack=130589 Win=0
123 8.258954245   0.240782678 128.119.245.12   192.168.49.128   TCP      62 [TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=130589 Wi
124 8.258991471   0.000037226 192.168.49.128   128.119.245.12   TCP    1516 [TCP Window Full] 45804 → 80 [ACK] Seq=130589 Ack=1 Win=
125 8.259442054   0.000450583 128.119.245.12   192.168.49.128   TCP      62 [TCP ZeroWindow] 80 → 45804 [ACK] Seq=1 Ack=132049 Win=0
126 8.259582936   0.000140882 128.119.245.12   192.168.49.128   TCP      62 [TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=132049 Wi
127 8.259594931   0.000011995 192.168.49.128   128.119.245.12   TCP   10276 [TCP Window Full] 45804 → 80 [PSH, ACK] Seq=132049 Ack=1
128 8.259772447   0.000177516 128.119.245.12   192.168.49.128   TCP      62 [TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=132049 Wi
```

9. The minimum amount of available buffer space advertised by the client to gaia.cs.umass.edu is **64240 bytes.**

10. Yes, there were 2 retransmitted segments in the trace file form gaia.cs.umass.edu to client (source)

- Just by looking through the sequence number of all the segments that are transmitted. Retransmitted segments will have the same sequence number as a previously sent segment. (also we can directly see in the trace file above the TCP duplicate ACK)

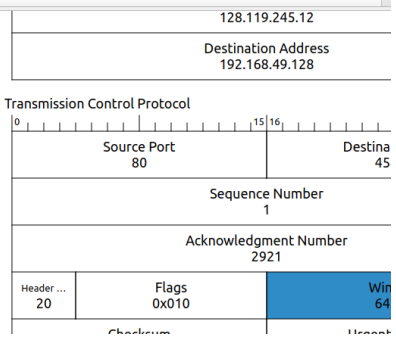
```
75 8.017383822   0.000000064 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=66349 Win=64240 Len=0
76 8.017383884   0.000000062 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=67809 Win=62780 Len=0
77 8.017383946   0.000000062 128.119.245.12   192.168.49.128   TCP      62 [TCP Dup ACK 76#1] 80 → 45804 [ACK] Seq=1 Ack=67809 Win=62780 Len=0
78 8.017384031   0.000000085 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=69269 Win=61320 Len=0
79 8.017384107   0.000000076 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=70729 Win=59860 Len=0

144 8.512685275   0.000000278 128.119.245.12   192.168.49.128   TCP      62 [TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=146649 Win=2920 Len=0
145 8.512685354   0.000000079 128.119.245.12   192.168.49.128   TCP      62 [TCP Dup ACK 143#1] 80 → 45804 [ACK] Seq=1 Ack=146649 Win=2920 Len=0
146 8.512685414   0.000000060 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=148109 Win=1460 Len=0
147 8.512727846   0.000042432 192.168.49.128   128.119.245.12   TCP    1516 [TCP Window Full] 45804 → 80 [ACK] Seq=148109 Ack=1 Win=64240 Len=1460
148 8.513410561   0.000682715 128.119.245.12   192.168.49.128   TCP      62 [TCP ZeroWindow] 80 → 45804 [ACK] Seq=1 Ack=149569 Win=0 Len=0
```

11. For the first 10 TCP segments the receiver is acknowledging the 2 ACK for each segment. Hence, total ACK's for the first 10 TCP segments is **20**.

- Here in first 10 segments the size of 1 segment sent by the client (source) is 2920 and gaia.cs.umass.edu is acknowledging 2 ACK's (each of size 1460) for this segment (we can check this in the segment frame 12)

```
  9 7.768257039   2.391225682 192.168.49.128   128.119.245.12   TCP      76 45804 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1 TSva
 10 8.010958724   0.242701685 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
 11 8.011055740   0.000097016 192.168.49.128   128.119.245.12   TCP      56 45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
 12 8.011292703   0.000236963 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2920 [TCP segmen
 13 8.011437465   0.000144762 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Len=2920 [TCP seg
 14 8.011997788   0.000560323 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=1461 Win=64240 Len=0
 15 8.011997945   0.000000157 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=2921 Win=64240 Len=0
 16 8.014038104   0.002040159 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=5841 Ack=1 Win=64240 Len=2920 [TCP seg
 17 8.014192281   0.000154177 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=8761 Ack=1 Win=64240 Len=2920 [TCP seg
