

1. Client computer (source):

IP address: 192.168.1.102

TCP port number: 1161

1	0.000000	192.168.1.102	128.119.245.12	Destination address	62	1161 → 80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
2	0.023172	128.119.245.12	192.168.1.102	TCP	62	80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
Frame 1: 62 bytes on wire (496 bits), 62 bytes captured (496 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, Dst Port: 80, Seq: 0, Len: 0						

2. Server (destination)

IP address: 128.119.245.12

TCP port number: 80

1	0.000000	192.168.1.102	128.119.245.12	TCP	62	1161 → 80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
2	0.023172	128.119.245.12	192.168.1.102	TCP	62	80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
Frame 2: 62 bytes on wire (496 bits), 62 bytes captured (496 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)						
Internet Protocol Version 4, Src: 128.119.245.12, Dst: 192.168.1.102						
Transmission Control Protocol, Src Port: 80, Dst Port: 1161, Seq: 0, Ack: 1, Len: 0						

3. Client computer (source):

IP address: 10.0.0.8

TCP port number: 58345

Here we can see the 3 way handshake:

1. SYN Seq=0
2. SYN, ACK Seq=0 Ack=1
3. ACK Seq=1 Ack=1

27	1.773721	10.0.0.8	128.119.245.12	TCP	66	58346 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM=1
28	1.921725	128.119.245.12	10.0.0.8	TCP	60	80 → 58234 [RST] Seq=1 Win=0 Len=0
29	1.922018	128.119.245.12	10.0.0.8	TCP	66	80 → 58345 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1400 SACK_PERM=1 WS=128
30	1.922190	10.0.0.8	128.119.245.12	TCP	54	58345 → 80 [ACK] Seq=1 Ack=1 Win=131584 Len=0

4. The sequence number of the TCP SYN segment that is used to initiate the TCP connection between the client computer and gaia.cs.umass.edu is 0.

The SYN flag is set to 1 and it indicates that this segment is a SYN segment.

1	0.000000	192.168.1.102	128.119.245.12	TCP	62	1161 → 80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
2	0.023172	128.119.245.12	192.168.1.102	TCP	62	80 → 1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
3	0.023265	192.168.1.102	128.119.245.12	TCP	54	1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0

> Frame 1: 62 bytes on wire (496 bits), 62 bytes captured (496 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, Dst Port: 80, Seq: 0, Len: 0

Source Port: 1161

Destination Port: 80

[Stream index: 0]

[TCP Segment Len: 0]

Sequence Number: 0 (relative sequence number)

Sequence Number (raw): 232129012

[Next Sequence Number: 1 (relative sequence number)]

Acknowledgment Number: 0

Acknowledgment number (raw): 0

0111 = Header Length: 28 bytes (7)

▼ Flags: 0x002 (SYN)

000. = Reserved: Not set

...0 = Nonce: Not set

.... 0... = Congestion Window Reduced (CWR): Not set

.... .0.. = ECN-Echo: Not set

.... ..0. = Urgent: Not set

.... ...0 = Acknowledgment: Not set

.... 0... = Push: Not set

....0.. = Reset: Not set

>1. = Syn: Set

....0 = Fin: Not set

[TCP Flags:S.]

5. The sequence number of the SYNACK segment from gaia.cs.umass.edu to the client computer in reply to the SYN has the value of 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 gaia.cs.umass.edu by adding 1 to the initial sequence number of SYN segment from the client computer (i.e. the sequence number of the SYN segment initiated by the client computer is 0).

The SYN flag and Acknowledgement flag in the segment are set to 1 and they indicate that this segment is a SYNACK segment.

1	0.000000	192.168.1.102	128.119.245.12	TCP	62	1161 → 80	[SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
2	0.023172	128.119.245.12	192.168.1.102	TCP	62	80 → 1161	[SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
3	0.023265	192.168.1.102	128.119.245.12	TCP	54	1161 → 80	[ACK] Seq=1 Ack=1 Win=17520 Len=0

> Frame 2: 62 bytes on wire (496 bits), 62 bytes captured (496 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)

> Internet Protocol Version 4, Src: 128.119.245.12, Dst: 192.168.1.102

▼ Transmission Control Protocol, Src Port: 80, Dst Port: 1161, Seq: 0, Ack: 1, Len: 0

Source Port: 80

Destination Port: 1161

[Stream index: 0]

[TCP Segment Len: 0]

Sequence Number: 0 (relative sequence number)

Sequence Number (raw): 883061785

[Next Sequence Number: 1 (relative sequence number)]

Acknowledgment Number: 1 (relative ack number)

Acknowledgment number (raw): 232129013

0111 = Header Length: 28 bytes (7)

▼ 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.]

