

CS 494/594 Homework 3 (Spring 2018) Instructor: Dr. Nirupama Bulusu
Due Date: 5/28/2019

For 594 students only: Review the paper: “Fastpass: A Centralized “Zero-Queue” Datacenter Network”, Perry et al, ACM SIGCOMM 2014.

(10 points) Pipelining

Consider an idealized case of two hosts, one located in the United States and the other located in Australia. The speed of light round-trip propagation delay between the two end systems, RTT, is approximately 200 milliseconds. Suppose that they are connected by a channel with a transmission rate of R , of 1 Gbps (10^9 bits per second). With the pipelined protocol with a pipeline of N packets, assuming no packet loss, how big would the window size have to be for the channel utilization to be greater than 90 percent. Suppose that the size of the data packet is 2048 bytes, including both header fields and data

$$RTT = 200 \text{ ms} = 200 * 10^{-3} \text{ sec}$$

$$\text{Packet size} = 2048 \text{ byte} = 2048 * 8 = 16384 \text{ bits}$$

$$\text{Link speed} = 1 \text{ Gbps} = 10^9 \text{ bit/sec}$$

$$\text{Transmission time} = \text{packet size} / \text{link speed} = 16384 / 10^9 = 1.6 * 10^{-5} \text{ sec}$$

$$\text{Utilization} = 0.90 = n * T / (T + RTT) = n * 1.6 * 10^{-5} / (1.6 * 10^{-5} + 200 * 10^{-3})$$

$$n = 5454.88 = 5455$$

2. (20 points) TCP Congestion and Flow Control

Suppose a TCP Reno sender (congestion avoidance, fast retransmit, fast recovery) has an $ssthresh = 16$ and a $cwnd = 2$. The sender has no outstanding unacknowledged segments and 200 more segments left to transmit. In addition, the receiver it is sending to currently has an empty socket buffer that can hold up to 20 segments. Excluding the TCP FIN handshake at the end of the transfer, how many more roundtrips does it take for the transfer to finish? Assume there is no packet loss. For each round-trip, show how many segments are transmitted.

Increase in $cwnd$ will occur exponentially during slow start phase until $ssthresh$ is reached. after that growth in $cwnd$ will be linear in nature. these increase in $cwnd$ occurs after receiving ACK's from receiver.

$$\text{Total number of segment sent } 2+4+8+16+17+18+19+20 = 104.$$

$$\text{Number of round trip upto now} = 8$$

$cwnd$ remains constant, 5 more rounds are required to send 200 segments.

$$\text{Total number of segments sent} = 2 + 4 + 8 + 16 + 17 + 18 + 19 + 20 + 20 + 20 + 20 + 20 + 16 = 200$$

$$\text{Total of round trips required} = 8 + 5 = 13 \text{ RTT's}$$

3. (20 points) Wireshark Lab: TCP

1

Client computer: IP address: 192.168.1.102 TCP port number: 1161

No.	Time	Source	Destination	Protocol	Length	Info
199	06:44:25.867722	192.168.1.102	128.119.245.12	HTTP	104	POST /ethereal-labs/lab3-1-reply.htm HTTP/1.1 (text/plain)
203	06:44:26.031556	128.119.245.12	192.168.1.102	HTTP	784	HTTP/1.1 200 OK (text/html)

> Frame 199: 104 bytes on wire (832 bits), 104 bytes captured (832 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: 164041, Ack: 1, Len: 50

Source Port: 1161

Destination Port: 80

2

Destination computer: gaia.cs.umass.edu IP address: 128.119.245.12 TCP port number: 80

No.	Time	Source	Destination	Protocol	Length	Info
199	06:44:25.867722	192.168.1.102	128.119.245.12	HTTP	104	POST /ethereal-labs/lab3-1-reply.htm HTTP/1.1 (text/plain)
203	06:44:26.031556	128.119.245.12	192.168.1.102	HTTP	784	HTTP/1.1 200 OK (text/html)

> Frame 203: 784 bytes on wire (6272 bits), 784 bytes captured (6272 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: 1, Ack: 164091, Len: 730

Source Port: 80

Destination Port: 1161

3

No.	Time	Source	Destination	Protocol	Length	Info
164	23:42:20.881554	10.235.50.222	128.119.245.12	HTTP	698	POST /wireshark-labs/lab3-1-reply.htm HTTP/1.1 (text/plain)
208	23:42:20.987652	128.119.245.12	10.235.50.222	HTTP	831	HTTP/1.1 200 OK (text/html)