 18 8.014353332   0.000161051 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=11681 Ack=1 Win=64240 Len=2920 [TCP se
 19 8.014513975   0.000160643 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=4381 Win=64240 Len=0
 20 8.014516198   0.000002223 192.168.49.128   128.119.245.12   TCP    2976 45804 → 80 [PSH, ACK] Seq=14601 Ack=1 Win=64240 Len=2920 [TCP se
 21 8.014514139  -0.000002059 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=5841 Win=64240 Len=0
 22 8.014514213   0.000000074 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=7301 Win=64240 Len=0
 23 8.014514300   0.000000087 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=8761 Win=64240 Len=0
 24 8.014514371   0.000000071 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=10221 Win=64240 Len=0
 25 8.014703025   0.000188654 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=11681 Win=64240 Len=0
 26 8.014703127   0.000000102 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=13141 Win=64240 Len=0
 27 8.014849459   0.000146332 128.119.245.12   192.168.49.128   TCP      62 80 → 45804 [ACK] Seq=1 Ack=14601 Win=64240 Len=0
```

```
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 0]
Sequence Number: 1    (relative sequence number)
Sequence Number (raw): 7432430
[Next Sequence Number: 1    (relative sequence number)]
Acknowledgment Number: 2921    (relative ack number)
Acknowledgment number (raw): 1549969264
0101 .... = Header Length: 20 bytes (5)
▸ Flags: 0x010 (ACK)
Window: 64240
[Calculated window size: 64240]
[Window size scaling factor: -2 (no window scaling used)]
Checksum: 0x2cc8 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
▸ [Timestamps]
▾ [SEQ/ACK analysis]
  [This is an ACK to the segment in frame: 12]
  [The RTT to ACK the segment was: 0.000705242 seconds]
  [iRTT: 0.242798701 seconds]
```



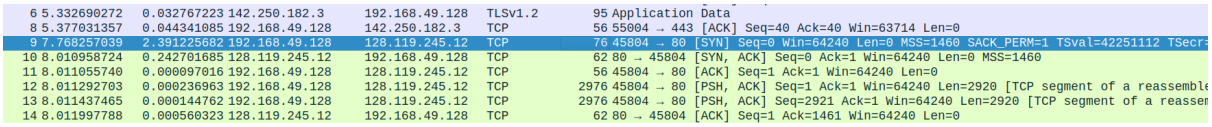
12. A - 7.768257039 seconds (connection establishment request)

B - 14.235433762 seconds (closing connection)

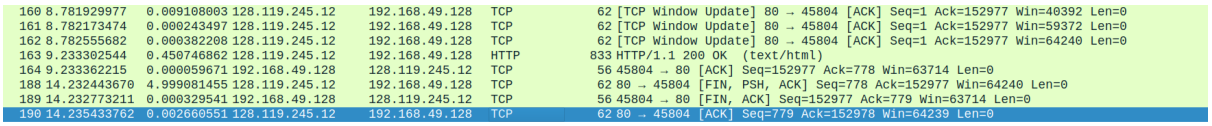
Throughput = Total File size / (B-A)

= 152976 / 6.467176723

= **23654.216755196 bytes / second**



6	5.332690272	0.032767223	142.250.182.3	192.168.49.128	TLSv1.2	95	Application Data
8	5.377031357	0.044341085	192.168.49.128	142.250.182.3	TCP	56	55004 → 443 [ACK] Seq=40 Ack=40 Win=63714 Len=0
9	7.768257039	2.391225682	192.168.49.128	128.119.245.12	TCP	76	45804 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1 TSval=42251112 TSecr=
10	8.010958724	0.242701685	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
11	8.011055740	0.000097016	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
12	8.011292703	0.000236963	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=1 Ack=1 Win=64240 Len=2920 [TCP segment of a reassemble
13	8.011437465	0.000144762	192.168.49.128	128.119.245.12	TCP	2976	45804 → 80 [PSH, ACK] Seq=2921 Ack=1 Win=64240 Len=2920 [TCP segment of a reassem
14	8.011997788	0.000560323	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=1 Ack=1461 Win=64240 Len=0

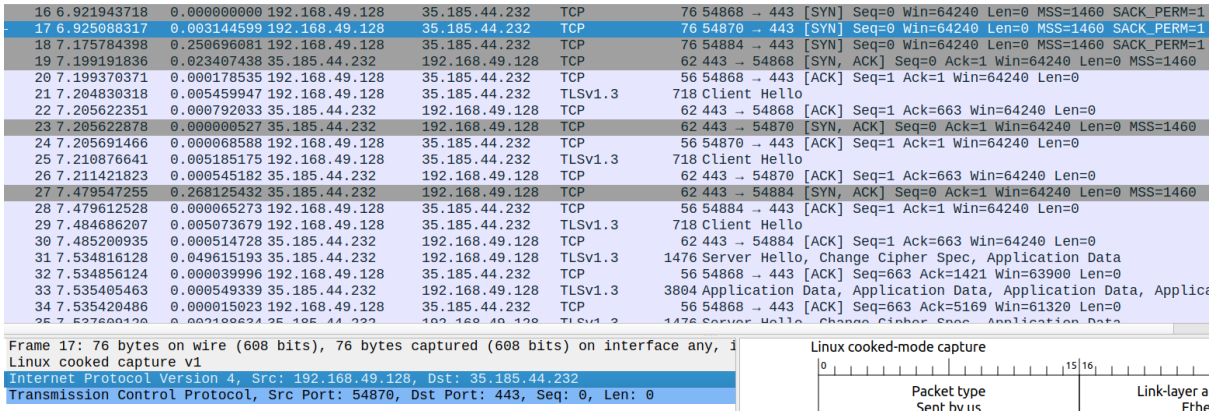


160	8.781929977	0.009108003	128.119.245.12	192.168.49.128	TCP	62	[TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=152977 Win=40392 Len=0
161	8.782173474	0.000243497	128.119.245.12	192.168.49.128	TCP	62	[TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=152977 Win=59372 Len=0
162	8.782555682	0.000382208	128.119.245.12	192.168.49.128	TCP	62	[TCP Window Update] 80 → 45804 [ACK] Seq=1 Ack=152977 Win=64240 Len=0
163	9.233302544	0.450746862	128.119.245.12	192.168.49.128	HTTP	833	HTTP/1.1 200 OK (text/html)
164	9.233362215	0.000059671	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [ACK] Seq=152977 Ack=778 Win=63714 Len=0
188	14.232443670	4.999081455	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [FIN, PSH, ACK] Seq=778 Ack=152977 Win=64240 Len=0
189	14.232773211	0.000329541	192.168.49.128	128.119.245.12	TCP	56	45804 → 80 [FIN, ACK] Seq=152977 Ack=779 Win=63714 Len=0
190	14.235433762	0.002660551	128.119.245.12	192.168.49.128	TCP	62	80 → 45804 [ACK] Seq=779 Ack=152978 Win=64239 Len=0

PART - B