6. Sequence number : 1

4	0.026477	192.168.1.102	128.119.245.12	TCP	619	1161 → 80	[PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565 [TCP segment of a reassembled PDU]
5	0.041737	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
6	0.053937	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=566 Win=6780 Len=0
7	0.054026	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
8	0.054690	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
9	0.077294	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	0.077405	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
11	0.078157	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
12	0.124085	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=2406 Win=11680 Len=0

....0... = ECN-Echo: Not set

....0... = Urgent: Not set

....1... = Acknowledgment: Set

....1... = Push: Set

....0... = Reset: Not set

....0... = Syn: Not set

....0... = Fin: Not set

[TCP Flags:AP...]

Window: 17520

[Calculated window size: 17520]

[Window size scaling factor: -2 (no window scaling used)]

Checksum: 0x1fbd [unverified]

[Checksum Status: Unverified]

Urgent Pointer: 0

▼ [SEQ/ACK analysis]

[IRTT: 0.023265000 seconds]

[Bytes in flight: 565]

[Bytes sent since last PSH flag: 565]

▼ [Timestamps]

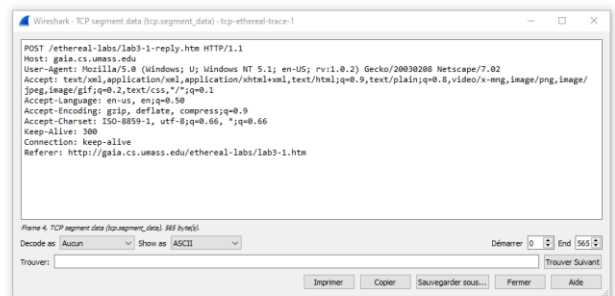
[Time since first frame in this TCP stream: 0.026477000 seconds]

[Time since previous frame in this TCP stream: 0.003212000 seconds]

TCP payload (565 bytes)

[\[Reassembled PDU in frame: 199\]](#)

TCP segment data (565 bytes)



7. The first six segments in the TCP connection including the segment containing the HTTP POST are: 4, 5, 7, 8, 10, 11.

Segment 1: Sequence nb 1

Segment 2: Sequence nb 566

Segment 3: Sequence nb 2026

Segment 4: Sequence nb 3486

Segment 5: Sequence nb 4946

Segment 6: Sequence nb 6406

The ACKs segments numbers are: 6, 9, 12, 14, 15, 16.

To calculate the RTT value for each of the six segments we will write the segment sent time, and the ACK received time and subtract the sent time from the ACK received time:

The value of the time segments is sent/received is mentioned in the timestamps.

Estimated RTT Value= $0.875 \times \text{RTT} + 0.125 \times \text{RTT Value}$

	Sent Time	ACK received	RTT Value	Estimated RTT Value
Segment 1	0.026477	0.053937	$0.053937 - 0.026477 =$ 0.02746	0.02746
Segment 2	0.041737	0.077294	$0.077294 - 0.041737 =$ 0.035557	0.02847
Segment 3	0.054026	0.124085	$0.124085 - 0.054026 =$ 0.070059	0.03366
Segment 4	0.05469	0.169118	$0.169118 - 0.05469 =$ 0.114428	0.04375
Segment 5	0.077405	0.217299	$0.217299 - 0.077405 =$ 0.139894	0.055768
Segment 6	0.078157	0.267802	$0.267802 - 0.078157 =$ 0.189645	0.0725

8. Segment 1 Length: 565
 Segment 2 Length: 1460
 Segment 3 Length: 1460
 Segment 4 Length: 1460
 Segment 5 Length: 1460
 Segment 6 Length: 1460

4	0.026477	192.168.1.102	128.119.245.12	TCP	619	1161 → 80	[PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565 [TCP segment of a reassembled PDU]
5	0.041737	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
6	0.053937	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=566 Win=6780 Len=0
7	0.054026	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
8	0.054690	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
9	0.077294	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	0.077405	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
11	0.078157	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
12	0.124085	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=3486 Win=11680 Len=0
13	0.124185	192.168.1.102	128.119.245.12	TCP	1201	1161 → 80	[PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147 [TCP segment of a reassembled PDU]
14	0.169118	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	0.217299	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	0.267802	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=7866 Win=20440 Len=0
17	0.304807	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=9013 Win=23360 Len=0
18	0.305040	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=9013 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
19	0.305813	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=10473 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
20	0.306692	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=11933 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]

