

## Lab 2: TCP

### 1. Capturing a bulk TCP transfer from your computer to a remote server.

The screenshot shows a Wireshark capture of a bulk TCP transfer. The packet list displays a series of ACK packets from the destination to the source. The packet details pane shows the structure of an IP packet and a TCP segment.

No.	Time	Source	Destination	Protocol	Length	Info
148	3.210183	128.119.245.12	192.168.1.89	TCP	54	80 → 56549 [ACK] Seq=1 Ack=134710 Win=1432 Len=0
149	3.243520	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=137630 Win=1432 Len=0
150	3.289147	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=140550 Win=1432 Len=0
151	3.309530	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=143470 Win=1432 Len=0
152	3.343131	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=146390 Win=1432 Len=0
153	3.398690	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=149310 Win=1432 Len=0
154	3.533722	128.119.245.12	192.168.1.89	TCP	56	80 → 56549 [ACK] Seq=1 Ack=152230 Win=1432 Len=0

Frame 1: 55 bytes on wire (440 bits), 55 bytes captured (440 bits) on interface \Device\NPF\_{45498BD0-0010-0020-ad a1 dc dd 01 bb fb 6f} (1c:1b:68:d4:22:a0)

Ethernet II, Src: IntelCor\_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRISGro\_d4:22:a0 (1c:1b:68:d4:22:a0)

Internet Protocol Version 4, Src: 192.168.1.89, Dst: 18.164.173.161

0100 .... = Version: 4  
.... 0101 = Header Length: 20 bytes (5)  
> Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)  
Total Length: 41  
Identification: 0xb48f (46223)  
> 010. .... = Flags: 0x2, Don't fragment  
...0 0000 0000 0000 = Fragment Offset: 0  
Time to Live: 128  
Protocol: TCP (6)

0000 1c 1b 68 d4 22 a0 f0 77  
0010 00 29 b4 8f 40 00 80 06  
0020 ad a1 dc dd 01 bb fb 6f  
0030 00 ff 82 62 00 00 00 00

wireshark\_Wi-Fi9GNLV1.pcapng | Packets: 168 · Displayed: 168 (100.0%) | Profile: Default

### 2. A first look at the captured trace.

1. Computer (source) IP address: 192.168.1.89 and TCP port number: 57392

The screenshot shows a Wireshark capture filtered by TCP. The packet list displays a series of TCP packets. The packet details pane shows the structure of a TCP segment.

No.	Time	Source	Destination	Protocol	Length	Info
208	11.955982	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=149300 Win=183296 Len=0
209	11.991942	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=152220 Win=183296 Len=0
210	11.997854	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=153029 Win=183296 Len=0
211	11.999621	128.119.245.12	192.168.1.89	HTTP	831	HTTP/1.1 200 OK (text/html)
212	12.049440	192.168.1.89	128.119.245.12	TCP	54	57532 → 80 [ACK] Seq=153029 Ack=778 Win=64768 Len=0
222	16.642918	192.168.1.89	72.21.91.29	TCP	66	57533 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=0
223	16.672735	72.21.91.29	192.168.1.89	TCP	66	80 → 57533 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0

Frame 1: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface \Device\NPF\_{45498BD0-0010-0020-46 32 e0 30 01 bb 69 14} (1c:1b:68:d4:22:a0)

Ethernet II, Src: IntelCor\_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRISGro\_d4:22:a0 (1c:1b:68:d4:22:a0)

Internet Protocol Version 4, Src: 192.168.1.89, Dst: 31.13.70.50

Transmission Control Protocol, Src Port: 57392, Dst Port: 443, Seq: 1, Ack: 1, Len: 0

Source Port: 57392  
Destination Port: 443  
[Stream index: 0]  
[Conversation completeness: Incomplete (36)]  
[TCP Segment Len: 0]  
Sequence Number: 1 (relative sequence number)  
Sequence Number (raw): 1762951748  
[Next Sequence Number: 1 (relative sequence number)]

0000 1c 1b 68 d4 22 a0 f0 77  
0010 00 28 65 22 40 00 80 06  
0020 46 32 e0 30 01 bb 69 14  
0030 00 00 27 5b 00 00 00 00

Transmission Control Protocol: Protocol | Packets: 223 · Displayed: 186 (83.4%) · Dropped: 0 (0.0%) | Profile: Default