1. IP address and TCP port number used by the client computer are **192.168.49.128** and **54868** respectively.

2. IP address and TCP port number used by the https://cse.iith.ac.in/ are **35.185.44.232** and **443** respectively.

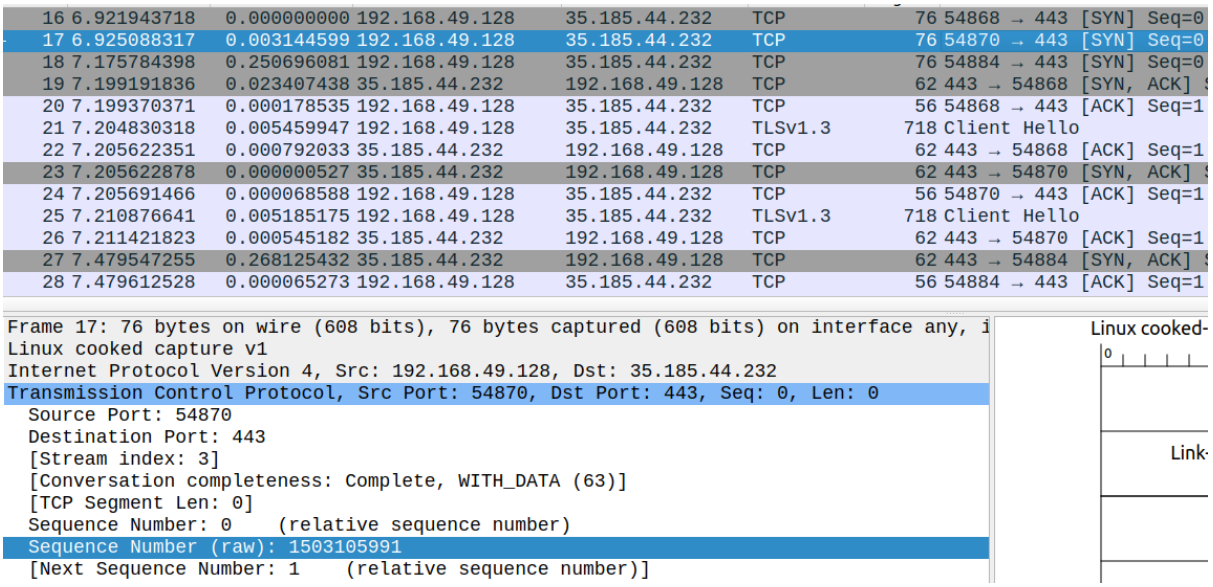


Reference image for Q1 & Q2

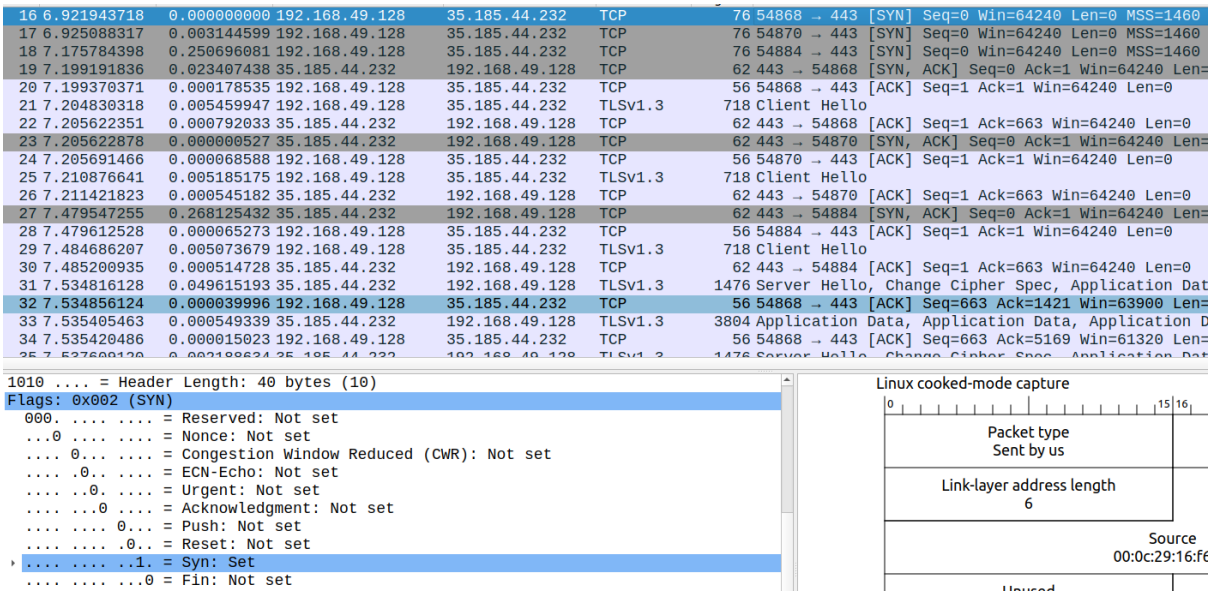
3. Total 3 connection establishment requests are sent to https://cse.iith.ac.in/ form source (client computer) and for those the sequence numbers are given as below.
   1st - 1972446035
   2nd - **1503105991**
   3rd - 2270850410
   But looking forward in the trace file the 1st and 3rd connection are closed.

