Course: Computer Networks(ECE/CSC 570)
Instructor: Mihail L. Sichitiu
Description: Spring 2016, Wireshark Assignment 6 Solutions.
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(*my_trace* refers to the capture from my upload, *ethereal_trace* refers to the given pcap)

Answer to Q. No. 1:

From the SYN packet above from ethereal_trace, we can see that,

IP Address of the requesting Host : **192.168.1.102**
Port address used by the host process : **1161**

Answer to Q. No. 2:

From the same snapshot above,

IP Address of the server gaia.cs.umass.edu : **128.119.245.12**
TCP port number : **80**

Answer to Q. No. 3:

```
57  13.861853              192.168.0.16    128.119.245.12    TCP    53185 → 80 [SYN] Seq=0 Win=65535 Len
58  13.895277              128.119.245.12  192.168.0.16      TCP    80 → 53185 [SYN, ACK] Seq=0 Ack=1 Wi
59  13.895352              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=1 Ack=1 Win=131
60  13.895720              192.168.0.16    128.119.245.12    TCP    53185 → 80 [PSH, ACK] Seq=1 Ack=1 Wi
61  13.896838              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=656 Ack=1 Win=1
62  13.896839              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=2104 Ack=1 Win=
63  13.928576              128.119.245.12  192.168.0.16      TCP    80 → 53185 [ACK] Seq=1 Ack=656 Win=3
64  13.928692              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=3552 Ack=1 Win=
65  13.929840              128.119.245.12  192.168.0.16      TCP    80 → 53185 [ACK] Seq=1 Ack=2104 Win=
66  13.929909              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=5000 Ack=1 Win=
```

```
Frame 57: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface 0
Ethernet II, Src: Apple_0c:6b:03 (a0:99:9b:0c:6b:03), Dst: Netgear_f6:28:ea (50:6a:03:f6:28:ea)
Internet Protocol Version 4, Src: 192.168.0.16, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 53185 (53185), Dst Port: 80 (80), Seq: 0, Len: 0
    Source Port: 53185
    Destination Port: 80
    [Stream index: 1]
    [TCP Segment Len: 0]
    Sequence number: 0     (relative sequence number)
    Acknowledgment number: 0
    Header Length: 44 bytes
  ▶ Flags: 0x002 (SYN)
    Window size value: 65535
    [Calculated window size: 65535]
```

From the SYN packet sent by my computer to the upload server(my_trace), we saw that

IP Address of my system : **192.168.0.16**
TCP port number : **53185**

Answer to Q. No. 4:

From the SYN snapshot of my_trace above, we can see that,

The Sequence No. of the SYN segment = **0** (Signifies initialization of transfer)
How do we know = **The SYN flag in the TCP header is set.**

Answer to Q. No. 5:

```
57  13.861853              192.168.0.16    128.119.245.12    TCP    53185 → 80 [SYN] Seq=0 Win=65535 Len=
58  13.895277              128.119.245.12  192.168.0.16      TCP    80 → 53185 [SYN, ACK] Seq=0 Ack=1 Win
59  13.895352              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=1 Ack=1 Win=1317
60  13.895720              192.168.0.16    128.119.245.12    TCP    53185 → 80 [PSH, ACK] Seq=1 Ack=1 Win
61  13.896838              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=656 Ack=1 Win=13
62  13.896839              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=2104 Ack=1 Win=1
63  13.928576              128.119.245.12  192.168.0.16      TCP    80 → 53185 [ACK] Seq=1 Ack=656 Win=30
64  13.928692              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=3552 Ack=1 Win=1
65  13.929840              128.119.245.12  192.168.0.16      TCP    80 → 53185 [ACK] Seq=1 Ack=2104 Win=3
66  13.929909              192.168.0.16    128.119.245.12    TCP    53185 → 80 [ACK] Seq=5000 Ack=1 Win=1
```

```
    Destination Port: 53185
    [Stream index: 1]
    [TCP Segment Len: 0]
    Sequence number: 0     (relative sequence number)
    Acknowledgment number: 1     (relative ack number)
    Header Length: 40 bytes
  ▼ 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
```

From the SYNACK packet's snapshot from my_trace above, we see that,

- Sequence no = **0**
- Value of acknowledgment = **1**
- This packet is a reply to the previous SYN packet by the client which had a sequence no 0, so the next segment that server expects is 1, that's how the ACK no comes in the field.
- Both SYN and ACK flags are set, so we know that it's a SYNACK segment.