> Frame 164: 698 bytes on wire (5584 bits), 698 bytes captured (5584 bits) on interface 0

> Ethernet II, Src: Microsof_1d:d6:11 (bc:83:85:1d:d6:11), Dst: BenuNetw_03:62:d5 (f4:3e:9d:03:62:d5)

> Internet Protocol Version 4, Src: 10.235.50.222, Dst: 128.119.245.12

✓ Transmission Control Protocol, Src Port: 62683, Dst Port: 80, Seq: 152391, Ack: 1, Len: 644

Source Port: 62683

Destination Port: 80

4

Sequence number of the TCP SYN segment is used to initiate the TCP connection between the client computer and gaia.cs.umass.edu. The value is 0 in this trace. The SYN flag is set to 1 and it indicates that this segment is a SYN segment.

No.	Time	Source	Destination	Protocol	Length	Info
1	06:44:20.570381	192.168.1.102	128.119.245.12	TCP	62	1161 → 80 [SYN] Seq=0 Win=16384 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

Source Port: 1161

Destination Port: 80

[Stream index: 0]

[TCP Segment Len: 0]

Sequence number: 0 (relative sequence number)

[Next sequence number: 0 (relative sequence number)]

Acknowledgment number: 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

>0... = Syn: Set

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

5

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 in this trace. 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.

No.	Time	Source	Destination	Protocol	Length	Info
1	06:44:20.570381	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	06:44:20.593553	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...

```

> 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)
  [Next 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
    ....0... = Fin: Not set
  [TCP Flags: .....A..S.]

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6

TCP segment containing the HTTP POST command. The sequence number of this segment has the value of 1.

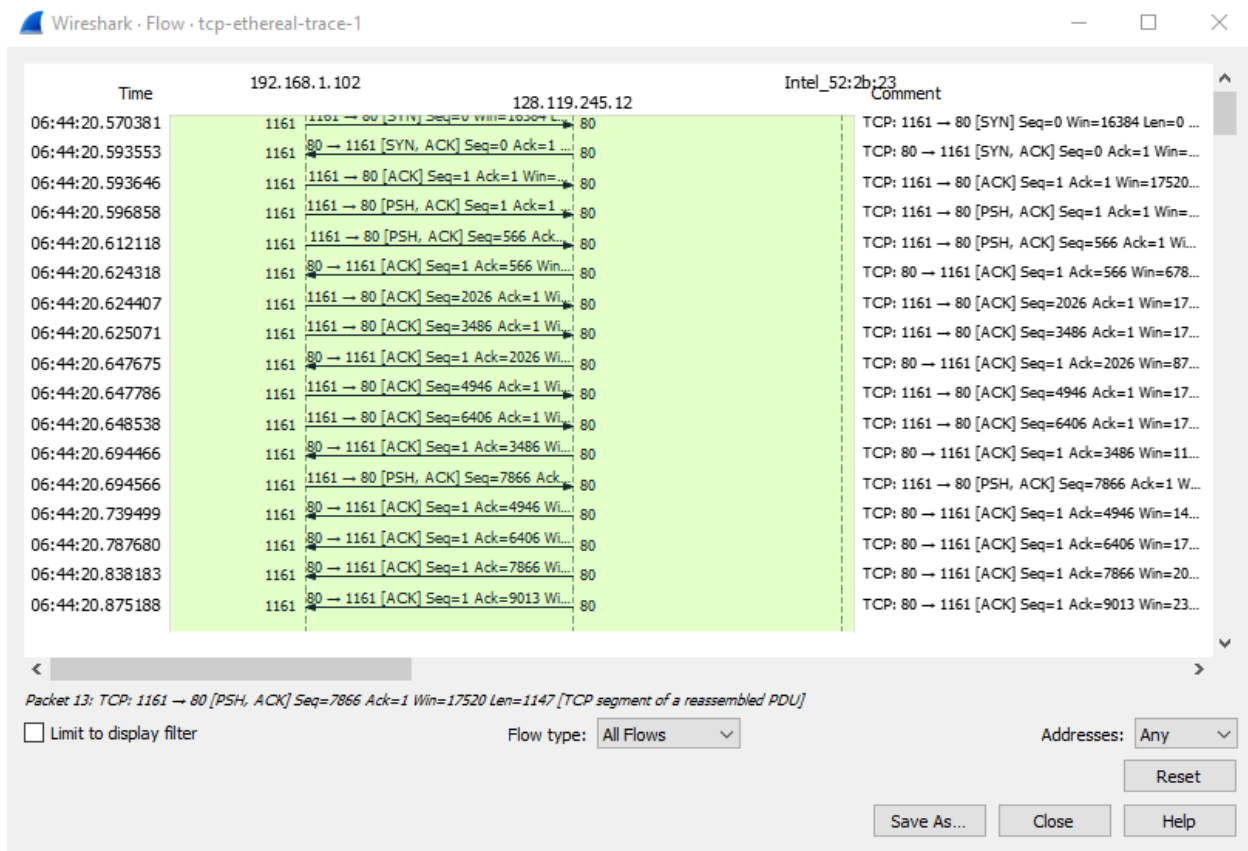
No.	Time	Source	Destination	Protocol	Length	Info
199	06:44:25.867722	192.168.1.102	128.119.245.12	HTTP	104	POST /ethereal-labs/lab3-1-reply.htm HTTP/1.1 (text/plain)
203	06:44:26.031556	128.119.245.12	192.168.1.102	HTTP	784	HTTP/1.1 200 OK (text/html)

