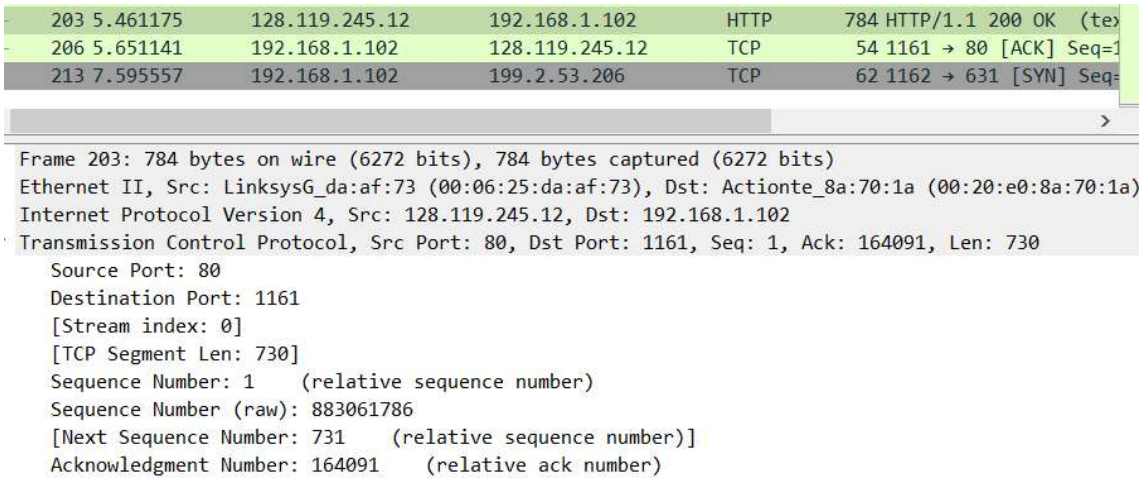
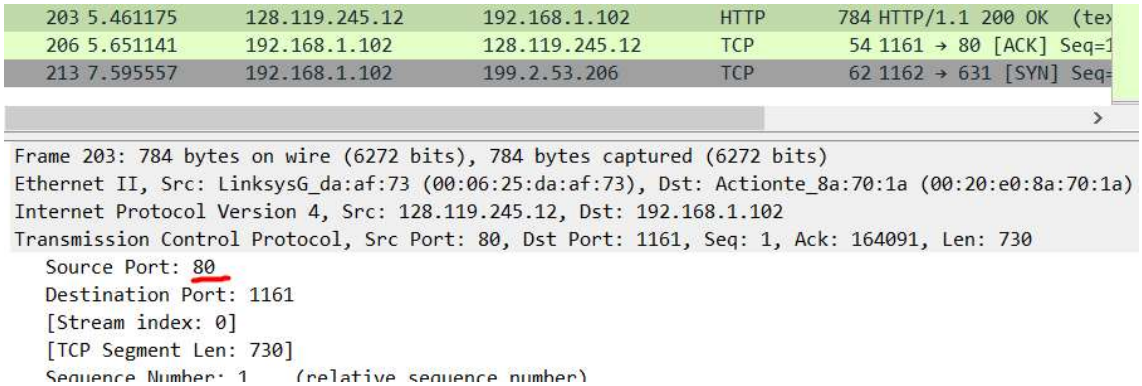
1.



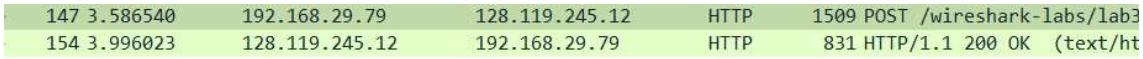
According to above figure, the client computer (source)'s IP address is 192.168.1.102 and the TCP port number is 1161.

2.

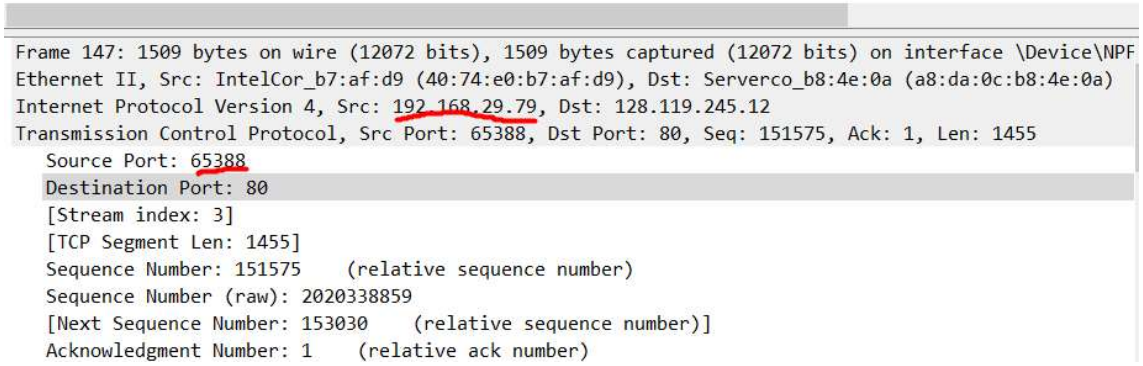


According to above figure, the IP address of gaia.cs.umass.edu is 128.119.245.12 and the TCP port number is 80.

3.