2. Destination computer: gaia.cs.umass.edu IP address: 31.13.70.50 and TCP port number: 443.

The screenshot shows a Wireshark packet capture on the 'tcp' filter. The packet list shows several packets, with packet 223 selected. The packet details pane shows the following information:

- Frame 1: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface \Device\NPF\_{454988D0...}
- Ethernet II, Src: IntelCor\_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRISGro\_d4:22:a0 (1c:1b:68:d4:22:a0)
- Internet Protocol Version 4, Src: 192.168.1.89, Dst: 31.13.70.50
- Transmission Control Protocol, Src Port: 57392, Dst Port: 443, Seq: 1, Ack: 1, Len: 0
  - Source Port: 57392
  - Destination Port: 443
  - [Stream index: 0]
  - [Conversation completeness: Incomplete (36)]
  - [TCP Segment Len: 0]
  - Sequence Number: 1 (relative sequence number)
  - Sequence Number (raw): 1762951748
  - [Next Sequence Number: 1 (relative sequence number)]

The status bar at the bottom indicates: Packets: 223 · Displayed: 186 (83.4%) · Dropped: 0 (0.0%) · Profile: Default

3. IP address: 192.168.1.89 and TCP port number: 57392

The screenshot shows a Wireshark packet capture on the 'tcp' filter. The packet list shows several packets, with packet 223 selected. The packet details pane shows the following information:

- Frame 1: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface \Device\NPF\_{454988D0...}
- Ethernet II, Src: IntelCor\_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRISGro\_d4:22:a0 (1c:1b:68:d4:22:a0)
- Internet Protocol Version 4, Src: 192.168.1.89, Dst: 31.13.70.50
- Transmission Control Protocol, Src Port: 57392, Dst Port: 443, Seq: 1, Ack: 1, Len: 0
  - Source Port: 57392
  - Destination Port: 443
  - [Stream index: 0]
  - [Conversation completeness: Incomplete (36)]
  - [TCP Segment Len: 0]
  - Sequence Number: 1 (relative sequence number)
  - Sequence Number (raw): 1762951748
  - [Next Sequence Number: 1 (relative sequence number)]

The status bar at the bottom indicates: Packets: 223 · Displayed: 186 (83.4%) · Dropped: 0 (0.0%) · Profile: Default

### 3. TCP Basics

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

The image displays two screenshots of the Wireshark network protocol analyzer. The top screenshot shows a packet list with several TCP segments. The bottom screenshot shows the detailed view of a specific TCP segment (packet 223), highlighting the 'Sequence Number: 1' field.

**Wireshark Packet List (Top Screenshot):**

No.	Time	Source	Destination	Protocol	Length	Info
208	11.955982	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=149300 Win=183296 Len=0
209	11.991942	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=152220 Win=183296 Len=0
210	11.997854	128.119.245.12	192.168.1.89	TCP	56	80 → 57532 [ACK] Seq=1 Ack=153029 Win=183296 Len=0
211	11.999621	128.119.245.12	192.168.1.89	HTTP	831	HTTP/1.1 200 OK (text/html)
212	12.049440	192.168.1.89	128.119.245.12	TCP	54	57532 → 80 [ACK] Seq=153029 Ack=778 Win=64768 Len=0
222	16.642918	192.168.1.89	72.21.91.29	TCP	66	57533 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=0
223	16.672735	72.21.91.29	192.168.1.89	TCP	66	80 → 57533 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0

**Wireshark Packet Details (Bottom Screenshot):**

Transmission Control Protocol, Src Port: 57392, Dst Port: 443, Seq: 1, Ack: 1, Len: 0

- Source Port: 57392
- Destination Port: 443
- [Stream index: 0]
- [Conversation completeness: Incomplete (36)]
- [TCP Segment Len: 0]
- Sequence Number: 1 (relative sequence number)**
- Sequence Number (raw): 1762951748
- [Next Sequence Number: 1 (relative sequence number)]
- Acknowledgment Number: 1 (relative ack number)
- Acknowledgment number (raw): 693406420

Summary: Packets: 223 · Displayed: 186 (83.4%) · Dropped: 0 (0.0%) · Profile: Default