Answer to Q. No. 6:

```
 3  0.023265                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
 4  0.026477                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520
 5  0.041737                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=1752
 6  0.053937                    128.119.245.12  192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=
 7  0.054026                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Le
 8  0.054690                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Le
 9  0.077294                    128.119.245.12  192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Ler
10  0.077405                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Le
11  0.078157                    192.168.1.102   128.119.245.12   TCP   1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Le
12  0.124085                    128.119.245.12  192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Le
```

```
▶ Frame 4: 619 bytes on wire (4952 bits), 619 bytes captured (4952 bits)
▶ Ethernet II, Src: Actionte_8a:70:1a (00:20:e0:8a:70:1a), Dst: LinksysG_da:af:73 (00:06:25:da:af:73)
▶ Internet Protocol Version 4, Src: 192.168.1.102, Dst: 128.119.245.12
▼ Transmission Control Protocol, Src Port: 1161 (1161), Dst Port: 80 (80), Seq: 1, Ack: 1, Len: 565
    Source Port: 1161
    Destination Port: 80
    [Stream index: 0]
    [TCP Segment Len: 565]
    Sequence number: 1      (relative sequence number)
    [Next sequence number: 566      (relative sequence number)]
    Acknowledgment number: 1     (relative ack number)
    Header Length: 20 bytes
  ▶ Flags: 0x018 (PSH, ACK)
    Window size value: 17520
    [Calculated window size: 17520]
    [Window size scaling factor: -2 (no window scaling used)]
  ▶ Checksum: 0x1fbd [validation disabled]
    Urgent pointer: 0
  ▶ [SEQ/ACK analysis]
▼ Data (565 bytes)
    Data: 504f5354202f657468657265616c2d6c6162732f6c616233...
    [Length: 565]
```

```
0030  44 70 1f bd 00 00 50 4f  53 54 20 2f 65 74 68 65   Dp....PO ST /ethe
0040  72 65 61 6c 2d 6c 61 62  73 2f 6c 61 62 33 2d 31   real-lab s/lab3-1
0050  2d 72 65 70 6c 79 2e 68  74 6d 20 48 54 54 50 2f   -reply.h tm HTTP/
```

From the snapshot of ethereal_trace above, we can see that the Data field contains the HTTP POST method's invocation, that's how we know that the packet no. 4 above is the first one sent by the client machine to the upload server.

The sequence no. is = **1**

Answer to Q. No. 7:

The following are the first 6 segments and their acknowledgments respectively.

```
  2 0.023172              128.119.245.12   192.168.1.102    TCP   80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SAC
  3 0.023265              192.168.1.102    128.119.245.12   TCP   1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
  4 0.026477              192.168.1.102    128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565
  5 0.041737              192.168.1.102    128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460
  6 0.053937              128.119.245.12   192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
  7 0.054026              192.168.1.102    128.119.245.12   TCP   1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460
  8 0.054690              192.168.1.102    128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=3486 Ack=1 Win=17520 Len=1460
  9 0.077294              128.119.245.12   192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
 10 0.077405              192.168.1.102    128.119.245.12   TCP   1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460
 11 0.078157              192.168.1.102    128.119.245.12   TCP   1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460
 12 0.124085              128.119.245.12   192.168.1.102    TCP   80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
 13 0.124185              192.168.1.102    128.119.245.12   TCP   1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147
```

The Segments

No.	▲ Time	Source	Destination	Protoco L	Info
5 0.041737		192.168.1.102	128.119.245.12	TCP	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460
6 0.053937		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
7 0.054026		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460
8 0.054690		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460
9 0.077294		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
10 0.077405		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460
11 0.078157		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460
12 0.124085		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
13 0.124185		192.168.1.102	128.119.245.12	TCP	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147
14 0.169118		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15 0.217299		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16 0.267802		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0

```
▶ Frame 15: 60 bytes on wire (480 bits), 60 bytes captured (480 bits)
▶ Ethernet II, Src: LinksysG_da:af:73 (00:06:25:da:af:73), Dst: Actionte_8a:70:1a (00:20:e0:8a:70:1a)
```

The ACK packets

From the above snapshots, we calculate the following,

Segment 1:
Sequence No = 1
Size = 565
Sent time = 0.026477
Acknowledgement Received Time(With ACK value 566) = 0.053937
RTT = 0.02746 Seconds
Estimated RTT = RTT at the beginning = 0.02746 Seconds.

