

Lab3 - TCP

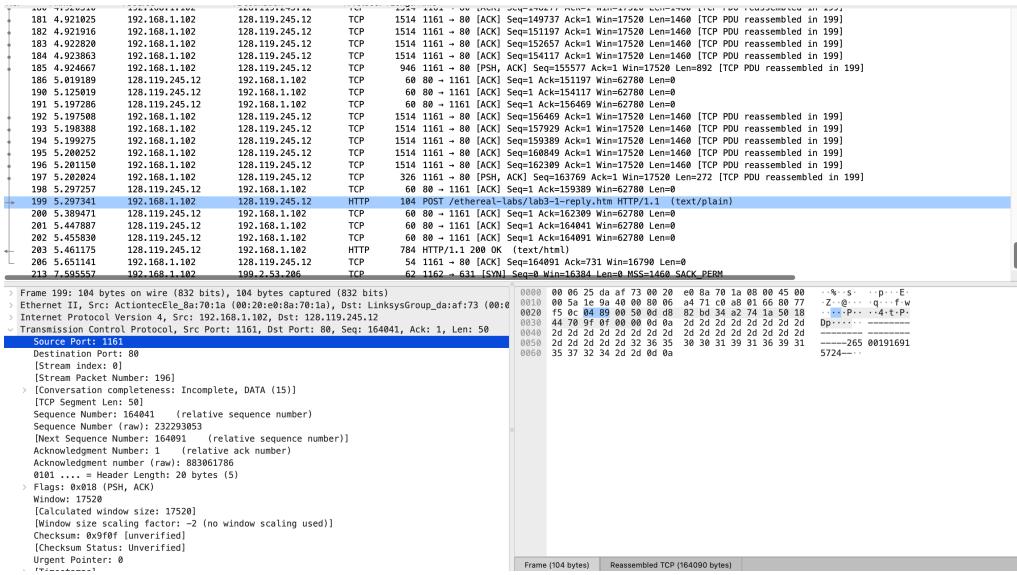
Jiaxi Zhang

March 16, 2025

1 At a first look at the captured trace

1.1 In tcptethereal-trace-1

The IP address of the client computer is 192.168.1.102, and the TCP port number used by the client computer is 1161. The IP address of gaia.cs.umass.edu is 128.119.245.12, and the TCP port number used by the server is 80. It can be seen in the following two figures.



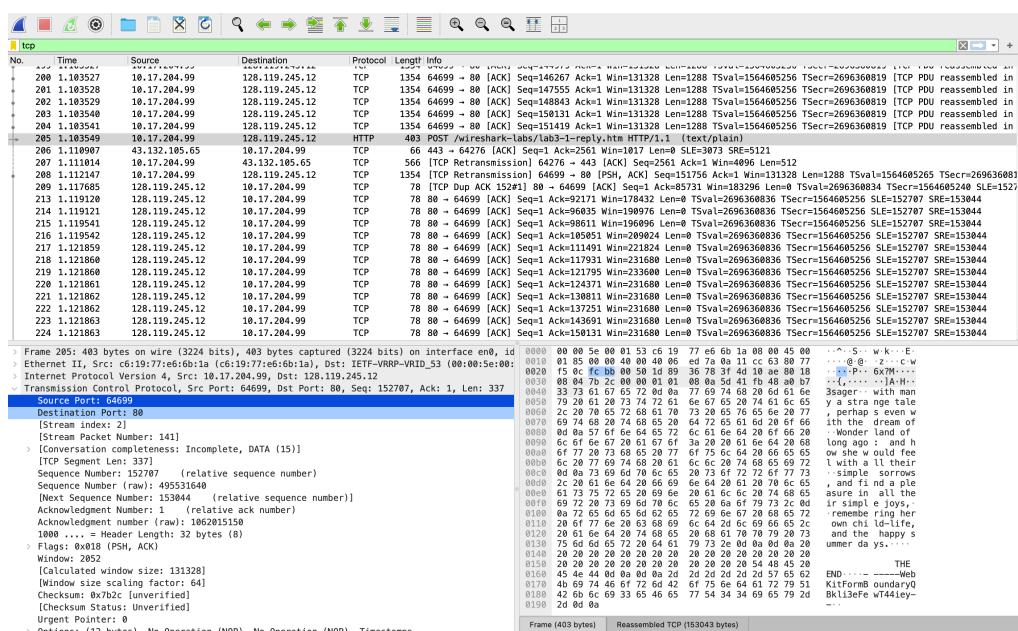
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Frame 199: 104 bytes on wire (832 bits), 104 bytes captured (832 bits)
Ethernet II, Src: ActiontecEle_8a:70:1a (00:20:e0:8a:70:1a), Dst: LinksysGroup_da:af:73
(00:06:25:da:af:73)
Internet Protocol Version 4, Src: 192.168.1.102, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 1161, Dst Port: 80, Seq: 164041, Ack: 1, Len: 50
    Source Port: 1161
    Destination Port: 80
    [Stream index: 0]
    [Stream Packet Number: 196]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 50]
    Sequence Number: 164041      (relative sequence number)
    Sequence Number (raw): 232293053
    [Next Sequence Number: 164091      (relative sequence number)]
    Acknowledgment Number: 1      (relative ack number)
    Acknowledgment number (raw): 883061786
    0101 .... = Header Length: 20 bytes (5)
    Flags: 0x018 (PSH, ACK)
    Window: 17520
    [Calculated window size: 17520]
    [Window size scaling factor: -2 (no window scaling used)]
    Checksum: 0x9f0f [unverified]
    [Checksum Status: Unverified]
    Urgent Pointer: 0
    [Timestamps]
    [SEQ/ACK analysis]
    TCP payload (50 bytes)
    TCP segment data (50 bytes)
[122 Reassembled TCP Segments (164090 bytes): #4(565), #5(1460), #7(1460), #8(1460), #10(1460),
#11(1460), #13(1447), #18(1460), #19(1460), #20(1460), #21(1460), #22(1460), #23(892), #30(1460),
#31(1460), #32(1460), #33(1460), #34(1460), ]
Hypertext Transfer Protocol
MIME Multipart Media Encapsulation, Type: multipart/form-data, Boundary:
"-----265001916915724"