```

> Frame 199: 104 bytes on wire (832 bits), 104 bytes captured (832 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: 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)
    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
    ....1... = Push: Set
    ....0... = Reset: Not set
    ....0... = Syn: Not set
    ....0... = Fin: Not set
  [TCP Flags: .....AP...]

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7



Segment 1 sequence number: 1

Segment 2 sequence number: 566

Segment 3 sequence number: 2026

Segment 4 sequence number: 3486

Segment 5 sequence number: 4946

Segment 6 sequence number: 6406

$$\text{EstimatedRTT} = 0.875 * \text{EstimatedRTT} + 0.125 * \text{SampleRTT}$$

EstimatedRTT after the receipt of the ACK of segment 1: EstimatedRTT = RTT for Segment 1 = 0.02746 second

EstimatedRTT after the receipt of the ACK of segment 2: EstimatedRTT = $0.875 * 0.02746 + 0.125 * 0.035557 = 0.0285$

EstimatedRTT after the receipt of the ACK of segment 3: EstimatedRTT = $0.875 * 0.0285 + 0.125 * 0.070059 = 0.0337$

EstimatedRTT after the receipt of the ACK of segment 4: EstimatedRTT = $0.875 * 0.0337 + 0.125 * 0.11443 = 0.0438$

EstimatedRTT after the receipt of the ACK of segment 5: EstimatedRTT = $0.875 * 0.0438 + 0.125 * 0.13989 = 0.0558$

EstimatedRTT after the receipt of the ACK of segment 6: EstimatedRTT = $0.875 * 0.0558 + 0.125 * 0.18964 = 0.0725$ second

tcp-ethereal-trace-1

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-/> Expression

No.	Time	Source	Destination	Protocol	Length	Info
4	06:44:20.596858	192.168.1.102	128.119.245.12	TCP	619	1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565 [TCP se..
5	06:44:20.612118	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP..
6	06:44:20.624318	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
7	06:44:20.624407	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP seg..
8	06:44:20.625071	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP seg..
9	06:44:20.647675	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	06:44:20.647786	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP seg..
11	06:44:20.648538	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP seg..
12	06:44:20.694466	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
13	06:44:20.694566	192.168.1.102	128.119.245.12	TCP	1201	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147 [TC...
14	06:44:20.739499	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	06:44:20.787680	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	06:44:20.838183	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0
17	06:44:20.875188	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=9013 Win=23360 Len=0
18	06:44:20.875421	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=9013 Ack=1 Win=17520 Len=1460 [TCP seg..
19	06:44:20.876104	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=10473 Ack=1 Win=17520 Len=1460 [TCP se..