## 5. Syn: 0 Ack: 1 Seq: 1

```
> Frame 1: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface \Device\NPF_{45498BDF-190F-4733-AD59-68C706C2751B}, Id 0
> Ethernet II, Src: IntelCor_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRI50ro_d4:22:a0 (1c:1b:68:d4:22:a0)
> Internet Protocol Version 4, Src: 192.168.1.89, Dst: 31.13.70.58
▼ Transmission Control Protocol, Src Port: 57392, Dst Port: 443, Seq: 1, Ack: 1, Len: 0
  Source Port: 57392
  Destination Port: 443
  [Stream index: 0]
  [Conversation completeness: Incomplete (36)]
  [TCP Segment Len: 0]
  Sequence Number: 1 (relative sequence number)
  Sequence Number (raw): 1762951748
  [Next Sequence Number: 1 (relative sequence number)]
  Acknowledgment Number: 1 (relative ack number)
  Acknowledgment number (raw): 693486420
  0101 .... = Header Length: 20 bytes (5)
▼ Flags: 0x014 (RST, 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
  3....1... = Reset: Set
  .....0... = Syn: Not set
  .....0... = Fin: Not set
  [TCP Flags: .....A.R...]
  Window: 0
  [Calculated window size: 0]
  [Window size scaling factor: -1 (unknown)]
  Checksum: 0x275b [unverified]
  Transmission Control Protocol: Protocol
```

## 6. Segment:29 and sequence number : 1 POST

```
No. Time Source Destination Protocol Length Info
1 0.000000 192.168.1.89 31.13.70.58 TCP 54 57392 → 443 [RST, ACK] Seq=1 Ack=1 Win=0 Len=0
2 0.000000 208017900:8981:7040L 240312890:F231c6:f TCP 74 57400 → 443 [RST, ACK] Seq=1 Ack=1 Win=0 Len=0
3 0.000011 208017900:8981:7040L 240312890:F231c6:f TCP 74 57400 → 443 [RST, ACK] Seq=1 Ack=1 Win=0 Len=0
4 4.145532 192.168.1.89 192.168.1.89 TCP 55 57519 → 443 [ACK] Seq=1 Ack=1 Win=255 Len=0 [TCP segment of a reassembled PDU]
6 4.188342 18.164.153.200 192.168.1.89 TCP 64 842 → 57519 [ACK] Seq=1 Ack=2 Win=133 Len=0 SLE=1 SRE=2
7 4.224284 192.168.1.89 192.168.1.89 TCP 55 57519 → 443 [ACK] Seq=1 Ack=1 Win=255 Len=0 [TCP segment of a reassembled PDU]
8 4.253070 192.168.1.89 192.168.1.89 TCP 64 842 → 57519 [ACK] Seq=1 Ack=2 Win=133 Len=0 SLE=1 SRE=2
11 9.073370 192.168.1.89 192.168.1.89 TCP 55 57517 → 80 [ACK] Seq=1 Ack=1 Win=255 Len=0
12 9.175217 192.168.1.89 192.168.1.89 TCP 54 86 → 57517 [ACK] Seq=1 Ack=1 Win=255 Len=0
16 10.830800 192.168.1.89 192.168.1.89 TCP 54 57517 → 80 [FIN, ACK] Seq=1 Ack=1 Win=255 Len=0
17 10.830800 192.168.1.89 192.168.1.89 TCP 66 57511 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM
18 10.830800 192.168.1.89 192.168.1.89 TCP 66 57512 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 WS=256 SACK_PERM
24 10.104993 192.168.1.89 192.168.1.89 TCP 54 86 → 57517 [ACK] Seq=1 Ack=1 Win=255 Len=0
25 10.104993 192.168.1.89 192.168.1.89 TCP 66 86 → 57511 [SYN, ACK] Seq=0 Ack=1 Win=25200 Len=0 MSS=1460 SACK_PERM WS=128
26 10.104993 192.168.1.89 192.168.1.89 TCP 66 86 → 57512 [SYN, ACK] Seq=0 Ack=1 Win=25200 Len=0 MSS=1460 SACK_PERM WS=128
27 10.104700 192.168.1.89 192.168.1.89 TCP 54 57511 → 80 [ACK] Seq=1 Ack=1 Win=65536 Len=0
28 10.104990 192.168.1.89 192.168.1.89 TCP 54 57512 → 80 [ACK] Seq=1 Ack=1 Win=65536 Len=0
29 10.105001 192.168.1.89 192.168.1.89 TCP 761 57512 → 80 [PSH, ACK] Seq=1 Ack=1 Win=65536 Len=767 [TCP segment of a reassembled PDU]
30 10.104993 192.168.1.89 192.168.1.89 TCP 1104 57512 → 80 [ACK] Seq=704 Ack=1 Win=65536 Len=1104 [TCP segment of a reassembled PDU]
35 10.279440 192.168.1.89 192.168.1.89 TCP 54 86 → 57512 [ACK] Seq=1 Ack=704 Win=30720 Len=0
36 10.279502 192.168.1.89 192.168.1.89 TCP 1514 57512 → 80 [ACK] Seq=13948 Ack=1 Win=65536 Len=1400 [TCP segment of a reassembled PDU]

> Frame 29: 761 bytes on wire (6088 bits), 761 bytes captured (6088 bits) on interface \Device\NPF_{45498BDF-190F-4733-AD59-68C706C2751B}, Id 0
> Ethernet II, Src: IntelCor_fb:80:83 (f0:77:c3:fb:80:83), Dst: ARRI50ro_d4:22:a0 (1c:1b:68:d4:22:a0)
> Internet Protocol Version 4, Src: 192.168.1.89, Dst: 192.168.1.89
▼ Transmission Control Protocol, Src Port: 57512, Dst Port: 80, Seq: 1, Ack: 1, Len: 767
  Source Port: 57512
  Destination Port: 80
  [Stream index: 7]
  [Conversation completeness: Incomplete, DATA (15)]
  [TCP Segment Len: 767]
  Sequence Number: 1 (relative sequence number)
  Sequence Number (raw): 417705417
  [Next Sequence Number: 768 (relative sequence number)]
  Acknowledgment Number: 1 (relative ack number)
  Acknowledgment number (raw): 2409597148
  0001 .... = Header Length: 20 bytes (5)
▼ Flags: 0x012 (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
  ....0... = Push: Set
  3....1... = Reset: Not set
  .....0... = Syn: Not set
  .....0... = Fin: Not set
  [TCP Flags: .....A.P...]
  Window: 256
  [Calculated window size: 69536]
  [Window size scaling factor: 256]
  Transmission Control Protocol: Protocol
```