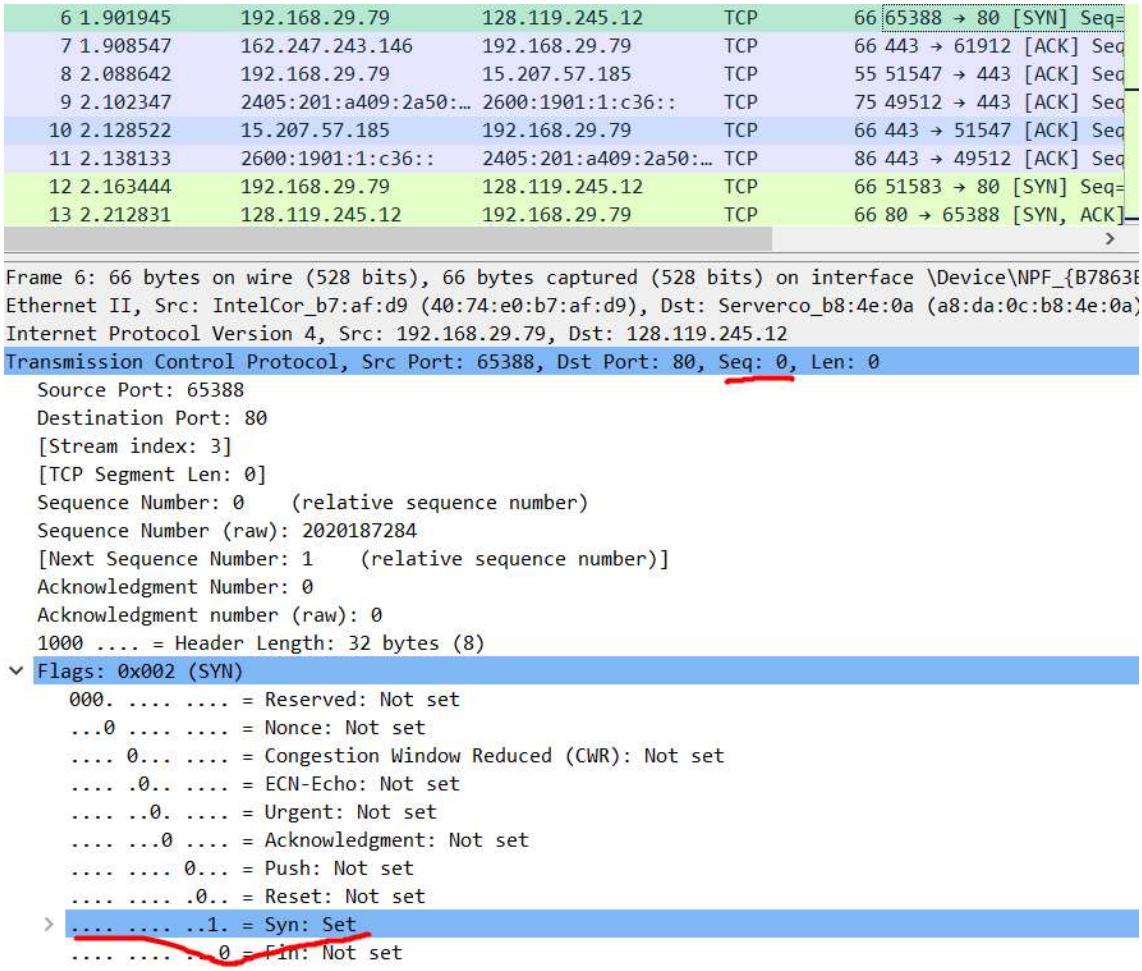
147	3.586540	192.168.29.79	128.119.245.12	HTTP	1509 POST /wireshark-labs/lab3
154	3.996023	128.119.245.12	192.168.29.79	HTTP	831 HTTP/1.1 200 OK (text/ht



```
Frame 147: 1509 bytes on wire (12072 bits), 1509 bytes captured (12072 bits) on interface \Device\NPF
Ethernet II, Src: IntelCor_b7:af:d9 (40:74:e0:b7:af:d9), Dst: Serverco_b8:4e:0a (a8:da:0c:b8:4e:0a)
Internet Protocol Version 4, Src: 192.168.29.79, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 65388, Dst Port: 80, Seq: 151575, Ack: 1, Len: 1455
   Source Port: 65388
   Destination Port: 80
   [Stream index: 3]
   [TCP Segment Len: 1455]
   Sequence Number: 151575    (relative sequence number)
   Sequence Number (raw): 2020338859
   [Next Sequence Number: 153030    (relative sequence number)]
   Acknowledgment Number: 1    (relative ack number)
```

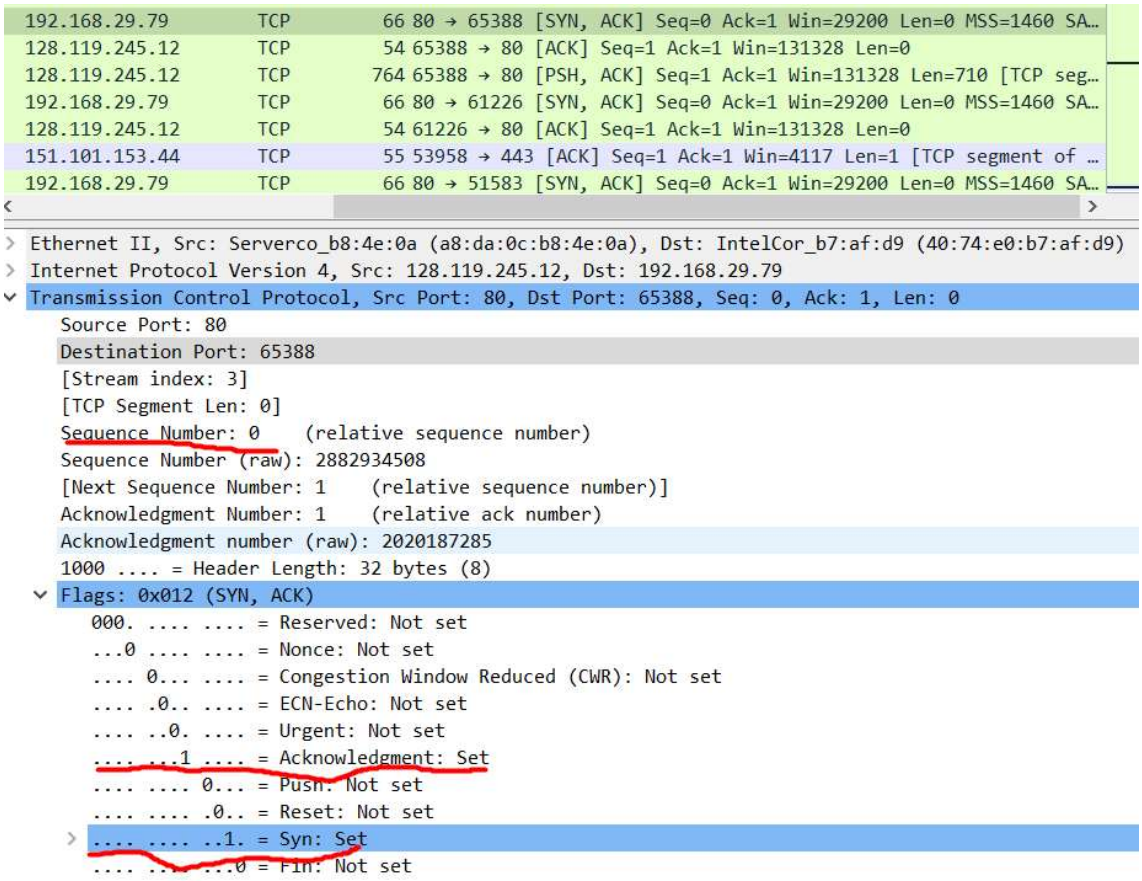
According to above figure, my client computer's IP address is 192.168.29.79 and the TCP port is 65388

4.