> Frame 16: 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)

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

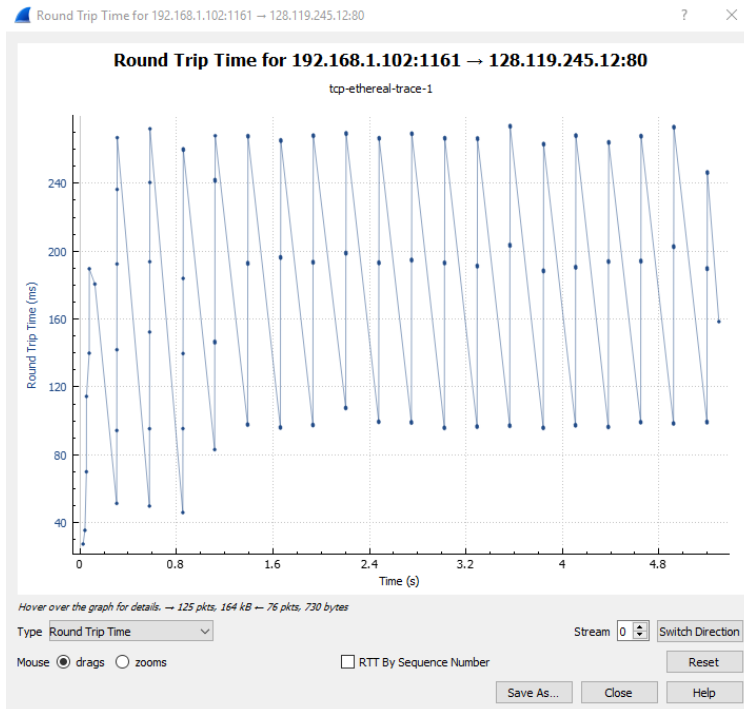
> Transmission Control Protocol, Src Port: 80, Dst Port: 1161, Seq: 1, Ack: 7866, Len: 0

0000 00 20 e0 8a 70 1a 00 06 25 da af 73 08 00 45 00 . . . p . . . % . . s . . E .

0010 00 28 58 77 40 00 37 06 b3 c6 80 77 f5 0c c0 a8 . (Xw@ 7 w

0020 01 66 00 50 04 89 34 a2 74 1a 0d d6 20 ae 50 10 . f . P . . 4 . t P .

0030 4f d8 4c 50 00 00 93 c0 00 00 63 ed 0 . LP c . .



8

Length of the first TCP segment (containing the HTTP POST): 565 bytes Length of each of the other five TCP segments: 1460 bytes (MSS)

No.	Time	Source	Destination	Protocol	Length	Info
1	06:44:20.570381	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	06:44:20.593553	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	06:44:20.593646	192.168.1.102	128.119.245.12	TCP	54	1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
4	06:44:20.596858	192.168.1.102	128.119.245.12	TCP	619	1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565 [TCP se...
5	06:44:20.612118	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP...
6	06:44:20.624318	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
7	06:44:20.624407	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP seg...
8	06:44:20.625071	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP seg...
9	06:44:20.647675	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	06:44:20.647786	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP seg...
11	06:44:20.648538	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP seg...
12	06:44:20.694466	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
13	06:44:20.694566	192.168.1.102	128.119.245.12	TCP	1201	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147 [TC...
14	06:44:20.739499	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	06:44:20.787680	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	06:44:20.828182	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0

> Frame 11: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 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: 6406, Ack: 1, Len: 1460

9

The minimum amount of buffer space (receiver window) advertised at gaia.cs.umass.edu for the entire trace is 5840 bytes, which shows in the first acknowledgement from the server. This receiver window grows steadily until a maximum receiver buffer size of 62780 bytes. The sender is never throttled due to lacking of receiver buffer space by inspecting this trace.

No.	Time	Source	Destination	Protocol	Length	Info
1	06:44:20.570381	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	06:44:20.593553	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	06:44:20.593646	192.168.1.102	128.119.245.12	TCP	54	1161 → 80 [ACK] Seq=1 Ack=1 Win=17520 Len=0
4	06:44:20.596858	192.168.1.102	128.119.245.12	TCP	619	1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=565 [TCP se...
5	06:44:20.612118	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP...
6	06:44:20.624318	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=566 Win=6780 Len=0
7	06:44:20.624407	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len=1460 [TCP seg...
8	06:44:20.625071	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP seg...
9	06:44:20.647675	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=0
10	06:44:20.647786	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len=1460 [TCP seg...
11	06:44:20.648538	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=1460 [TCP seg...
12	06:44:20.694466	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len=0
13	06:44:20.694566	192.168.1.102	128.119.245.12	TCP	1201	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=17520 Len=1147 [TC...
14	06:44:20.739499	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0
15	06:44:20.787680	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=6406 Win=17520 Len=0
16	06:44:20.828182	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0