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1.2 In my trace

The IP address of the client computer is 10.17.204.99, and the TCP port number used by the client computer is 64699.



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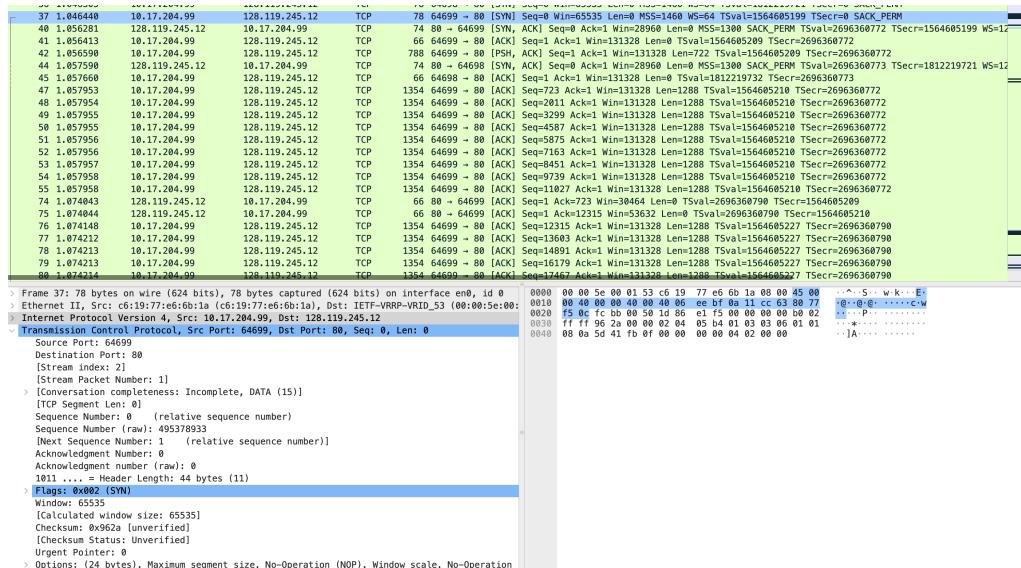
Frame 205: 403 bytes on wire (3224 bits), 403 bytes captured (3224 bits) on interface en0, id 0
Ethernet II, Src: c6:19:77:e6:6b:1a (c6:19:77:e6:6b:1a), Dst: IETF-VRRP-VRID_53 (00:00:5e:00:01:53)
Internet Protocol Version 4, Src: 10.17.204.99, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 64699, Dst Port: 80, Seq: 152707, Ack: 1, Len: 337
    Source Port: 64699
    Destination Port: 80
    [Stream index: 2]
    [Stream Packet Number: 141]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 337]
    Sequence Number: 152707 (relative sequence number)
    Sequence Number (raw): 495531640
    [Next Sequence Number: 153044 (relative sequence number)]
    Acknowledgment Number: 1 (relative ack number)
    Acknowledgment number (raw): 1062015150
    1000 .... = Header Length: 32 bytes (8)
    Flags: 0x018 (PSH, ACK)
    Window: 2052
    [Calculated window size: 131328]
    [Window size scaling factor: 64]
    Checksum: 0x7b2c [unverified]
    [Checksum Status: Unverified]
    Urgent Pointer: 0
    Options: (12 bytes), No-Operation (NOP), No-Operation (NOP), Timestamps
    [Timestamps]
    [SEQ/ACK analysis]
    TCP payload (337 bytes)
    TCP segment data (337 bytes)
[...]121 Reassembled TCP Segments (153043 bytes): #42(722), #47(1288), #48(1288), #49(1288),
#50(1288), #51(1288), #52(1288), #53(1288), #54(1288), #55(1288), #76(1288), #77(1288), #78(1288),
#79(1288), #80(1288), #81(1288), #82(1288), #8]
Hypertext Transfer Protocol
MIME Multipart Media Encapsulation, Type: multipart/form-data, Boundary: "----"
WebKitFormBoundaryQBkli3eFewT44iey"

```

2 TCP Basics

2.1

Answer: The sequence number of the TCP SYN segment is 0. The SYN flag is set to 1 in the segment, which identifies the segment as a SYN segment.



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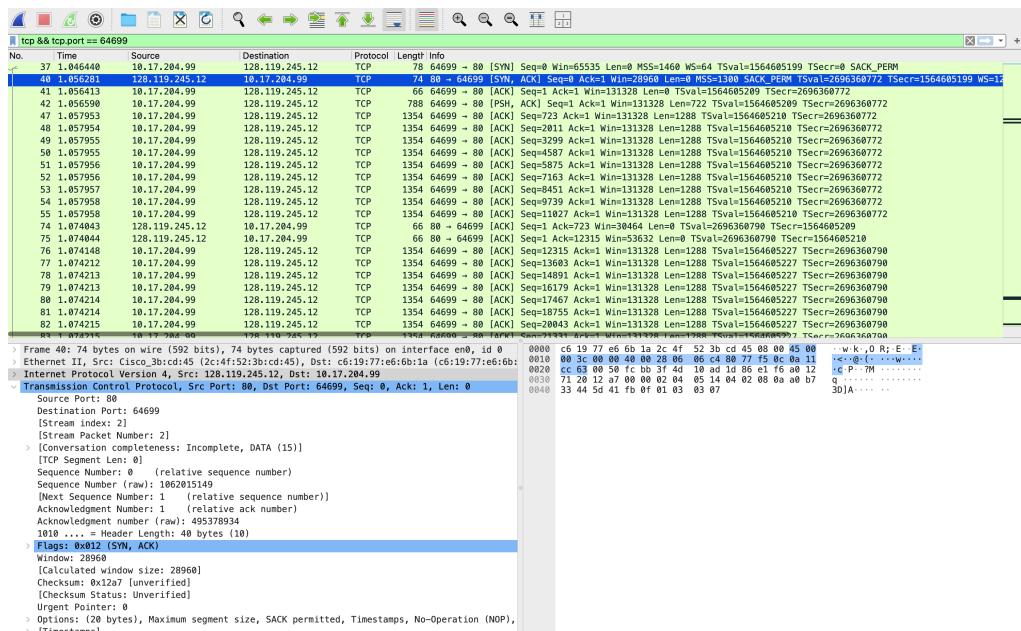
Frame 37: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface en0, id 0
Ethernet II, Src: c6:19:77:e6:6b:1a (c6:19:77:e6:6b:1a), Dst: IETF-VRRP-VRID_53 (00:00:05:e0:01:53)
Internet Protocol Version 4, Src: 10.17.204.99, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 64699, Dst Port: 80, Seq: 0, Len: 0