Now for other segments, the Estimated RTT is calculated as,

```
EstimatedRTT = (1- a)*EstimatedRTT + a*SampleRTT
```

```
Where a = 0.125 typically()As discussed in class
So,
EstimatedRTT = 0.875 * EstimatedRTT + 0.125 * SampleRTT
```

Segment 2:
Sequence No = 566
Size = 1460
Sent time = 0.041737
Acknowledgement Received Time(With ACK value 2026) = 0.077294

RTT = 0.035557 Seconds
Estimated RTT at this point = 0.02746
Estimated RTT = 0.875 * EstimatedRTT + **0.125** * SampleRTT
= 0.875 * 0.02746 + 0.125 * 0.035557 = 0.02847 Seconds.

Segment 3:
Sequence No = 2026
Size = 1460
Sent time = 0.054026
Acknowledgement Received Time(With ACK value 3486) = 0.124085
RTT = 0.070059 Seconds
Estimated RTT at this point = 0.02847
Estimated RTT = 0.875 * EstimatedRTT + **0.125** * SampleRTT
= 0.875 *0.02847 + 0.125 * 0.070059 =0.033668 Seconds.

Segment 4:
Sequence No = 3486
Size = 1460
Sent time = 0.054690
Acknowledgement Received Time(With ACK value 4946) = 0.169118
RTT = 0.11443 Seconds
Estimated RTT at this point =0.033668
Estimated RTT = 0.875 * EstimatedRTT + **0.125** * SampleRTT
= 0.875 * 0.033668 + 0.125 * 0.11443 = 0.04376 Seconds.

Segment 5 :
Sequence No =4946
Size =1460
Sent time =0.077405
Acknowledgement Received Time(With ACK value 6406) =0.217299
RTT = 0.13989 Seconds
Estimated RTT at this point = 0.04376
Estimated RTT = 0.875 * EstimatedRTT + **0.125** * SampleRTT
= 0.875 * 0.04376 + 0.125 * 0.13989 = 0.05577 Seconds.

Segment 6:
Sequence No =6406
Size =1460
Sent time =0.078157

Acknowledgement Received Time(With ACK value 7866) =0.267802
RTT = 0.18964 Seconds
Estimated RTT at this point = 0.05577
Estimated RTT = 0.875 * EstimatedRTT + **0.125** * SampleRTT
= 0.875 * 0.05577 + 0.125 * 0.18964 = 0.07250 Seconds.

Answer to Q. No. 8:

As already mentioned in the above answer and the snapshots, the lengths are as follows,

Segment 1:
Size = 565 bytes

Segment 2:
Size = 1460 bytes

Segment 3:
Size = 1460 bytes

Segment 4:
Size = 1460 bytes

Segment 5 :
Size =1460 bytes

Segment 6:
Size =1460 bytes

Answer to Q. No. 9:

The below snapshot shows the sent segments from the receiver side **sorted** by the IP address of the receiver. We can clearly see that the minimum window side advertised by the receiver is **5840** in segment 2 of the trace. It gradually increases after that as we found that the receiver was never full with respect to it's buffer and hence the sender was **never throttled** due to this.

	Time	Source ▲	Destination	Protoco	L	Info
2	0.023172	128.119.245.12	192.168.1.102	TCP		80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
6	0.053937	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
9	0.077294	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
12	0.124085	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
14	0.169118	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	0.217299	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	0.267802	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0
17	0.304807	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=9013 Win=23360 Len=0
24	0.356437	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=10473 Win=26280 Len=0
25	0.400164	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=11933 Win=29200 Len=0
26	0.448613	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=13393 Win=32120 Len=0
27	0.500029	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=14853 Win=35040 Len=0
28	0.545052	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=16313 Win=37960 Len=0
29	0.576417	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=17205 Win=37960 Len=0
36	0.626496	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=18665 Win=40880 Len=0
37	0.672796	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=20125 Win=43800 Len=0
38	0.730684	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=21585 Win=46720 Len=0
39	0.772990	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=23045 Win=49640 Len=0
40	0.820622	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=24505 Win=52560 Len=0
41	0.853186	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=25397 Win=52560 Len=0
48	0.899423	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=26857 Win=55480 Len=0
49	0.949545	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=28317 Win=58400 Len=0
50	0.994715	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=29777 Win=61320 Len=0
51	1.039820	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=31237 Win=62780 Len=0
52	1.117097	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=33589 Win=62780 Len=0
59	1.200421	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=35049 Win=62780 Len=0
60	1.265026	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=37969 Win=62780 Len=0
61	1.362074	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=40889 Win=62780 Len=0
62	1.389886	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=41781 Win=62780 Len=0
69	1.488313	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=44701 Win=62780 Len=0
70	1.584980	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=47621 Win=62780 Len=0
71	1.661513	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=49973 Win=62780 Len=0

