

CSE 3300 - Homework 3

Prof. Bing Wang

Nicholas Lambourne - 2749404 - ndl17004

Problem 1

Part (a)

$$\text{Nodal Delay} = d_{\text{nodal}} = d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}} + d_{\text{proc}}$$

Ignore queuing delay, propagation delay, processing delay (leaving only transmission delay). There are two nodes.

$$\text{Total delay} = 2 \cdot d_{\text{trans}}$$

$$d_{\text{trans}} = \frac{L}{R}, L = \text{packet length}, R = \text{bandwidth}.$$

$$\text{Total delay} = 2 \cdot \frac{64,000 \text{ bits}}{100,000 \text{ bps}}$$

$$\text{Total delay} = 1.28 \text{ seconds}$$

Part (b)

Section (1)

Segment size = 1,000bytes. Each segment has header size = 40bits.

Number of segments = 64,000/8,000 = 8 segments

Therefore total segment size = 1,000bytes + 40bits = 8,040bits

$d_{trans} = \frac{L}{R}$, $L = 8,040$ (packet length), $R = 100,000bps$ (bandwidth).

Total delay = $2 \cdot \frac{8,040bits}{100,000bps} \cdot 1 \text{ segment} + \frac{8,040bits}{100,000bps} \cdot 7 \text{ segments}$

Total delay = 0.7236 seconds

Section (2)

Segment size = 100bytes. Each segment has header size = 40bits.

Number of segments = 64,000bits/800bits = 80 segments.

Therefore total segment size = 100bytes + 40bits = 840bits

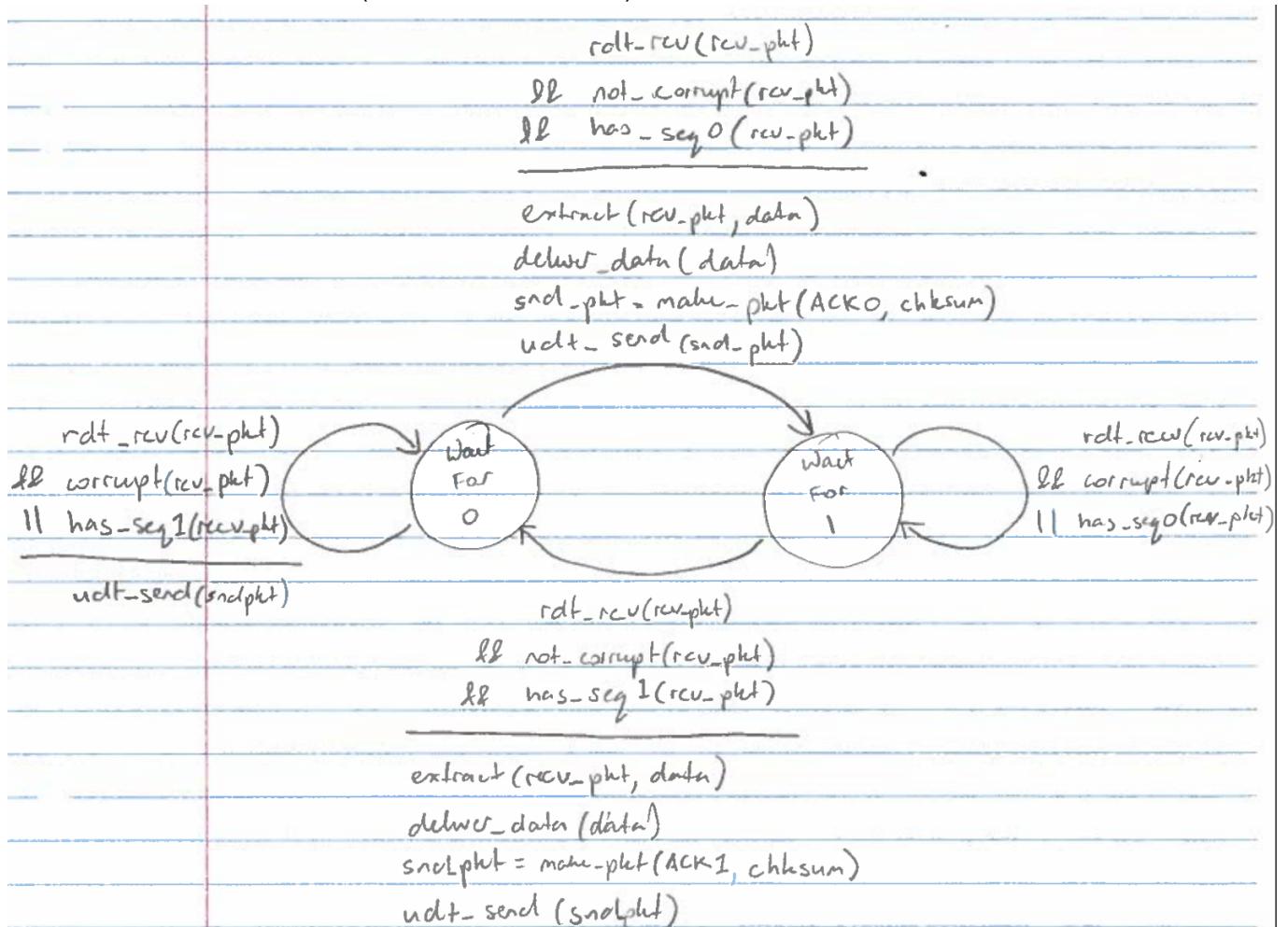
$d_{trans} = \frac{L}{R}$, $L = 840$ (packet length), $R = 100,000bps$ (bandwidth).

Total delay = $2 \cdot \frac{840bits}{100,000bps} \cdot 1 \text{ segment} + \frac{840bits}{100,000bps} \cdot 79 \text{ segments}$.

Total delay = 0.6804 seconds

Problem 2

FSM of receiver side of rdt3.0 (it's the same as rdt2.2).