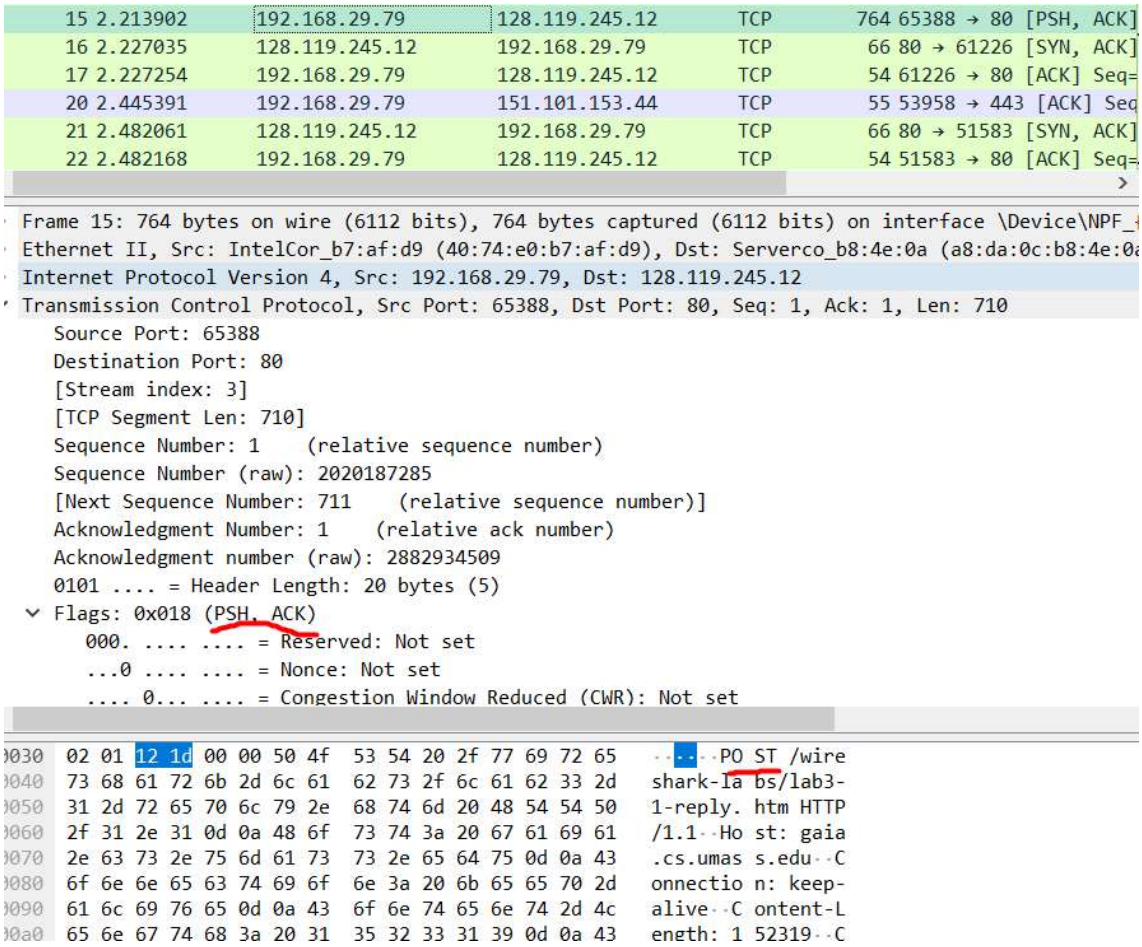
The sequence number of the TCP SYN segment is 0 since it is used to imitate the TCP connection between the client computer and gaia.cs.umass.edu. According to above figure, in the Flags section, the Syn flag is set to 1 which indicates that this segment is a SYN segment.

5.



According to the above figure, the sequence number of the SYNACK segment sent by gaia.cs.umass.edu to the client computer in reply to the SYN is 0. The value of the acknowledgement field in the SYNACK segment is 1. The value of the ACKnowledgement field in the SYNACK segment is determined by the server gaia.cs.umass.edu. The server adds 1 to the initial sequence number of SYN segment form the client computer. For this case, the initial sequence number of SYN segment from the client computer is 0, thus the value of the ACKnowledgement field in the SYNACK segment is 1. A segment will be identified as a SYNACK segment if both SYN flag and Acknowledgement in the segment are set to 1.

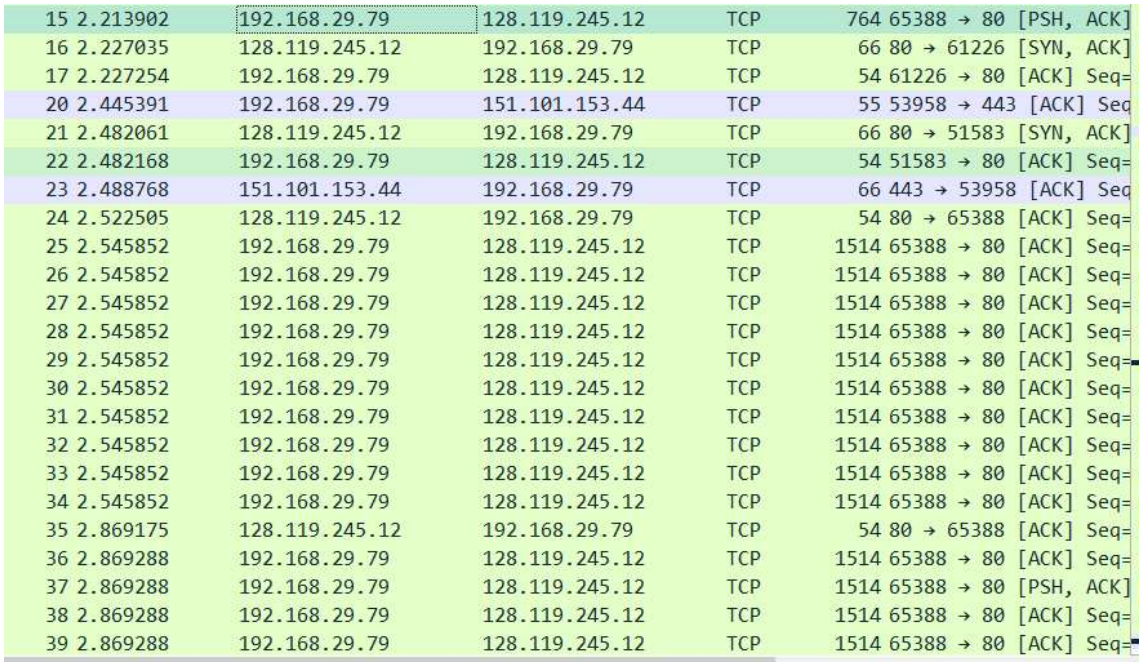
6.



According to above figure, the segment No.15 contains the HTTP POST command, the sequence number of this segment is 1.