    Source Port: 64699
    Destination Port: 80
    [Stream index: 2]
    [Stream Packet Number: 1]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 0]
    Sequence Number: 0 (relative sequence number)
    Sequence Number (raw): 495378933
    [Next Sequence Number: 1 (relative sequence number)]
    Acknowledgment Number: 0
    Acknowledgment number (raw): 0
    1011 .... = Header Length: 44 bytes (11)
    Flags: 0x002 (SYN)
    Window: 65535
    [Calculated window size: 65535]
    Checksum: 0x962a [unverified]
    [Checksum Status: Unverified]
    Urgent Pointer: 0
    Options: (24 bytes), Maximum segment size, No-Operation (NOP), Window scale, No-Operation (NOP), No-Operation (NOP), Timestamps, SACK permitted, End of Option List (EOL), End of Option List (EOL)
    [Timestamps]

```

2.2

The sequence number of the SYNACK segment is 0. The Acknowledgement field in the SYNACK segment is

1. The Acknowledgement field in the SYNACK segment is determined by the sequence number of the SYN segment plus 1. Both the SYN and ACK flags are set to 1 in the segment, which identifies the segment as a SYNACK segment.



Frame 40: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface en0, id 0
Ethernet II, Src: Cisco_3b:cd:45 (2c:4f:52:3b:cd:45), Dst: c6:19:77:e6:6b:1a (c6:19:77:e6:6b:1a)
Internet Protocol Version 4, Src: 128.119.245.12, Dst: 10.17.204.99
Transmission Control Protocol, Src Port: 80, Dst Port: 64699, Seq: 0, Ack: 1, Len: 0
 Source Port: 80
 Destination Port: 64699
 [Stream index: 2]
 [Stream Packet Number: 2]
 [Conversation completeness: Incomplete, DATA (15)]
 [TCP Segment Len: 0]
 Sequence Number: 0 (relative sequence number)
 Sequence Number (raw): 1062015149
 [Next Sequence Number: 1 (relative sequence number)]
 Acknowledgment Number: 1 (relative ack number)
 Acknowledgment number (raw): 495378934
 1010 = Header Length: 40 bytes (10)
 Flags: 0x012 (SYN, ACK)
 000. = Reserved: Not set
 ...0 = Accurate ECN: Not set
 0. = Congestion Window Reduced: 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.]
 Window: 28960
 [Calculated window size: 28960]
 Checksum: 0x12a7 [unverified]
 [Checksum Status: Unverified]
 Urgent Pointer: 0
 Options: (20 bytes), Maximum segment size, SACK permitted, Timestamps, No-Operation (NOP),
 Window scale
 [Timestamps]
 [SEQ/ACK analysis]