Problem 3

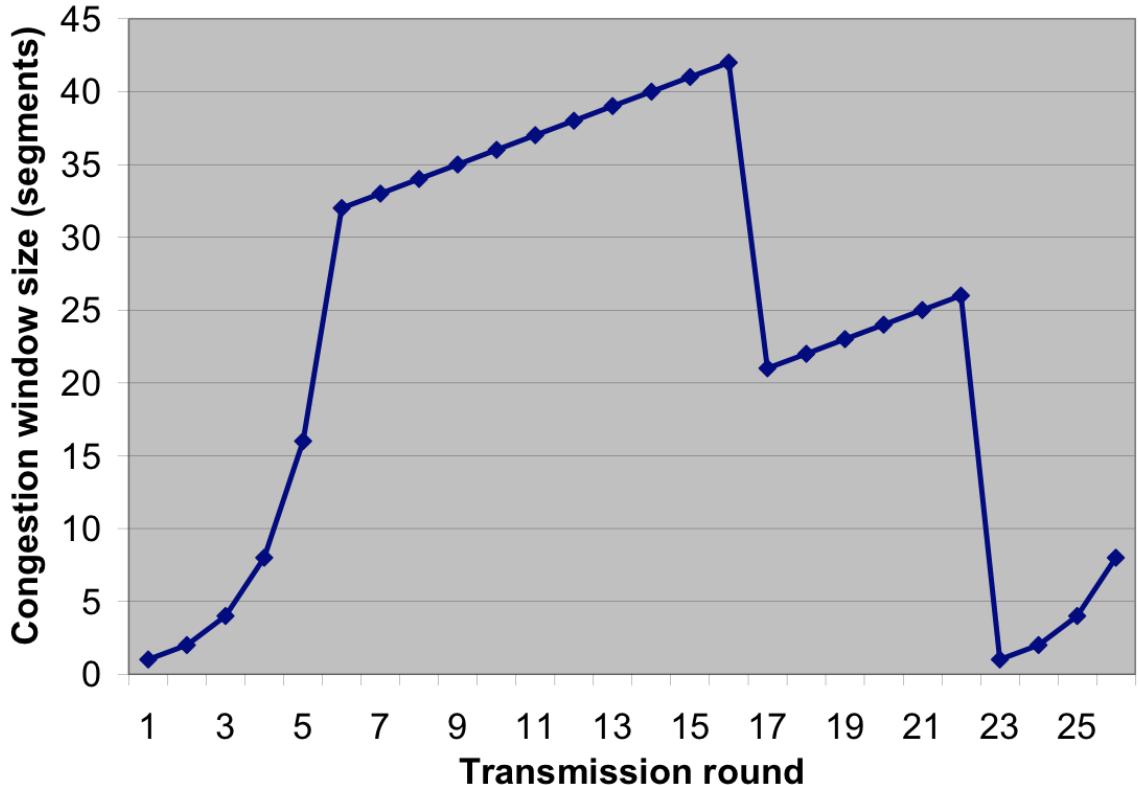


Fig. 1: TCP congestion window size.

1. Slow start is operating over the following intervals, these intervals are evident because of their exponential growth:
 - 1 - 6
 - 23 - 26
2. TCP Congestion Avoidance is composed of two parts, additive increase and multiplicative decrease. Both of these are evident in Figure 1:
 - Additive Increase (visible as areas of linear increase):
 - 6 - 16
 - 17 - 22
 - Multiplicative Decrease (visible as areas of sharp linear decrease):
 - 16 - 17
 - 22 - 23
3. In TCP Reno congestion avoidance, **Triple Duplicate ACK** is responded to by cutting the congestion window (cwnd) in half, which is what can be seen after the 16th transmission round.
4. In CTOP Reno congestion avoidance, a **timeout** will result in the cwnd being set to 1, which is what happens after the 22nd transmission round.
5. The initial value of the threshold is **32**, which is visible as the point when the initial growth transforms from exponential to linear growth.
6. On a loss event, the threshold (ssthresh) is set to $\frac{1}{2}$ of the congestion window size prior to the loss event. The initial threshold value at the 18th transmission round is $ssthresh = \frac{1}{2} \cdot 42 = 21$
7. The initial value of ssthresh at the 24th transmission round is 1.
8. The 70th packet is send in the 7th round:
 - Round 1: Packets 1 - 1

- Round 2: Packets 2 - 3
 - Round 3: Packets 4 - 7
 - Round 4: Packets 8 - 15
 - Round 5: Packets 16 - 31
 - Round 6: Packets 32 - 63
 - Round 7: Packets 64 - 96 (Including 70th packet)
9. Following packet loss detected by triple duplicate ACK after the 26th transmission round, the TCP Reno congestion avoidance protocol will respond by setting both the threshold and congestion window size to half the previous cwnd (8). $\frac{1}{2} \cdot 8 = 4$.

Problem 4 - Wireshark Explore TCP Lab

1. IP Address of Source: 192.168.1.102, Port: 1161. (Image below).

tcp

| No. | Time | Source | Destination | Protocol | Length | Info |
|-----|----------|----------------|----------------|----------|--------|---|
| 191 | 5.197286 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=156469 Win=62780 Len=0 |
| 192 | 5.197508 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=156469 Ack=1 Win=17520 Len=1460 [TCP s] |
| 193 | 5.198388 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=157929 Ack=1 Win=17520 Len=1460 [TCP s] |
| 194 | 5.199275 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=159389 Ack=1 Win=17520 Len=1460 [TCP s] |
| 195 | 5.200252 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=160849 Ack=1 Win=17520 Len=1460 [TCP s] |
| 196 | 5.201150 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=162309 Ack=1 Win=17520 Len=1460 [TCP s] |
| 197 | 5.202024 | 192.168.1.102 | 128.119.245.12 | TCP | 326 | 1161 → 80 [PSH, ACK] Seq=163769 Ack=1 Win=17520 Len=272 [TCP s] |
| 198 | 5.297257 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=159389 Win=62780 Len=0 |
| 199 | 5.297341 | 192.168.1.102 | 128.119.245.12 | HTTP | 104 | POST /ethereal-labs/lab3-1-reply.htm HTTP/1.1 (text/plain) |
| 200 | 5.389471 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=162309 Win=62780 Len=0 |
| 201 | 5.447887 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=164041 Win=62780 Len=0 |
| 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) |
| 206 | 5.651141 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161 → 80 [ACK] Seq=164091 Ack=731 Win=16790 Len=0 |
| 213 | 7.595557 | 192.168.1.102 | 199.2.53.206 | TCP | 62 | 1162 → 631 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM= |

Transmission Control Protocol, Src Port: 1161, Dst Port: 80, Seq: 164041, Ack: 1, Len: 50

Source Port: 1161

Destination Port: 80

[Stream index: 0]

[TCP Segment Len: 50]

Sequence number: 164041 (relative sequence number)

[Next sequence number: 164091 (relative sequence number)]