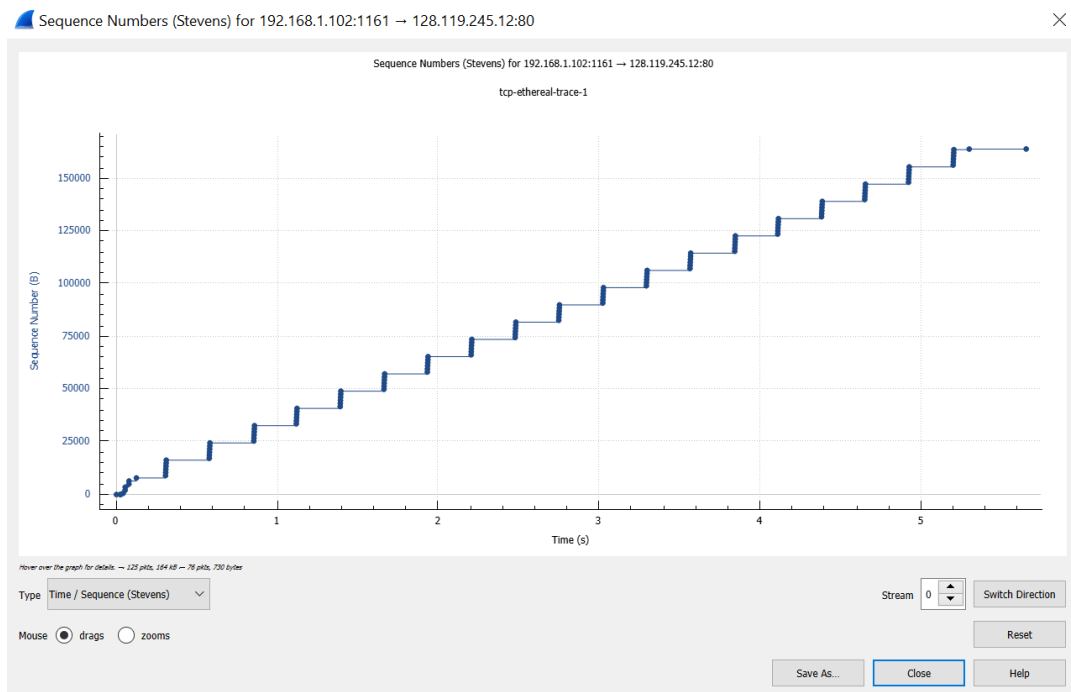
9. The minimum amount of available buffer space advertised at the received for the entire trace is 5840 bytes

1	0.000000	192.168.1.102	128.119.245.12	TCP	62	1161 → 80	[SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1
2	0.023172	128.119.245.12	192.168.1.102	TCP	62	80 → 1161	[SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1
3	0.023265	192.168.1.102	128.119.245.12	TCP	54	1161 → 80	[ACK] Seq=1 Ack=1 Win=17520 Len=0

The lack of receiver buffer space never throttles the sender because the receiver window grows until the maximum receiver buffer size of 62780 bytes

202	5.455830	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=164091 Win=62780 Len=0
203	5.461175	128.119.245.12	192.168.1.102	HTTP	784	HTTP/1.1 200 OK	(text/html)

10. There are no retransmitted segments in the trace file.



6	0.053937	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=566 Win=6780 Len=0
7	0.054026	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
8	0.054690	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
9	0.077294	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	0.077405	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
11	0.078157	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80	[ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP segment of a reassembled PDU]
12	0.124085	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=3486 Win=11680 Len=0
13	0.124185	192.168.1.102	128.119.245.12	TCP	1201	1161 → 80	[PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147 [TCP segment of a reassembled PDU]
14	0.169118	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	0.217299	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	0.267802	128.119.245.12	192.168.1.102	TCP	60	80 → 1161	[ACK] Seq=1 Ack=7866 Win=20440 Len=0

12. The throughput for the TCP connection is defined as the amount of data to transmit divided by the transmission time.

The amount of data to transmit: $164091 - 1 = 164090$ bytes

The first ACK for the first segment that was sent = 1.

The last ACK of the last segment sent = 164091.

The transmission time: $5.45583 - 0.026477 = 5.429353$ sec

(the last – the first TCP segment was received)

The throughput is: $164090 / 5.429353 = 30222$ bytes/sec = 30.222 Kbyte/sec

13. The TCP slow start phase begins and ends after 0.3 seconds (from 0 to 0.3 sec).

The congestion avoidance takes over after those 0.3 seconds through the entire connection.

The congestion does not seem to be caused by flow control (the receiver window size is larger than 5 packets). This might be caused because the HTTP server has enforced a rate-limit of some sort.