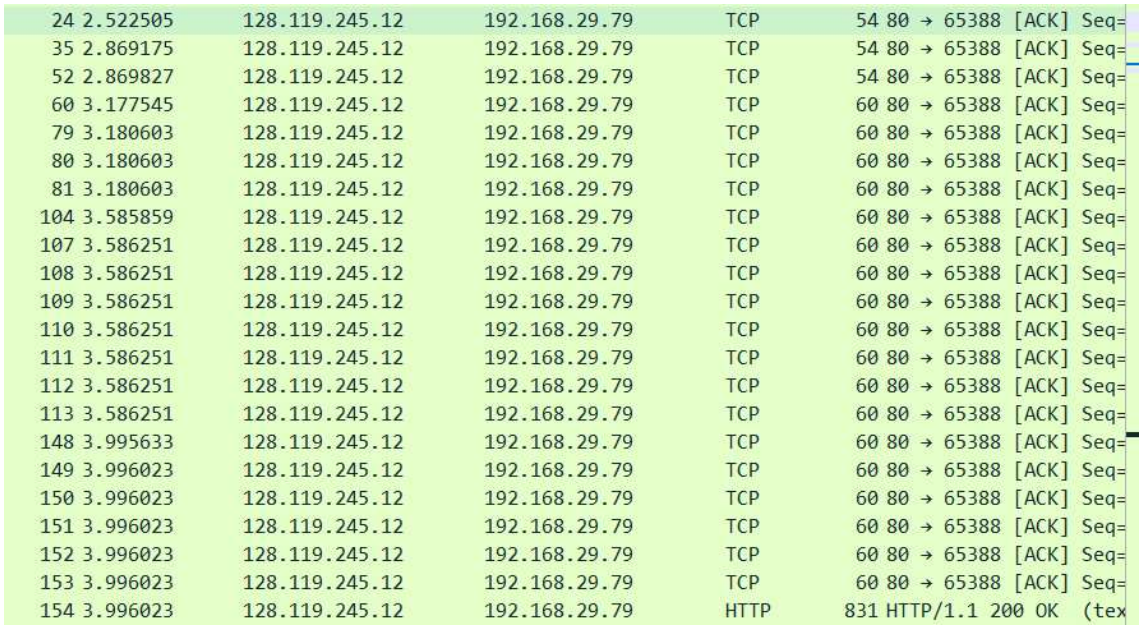
7.

Segments 1-6



15	2.213902	192.168.29.79	128.119.245.12	TCP	764 65388 → 80 [PSH, ACK]
16	2.227035	128.119.245.12	192.168.29.79	TCP	66 80 → 61226 [SYN, ACK]
17	2.227254	192.168.29.79	128.119.245.12	TCP	54 61226 → 80 [ACK] Seq=
20	2.445391	192.168.29.79	151.101.153.44	TCP	55 53958 → 443 [ACK] Seq
21	2.482061	128.119.245.12	192.168.29.79	TCP	66 80 → 51583 [SYN, ACK]
22	2.482168	192.168.29.79	128.119.245.12	TCP	54 51583 → 80 [ACK] Seq=
23	2.488768	151.101.153.44	192.168.29.79	TCP	66 443 → 53958 [ACK] Seq
24	2.522505	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=
25	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
26	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
27	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
28	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
29	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
30	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
31	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
32	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
33	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
34	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
35	2.869175	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=
36	2.869288	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
37	2.869288	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [PSH, ACK]
38	2.869288	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=
39	2.869288	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=

ACK of segments 1-6



24	2.522505	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=
35	2.869175	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=
52	2.869827	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=
60	3.177545	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
79	3.180603	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
80	3.180603	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
81	3.180603	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
104	3.585859	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
107	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
108	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
109	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
110	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
111	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
112	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
113	3.586251	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
148	3.995633	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
149	3.996023	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
150	3.996023	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
151	3.996023	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
152	3.996023	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
153	3.996023	128.119.245.12	192.168.29.79	TCP	60 80 → 65388 [ACK] Seq=
154	3.996023	128.119.245.12	192.168.29.79	HTTP	831 HTTP/1.1 200 OK (tex

According to above figures, the segments 1-6 are No. 15, 25, 26, 27, 28 and 29. The ACK of segments 1-6 are No. 24, 35, 52, 60, 79 and 80.

Segment 1 sequence number is 1

Segment 2 sequence number is 711

Segment 3 sequence number is 2171

Segment 4 sequence number is 3631
Segment 5 sequence number is 5091
Segment 6 sequence number is 6551

Recording the sending time and received time of ACKs:

	Sent time	ACK received time	RTT
Segment 1	2.213902	2.522505	0.308603
Segment 2	2.545852	2.869175	0.323323
Segment 3	2.545852	2.869827	0.323975
Segment 4	2.545852	3.177545	0.631693
Segment 5	2.545852	3.180603	0.634751
Segment 6	2.545852	3.180603	0.634751

According to the formula: EstimatedRTT = 0.875 * EstimatedRTT + 0.125 * SampleRTT
EstimatedRTT after the receipt of the ACK of segment 1:
EstimatedRTT = RTT for Segment 1 = 0.308603 s