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

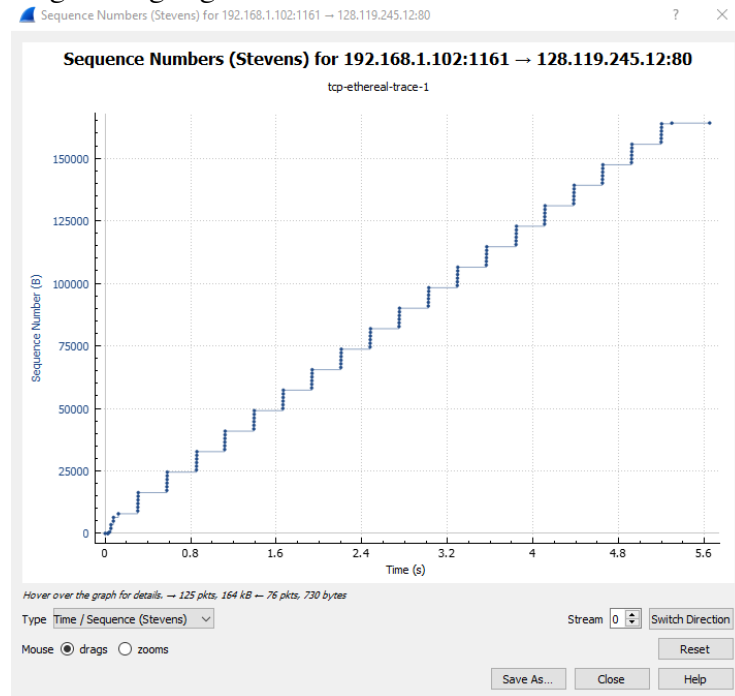
> Ethernet II, Src: LinksysG_da:af:73 (00:06:25:da:af:73), Dst: Actionte_8a:70:1a (00:20:e0:8a:70:1a)

> 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

10

There are no retransmitted segments in the trace file. We can verify this by checking the sequence numbers of the TCP segments in the trace file. In the TimeSequence-Graph (Stevens) of this trace, all sequence numbers from the source (192.168.1.102) to the destination (128.119.245.12) are increasing monotonically with respect to time. If there is a retransmitted segment, the sequence number of this retransmitted segment should be smaller than those of its neighboring segments.



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The difference between the acknowledged sequence numbers of two consecutive ACKs indicates the data received by the server between these two ACKs. By inspecting the amount of acknowledged data by each ACK, there are cases where the receiver is ACKing every other segment. For example, segment of No. 80 acknowledged data with 2920 bytes = 1460*2 bytes.