Acknowledgment number: 1 (relative ack number)

0101 = Header Length: 20 bytes (5)

Flags: 0x018 (PSH, ACK)

Window size value: 17520

[Calculated window size: 17520]

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

Checksum: 0x9f0f [unverified]

[Checksum Status: Unverified]

Urgent pointer: 0

► [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(1147), #18(1460), #19(1460), #20(1460)]

► Hypertext Transfer Protocol

► MIME Multipart Media Encapsulation, Type: multipart/form-data, Boundary: "-----265001916915724"

2. IP Address of gaia.cs.umass.edu, Port 80. (Image below).

tcp

| No. | Time | Source | Destination | Protocol | Length | Info |
|-----|----------|----------------|----------------|----------|--------|--|
| 98 | 2.476576 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=74549 Win=62780 Len=0 |
| 105 | 2.576633 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=77469 Win=62780 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 |
| 106 | 2.672045 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=80389 Win=62780 Len=0 |
| 107 | 2.747257 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=82741 Win=62780 Len=0 |
| 114 | 2.847009 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=85661 Win=62780 Len=0 |
| 115 | 2.944420 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=88581 Win=62780 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 |
| 116 | 3.020822 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=90933 Win=62780 Len=0 |
| 123 | 3.117302 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=93853 Win=62780 Len=0 |
| 124 | 3.216127 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=96773 Win=62780 Len=0 |
| 125 | 3.291672 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=99125 Win=62780 Len=0 |
| 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 S |
| 203 | 5.461175 | 128.119.245.12 | 192.168.1.102 | HTTP | 784 | HTTP/1.1 200 OK (text/html) |
| 199 | 5.297341 | 192.168.1.102 | 128.119.245.12 | HTTP | 104 | POST /ethereal-labs/lab3-1-reply.htm HTTP/1.1 (text/plain) |

Ethernet II, Src: Linksys0_d:af:73 (00:06:25:da:af:73), Dst: PremaxPe_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: 1, Ack: 164091, Len: 730

Source Port: 80

Destination Port: 1161

[Stream index: 0]

[TCP Segment Len: 730]

Sequence number: 1 (relative sequence number)

[Next sequence number: 731 (relative sequence number)]

Acknowledgment number: 164091 (relative ack number)

0101 = Header Length: 20 bytes (5)

Flags: 0x018 (PSH, ACK)

Window size value: 62780

[Calculated window size: 62780]

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

Checksum: 0xa920 [unverified]

[Checksum Status: Unverified]

Urgent pointer: 0

► [SEQ/ACK analysis]

TCP payload (730 bytes)

► Hypertext Transfer Protocol

► Line-based text data: text/html

3. IP address of my computer 67.221.95.165, port 63976 (Image below).

tcp

| No. | Time | Source | Destination | Protocol | Length | Info |
|--|----------|----------------|----------------|----------|--------|--|
| 37 | 5.507151 | 67.221.95.165 | 128.119.245.12 | TCP | 66 | 63911 → 80 [FIN, ACK] Seq=1 Ack=1 Win=4100 Len=0 TSval=1059554084 TSecr=3429355781 |
| ... | 5.512307 | 67.221.95.165 | 128.119.245.12 | TCP | 78 | 63976 → 80 [SYN] Seq=0 Win=65535 Len=0 MSS=1460 WS=32 TSval=1059554089 TSecr=0 SACK_ |
| 41 | 5.516611 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63911 [ACK] Seq=1 Ack=2 Win=227 Len=0 TSval=3429379843 TSecr=1059554084 |
| 42 | 5.519023 | 128.119.245.12 | 67.221.95.165 | TCP | 74 | 80 → 63976 [SYN, ACK] Seq=0 Ack=1 Win=1238 TSval=1059554095 TSecr=3429379845 |
| 43 | 5.519082 | 67.221.95.165 | 128.119.245.12 | TCP | 66 | 63976 → 80 [ACK] Seq=1 Ack=1 Win=131200 Len=0 TSval=1059554095 TSecr=3429379845 |
| 44 | 5.519473 | 67.221.95.165 | 128.119.245.12 | TCP | 753 | 63976 → 80 [PSH, ACK] Seq=1 Ack=1 Win=131200 Len=687 TSval=1059554095 TSecr=3429379845 |
| 45 | 5.519546 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=688 Ack=1 Win=131200 Len=1238 TSval=1059554095 TSecr=3429379845 |
| 46 | 5.519547 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=1926 Ack=1 Win=131200 Len=1238 TSval=1059554095 TSecr=3429379845 |
| 47 | 5.522095 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=688 Win=3706880 Len=0 TSval=3429379845 TSecr=1059554095 |
| 48 | 5.522179 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=3164 Ack=1 Win=131200 Len=1238 TSval=1059554098 TSecr=3429379845 |
| 49 | 5.522180 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=4402 Ack=1 Win=131200 Len=1238 TSval=1059554098 TSecr=3429379845 |
| 50 | 5.527770 | 128.119.245.12 | 67.221.95.165 | TCP | 78 | 80 → 63976 [ACK] Seq=1 Ack=1 Win=33920 Len=0 TSval=3429379854 TSecr=1059554095 SLE=6 |
| 51 | 5.527778 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=3164 Win=35328 Len=0 TSval=3429379854 TSecr=1059554095 |
| 52 | 5.527855 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=5640 Ack=1 Win=131200 Len=1238 TSval=1059554103 TSecr=342937985 |
| 53 | 5.527855 | 67.221.95.165 | 128.119.245.12 | TCP | 1304 | 63976 → 80 [ACK] Seq=6878 Ack=1 Win=131200 Len=1238 TSval=1059554103 TSecr=342937985 |
| ► Frame 40: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface 0 | | | | | | |
| ► Ethernet II, Src: Apple_12:5e:b5 (28:cf:e9:12:5e:b5), Dst: Cisco_ff:fc:c8 (00:08:e3:ff:fc:c8) | | | | | | |
| ► Internet Protocol Version 4, Src: 67.221.95.165 Dst: 128.119.245.12 | | | | | | |
| ► Transmission Control Protocol, Src Port: 63976, Dst Port: 80, Seq: 0, Len: 0 | | | | | | |
| <pre>0000 00 08 e3 ff fc c8 28 cf e9 12 5e b5 08 00 45 00(. .^...E. 0010 00 40 00 00 40 00 00 06 21 b2 43 dd 5f a5 80 77 :@..@. !.C...w 0020 f5 0c f9 e8 00 50 75 12 ed aa 00 00 00 b0 02Pu. 0030 ff ff fe af 00 00 02 04 05 b4 01 03 03 05 01 01 0040 08 0a 3f 27 83 29 00 00 00 00 04 02 00 00 ..?'..</pre> | | | | | | |