2.3

The sequence number of the TCP segment containing the HTTP POST command is 152707.

```
[*] Tcp && tcp.port == 64699 && http.request.method == "POST"
No. Time Source Destination Protocol Length Info
+- 285 1.183549 18.17.284.99 128.119.245.12 HTTP 483 POST /wireshark-labs/lab3-1-reply.htm HTTP/1.1 (text/plain)

Transmission Control Protocol, Src Port: 64699, Dst Port: 80, Seq: 152707, Ack: 1, Len: 337
Source Port: 64699
Destination Port: 80
[Stream index: 2]
[Stream end: 2]
[Stream Packet Number: 141]
[Conversation completeness: Incomplete, DATA (15)]
[TCP Segment Len: 337]
Sequence Number: 152707 (relative sequence number)
Sequence Number (raw): 495531640
Relative Sequence Number: 153043 (relative sequence number)
Acknowledgment Number: 1 (relative ack number)
Acknowledgment Number (raw): 1062815158
1000.... = Header Length: 32 bytes (8)
Flags: 0x010 (PSH ACK)
000..... = Reserved: Not set
...0..... = Emergency EOF: Not set
....0.... = Congestion Window Reduced: Not set
....0.... = ECN-Echo: Not set
....0.... = Urgent: Not set
....1.... = Acknowledgment: Set
....1.... = Push: Set
....0.... = Reset: Not set
....0.... = Sync: Not set

Frame (403 bytes) Ressembled TCP (153043 bytes)
```

```

Frame 205: 403 bytes on wire (3224 bits), 403 bytes captured (3224 bits) on interface en0, id 0
Ethernet II, Src: c6:19:77:e6:6b:1a (c6:19:77:e6:6b:1a), Dst: IETF-VRRP-VRID_53 (00:00:5e:00:01:53)
Internet Protocol Version 4, Src: 10.17.204.99, Dst: 128.119.245.12
Transmission Control Protocol, Src Port: 64699, Dst Port: 80, Seq: 152707, Ack: 1, Len: 337
    Source Port: 64699
    Destination Port: 80
    [Stream index: 2]
    [Stream Packet Number: 141]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 337]
    Sequence Number: 152707      (relative sequence number)
    Sequence Number (raw): 495531640
    [Next Sequence Number: 153044      (relative sequence number)]
    Acknowledgment Number: 1      (relative ack number)
    Acknowledgment number (raw): 1062015150
    1000 .... = Header Length: 32 bytes (8)
    Flags: 0x018 (PSH, ACK)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Accurate ECN: Not set
        .... 0.... .... = Congestion Window Reduced: Not set
        .... .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: 2052
    [Calculated window size: 131328]
    [Window size scaling factor: 64]
    Checksum: 0xb2c [unverified]
    [Checksum Status: Unverified]
    Urgent Pointer: 0
    Options: (12 bytes), No-Operation (NOP), No-Operation (NOP), Timestamps
    [Timestamps]
    [SEQ/ACK analysis]
    TCP payload (337 bytes)
    TCP segment data (337 bytes)
[ [...]121 Reassembled TCP Segments (153043 bytes): #42(722), #47(1288), #48(1288), #49(1288),
#50(1288), #51(1288), #52(1288), #53(1288), #54(1288), #55(1288), #76(1288), #77(1288), #78(1288),
#79(1288), #80(1288), #81(1288), #82(1288), #8]
Hypertext Transfer Protocol
MIME Multipart Media Encapsulation, Type: multipart/form-data, Boundary: "----"
WebKitFormBoundaryQBkli3eFewT44iey"

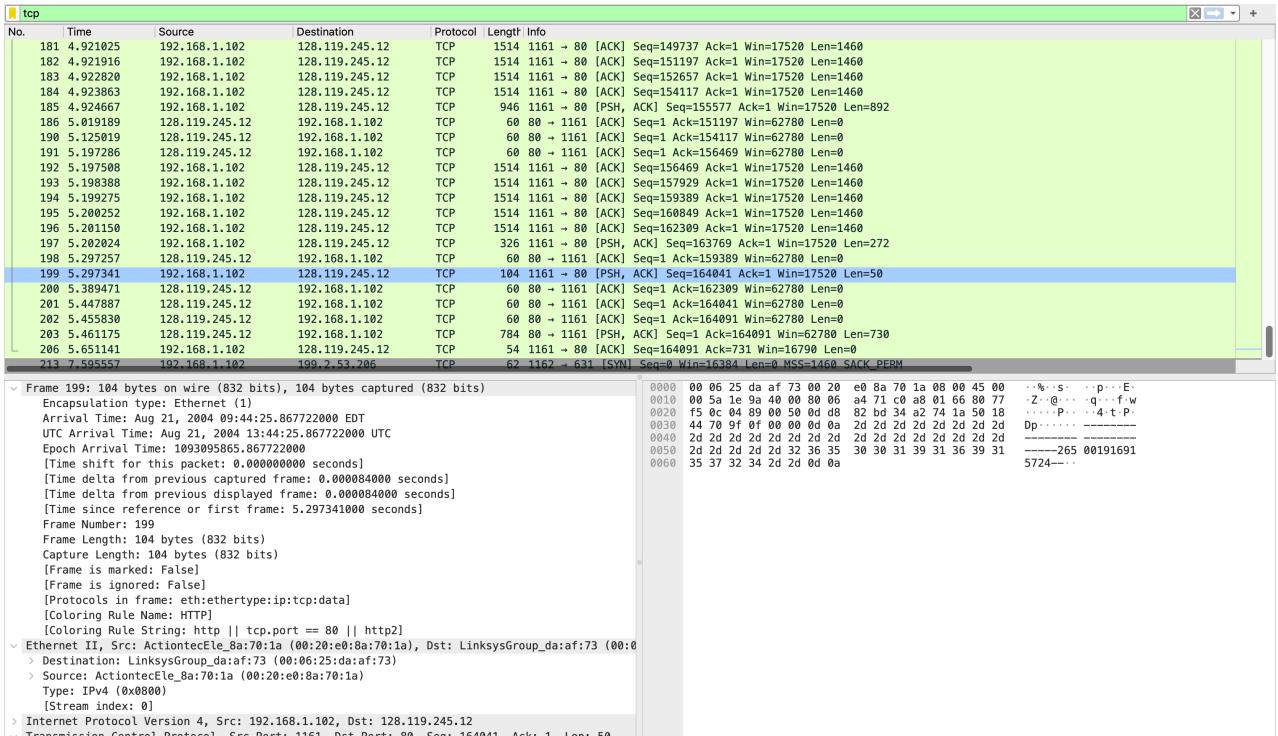
```