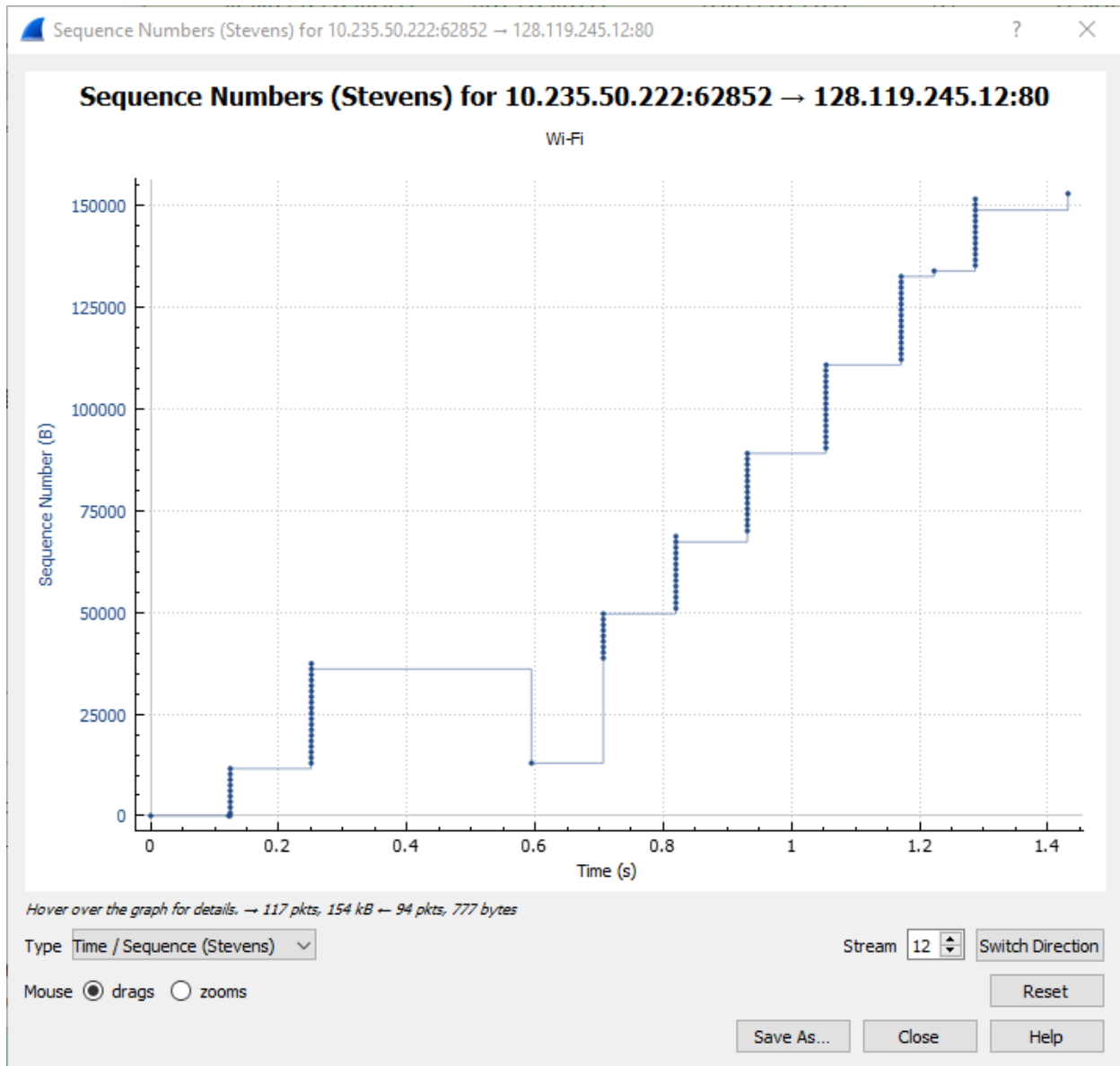
No.	Time	Source	Destination	Protocol	Length	Info
76	06:44:22.235635	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=55813 Ack=1 Win=17520 Len=1460 [TCP se...
77	06:44:22.236532	192.168.1.102	128.119.245.12	TCP	946	1161 → 80 [PSH, ACK] Seq=57273 Ack=1 Win=17520 Len=892 [TC...
78	06:44:22.328608	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=52893 Win=62780 Len=0
79	06:44:22.430444	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=55813 Win=62780 Len=0
80	06:44:22.501261	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=58165 Win=62780 Len=0
81	06:44:22.501480	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=58165 Ack=1 Win=17520 Len=1460 [TCP se...
82	06:44:22.502260	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=59625 Ack=1 Win=17520 Len=1460 [TCP se...
83	06:44:22.503138	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=61085 Ack=1 Win=17520 Len=1460 [TCP se...
84	06:44:22.504017	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=62545 Ack=1 Win=17520 Len=1460 [TCP se...
85	06:44:22.505151	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=64005 Ack=1 Win=17520 Len=1460 [TCP se...
86	06:44:22.505967	192.168.1.102	128.119.245.12	TCP	946	1161 → 80 [PSH, ACK] Seq=65465 Ack=1 Win=17520 Len=892 [TC...
87	06:44:22.599450	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=61085 Win=62780 Len=0
88	06:44:22.697063	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=64005 Win=62780 Len=0
89	06:44:22.773576	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=66357 Win=62780 Len=0
90	06:44:22.773792	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=66357 Ack=1 Win=17520 Len=1460 [TCP se...
91	06:44:22.774506	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=67817 Ack=1 Win=17520 Len=1460 [TCP se...

> Frame 88: 60 bytes on wire (480 bits), 60 bytes captured (480 bits)
 > Ethernet II, Src: Linksys_Giga: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: 1, Ack: 64005, Len: 0

12

The file is 177851 bytes and that by the total time 7.596 seconds and average throughput is 23413.77 bytes per second

13 and 14



The slow start of the TCP seems to begin at about 0.12 seconds and then ends at about 0.25 seconds. Congestion avoidance takes over at about 0.7 seconds because it cut down the amount being sent.