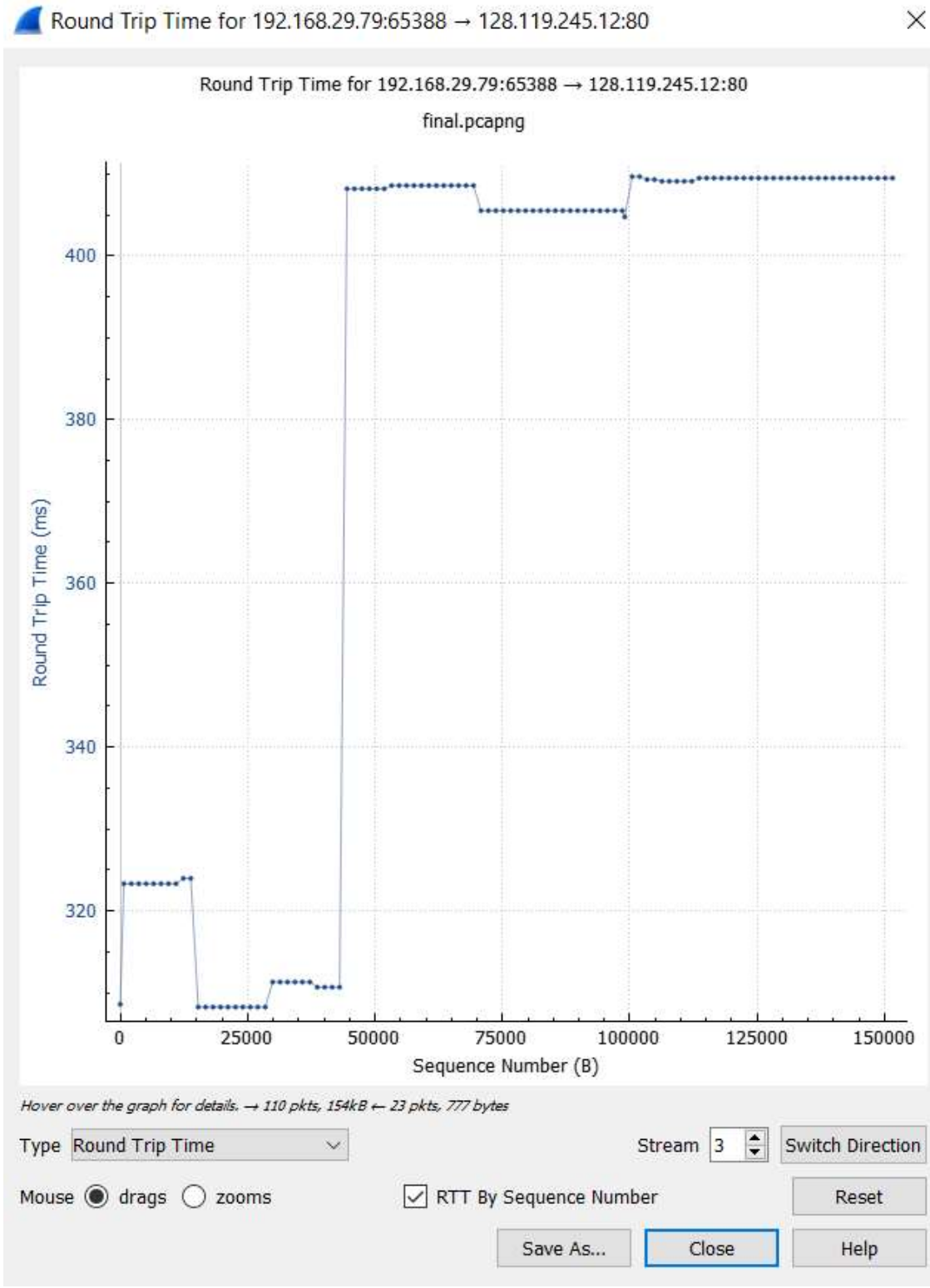
EstimatedRTT after the receipt of the ACK of segment 2:
EstimatedRTT = 0.875 * 0.308603 + 0.125 * 0.323323= 0.310443 s

EstimatedRTT after the receipt of the ACK of segment 3:
EstimatedRTT = 0.875 * 0.310443 + 0.125 * 0.323975= 0.3121345 s

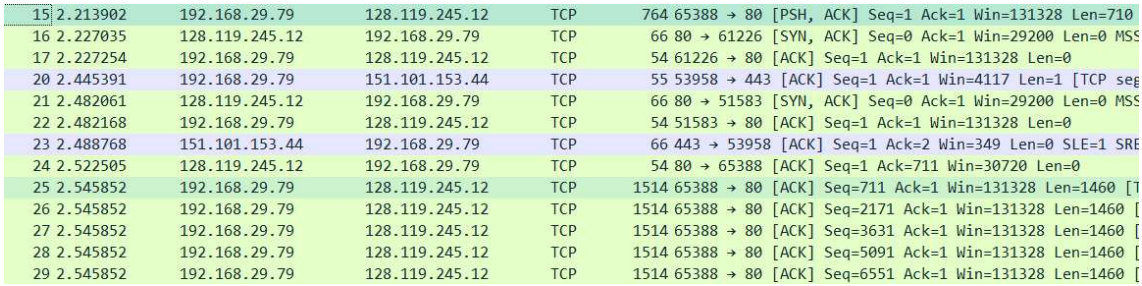
EstimatedRTT after the receipt of the ACK of segment 4:
EstimatedRTT = 0.875 * 0.3121345 + 0.125 * 0.631693= 0.3520793125 s

EstimatedRTT after the receipt of the ACK of segment 5:
EstimatedRTT = 0.875 * 0.3520793125 + 0.125 * 0.634751= 0.3874132734375 s

EstimatedRTT after the receipt of the ACK of segment 6:
EstimatedRTT = 0.875 *0.3874132734375 + 0.125 * 0.634751= 0.4183304892578125 s


Round Trip Time for 192.168.29.79:65388 → 128.119.245.12:80
Round Trip Time for 192.168.29.79:65388 → 128.119.245.12:80
final.pcapng
Round Trip Time (ms)
400
380
360
340
320
0
25000
50000
75000
100000
125000
150000
Sequence Number (B)
Hover over the graph for details. → 110 pkts, 154kB ← 23 pkts, 777 bytes
Type
Round Trip Time
Stream
3
Switch Direction
Mouse
drags
zooms
RTT By Sequence Number
Reset
Save As...
Close
Help

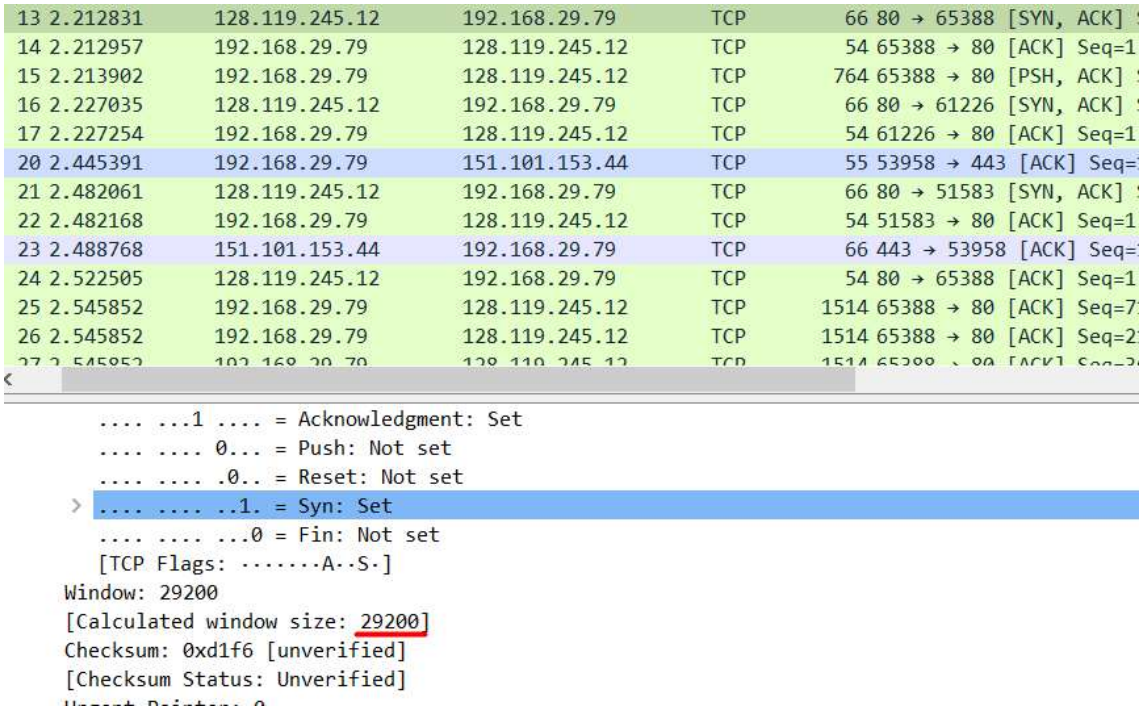
8.