4. The (relative) sequence number of the TCP SYN segment used to initiate the request was 0. The segment is marked as a SYN segment by the setting of a flag in the TCP Flags (Syn: Set) - see image below.

tcp

| No. | Time | Source | Destination | Protocol | Length | Info |
|---|----------|----------------|----------------|----------|--------|--|
| 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 S |
| 3 | 0.023265 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0 |
| 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 |
| 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 |
| 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 |
| 8 | 0.054690 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460 |
| 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 |
| 11 | 0.078157 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460 |
| 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 |
| 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 |
| ► Frame 1: 62 bytes on wire (496 bits), 62 bytes captured (496 bits) | | | | | | |
| ► Ethernet II, Src: PremaxPe_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) | | | | | | |
| Acknowledgment number: 0 | | | | | | |
| 0111 = Header Length: 28 bytes (7) | | | | | | |
| ▼ Flags: 0x0002 (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 | | | | | | |
| ►0.1. = Syn: Set | | | | | | |

5. The (relative) sequence number of the TCP ACK segment sent in response to the initiation request by the server at gaia.cs.umass.edu was 0. The provided Acknowledgement number was 1. The segment is marked as SYN and ACK by the setting of two flags in the TCP segment flags, ACK (A) and SYN (S). See image below.

Screenshot of Wireshark showing a TCP connection between 192.168.1.102 and 128.119.245.12. The sequence number for the SYN segment is 0.

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)
- Acknowledgment number: 1 (relative ack number)
- 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
- [Expert Info (Chat/Sequence): Connection establish acknowledge (SYN+ACK): server port 80]
 - [Connection establish acknowledge (SYN+ACK): server port 80]
 - [Severity level: Chat]
 - [Group: Sequence]
 -0 = Fin: Not set
 - [TCP Flags:A..S..]

6. The (relative) sequence number of the TCP segment containing the POST command is 1 (the POST command can be seen in the data area, see image below).

Screenshot of Wireshark showing a TCP connection between 192.168.1.102 and 128.119.245.12. The sequence number for the SYN segment is 0.

Transmission Control Protocol, Src Port: 1161, Dst Port: 80, Seq: 1, Ack: 1, Len: 565

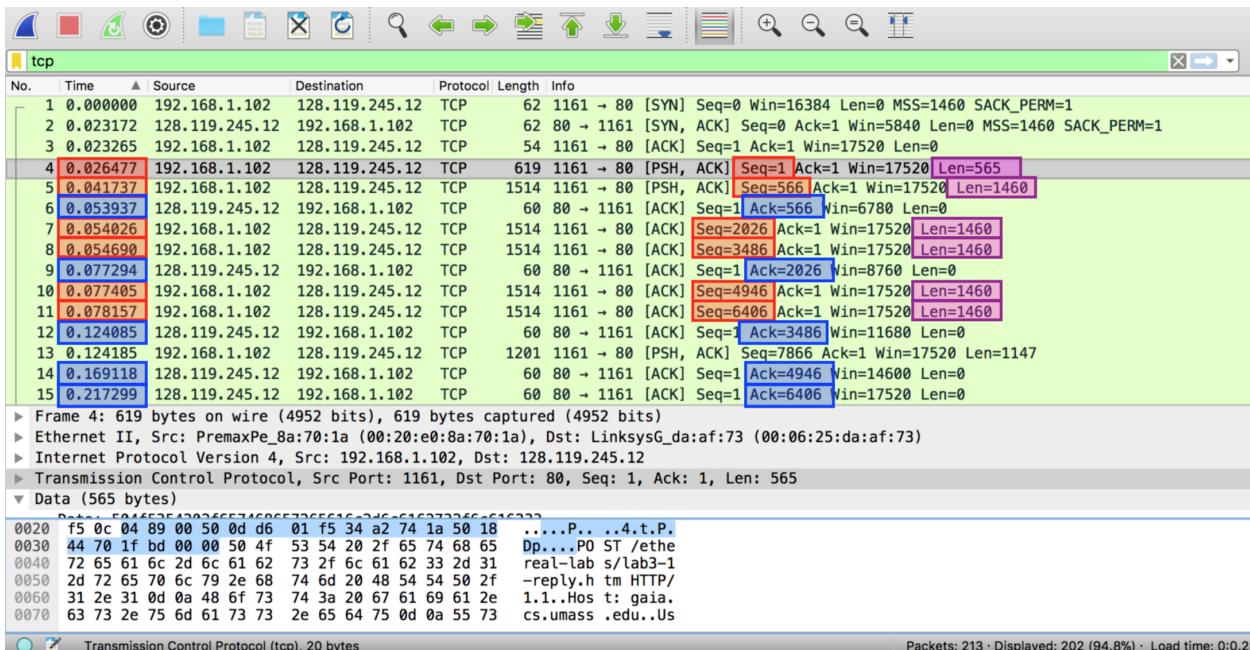
- Source Port: 1161
- Destination Port: 80
- [Stream index: 0]
- [TCP Segment Len: 565]
- Sequence number: 1 (relative sequence number)
- [Next sequence number: 566 (relative sequence number)]
- Acknowledgment number: 1 (relative ack number)
- 0101 = Header Length: 20 bytes (5)
- Flags: 0x018 (PSH, ACK)
 - Window_size_value: 17520

```

0000 00 06 25 da f7 00 20 e0 8a 70 1a 08 00 45 00 .%..s. ..p..E.
0010 02 5d 1e 21 40 00 80 06 a2 e7 c0 a8 01 66 80 77 .].!@... ....f.w
0020 f5 0c 04 89 00 50 0d d6 01 f5 34 a2 74 1a 50 18 .....P. 4.t.P.
0030 44 70 1f bd 00 00 50 4f 53 54 20 2f 65 74 68 65 Dp...PO ST/etbe
0040 72 65 61 6c 2d 61 62 73 2f 66 61 62 33 2d 31 real-lab s/lab3-1
0050 2d 72 65 70 6c 79 2e 68 74 6a 20 48 54 54 50 2f -reply.h tm HTTP/

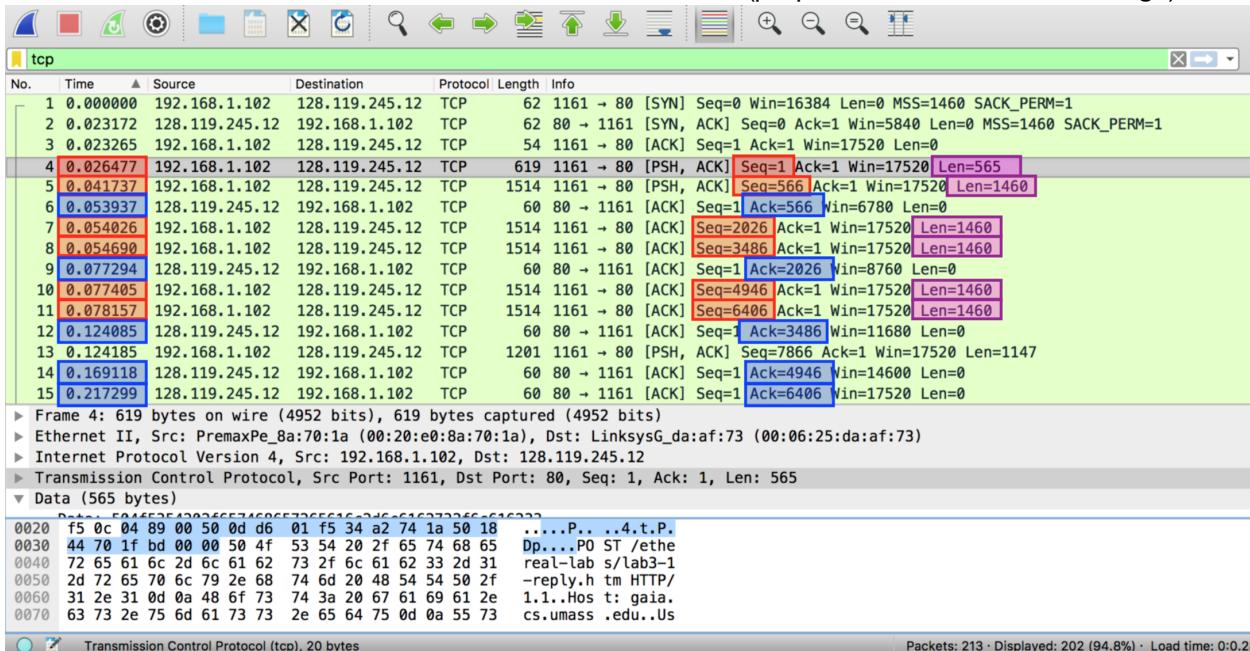
```