7. Segment 1: seq number: 1, segment 2: seq number: 579, segment 3: seq number: 716, segment 4: seq number: 2164, segment 5: seq number: 362, segment 6: seq number: 5060.

Recording the sending time and received time of ACKs:

	Sent time	ACK received time	RTT
Segment 1	0.271257000	0.366931000	0.095674
Segment 2	0.271425000	0.367289000	0.095864
Segment 3	0.271797000	0.368617000	0.09682
Segment 4	0.271798000	0.369952000	0.098154
Segment 5	0.367081000	0.479965000	0.112884
Segment 6	0.368711000	0.482492000	0.113781

According to the formula:  $\text{EstimatedRTT} = 0.875 * \text{EstimatedRTT} + 0.125 * \text{SampleRTT}$

EstimatedRTT after the receipt of the ACK of segment 1:

EstimatedRTT = RTT for Segment 1 = 0.095674 s

EstimatedRTT after the receipt of the ACK of segment 2:

EstimatedRTT =  $0.875 * 0.095674 + 0.125 * 0.095864 = 0.09569775$  s

EstimatedRTT after the receipt of the ACK of segment 3:

EstimatedRTT =  $0.875 * 0.09569775 + 0.125 * 0.09682 = 0.09583803125$  s

EstimatedRTT after the receipt of the ACK of segment 4:

EstimatedRTT =  $0.875 * 0.09583803125 + 0.125 * 0.098154 = 0.09612752734$  s

EstimatedRTT after the receipt of the ACK of segment 5:

EstimatedRTT =  $0.875 * 0.09612752734 + 0.125 * 0.112884 = 0.09822208642$  s

EstimatedRTT after the receipt of the ACK of segment 6:

EstimatedRTT =  $0.875 * 0.09822208642 + 0.125 * 0.113781 = 0.10016695061$  s



8. length: 578 bytes

6	0.27125700	192.168.1.8	128.119.245.12	TCP	644 60706 > http [PSH, ACK] Seq=1 Ack=1 win=131760 Len=578
7	0.27142500	192.168.1.8	128.119.245.12	TCP	203 60706 > http [PSH, ACK] Seq=579 Ack=1 win=131760 Len=137
8	0.27179700	192.168.1.8	128.119.245.12	TCP	1514 60706 > http [ACK] Seq=716 Ack=1 win=131760 Len=1448 TSv
9	0.27179800	192.168.1.8	128.119.245.12	TCP	1514 60706 > http [ACK] Seq=2164 Ack=1 win=131760 Len=1448 TS
10	0.36693100	128.119.245.12	192.168.1.8	TCP	66 http > 60706 [ACK] Seq=1 Ack=579 win=7040 Len=0 TSval=2
11	0.36708100	192.168.1.8	128.119.245.12	TCP	1514 60706 > http [ACK] Seq=3612 Ack=1 win=131760 Len=1448 TS
12	0.36728900	128.119.245.12	192.168.1.8	TCP	66 http > 60706 [ACK] Seq=1 Ack=716 win=8192 Len=0 TSval=2
13	0.36861700	128.119.245.12	192.168.1.8	TCP	66 http > 60706 [ACK] Seq=1 Ack=2164 win=11008 Len=0 TSval=
14	0.36871100	192.168.1.8	128.119.245.12	TCP	1514 60706 > http [ACK] Seq=5060 Ack=1 win=131760 Len=1448 TS
15	0.36871200	192.168.1.8	128.119.245.12	TCP	1514 60706 > http [ACK] Seq=6508 Ack=1 win=131760 Len=1448 TS

Options: (12 bytes), No-Operation (NOP), No-Operation (NOP), Timestamps

- No-Operation (NOP)
- No-Operation (NOP)
- Timestamps: TSval 85391598, Tsecr 2261446230
  - Kind: Timestamp (8)
  - Length: 10
  - Timestamp value: 85391598
  - Timestamp echo reply: 2261446230

[SEQ/ACK analysis]

Data (578 bytes)

Data: 504f5354202f776972657368617262d6c6162732f6c6162...

[Length: 578]

9. Window: 256

[Conversation completeness: Incomplete (28)]
[TCP Segment Len: 0]
Sequence Number: 2 (relative sequence number)
Sequence Number (raw): 1449501722
[Next Sequence Number: 3 (relative sequence number)]
Acknowledgment Number: 1 (relative ack number)
Acknowledgment number (raw): 947964855
0101 .... = Header Length: 20 bytes (5)
✓ Flags: 0x011 (FIN, 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
> .... .... ...1 = Fin: Set
> [TCP Flags: .....A...F]
Window: 256
[Calculated window size: 256]
[Window size scaling factor: -1 (unknown)]
Checksum: 0x37a0 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
✓ [Timestamps]
[Time since first frame in this TCP stream: 0.965229000 seconds]
[Time since previous frame in this TCP stream: 0.863382000 seconds]

Transmission Control Protocol: Protocol

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 Time Sequence-Graph (Stevens) of this trace, all sequence numbers from the source (192.168.1.89) to the destination (31.13.70.50) 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.

11.

The difference between the acknowledged sequence numbers of two consecutive ACKs indicates the data received by the server between these two ACKs. The receiver is ACKing every other segment. For example, segment of No. 13 acknowledged data with 1430 bytes.