15	2.213902	192.168.29.79	128.119.245.12	TCP	764 65388 → 80 [PSH, ACK] Seq=1 Ack=1 Win=131328 Len=710
16	2.227035	128.119.245.12	192.168.29.79	TCP	66 80 → 61226 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS
17	2.227254	192.168.29.79	128.119.245.12	TCP	54 61226 → 80 [ACK] Seq=1 Ack=1 Win=131328 Len=0
20	2.445391	192.168.29.79	151.101.153.44	TCP	55 53958 → 443 [ACK] Seq=1 Ack=1 Win=4117 Len=1 [TCP seg
21	2.482061	128.119.245.12	192.168.29.79	TCP	66 80 → 51583 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS
22	2.482168	192.168.29.79	128.119.245.12	TCP	54 51583 → 80 [ACK] Seq=1 Ack=1 Win=131328 Len=0
23	2.488768	151.101.153.44	192.168.29.79	TCP	66 443 → 53958 [ACK] Seq=1 Ack=2 Win=349 Len=0 SLE=1 SRE
24	2.522505	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=1 Ack=711 Win=30720 Len=0
25	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=711 Ack=1 Win=131328 Len=1460 [T
26	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=2171 Ack=1 Win=131328 Len=1460 [
27	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=3631 Ack=1 Win=131328 Len=1460 [
28	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=5091 Ack=1 Win=131328 Len=1460 [
29	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=6551 Ack=1 Win=131328 Len=1460 [

The length of the first TCP segment is 710 bytes. The length of each of the following five TCP segments is 1460 bytes.

9.

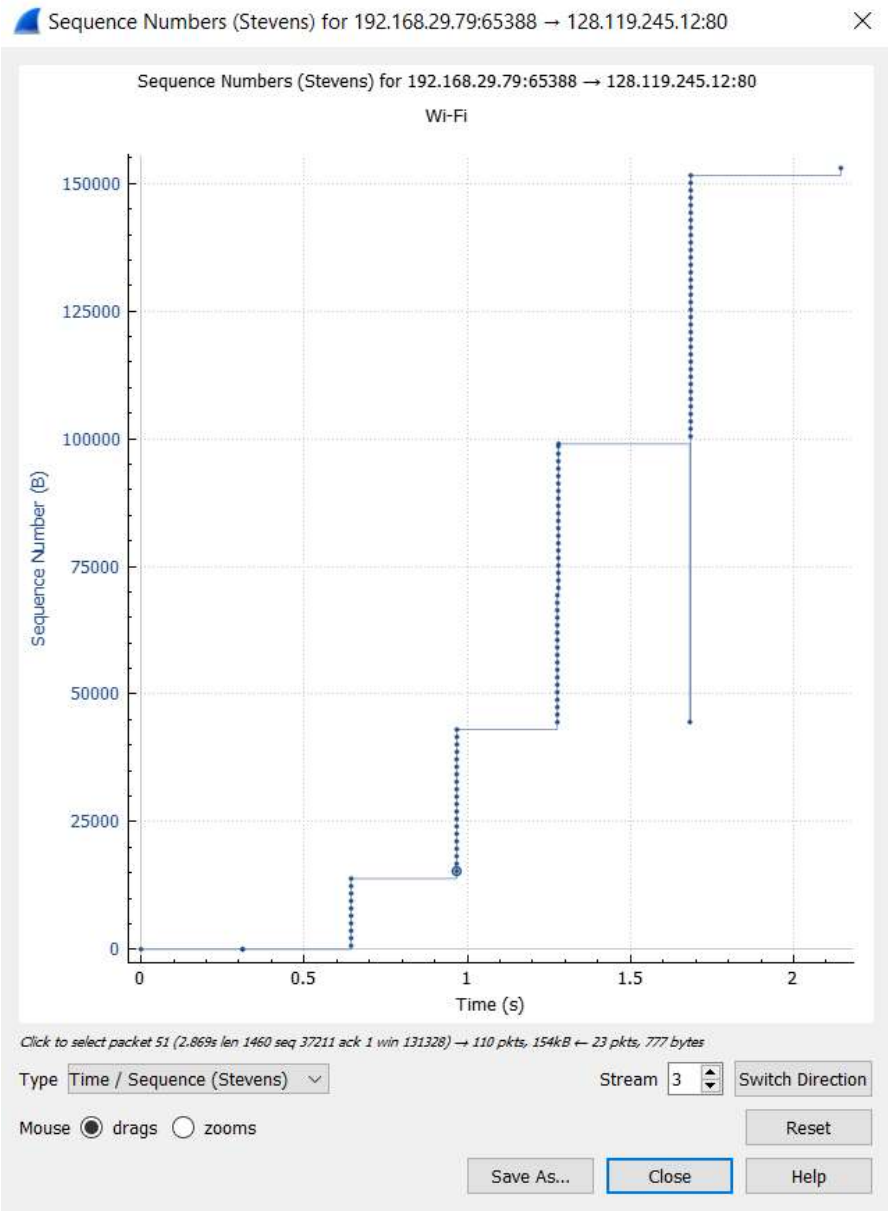


13	2.212831	128.119.245.12	192.168.29.79	TCP	66 80 → 65388 [SYN, ACK]
14	2.212957	192.168.29.79	128.119.245.12	TCP	54 65388 → 80 [ACK] Seq=1
15	2.213902	192.168.29.79	128.119.245.12	TCP	764 65388 → 80 [PSH, ACK]
16	2.227035	128.119.245.12	192.168.29.79	TCP	66 80 → 61226 [SYN, ACK]
17	2.227254	192.168.29.79	128.119.245.12	TCP	54 61226 → 80 [ACK] Seq=1
20	2.445391	192.168.29.79	151.101.153.44	TCP	55 53958 → 443 [ACK] Seq=
21	2.482061	128.119.245.12	192.168.29.79	TCP	66 80 → 51583 [SYN, ACK]
22	2.482168	192.168.29.79	128.119.245.12	TCP	54 51583 → 80 [ACK] Seq=1
23	2.488768	151.101.153.44	192.168.29.79	TCP	66 443 → 53958 [ACK] Seq=
24	2.522505	128.119.245.12	192.168.29.79	TCP	54 80 → 65388 [ACK] Seq=1
25	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=7
26	2.545852	192.168.29.79	128.119.245.12	TCP	1514 65388 → 80 [ACK] Seq=2

```
    .... ...1 .... = Acknowledgment: Set
    .... .... 0... = Push: Not set
    .... .... .0.. = Reset: Not set
  > .... .... ..1. = Syn: Set
    .... .... ...0 = Fin: Not set
    [TCP Flags: ·····A··S·]
  Window: 29200
  [Calculated window size: 29200]
  Checksum: 0xd1f6 [unverified]
  [Checksum Status: Unverified]
```