7. The answers for Question 7 are included in the table below (blue and red annotated values in image) $\text{Estimated RTT} = 0.875 \cdot \text{Last ERTT} + 0.125 \cdot \text{Sample RTT}$:



| Sequence Number | Time Sent (Relative) | Time ACK Received (Relative) | RTT | Estimated RTT |
|-----------------|----------------------|------------------------------|-----------|---------------|
| 1 | 0.026477 | 0.053937 | 0.027460s | 0.027460s |
| 566 | 0.041737 | 0.077294 | 0.035557s | 0.028472125s |
| 2026 | 0.054026 | 0.124085 | 0.070059s | 0.033670484s |
| 3486 | 0.054690 | 0.169118 | 0.114428s | 0.043765174s |
| 4946 | 0.077405 | 0.217299 | 0.139894s | 0.05578127s |
| 6406 | 0.078157 | 0.267802 | 0.189645s | 0.072514242s |

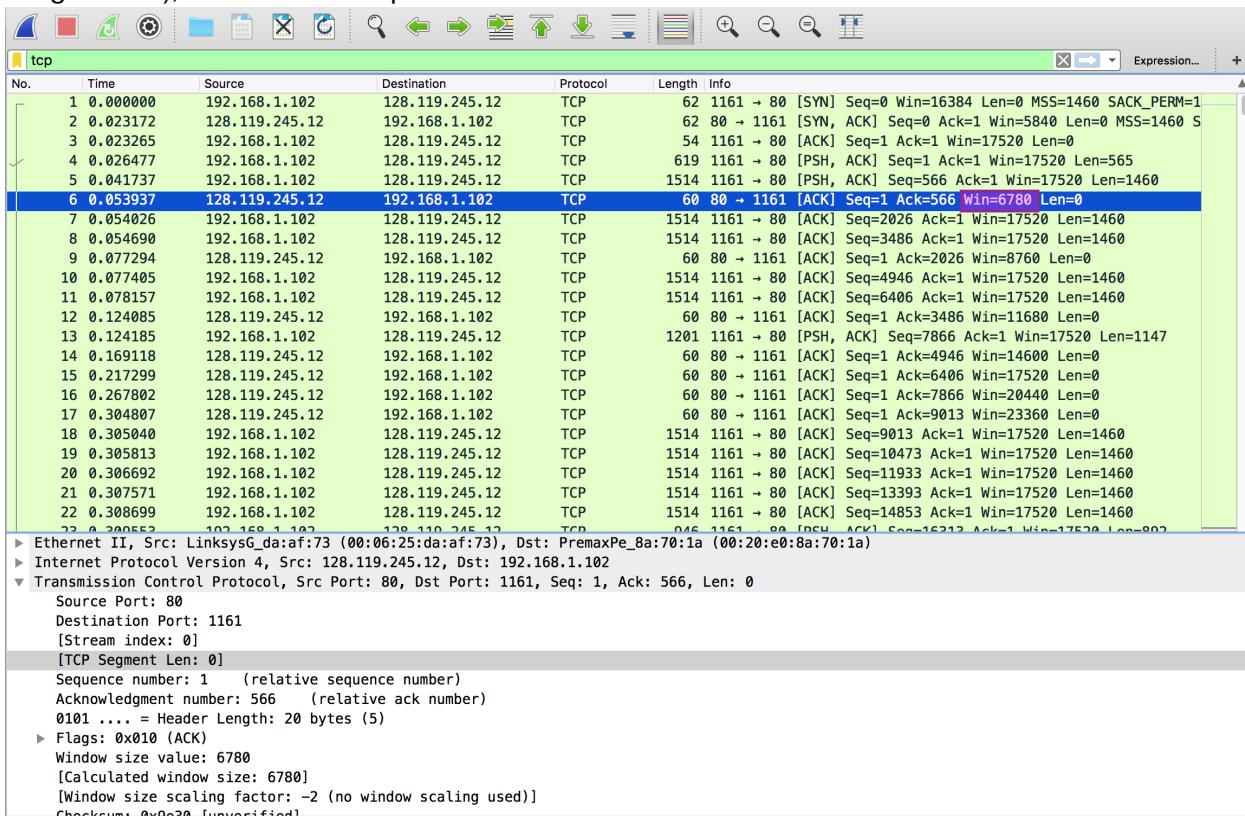
8. The answers for Question 8 are included in the table below (purple annotated values in image):