2.4

There is some problem in my own trace (retransmission) which affects the answer for this question. So I use the tcptetherreal-trace-1 to answer this question.

Segment Number	Seq	Sent Time	Who ACKs it?	ACK Received Time	RTT (s)
1 (Frame 199)	164041	5.297341	Frame202 (Ack=164091)	5.455830	0.158489
2 (Frame 200)	1	5.389471	Frame206 (Ack=731)	5.651141	0.26167
3 (Frame 201)	1	5.447887	Frame206 (Ack=731)	5.651141	0.203254
4 (Frame 202)	1	5.455830	Frame206 (Ack=731)	5.651141	0.195311
5 (Frame 203)	1	5.461175	Frame206 (Ack=731)	5.651141	0.189966
6 (Frame 206)	164091	5.651141	Not detected	N/A	N/A

Table 1: Sequence Numbers, Timestamps, and RTT Values of First Six TCP Segments



Since in the example trace, I cannot find the ACK segment for the last segment (the next segment frame 213 is on the different TCP because the port number is different), so I cannot calculate the RTT for the last segment.

Calculating the Estimated RTT:

$$\text{EstimatedRTT} = (1 - \alpha) \times \text{EstimatedRTT} + \alpha \times \text{SampleRTT}$$

where $\alpha = 0.125$, so $1 - \alpha = 0.875$.

$$\text{EstimatedRTT}_{199} = 0.158489$$

$$\text{EstimatedRTT}_{200} = 0.875 \times 0.158489 + 0.125 \times 0.26167 = 0.1714$$

$$\text{EstimatedRTT}_{201} = 0.875 \times 0.1714 + 0.125 \times 0.203254 = 0.1754$$

$$\text{EstimatedRTT}_{202} = 0.875 \times 0.1754 + 0.125 \times 0.195311 = 0.1779$$

$$\text{EstimatedRTT}_{203} = 0.875 \times 0.1779 + 0.125 \times 0.189966 = 0.1794$$

$$\text{EstimatedRTT}_{203} = N/A$$

2.5

the length of each of the first six TCP segments:

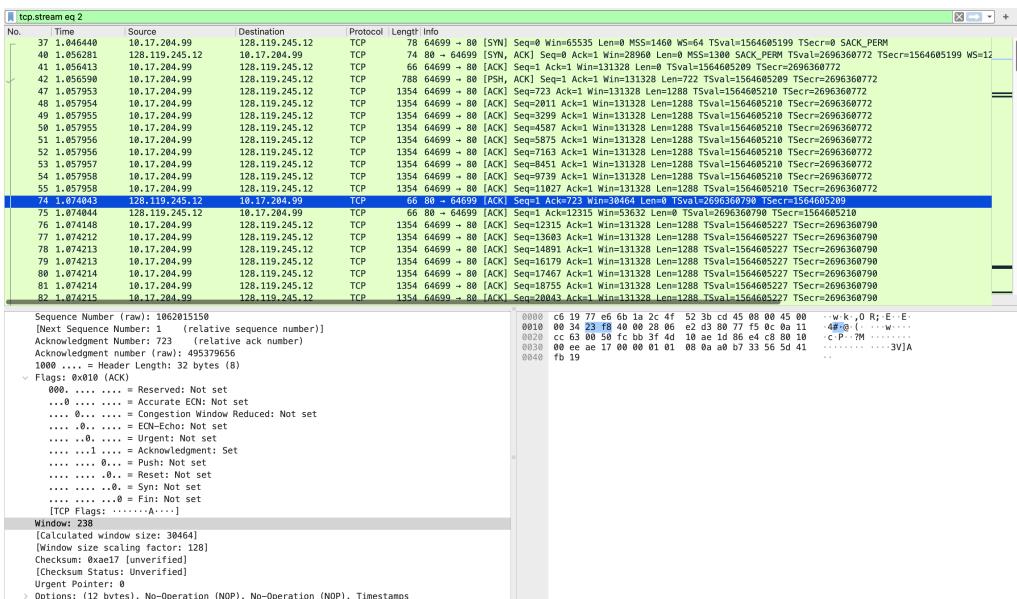
Segment Number	Length	Segment Number	Length
1 (Frame 199)	50	4 (Frame 202)	0
2 (Frame 200)	0	5 (Frame 203)	730
3 (Frame 201)	0	6 (Frame 206)	0

Table 2: Length of First Six TCP Segments

2.6

I will turn back to my own trace to answer this question (9.What is the minimum amount of available buffer space advertised at the received for the entire trace? Does the lack of receiver buffer space ever throttle the sender?) and the following questions.

The minimum amount of available buffer space advertised at the receiver for the entire trace is 238 bytes. And the calculated window size is 30464 bytes. According to the next line, we can find that the lack of receiver buffer space does not throttle the sender because the window size is larger and the sender does not have to wait for the receiver to free up buffer space.



```
Frame 74: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface en0, id 0
Ethernet II, Src: Cisco_3b:cd:45 (2c:4f:52:3b:cd:45), Dst: c6:19:77:e6:6b:1a (c6:19:77:e6:6b:1a)
Internet Protocol Version 4, Src: 128.119.245.12, Dst: 10.17.204.99
Transmission Control Protocol, Src Port: 80, Dst Port: 64699, Seq: 1, Ack: 723, Len: 0
    Source Port: 80
    Destination Port: 64699
    [Stream index: 2]
    [Stream Packet Number: 14]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 0]
    Sequence Number: 1      (relative sequence number)
    Sequence Number (raw): 1062015150
    [Next Sequence Number: 1      (relative sequence number)]
    Acknowledgment Number: 723      (relative ack number)
    Acknowledgment number (raw): 495379656
    1000 .... = Header Length: 32 bytes (8)
    Flags: 0x010 (ACK)
        000 ..... = Reserved: Not set
        ....0 ..... = Accurate ECN: Not set
        .... 0.... = Congestion Window Reduced: Not set
        .... .0.. ... = ECN-Echo: Not set
        .... .0. .... = Urgent: Not set
        .... ..1 .... = Acknowledgment: Set
        .... ...0... = Push: Not set
        .... .... .0.. = Reset: Not set
        .... .... ..0. = Syn: Not set
        .... .... ...0 = Fin: Not set
        [TCP Flags: .....A....]
    Window: 238
    [Calculated window size: 30464]
    [Window size scaling factor: 128]
    Checksum: 0xaea17 [unverified]
    [Checksum Status: Unverified]
    Urgent Pointer: 0
    Options: (12 bytes), No-Operation (NOP), No-Operation (NOP), Timestamps
    [Timestamps]
    [SEQ/ACK analysis]
```

2.7

Yes, there are retransmitted segments in the trace. I used a filter.

tcp.analysis.retransmission || tcp.analysis.fast_retransmission

Also in the "info" column, we can find the retransmitted segments.