16	6.921943718	0.000000000	192.168.49.128	35.185.44.232	TCP	76 54868 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
17	6.925088317	0.003144599	192.168.49.128	35.185.44.232	TCP	76 54870 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
18	7.175784398	0.250696081	192.168.49.128	35.185.44.232	TCP	76 54884 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
19	7.199191836	0.023407438	35.185.44.232	192.168.49.128	TCP	62 443 → 54868 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
20	7.199370371	0.000178535	192.168.49.128	35.185.44.232	TCP	56 54868 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
21	7.204830318	0.005459947	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
22	7.205622351	0.000792033	35.185.44.232	192.168.49.128	TCP	62 443 → 54868 [ACK] Seq=1 Ack=663 Win=64240 Len=0
23	7.205622878	0.000000527	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
24	7.205691466	0.000068588	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
25	7.210876641	0.005185175	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
26	7.211421823	0.000545182	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1 Ack=663 Win=64240 Len=0
27	7.479547255	0.268125432	35.185.44.232	192.168.49.128	TCP	62 443 → 54884 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
28	7.479612528	0.000065273	192.168.49.128	35.185.44.232	TCP	56 54884 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
29	7.484686207	0.005073679	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello

92	7.817901679	0.000206947	35.185.44.232	192.168.49.128	TCP	62 443 → 54884 [ACK] Seq=5169 Ack=939 Win=64239 Len=0
93	7.878064296	0.060162617	35.185.44.232	192.168.49.128	TLSv1.3	117 Application Data
94	7.878093559	0.000029263	192.168.49.128	35.185.44.232	TCP	56 54868 → 443 [RST] Seq=939 Win=0 Len=0
95	7.881427290	0.003333731	35.185.44.232	192.168.49.128	TLSv1.3	117 Application Data
96	7.881520432	0.000093142	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1285 Ack=5230 Win=62780 Len=0
97	7.881756848	0.000236416	192.168.49.128	35.185.44.232	TLSv1.3	87 Application Data
98	7.882024810	0.000267962	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=5230 Ack=1316 Win=64240 Len=0
99	8.116328979	0.234304169	35.185.44.232	192.168.49.128	TLSv1.3	117 Application Data
100	8.116361441	0.000032462	192.168.49.128	35.185.44.232	TCP	56 54884 → 443 [RST] Seq=939 Win=0 Len=0
101	8.160195896	0.043834455	35.185.44.232	192.168.49.128	TLSv1.3	91 Application Data
102	8.160509519	0.000313623	35.185.44.232	192.168.49.128	TLSv1.3	87 Application Data

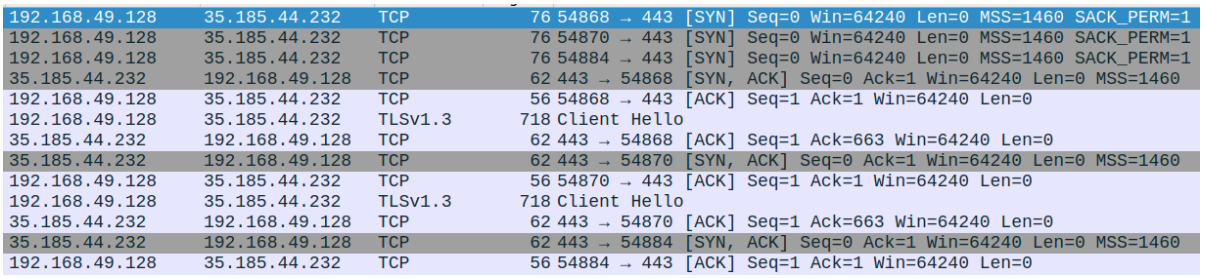


- The SYN flag bit is set to 1 in the TCP segment which identifies the segment as a SYN segment



SYN flag set to 1

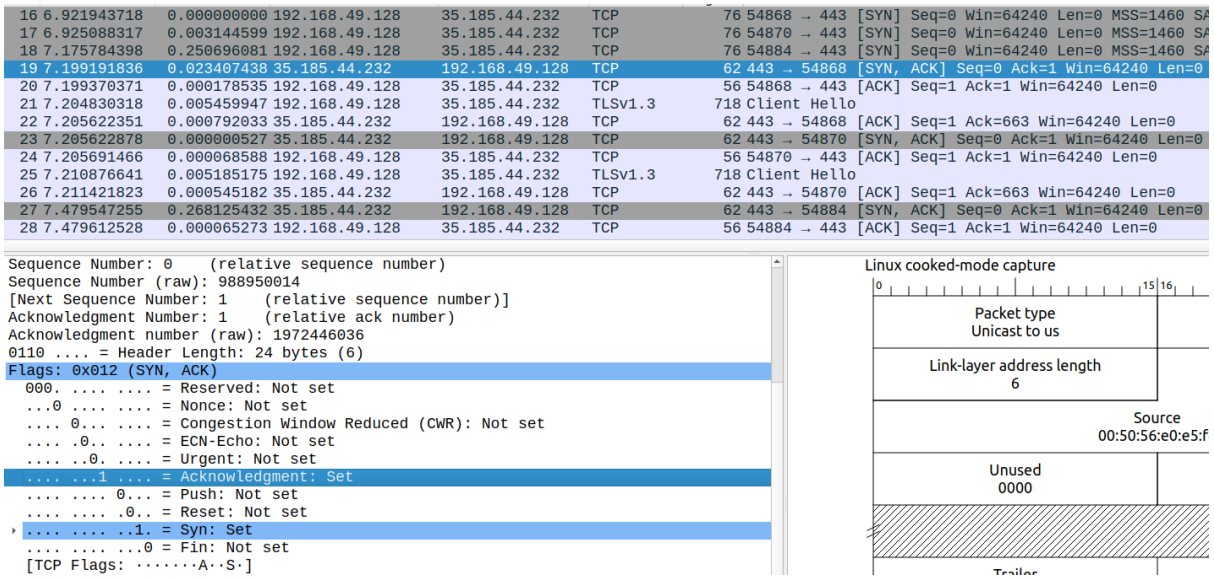
- No, the TCP receiver in this session will not be able to use Selective Acknowledgements (SACK) because it did not acknowledge support for the SACK option during the TCP handshake.