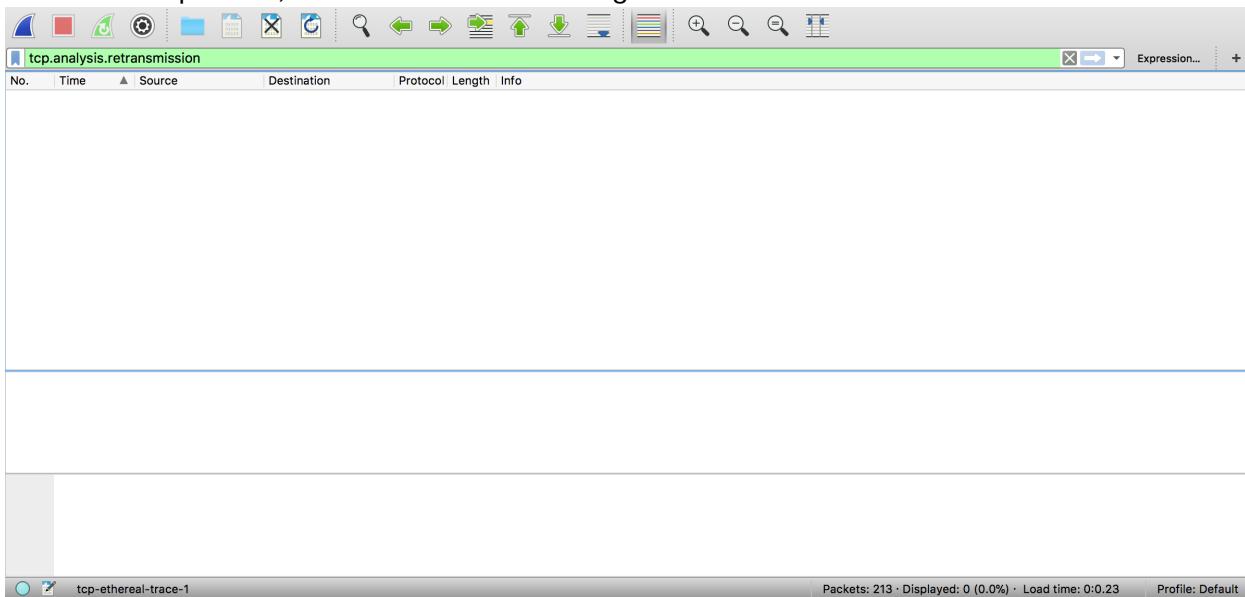
| Sequence Number | Length |
|-----------------|--------|
| 1 | 565 |
| 566 | 1460 |
| 2026 | 1460 |

| | |
|------|------|
| 3486 | 1460 |
| 4946 | 1460 |
| 6406 | 1460 |

9. The minimum amount of advertised buffer space at the receiver for the entire trace is: 6780 (see image below), thus the buffer space never throttles the sender.



10. No, there were no retransmitted segments. I used the `tcp.analysis.retransmission` filter and found no retransmitted packets, as can be seen in the image below.



11. The receiver typically only acknowledges one segment at a time (generally the length of the segment limit - 1460 bytes), but there were instances in which a cumulative ACK was sent for two segments. An example is included in the image below (purple highlighted area), it can be identified by seeing the Ack value is equal to 2*(Len) + Last Ack Value (though you have to make sure that an ACK hasn't been received for the intervening packet later).

| No. | Time | Source | Destination | Protocol | Length | Info |
|-----|----------|----------------|----------------|----------|--------|--|
| 50 | 0.994715 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 60 80 → 1161 [ACK] Seq=1 Ack=29777 Win=61320 Len=0 |
| 51 | 1.039820 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 60 80 → 1161 [ACK] Seq=1 Ack=31237 Win=62780 Len=0 |
| 52 | 1.117097 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 60 80 → 1161 [ACK] Seq=1 Ack=33589 Win=62780 Len=0 |
| 53 | 1.117333 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=33589 Ack=1 Win=17520 Len=1460 |
| 54 | 1.118133 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=35049 Ack=1 Win=17520 Len=1460 |
| 55 | 1.119029 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=36509 Ack=1 Win=17520 Len=1460 |
| 56 | 1.119858 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=37969 Ack=1 Win=17520 Len=1460 |
| 57 | 1.120902 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=39429 Ack=1 Win=17520 Len=1460 |
| 58 | 1.121891 | 192.168.1.102 | 128.119.245.12 | TCP | 946 | 1161 → 80 [PSH, ACK] Seq=40889 Ack=1 Win=17520 Len=892 |
| 59 | 1.200421 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=35049 Win=62780 Len=0 |
| 60 | 1.265026 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=37969 Win=62780 Len=0 |
| 61 | 1.362074 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=40889 Win=62780 Len=0 |
| 62 | 1.389886 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80 → 1161 [ACK] Seq=1 Ack=41781 Win=62780 Len=0 |
| 63 | 1.390110 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=41781 Ack=1 Win=17520 Len=1460 |
| 64 | 1.390824 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | 1161 → 80 [ACK] Seq=43241 Ack=1 Win=17520 Len=1460 |

Urgent pointer: 0

▼ [SEQ/ACK analysis]