2.8

From the trace, each TCP segment has a length of 1288 bytes. We can see from the screenshot below

Frame 47: Seq = 723, Len = 1288;

Frame 48: Seq = 2011, Len = 1288;

No.	Time	Source	Destination	Protocol	Length	Info
37	1.846448	10.17.204.99	128.119.245.12	TCP	78	64699 - 88 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=64 Tsvl=1564605199 Tscr=0 SACK_PERM
40	1.856281	10.17.204.99	128.119.245.12	TCP	78	64699 - 64599 [SYN, ACK] Seq=1 Win=20960 Len=0 MSS=1388 SACK_PERM Tsvl=2696360772 Tscr=1564605199 WS=12
41	1.856413	10.17.204.99	128.119.245.12	TCP	66	64699 - 88 [ACK] Seq=1 Ack=1 Win=13128 Len=0 Tsvl=1564605199 Tscr=2696360772 Tscr=1564605199 WS=12
42	1.856590	10.17.204.99	128.119.245.12	TCP	788	64699 - 88 [PSH, ACK] Seq=1 Ack=1 Win=13128 Len=722 Tsvl=1564605209 Tscr=2696360772
47	1.857953	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=723 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
48	1.857954	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=2011 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
49	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=3299 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
50	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=587 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
51	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=587 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
52	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=7163 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
53	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=7163 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
54	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=739 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
55	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=1127 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
74	1.870493	128.119.245.12	10.17.204.99	TCP	1354	64699 - 88 [ACK] Seq=739 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
75	1.870494	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=723 Win=53632 Len=0 Tsvl=2696360798 Tscr=1564605218
76	1.871448	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=1233 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
77	1.874212	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=13683 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
78	1.874213	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=14849 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
79	1.874213	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=16179 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
80	1.874213	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=17519 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
81	1.874214	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=18755 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
82	1.874215	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=20043 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
83	1.874215	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=21331 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
84	1.874216	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=22619 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
85	1.874217	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=23907 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
86	1.874217	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=25195 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
87	1.874218	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=26483 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
88	1.874218	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=27771 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
89	1.874219	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=29859 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
90	1.874220	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=30347 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798

I don't really find the receiver ACKing exactly every other segment, but I can find that the receiver's

delaying ACKing. Between Packets 55 and 75: The client sends multiple segments. The server sends Packet 75 (ACK=12315), skipping intermediate ACKs for segments like Packet 53 (Seq=8451) and Packet 54 (Seq=9739).

40	1.856281	10.17.204.99	128.119.245.12	TCP	78	64699 - 88 [SYN, ALKJ] Seq=0 Win=0 Len=0 MSS=1460 WS=64 Tsvl=1564605199 Tscr=0 SACK_PERM
41	1.856413	10.17.204.99	128.119.245.12	TCP	66	64699 - 88 [ACK] Seq=1 Ack=1 Win=13128 Len=0 Tsvl=1564605209 Tscr=2696360772
42	1.856590	10.17.204.99	128.119.245.12	TCP	788	64699 - 88 [PSH, ACK] Seq=1 Ack=1 Win=13128 Len=722 Tsvl=1564605209 Tscr=2696360772
47	1.857953	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=723 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
48	1.857954	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=2011 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
49	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=3299 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
50	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=587 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
51	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=587 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
52	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=7163 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
53	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=7163 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
54	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=9739 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
55	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=1127 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
74	1.870493	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=723 Win=53632 Len=0 Tsvl=2696360798 Tscr=1564605209
75	1.870494	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=12315 Win=13128 Len=0 Tsvl=1564605210 Tscr=2696360772
76	1.870494	128.119.245.12	10.17.204.99	TCP	1354	64699 - 88 [ACK] Seq=12315 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798

2.9

Total time: $T_{total} = T_{end} - T_{start} = 1.121956 - 1.046440 = 0.075516$ s.

37	1.846448	10.17.204.99	128.119.245.12	TCP	78	64699 - 88 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=64 Tsvl=1564605199 Tscr=0 SACK_PERM
40	1.856281	128.119.245.12	10.17.204.99	TCP	78	64699 - 64599 [SYN, ACK] Seq=1 Win=20960 Len=0 MSS=1388 SACK_PERM Tsvl=2696360772 Tscr=1564605199 WS=12
41	1.856413	10.17.204.99	128.119.245.12	TCP	66	64699 - 88 [ACK] Seq=1 Ack=1 Win=13128 Len=0 Tsvl=1564605209 Tscr=2696360772
50	1.857955	10.17.204.99	128.119.245.12	TCP	788	64699 - 88 [PSH, ACK] Seq=1 Ack=1 Win=13128 Len=722 Tsvl=1564605209 Tscr=2696360772
55	1.857955	10.17.204.99	128.119.245.12	TCP	1354	64699 - 88 [ACK] Seq=723 Ack=1 Win=13128 Len=1288 Tsvl=1564605218 Tscr=2696360772
74	1.870493	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=723 Win=53632 Len=0 Tsvl=2696360798 Tscr=1564605209
75	1.870494	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=12315 Win=13128 Len=0 Tsvl=1564605210 Tscr=2696360772
76	1.870494	128.119.245.12	10.17.204.99	TCP	1354	64699 - 88 [ACK] Seq=12315 Ack=1 Win=13128 Len=1288 Tsvl=1564605227 Tscr=2696360798
223	1.121863	128.119.245.12	10.17.204.99	TCP	78	64699 - 64599 [ACK] Seq=1 Ack=13691 Win=231680 Len=0 Tsvl=2696360836 Tscr=1564605256 SLE=152707 SRE=153044
225	1.121864	128.119.245.12	10.17.204.99	TCP	66	80 - 64699 [ACK] Seq=1 Ack=153044 Min=234752 Len=0 Tsvl=2696360836 Tscr=1564605256
226	1.121864	128.119.245.12	10.17.204.99	TCP	843	80 - 64699 [PSH, ACK] Seq=1 Ack=153044 Win=234752 Len=777 Tsvl=2696360836 Tscr=1564605256
227	1.121865	128.119.245.12	10.17.204.99	TCP	78	[TCP Dup ACK 225#] 80 - 64699 [ACK] Seq=778 Ack=153044 Win=234752 Len=0 Tsvl=2696360836 Tscr=1564605265 SLE=153044

And the final ack number is 153044.