SACK not permitted form receiver

4. As there were the 3 TCP establishment requests from the client computer to https://cse.iith.ac.in/. Therefore the sequence number of the SYNACK segment sent by https://cse.iith.ac.in/ to the client computer in reply to the SYN are as follows:
   1st - 988950014
   2nd - **992018642**
   3rd - 1218463236
   As tracking the trace file the 1st and 3rd connections are closed.

- The flag bits of SYN and ACK in the TCP segment identifies that this segment is SYNACK segment



```
16 6.921943718   0.000000000 192.168.49.128   35.185.44.232    TCP        76 54868 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SA
17 6.925088317   0.003144599 192.168.49.128   35.185.44.232    TCP        76 54870 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SA
18 7.175784398   0.250696081 192.168.49.128   35.185.44.232    TCP        76 54884 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SA
19 7.199191836   0.023407438 35.185.44.232    192.168.49.128   TCP        62 443 → 54868 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
20 7.199370371   0.000178535 192.168.49.128   35.185.44.232    TCP        56 54868 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
21 7.204830318   0.005459947 192.168.49.128   35.185.44.232    TLSv1.3   718 Client Hello
22 7.205622351   0.000792033 35.185.44.232    192.168.49.128   TCP        62 443 → 54868 [ACK] Seq=1 Ack=663 Win=64240 Len=0
23 7.205622878   0.000000527 35.185.44.232    192.168.49.128   TCP        62 443 → 54870 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
24 7.205691466   0.000068588 192.168.49.128   35.185.44.232    TCP        56 54870 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
25 7.210876641   0.005185175 192.168.49.128   35.185.44.232    TLSv1.3   718 Client Hello
26 7.211421823   0.000545182 35.185.44.232    192.168.49.128   TCP        62 443 → 54870 [ACK] Seq=1 Ack=663 Win=64240 Len=0
27 7.479547255   0.268125432 35.185.44.232    192.168.49.128   TCP        62 443 → 54884 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
28 7.479612528   0.000065273 192.168.49.128   35.185.44.232    TCP        56 54884 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
```

```
Sequence Number: 0    (relative sequence number)
Sequence Number (raw): 988950014
[Next Sequence Number: 1    (relative sequence number)]
Acknowledgment Number: 1    (relative ack number)
Acknowledgment number (raw): 1972446036
0110 .... = Header Length: 24 bytes (6)
Flags: 0x012 (SYN, ACK)
  000. .... .... = Reserved: Not set
  ...0 .... .... = Nonce: Not set
  .... 0... .... = Congestion Window Reduced (CWR): Not set
  .... .0.. .... = ECN-Echo: Not set
  .... ..0. .... = Urgent: Not set
  .... ...1 .... = Acknowledgment: Set
  .... .... 0... = Push: Not set
  .... .... .0.. = Reset: Not set
  .... .... ..1. = Syn: Set
  .... .... ...0 = Fin: Not set
  [TCP Flags: ·····A··S·]
```


- Value of the Acknowledgement field in the SYNACK segment for all those 3 connection are:
  1st - 1972446036
  2nd - **1503105992**
  3rd - 2270850411
- The https://cse.iith.ac.in/ determine that value as below
  Acknowledgment Number = Client's Initial Sequence Number + 1
  = **1503105991** + 1
  = **1503105992**
  "+1" indicates that the https://cse.iith.ac.in/ is acknowledging the client's SYN segment and https://cse.iith.ac.in/ is expecting the next sequence number to be one greater than the client's initial sequence number.