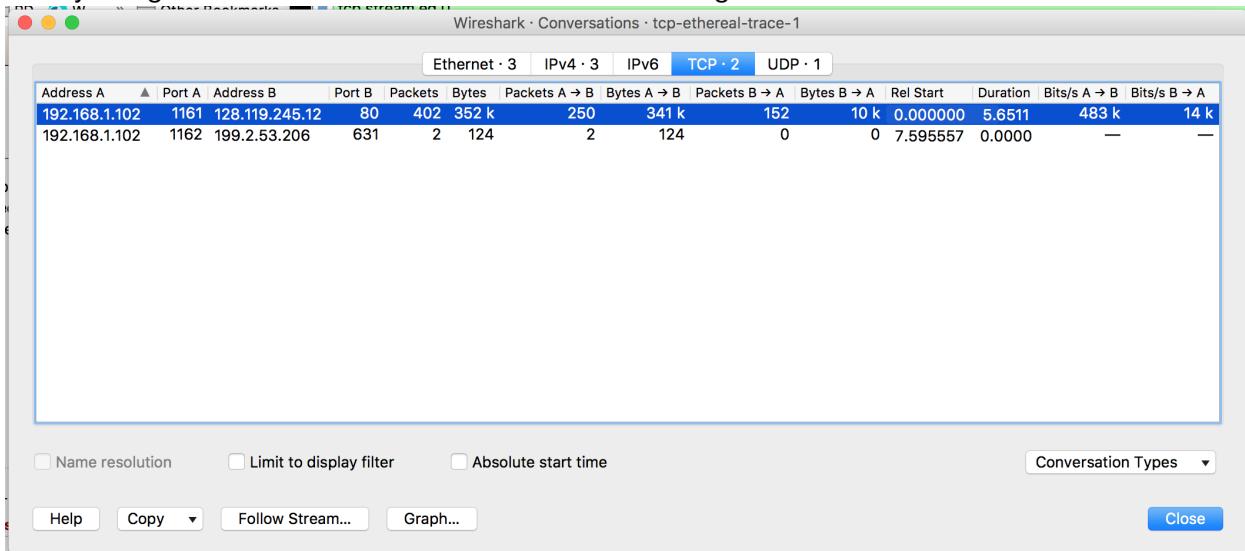
[This is an ACK to the segment in frame: 55] Last ACKed was 53, which isn't ACKed later

[The RTT to ACK the segment was: 0.145997000 seconds]

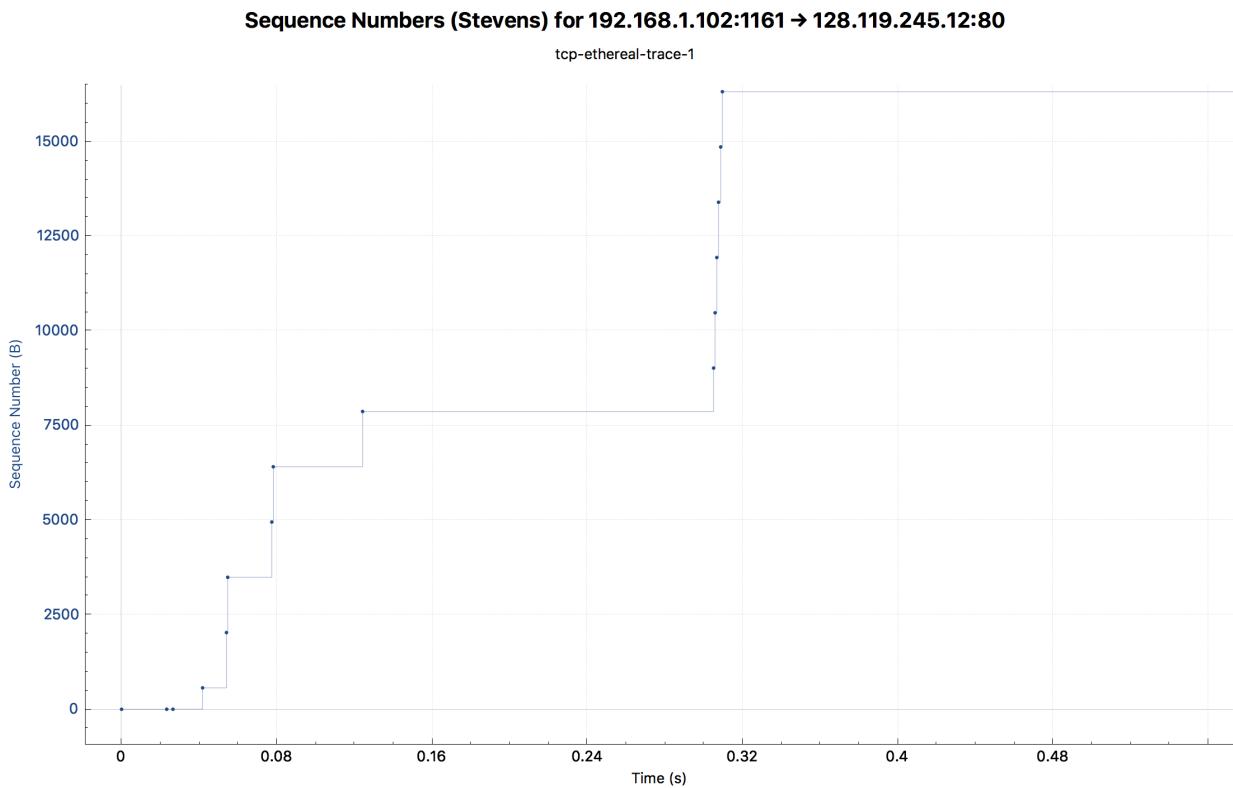
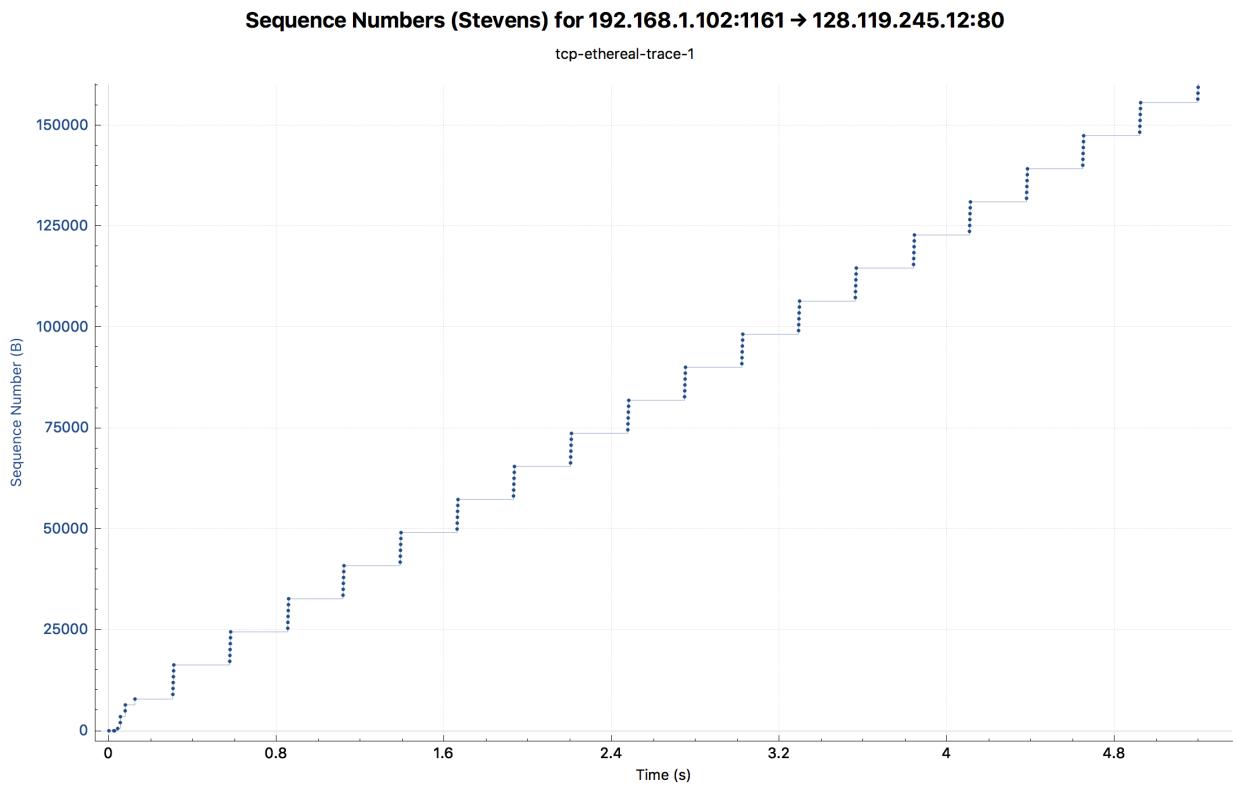
[iRTT: 0.023265000 seconds]

```
0000 00 20 e0 8a 70 1a 00 06 25 da af 73 08 00 45 00 . . . p... %..s..E.
0010 00 28 58 8b 40 00 37 06 b3 b2 80 77 f5 0c c0 a8 .(X.@.7. ....w...
0020 01 66 00 50 04 89 34 a2 74 1a 0d d6 96 45 50 10 .f.P..4. t....EP.
0030 f5 3c 31 54 00 00 8b 53 00 00 62 9f .<1T...S ..b.
```