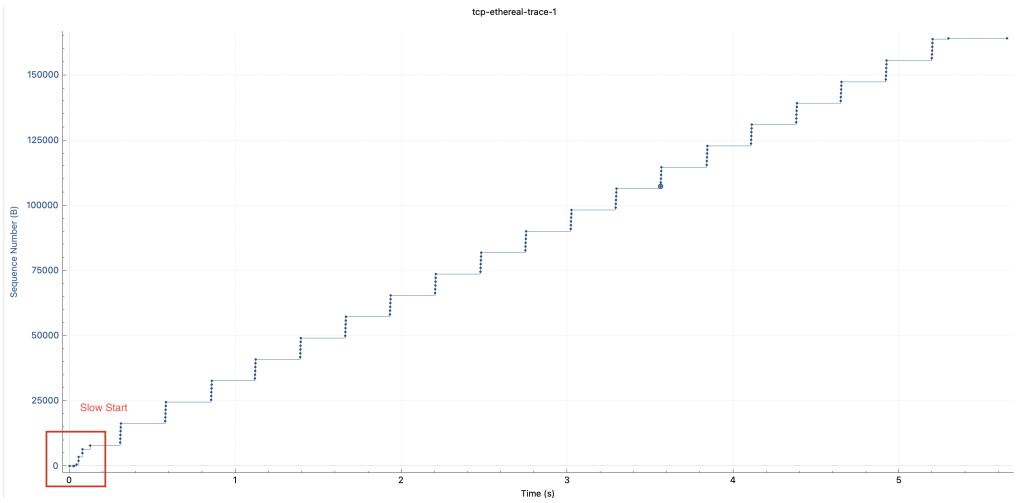
So the throughput is

$$153044 \times 8 / 0.075516 = 16213146.9 = 16.21 \text{ Mbps.}$$

3 TCP Congestion Control

3.1

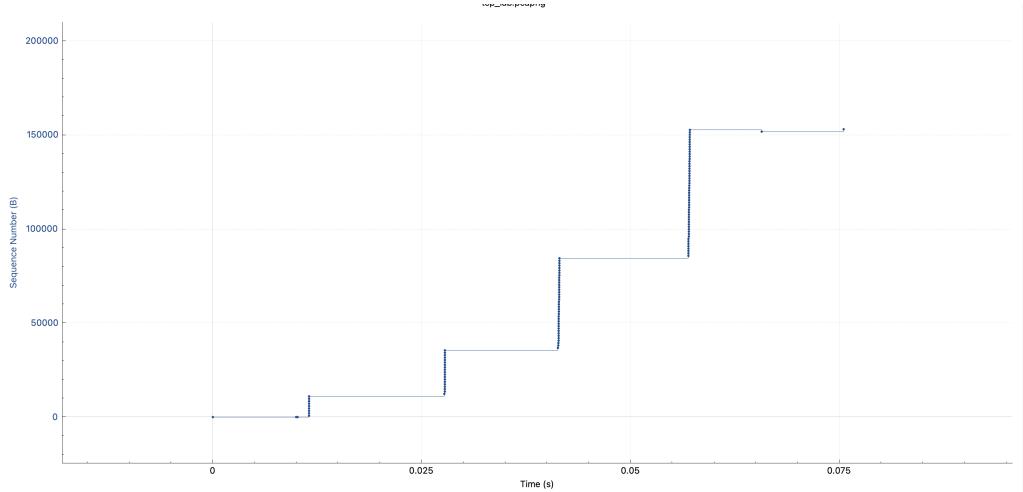
As required, using the tcp-ethereal-trace-1 to answer the first questions. The Slow start phase is around 0-0.2s(Marked by the red square), and the Congestion Avoidance phase is after 0.2s.



What's different from the ideal case is that sequence number increase remains smooth and linear after the slow start phase and no obvious packet loss like dramatic decrease, instead, the sequence number increases with a smooth transition.

3.2

Using my own trace to answer the second question. The whole trace is in the slow start phase since the sequence number increases exponentially. It is maybe because the data transferred is not large enough to trigger the congestion avoidance phase. So there is nowhere to see the congestion avoidance phase.



As a result, it is hard to tell the difference between this graph and the ideal case. However, it might because the initial congestion window here is larger than the ideal case, which is also a possible reason and difference here.