The minimum amount of available buffer space advertised at the received for the entire trace is indicated first ACK from the server, its value is 29200 bytes (shown in above figure). This window grows until it reaches the maximum receiver buffer size of 270848 bytes. According to the trace, the sender is never throttled due to lacking of receiver buffer space.

10.

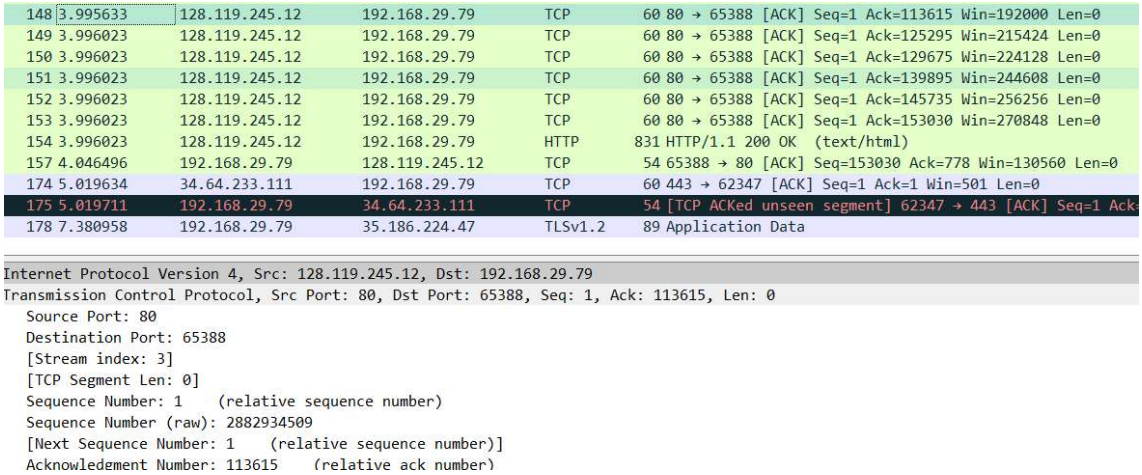


There is a retransmitted segment in the trace file since in the time sequence graph (stevens), all sequence numbers are monotonically increasing except one outlier (packet 103 is a retransmitted packet).

11.

The difference between the acknowledged sequence numbers of two consecutive ACKs indicates the data received by the server between these two ACKs.

The receiver is ACKing every other segment. For example, segment of No. 149 acknowledged data with 11680 bytes.



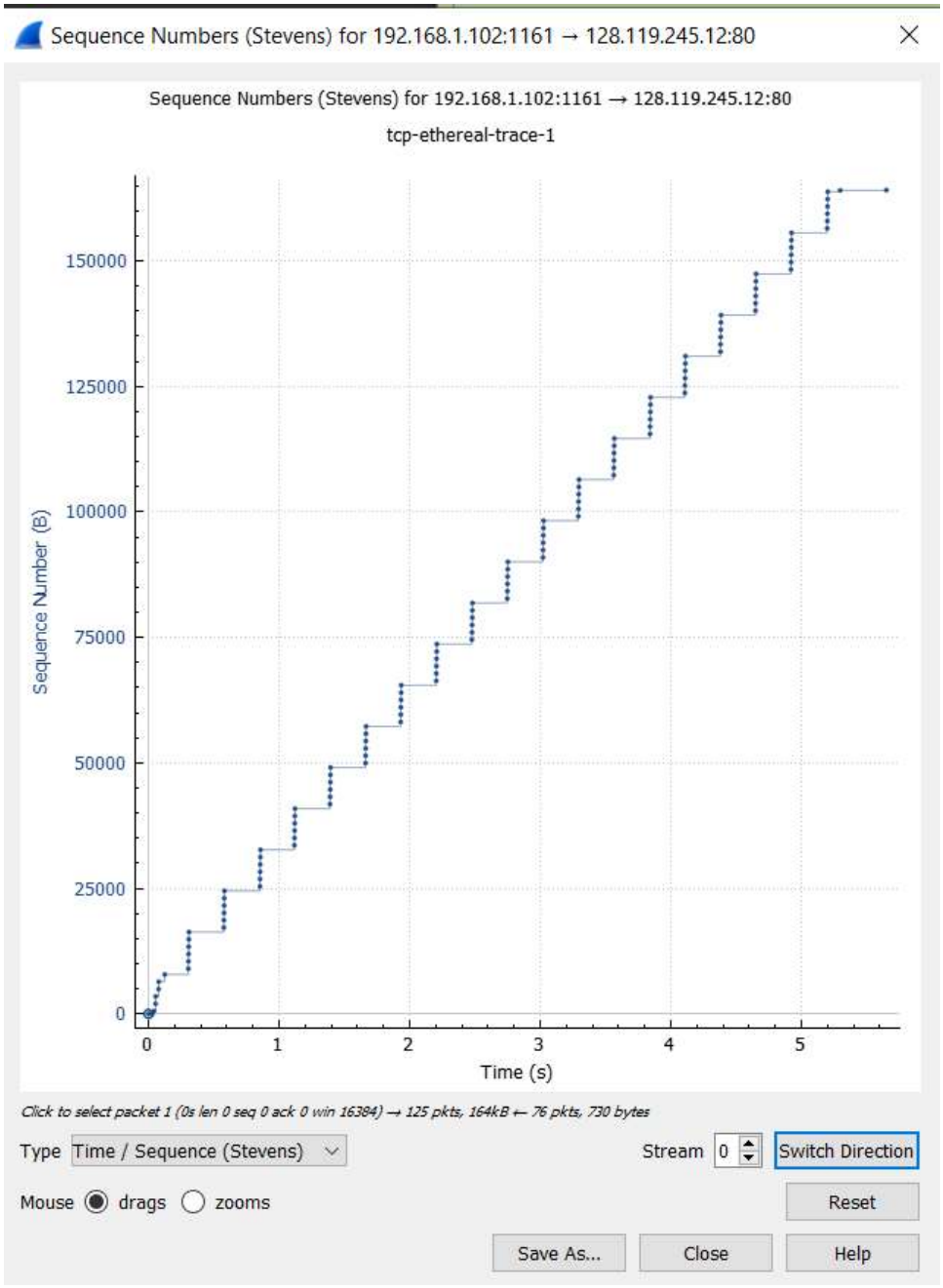
148	3.995633	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=113615 Win=192000 Len=0
149	3.996023	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=125295 Win=215424 Len=0
150	3.996023	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=129675 Win=224128 Len=0
151	3.996023	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=139895 Win=244608 Len=0
152	3.996023	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=145735 Win=256256 Len=0
153	3.996023	128.119.245.12	192.168.29.79	TCP	60	80 → 65388 [ACK] Seq=1 Ack=153030 Win=270848 Len=0
154	3.996023	128.119.245.12	192.168.29.79	HTTP	831	HTTP/1.1 200 OK (text/html)
157	4.046496	192.168.29.79	128.119.245.12	TCP	54	65388 → 80 [ACK] Seq=153030 Ack=778 Win=130560 Len=0
174	5.019634	34.64.233.111	192.168.29.79	TCP	60	443 → 62347 [ACK] Seq=1 Ack=1 Win=501 Len=0
175	5.019711	192.168.29.79	34.64.233.111	TCP	54	[TCP ACKed unseen segment] 62347 → 443 [ACK] Seq=1 Ack=
178	7.380958	192.168.29.79	35.186.224.47	TLSv1.2	89	Application Data

```
Internet Protocol Version 4, Src: 128.119.245.12, Dst: 192.168.29.79
Transmission Control Protocol, Src Port: 80, Dst Port: 65388, Seq: 1, Ack: 113615, Len: 0
   Source Port: 80
   Destination Port: 65388
   [Stream index: 3]
   [TCP Segment Len: 0]
   Sequence Number: 1    (relative sequence number)
   Sequence Number (raw): 2882934509
   [Next Sequence Number: 1    (relative sequence number)]
   Acknowledgement Number: 113615    (relative ack number)
```