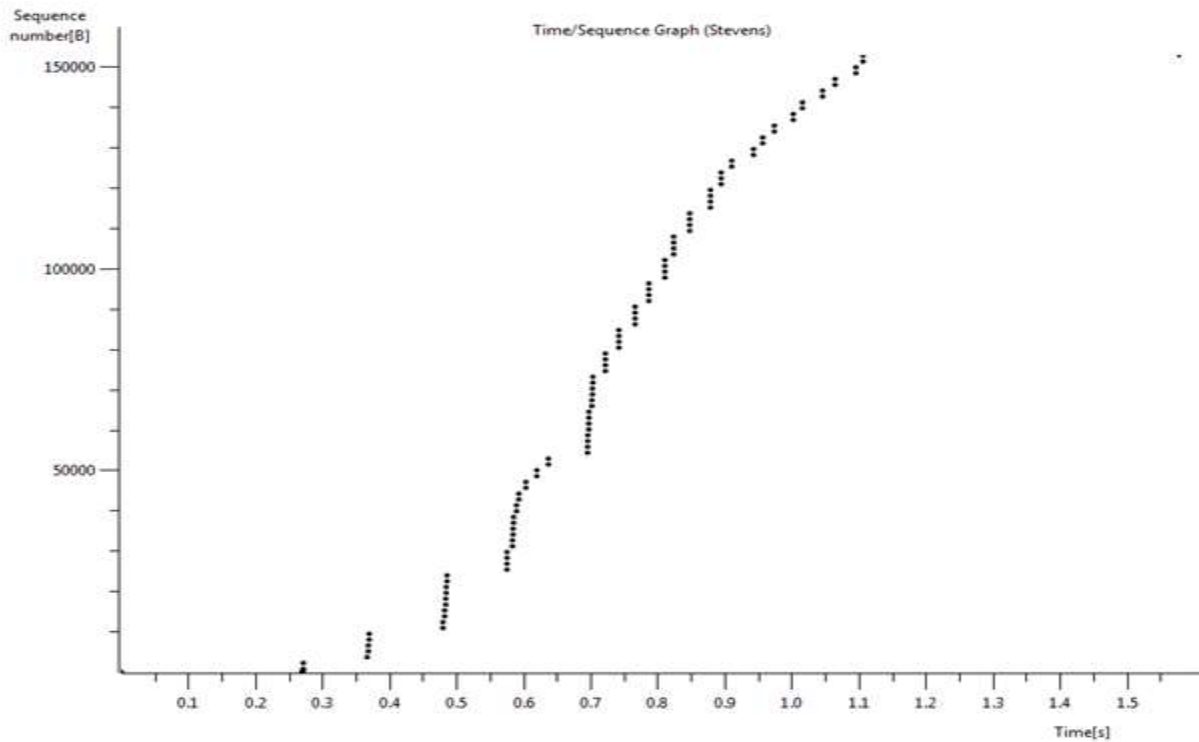
1	0.00000000	192.168.1.8	128.119.245.12	TCP	78	60706 > http	[SYN, Seq=0 win=65535 Len=0 MSS=1460 WS=16
4	0.26949200	128.119.245.12	192.168.1.8	TCP	74	http > 60706	[SYN, ACK] Seq=0 Ack=1 win=5792 Len=0 MSS=1
5	0.26960900	192.168.1.8	128.119.245.12	TCP	66	60706 > http	[ACK] Seq=1 Ack=1 win=131760 Len=0 TSval=85
6	0.27125700	192.168.1.8	128.119.245.12	TCP	644	60706 > http	[PSH, ACK] Seq=1 Ack=1 win=131760 Len=578 T
7	0.27142500	192.168.1.8	128.119.245.12	TCP	203	60706 > http	[PSH, ACK] Seq=579 Ack=1 win=131760 Len=137
8	0.27179700	192.168.1.8	128.119.245.12	TCP	1514	60706 > http	[ACK] Seq=716 Ack=1 win=131760 Len=1448 TSV
9	0.27179800	192.168.1.8	128.119.245.12	TCP	1514	60706 > http	[ACK] Seq=2164 Ack=1 win=131760 Len=1448 TS
10	0.36693100	128.119.245.12	192.168.1.8	TCP	66	http > 60706	[ACK] Seq=1 Ack=579 win=7040 Len=0 TSval=22
11	0.36708100	192.168.1.8	128.119.245.12	TCP	1514	60706 > http	[ACK] Seq=3612 Ack=1 win=131760 Len=1448 TS
12	0.36728900	128.119.245.12	192.168.1.8	TCP	66	http > 60706	[ACK] Seq=1 Ack=716 win=8192 Len=0 TSval=22
13	0.36861700	128.119.245.12	192.168.1.8	TCP	66	http > 60706	[ACK] Seq=1 Ack=2164 win=11008 Len=0 TSval=
14	0.36871100	192.168.1.8	128.119.245.12	TCP	1514	60706 > http	[ACK] Seq=5060 Ack=1 win=131760 Len=1448 TS
15	0.36871200	192.168.1.8	128.119.245.12	TCP	1514	60706 > http	[ACK] Seq=6508 Ack=1 win=131760 Len=1448 TS

12.

The alice.txt on the hard drive is 152,138 bytes, and the download time is 1.578736000 (First TCP segment) - 0.271257000 (last ACK) = 1.307479 second. Therefore, the throughput for the TCP connection is computed as 152,138/1.307479=116359.803867 bytes/second.

#### 4. TCP congestion control in action

13. The slow start of the TCP seems to begin at about 0.27 seconds and then ends at about 0.35 seconds. Congestion avoidance takes over at about 0.7 seconds because it cut down the amount being sent.



14. It is answered above.