Answer to Q. No. 10:

Whenever there's a retransmission, the Wireshark will show it as a retransmitted packet in **red color** and also show corresponding to which packet it got retransmitted In the trace, we didn't find any such capture. So we conclude that there were no retransmissions. Also we saw that the sequence numbers from the client to the server kept increasing monotonically as shown below, so there were in fact no retransmissions.

	tcp					
No.	Time	Source ▲	Destination	Protoco	L	Info
1	0.000000	192.168.1.102	128.119.245.12	TCP		1161 → 80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
3	0.023265	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
4	0.026477	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565
5	0.041737	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460
7	0.054026	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460
8	0.054690	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460
10	0.077405	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460
11	0.078157	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460
13	0.124185	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147
18	0.305040	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=9013 Ack=1 Win=17520 Len=1460
19	0.305813	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=10473 Ack=1 Win=17520 Len=1460
20	0.306692	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=11933 Ack=1 Win=17520 Len=1460
21	0.307571	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=13393 Ack=1 Win=17520 Len=1460
22	0.308699	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=14853 Ack=1 Win=17520 Len=1460
23	0.309553	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=16313 Ack=1 Win=17520 Len=892
30	0.576671	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=17205 Ack=1 Win=17520 Len=1460
31	0.577385	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=18665 Ack=1 Win=17520 Len=1460
32	0.578329	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=20125 Ack=1 Win=17520 Len=1460
33	0.579195	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=21585 Ack=1 Win=17520 Len=1460
34	0.580149	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=23045 Ack=1 Win=17520 Len=1460
35	0.581074	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=24505 Ack=1 Win=17520 Len=892
42	0.853405	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=25397 Ack=1 Win=17520 Len=1460
43	0.854076	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=26857 Ack=1 Win=17520 Len=1460
44	0.855036	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=28317 Ack=1 Win=17520 Len=1460
45	0.855878	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=29777 Ack=1 Win=17520 Len=1460
46	0.856802	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=31237 Ack=1 Win=17520 Len=1460
47	0.857683	192.168.1.102	128.119.245.12	TCP		1161 → 80 [PSH, ACK] Seq=32697 Ack=1 Win=17520 Len=892
53	1.117333	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=33589 Ack=1 Win=17520 Len=1460
54	1.118133	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=35049 Ack=1 Win=17520 Len=1460
55	1.119029	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=36509 Ack=1 Win=17520 Len=1460
56	1.119858	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=37969 Ack=1 Win=17520 Len=1460
57	1.120902	192.168.1.102	128.119.245.12	TCP		1161 → 80 [ACK] Seq=39429 Ack=1 Win=17520 Len=1460

Answer to Q. No. 11:

No.	Time	Source	Destination	Protocol	Len	Info
2	0.023172	128.119.245.12	192.168.1.102	TCP		80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460
6	0.053937	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
9	0.077294	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
12	0.124085	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
14	0.169118	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	0.217299	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	0.267802	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0
17	0.304807	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=9013 Win=23360 Len=0
24	0.356437	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=10473 Win=26280 Len=0
25	0.400164	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=11933 Win=29200 Len=0
26	0.448613	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=13393 Win=32120 Len=0
27	0.500029	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=14853 Win=35040 Len=0
28	0.545052	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=16313 Win=37960 Len=0
29	0.576417	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=17205 Win=37960 Len=0
36	0.626496	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=18665 Win=40880 Len=0
37	0.672796	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=20125 Win=43800 Len=0
38	0.730684	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=21585 Win=46720 Len=0
39	0.772990	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=23045 Win=49640 Len=0
40	0.820622	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=24505 Win=52560 Len=0
41	0.853186	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=25397 Win=52560 Len=0
48	0.899423	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=26857 Win=55480 Len=0
49	0.949545	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=28317 Win=58400 Len=0
50	0.994715	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=29777 Win=61320 Len=0
51	1.039820	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=31237 Win=62780 Len=0
52	1.117097	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=33589 Win=62780 Len=0
59	1.200421	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=35049 Win=62780 Len=0
60	1.265026	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=37969 Win=62780 Len=0
61	1.362074	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=40889 Win=62780 Len=0
62	1.389886	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=41781 Win=62780 Len=0
69	1.488313	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=44701 Win=62780 Len=0
70	1.584980	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=47621 Win=62780 Len=0
71	1.661513	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=49973 Win=62780 Len=0
78	1.758227	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=52893 Win=62780 Len=0
79	1.860063	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=55813 Win=62780 Len=0
80	1.930880	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=58165 Win=62780 Len=0
87	2.029069	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=61085 Win=62780 Len=0

From the first few ACK packets sent by receiving server, we see that

1. Between segments 2 and 6 = 566 - 1= **565** Bytes Acknowledged.
2. Between segments 6 and 9 = 2026 - 566 = **1460** Bytes Acknowledged.
3. Between segments 9 and 12 = 3486 - 2026= **1460** Bytes Acknowledged.
4. Between segments 12 and 14 = 4946 - 3486 = **1460** Bytes Acknowledged.
etc.

So looks like the typical size for which the ACKs are being sent is = **1460** Bytes

However, we do see some cumulative ACKs in the sequence.

No.	Time	Source	Destination	Protocol	Len	Info
96	2.311413	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=69277 Win=62780 Len=0
97	2.404228	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=72197 Win=62780 Len=0
98	2.476576	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=74549 Win=62780 Len=0
105	2.576633	128.119.245.12	192.168.1.102	TCP		80 → 1161 [ACK] Seq=1 Ack=77469 Win=62780 Len=0

For E.g. between segments **96 and 97** above, we have (72197 - 69277) = 2920 Bytes. Which is double of 1460 , which shows that two consecutive segments are getting ACKed together.

Answer to Q. No. 12:

The following is the first packet transferred.
Sent Time = 0.026477
Segment No = 1

```
   1 0.000000        192.168.1.102    128.119.245.12    TCP    1161 → 80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
   3 0.023265        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
   4 0.026477        192.168.1.102    128.119.245.12    TCP    1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565
   5 0.041737        192.168.1.102    128.119.245.12    TCP    1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460
   7 0.054026        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460
   8 0.054690        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460
```

The following is the last packet transferred.
Sent Time = 5.651141
Segment No = 164091

```
 195 5.200252        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=160849 Ack=1 Win=17520 Len=1460
 196 5.201150        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=162309 Ack=1 Win=17520 Len=1460
 197 5.202024        192.168.1.102    128.119.245.12    TCP    1161 → 80 [PSH, ACK] Seq=163769 Ack=1 Win=17520 Len=272
 199 5.297341        192.168.1.102    128.119.245.12    TCP    1161 → 80 [PSH, ACK] Seq=164041 Ack=1 Win=17520 Len=50
 206 5.651141        192.168.1.102    128.119.245.12    TCP    1161 → 80 [ACK] Seq=164091 Ack=731 Win=16790 Len=0
 213 7.595557        192.168.1.102    199.2.53.206      TCP    1162 → 631 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
```

Total Bytes Transferred = 164091 - 1 = 164090 Bytes
Time taken = 5.651141 - 0.026477 = 5.624664
Throughput = 164090/5.62= **29197.50 Bytes/Second**