12.

The alice.txt on the hard drive is 152,136 bytes, and the download time is 4.046496000 (First TCP segment) - 2.213902000 (last ACK) = 1.832594 second. Therefore, the throughput for the TCP connection is computed as 152,138/1.307479=83016.75 bytes/second

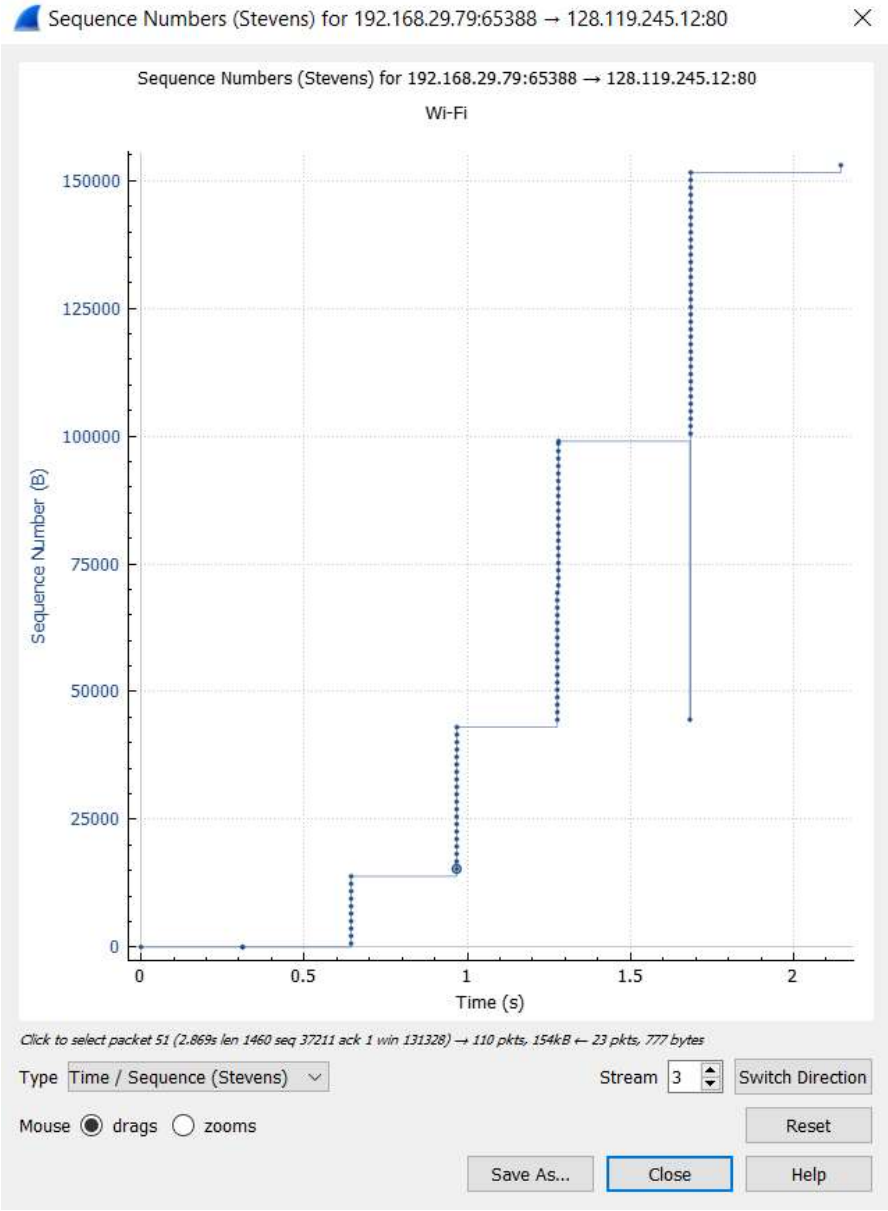
13.



The slow start of the TCP seems to begin at about 0.04 seconds and then ends at about 0.3 seconds. Afterwards, it seems that the TCP session is always in congestion avoidance state. In this case, we do not observe the expected linear increase behaviour, i.e. the TCP transmit

window does not grow linearly during this phase. In fact, it appears that the sender transmits packets in batches of 6 which is contrary to ideal behaviour.

14.



The slow start of the TCP seems to begin at about 0.31 seconds and then ends at about 0.62 seconds. Congestion avoidance takes over at about 1.7 seconds because it cut down

the amount of data being sent. This is in accordance with the ideal behaviour, though there’s a retransmision occuring