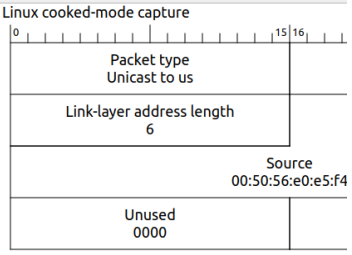
5. a.) Sequence number - 988950015

b.) Bytes in payload (field) - 1420

c.) No there are many more packets are coming regarding the request

22	7.205622351	0.000792033	35.185.44.232	192.168.49.128	TCP	62 443 → 54868 [ACK] Seq=1 Ack=663 Win=64240 Len=0
23	7.205622878	0.000000527	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
24	7.205691466	0.000068588	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
25	7.210876641	0.005185175	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
26	7.211421823	0.000545182	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1 Ack=663 Win=64240 Len=0
27	7.479547255	0.268125432	35.185.44.232	192.168.49.128	TCP	62 443 → 54884 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0
28	7.479612528	0.000065273	192.168.49.128	35.185.44.232	TCP	56 54884 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
29	7.484686207	0.005073679	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
30	7.485200935	0.000514728	35.185.44.232	192.168.49.128	TCP	62 443 → 54884 [ACK] Seq=1 Ack=663 Win=64240 Len=0
31	7.534816128	0.049615193	35.185.44.232	192.168.49.128	TLSv1.3	1476 Server Hello, Change Cipher Spec, Application Data
32	7.534856124	0.000039996	192.168.49.128	35.185.44.232	TCP	56 54868 → 443 [ACK] Seq=663 Ack=1421 Win=63900 Len=0
33	7.535405463	0.000549339	35.185.44.232	192.168.49.128	TLSv1.3	3804 Application Data, Application Data, Application Data
34	7.535420486	0.000015023	192.168.49.128	35.185.44.232	TCP	56 54868 → 443 [ACK] Seq=663 Ack=5169 Win=61320 Len=0

```
Frame 31: 1476 bytes on wire (11808 bits), 1476 bytes captured (11808 bits) on interfac
Linux cooked capture v1
Internet Protocol Version 4, Src: 35.185.44.232, Dst: 192.168.49.128
Transmission Control Protocol, Src Port: 443, Dst Port: 54868, Seq: 1, Ack: 663, Len: 1
  Source Port: 443
  Destination Port: 54868
  [Stream index: 2]
  [Conversation completeness: Complete, WITH_DATA (63)]
  [TCP Segment Len: 1420]
  Sequence Number: 1    (relative sequence number)
  Sequence Number (raw): 988950015
  [Next Sequence Number: 1421    (relative sequence number)]
  Acknowledgment Number: 663    (relative ack number)
  Acknowledgment number (raw): 1972446698
  0101 .... = Header Length: 20 bytes (5)
```



6. a.) The first segment of TCP connection was sent at - **8.303048060** seconds

b.) The ACK for the 1st segment of TCP connection was received at - **8.303076508** seconds

c.) RTT for the 1st data containing segment - **0.000028448** seconds

d.) The 2nd data containing segment is sent at - **8.312744027** seconds but the ACK is not received. Hence the cannot be calculated

e.) As we didn't get the RTT for the second segment (sample RTT) we can't calculate the estimated RTT.

We got the ACK for the frame 105 (1st segment) but didn't get the ACK for frame 107 (2nd segment)

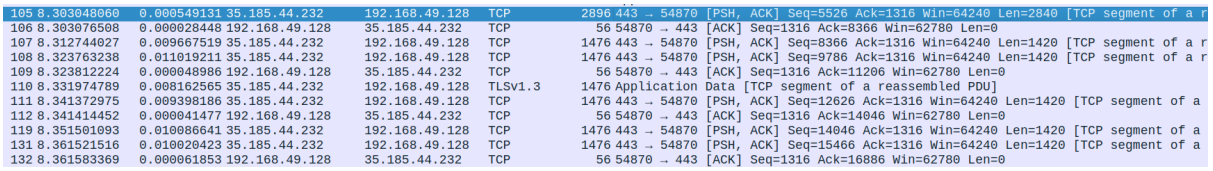
98	7.882024810	0.000267962	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=5230 Ack=1316 Win=64240 Len=0
99	8.116328979	0.234304169	35.185.44.232	192.168.49.128	TLSv1.3	117 Application Data
100	8.116361441	0.000032462	192.168.49.128	35.185.44.232	TCP	56 54884 → 443 [RST] Seq=939 Win=0 Len=0
101	8.160195896	0.043834455	35.185.44.232	192.168.49.128	TLSv1.3	91 Application Data
102	8.160509519	0.000313623	35.185.44.232	192.168.49.128	TLSv1.3	87 Application Data
103	8.161000612	0.000491093	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1316 Ack=5296 Win=62780 Len=0
104	8.302498929	0.141498317	35.185.44.232	192.168.49.128	TLSv1.3	286 Application Data
105	8.303048060	0.000549131	35.185.44.232	192.168.49.128	TCP	2896 443 → 54870 [PSH, ACK] Seq=5526 Ack=1316 Win=64240 Len=2840 [TCP segment of a
106	8.303076508	0.000028448	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1316 Ack=8366 Win=62780 Len=0
107	8.312744027	0.009667519	35.185.44.232	192.168.49.128	TCP	1476 443 → 54870 [PSH, ACK] Seq=8366 Ack=1316 Win=64240 Len=1420 [TCP segment of a
108	8.323763238	0.011019211	35.185.44.232	192.168.49.128	TCP	1476 443 → 54870 [PSH, ACK] Seq=9786 Ack=1316 Win=64240 Len=1420 [TCP segment of a
109	8.323812224	0.000048986	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1316 Ack=11206 Win=62780 Len=0

7. Length (payload + header) of each of the first four data carrying TCP segments are **2896, 1476, 1476, 1476** respectively.

104	8.302498929	0.141498317	35.185.44.232	192.168.49.128	TLSv1.3	286 Application Data
105	8.303048060	0.000549131	35.185.44.232	192.168.49.128	TCP	2896 443 → 54870 [PSH, ACK] Seq=5526 Ack=1316 Win=64240 Len=2840 [TCP segment of a r
106	8.303076508	0.000028448	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1316 Ack=8366 Win=62780 Len=0
107	8.312744027	0.009667519	35.185.44.232	192.168.49.128	TCP	1476 443 → 54870 [PSH, ACK] Seq=8366 Ack=1316 Win=64240 Len=1420 [TCP segment of a r
108	8.323763238	0.011019211	35.185.44.232	192.168.49.128	TCP	1476 443 → 54870 [PSH, ACK] Seq=9786 Ack=1316 Win=64240 Len=1420 [TCP segment of a r
109	8.323812224	0.000048986	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1316 Ack=11206 Win=62780 Len=0
110	8.331974789	0.008162565	35.185.44.232	192.168.49.128	TLSv1.3	1476 Application Data [TCP segment of a reassembled PDU]
111	8.341372975	0.009398186	35.185.44.232	192.168.49.128	TCP	1476 443 → 54870 [PSH, ACK] Seq=12626 Ack=1316 Win=64240 Len=1420 [TCP segment of a

8. a.) **64240** (Taking reference form the above image the https://cse.iith.ac.in/ is advertising 64240 window size to client computer)
   b.) As in this part the client (computer) is receiving the data form https://cse.iith.ac.in/ so the the receiver (https://cse.iith.ac.in/) would not throttle the client (computer).