Answer to Q. No. 13:
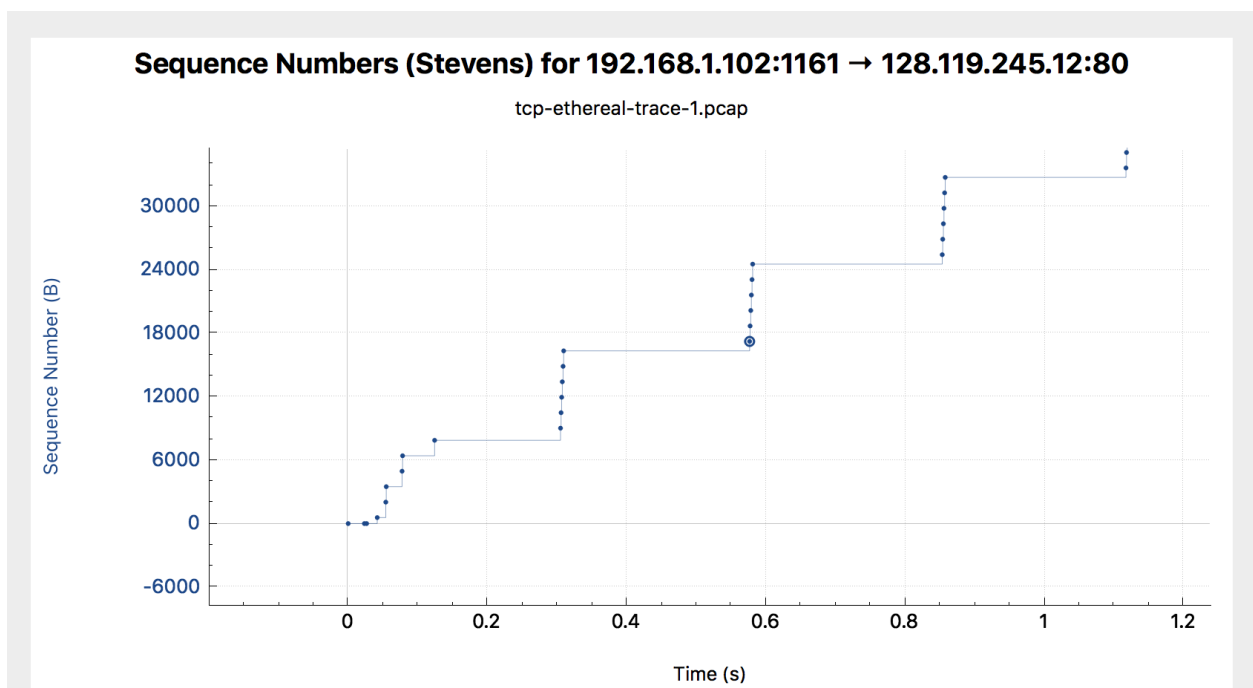
From the snapshot of *ethereal_trace* above, we see that the TCP slow start started at the beginning of the data transfer and continued till around 0.15 seconds till which it kept sending 2 new segments on each acknowledgement. But after that period, it enters a different mode of upper limit on transferring packets and it keeps sending 6 packets in regular batches. This behavior, however is little different than what expected because, it it has entered a congestion avoidance phase as the algorithm describes, it should have been additively increasing the no. of segments transferred, which it is not doing in this case. So, we can't really comment if it has entered the congestion avoidance phase, but yeah, it seems like around 0.15 to 0.20 seconds, it's slow start definitely ended. The limiting transfers after that may be due to any other reason like application layer not feeding the packets or computer being to slow to send them etc. However, we saw that the advertised receiver window was quite hight at all the times and hence we don't see that as the limiting criteria in this scenario.

Also, from the below snapshot of the Bytes_in_flight values(using Wireshark **tcp.analysis.bytes_in_flight**),

o.	Time		Source	Destination	Protoco	Info	Bytes In Flight	Length
5	0.041737		192.168.1.102	128.119.245.12	TCP	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=…	2025	
6	0.053937		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 …		
7	0.054026		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=2026 Ack=1 Win=1752…	2920	
8	0.054690		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=3486 Ack=1 Win=1752…	4380	
9	0.077294		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760…		
10	0.077405		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=4946 Ack=1 Win=1752…	4380	
11	0.078157		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=6406 Ack=1 Win=1752…	5840	
12	0.124085		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=3486 Win=1168…		
13	0.124185		192.168.1.102	128.119.245.12	TCP	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win…	5527	
14	0.169118		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=4946 Win=1460…		
15	0.217299		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=6406 Win=1752…		
16	0.267802		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=7866 Win=2044…		
17	0.304807		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=9013 Win=2336…		
18	0.305040		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=9013 Ack=1 Win=1752…	1460	
19	0.305813		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=10473 Ack=1 Win=175…	2920	
20	0.306692		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=11933 Ack=1 Win=175…	4380	
21	0.307571		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=13393 Ack=1 Win=175…	5840	
22	0.308699		192.168.1.102	128.119.245.12	TCP	1161 → 80 [ACK] Seq=14853 Ack=1 Win=175…	7300	
23	0.309553		192.168.1.102	128.119.245.12	TCP	1161 → 80 [PSH, ACK] Seq=16313 Ack=1 Wi…	8192	
24	0.356437		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=10473 Win=262…		
25	0.400164		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=11933 Win=292…		
26	0.448613		128.119.245.12	192.168.1.102	TCP	80 → 1161 [ACK] Seq=1 Ack=13393 Win=321…		