12. The throughput for the connection was 483k bits/sec (from the sender to the receiver) I calculated this by using the Statistics> Conversations> TCP. An image of the statistics are included below.



13. I cannot identify where the slow start ends and begins definitively (even in the zoomed second image), but it appears to conclude before 0.15 seconds (and, I assume, begins at t=0), after which congestion avoidance likely takes over. This data differs significantly from the model as described in class due to the fact that the data appears to be transferring at a fixed rate for most of the transfer, rather than increasing (this is likely due to it hitting the receiver window (RWND) limit). What I mean by that is the congestion window (cwnd) appears to reach a fixed maximum and never increases again. The model we have used in class has also always had loss events, none of which occur in this TCP connection.



14. Answer two questions of those above for my packet trace. I chose Q9 and Q10.

Q9) The minimum amount of advertised buffer space at the receiver for my entire trace was: 28960. (see

tcp.window_size<=

| No. | Time | Source | Destination | Protocol | Length | Info |
|-----|----------|----------------|---------------|----------|--------|--|
| 41 | 5.516611 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63911 [ACK] Seq=1 Ack=2 Win=227 Len=0 TSval=3429379843 TSecr=1059554084 |
| 42 | 5.519023 | 128.119.245.12 | 67.221.95.165 | TCP | 74 | 80 → 63976 [SYN, ACK] Seq=0 Ack=1 Win=28960 Len=0 MSS=1250 SACK_PERM=1 TSval=3429379843 TSecr=1059554084 |
| 47 | 5.522095 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=688 Win=3706880 Len=0 TSval=3429379845 TSecr=10595 |
| 50 | 5.527770 | 128.119.245.12 | 67.221.95.165 | TCP | 78 | 80 → 63976 [ACK] Seq=1 Ack=1 Win=33920 Len=0 TSval=3429379854 TSecr=105955409 |
| 51 | 5.527778 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=3164 Win=35328 Len=0 TSval=3429379854 TSecr=105955 |
| 56 | 5.529045 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=4402 Win=38272 Len=0 TSval=3429379855 TSecr=105955 |
| 59 | 5.529217 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=5640 Win=41088 Len=0 TSval=3429379856 TSecr=105955 |
| 62 | 5.534862 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=6878 Win=44032 Len=0 TSval=3429379861 TSecr=105955 |
| 65 | 5.535576 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=8116 Win=46976 Len=0 TSval=3429379861 TSecr=105955 |
| 66 | 5.535579 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=10592 Win=51840 Len=0 TSval=3429379861 TSecr=10595 |
| 73 | 5.536928 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=11830 Win=54784 Len=0 TSval=3429379862 TSecr=10595 |
| 74 | 5.536931 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=13068 Win=57728 Len=0 TSval=3429379863 TSecr=10595 |
| 75 | 5.536932 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=15544 Win=62592 Len=0 TSval=3429379863 TSecr=10595 |
| 84 | 5.541653 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=16782 Win=65536 Len=0 TSval=3429379868 TSecr=10595 |
| 87 | 5.543046 | 128.119.245.12 | 67.221.95.165 | TCP | 66 | 80 → 63976 [ACK] Seq=1 Ack=18020 Win=68480 Len=0 TSval=3429379869 TSecr=10595 |

▶ Frame 42: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
 ▶ Ethernet II, Src: Cisco_ff:fc:c8 (00:08:e3:ff:fc:c8), Dst: Apple_12:5e:b5 (28:cf:e9:12:5e:b5)
 ▶ Internet Protocol Version 4, Src: 128.119.245.12, Dst: 67.221.95.165
 ▶ Transmission Control Protocol, Src Port: 80, Dst Port: 63976, Seq: 0, Ack: 1, Len: 0

Q10) There were also no retransmitted packets in my trace.

tcp.analysis.retransmission

| No. | Time | Source | Destination | Protocol | Length | Info |
|-----|------|--------|-------------|----------|--------|------|
| | | | | | | |