9. a.) Buffer space advertise to https://cse.iith.ac.in/ is **62780**
   b.) The client computer has a sufficient large window size which can accommodate all the responses of https://cse.iith.ac.in/ are coming so the buffer space of client computer is not throttle.



105	8.303048060	0.000549131	35.185.44.232	192.168.49.128	TCP	2896	443 → 54870 [PSH, ACK] Seq=5526 Ack=1316 Win=64240 Len=2840 [TCP segment of a r
106	8.303076508	0.000028448	192.168.49.128	35.185.44.232	TCP	56	54870 → 443 [ACK] Seq=1316 Ack=8366 Win=62780 Len=0
107	8.312744027	0.009667519	35.185.44.232	192.168.49.128	TCP	1476	443 → 54870 [PSH, ACK] Seq=8366 Ack=1316 Win=64240 Len=1420 [TCP segment of a r
108	8.323763238	0.011019211	35.185.44.232	192.168.49.128	TCP	1476	443 → 54870 [PSH, ACK] Seq=9786 Ack=1316 Win=64240 Len=1420 [TCP segment of a r
109	8.323812224	0.000048986	192.168.49.128	35.185.44.232	TCP	56	54870 → 443 [ACK] Seq=1316 Ack=11206 Win=62780 Len=0
110	8.331974789	0.008162565	35.185.44.232	192.168.49.128	TLSv1.3	1476	Application Data [TCP segment of a reassembled PDU]
111	8.341372975	0.009398186	35.185.44.232	192.168.49.128	TCP	1476	443 → 54870 [PSH, ACK] Seq=12626 Ack=1316 Win=64240 Len=1420 [TCP segment of a
112	8.341414452	0.000041477	192.168.49.128	35.185.44.232	TCP	56	54870 → 443 [ACK] Seq=1316 Ack=14046 Win=62780 Len=0
119	8.351501093	0.010086641	35.185.44.232	192.168.49.128	TCP	1476	443 → 54870 [PSH, ACK] Seq=14046 Ack=1316 Win=64240 Len=1420 [TCP segment of a
131	8.361521516	0.010020423	35.185.44.232	192.168.49.128	TCP	1476	443 → 54870 [PSH, ACK] Seq=15466 Ack=1316 Win=64240 Len=1420 [TCP segment of a
132	8.361583369	0.000061853	192.168.49.128	35.185.44.232	TCP	56	54870 → 443 [ACK] Seq=1316 Ack=16886 Win=62780 Len=0

Reference image for Q8 & Q9

10. a.) NO
    b.) Just by looking for the duplicate ACK or going through the trace file checking that there are any sequence numbers repeated or not. But in this trace there was no such thing as a duplicate ACK or repeated sequence number (sending the same packet again).

11. a.) The client computer is acknowledging **5** TCP segments among the first **10** sent by https://cse.iith.ac.in/.
    b.) In this part the https://cse.iith.ac.in/ is sending the data to the client computer. Thus the data in 1, 3, 5, 6, 7 are acknowledge and of size **2840, 1420, 1420, 1420** but for 2, 4, 8, 9, 10 are not acknowledge but as we can see the information from the TCP header those are also of **1420** bytes.

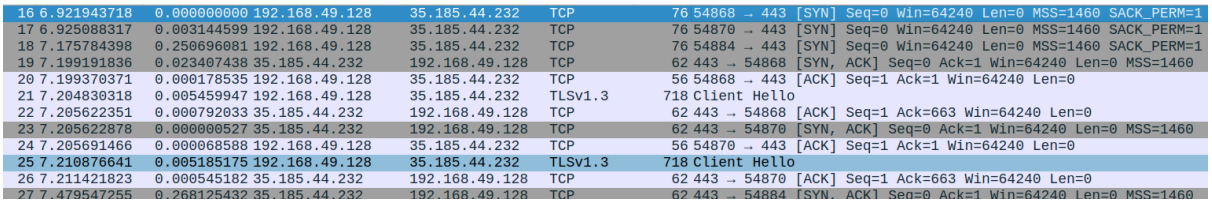
12. A - 6.921943718 (connection establishment timestamp)
    B - 17.280393905 (connection closed timestamp)
    The total data transferred can be calculated by taking the difference of the last packet (containing data form https://cse.iith.ac.in/ To client computer) sequence no. and 1st packet sequence no. + the data sent in the last packet.