we see that till packet no. 13 we see an increasing effect of the slow start which is changed due to some reason(Clearly not due to Receiver's window) and comes back to 1480 , after which it follows a repetitive pattern.

Answer to Q No. 14:

We do a similar analysis for the trace that we collected in our machine(my_trace). Below is the snapshot of the Steven's graph and the point where the increasing **Bytes_in_flight** value suddenly got decreased indicating the change in the congestion control mechanism. This change happens around 14 seconds as seen in the snapshot. From the Steven's graph, we can see that this graph looks more realistic in the sense that it looks exactly how it should be according to the algorithm. The segments transferred keeps increasing in a steady manner and indicates the congestion control in action, unlike the

previous graph where it was always limited to a constant no. of segments. Similar to the Q13, the slow start here also starts at the beginning and runs till the point as described above, the packet 176.

The Bytes In Flight Values:

No.	Time	Source	Destination	Protoco	Info	Bytes In Flight	Length
173	14.085413	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=68712 Win=16…		66
174	14.085463	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=93328 Ack=1 Win=13…	26064	1514
175	14.085464	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=94776 Ack=1 Win=13…	27512	1514
176	14.085511	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=96224 Ack=1 Win=13…	28960	1514
179	14.141290	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=70160 Win=16…		66
180	14.141293	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=71608 Win=17…		66
181	14.141294	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=73056 Win=17…		66
182	14.141295	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=74504 Win=17…		66
183	14.141295	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=75952 Win=18…		66
184	14.141296	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=77400 Win=18…		66
185	14.141297	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=78848 Win=18…		66
186	14.141297	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=80296 Win=18…		66
187	14.141298	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=81744 Win=18…		66
188	14.141299	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=83192 Win=18…		66
189	14.141299	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=84640 Win=18…		66
190	14.141301	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=86088 Win=18…		66
191	14.141302	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=87536 Win=18…		66
192	14.141302	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=88984 Win=18…		66
193	14.141303	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=90432 Win=18…		66
194	14.141361	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=91880 Win=18…		66
195	14.141362	128.119.245.12	192.168.0.16	TCP	80 → 53185 [ACK] Seq=1 Ack=93328 Win=18…		66
196	14.141374	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=97672 Ack=1 Win=13…	5792	1514
197	14.141374	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=99120 Ack=1 Win=13…	7240	1514
198	14.141375	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=100568 Ack=1 Win=1…	8688	1514
199	14.141376	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=102016 Ack=1 Win=1…	10136	1514
200	14.141376	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=103464 Ack=1 Win=1…	11584	1514
201	14.141377	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=104912 Ack=1 Win=1…	13032	1514
202	14.141445	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=106360 Ack=1 Win=1…	14480	1514
203	14.141445	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=107808 Ack=1 Win=1…	15928	1514
204	14.141446	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=109256 Ack=1 Win=1…	17376	1514
205	14.141447	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=110704 Ack=1 Win=1…	18824	1514
206	14.141447	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=112152 Ack=1 Win=1…	20272	1514
207	14.141448	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=113600 Ack=1 Win=1…	21720	1514
208	14.141448	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=115048 Ack=1 Win=1…	23168	1514
209	14.141450	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=116496 Ack=1 Win=1…	24616	1514
210	14.141450	192.168.0.16	128.119.245.12	TCP	53185 → 80 [ACK] Seq=117944 Ack=1 Win=1	26064	1514

The Steven's Graph:

Sequence Numbers (Stevens) for 192.168.0.16:53185 → 128.119.245.12:80

my_capture.pcapng