    Total data transferred = last Seq (993225308) - 1st Seq (992018642)
    + length of last packet (2896)
    = **1209562 bytes**

Throughput = total data transferred / (A-B)

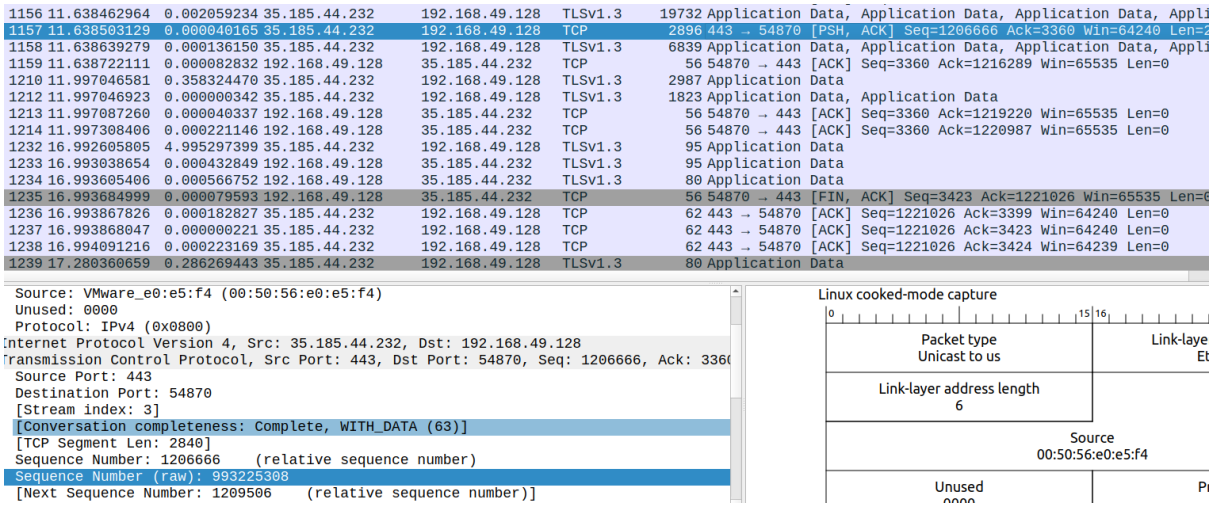
= 1209562 / (10.358450187)

= **116770.55719378 bytes / second**



16	6.921943718	0.000000000	192.168.49.128	35.185.44.232	TCP	76 54868 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
17	6.925088317	0.003144599	192.168.49.128	35.185.44.232	TCP	76 54870 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
18	7.175784398	0.250696081	192.168.49.128	35.185.44.232	TCP	76 54884 → 443 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM=1
19	7.199191836	0.023407438	35.185.44.232	192.168.49.128	TCP	62 443 → 54868 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
20	7.199370371	0.000178535	192.168.49.128	35.185.44.232	TCP	56 54868 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
21	7.204830318	0.005459947	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
22	7.205622351	0.000792033	35.185.44.232	192.168.49.128	TCP	62 443 → 54868 [ACK] Seq=1 Ack=663 Win=64240 Len=0
23	7.205622878	0.000000527	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460
24	7.205691466	0.000068588	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=1 Ack=1 Win=64240 Len=0
25	7.210876641	0.005185175	192.168.49.128	35.185.44.232	TLSv1.3	718 Client Hello
26	7.211421823	0.000545182	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1 Ack=663 Win=64240 Len=0
27	7.479547255	0.268125432	35.185.44.232	192.168.49.128	TCP	62 443 → 54884 [SYN, ACK] Seq=0 Ack=1 Win=64240 Len=0 MSS=1460

Taking 1st seq no. form connection in 17th frame



1156	11.638462964	0.002059234	35.185.44.232	192.168.49.128	TLSv1.3	19732 Application Data, Application Data, Application Data, Appli
1157	11.638503129	0.000040165	35.185.44.232	192.168.49.128	TCP	2896 443 → 54870 [PSH, ACK] Seq=1206666 Ack=3360 Win=64240 Len=2
1158	11.638639279	0.000136150	35.185.44.232	192.168.49.128	TLSv1.3	6839 Application Data, Application Data, Application Data, Appli
1159	11.638722111	0.000082832	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=3360 Ack=1216289 Win=65535 Len=0
1210	11.997046581	0.358324470	35.185.44.232	192.168.49.128	TLSv1.3	2987 Application Data
1212	11.997046923	0.000000342	35.185.44.232	192.168.49.128	TLSv1.3	1823 Application Data, Application Data
1213	11.997087260	0.000040337	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=3360 Ack=1219220 Win=65535 Len=0
1214	11.997308406	0.000221146	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [ACK] Seq=3360 Ack=1220987 Win=65535 Len=0
1232	16.992605805	4.995297399	35.185.44.232	192.168.49.128	TLSv1.3	95 Application Data
1233	16.993038654	0.000432849	192.168.49.128	35.185.44.232	TLSv1.3	95 Application Data
1234	16.993605406	0.000566752	192.168.49.128	35.185.44.232	TLSv1.3	80 Application Data
1235	16.993684999	0.000079593	192.168.49.128	35.185.44.232	TCP	56 54870 → 443 [FIN, ACK] Seq=3423 Ack=1221026 Win=65535 Len=0
1236	16.993867826	0.000182827	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1221026 Ack=3399 Win=64240 Len=0
1237	16.993868047	0.000000221	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1221026 Ack=3423 Win=64240 Len=0
1238	16.994091216	0.000223169	35.185.44.232	192.168.49.128	TCP	62 443 → 54870 [ACK] Seq=1221026 Ack=3424 Win=64239 Len=0
1239	17.280360659	0.286269443	35.185.44.232	192.168.49.128	TLSv1.3	80 Application Data

```
Source: VMware_e0:e5:f4 (00:50:56:e0:e5:f4)
Unused: 0000
Protocol: IPv4 (0x0800)
Internet Protocol Version 4, Src: 35.185.44.232, Dst: 192.168.49.128
Transmission Control Protocol, Src Port: 443, Dst Port: 54870, Seq: 1206666, Ack: 3360
Source Port: 443
Destination Port: 54870
[Stream index: 3]
[Conversation completeness: Complete, WITH_DATA (63)]
[TCP Segment Len: 2840]
Sequence Number: 1206666    (relative sequence number)
Sequence Number (raw): 993225308
[Next Sequence Number: 1209506    (relative sequence number)]
```


Last segment was sent in 1157th frame (taking seq no. of that frame)