# MSCI 445 Lab 3

June 5, 2017

Group 2

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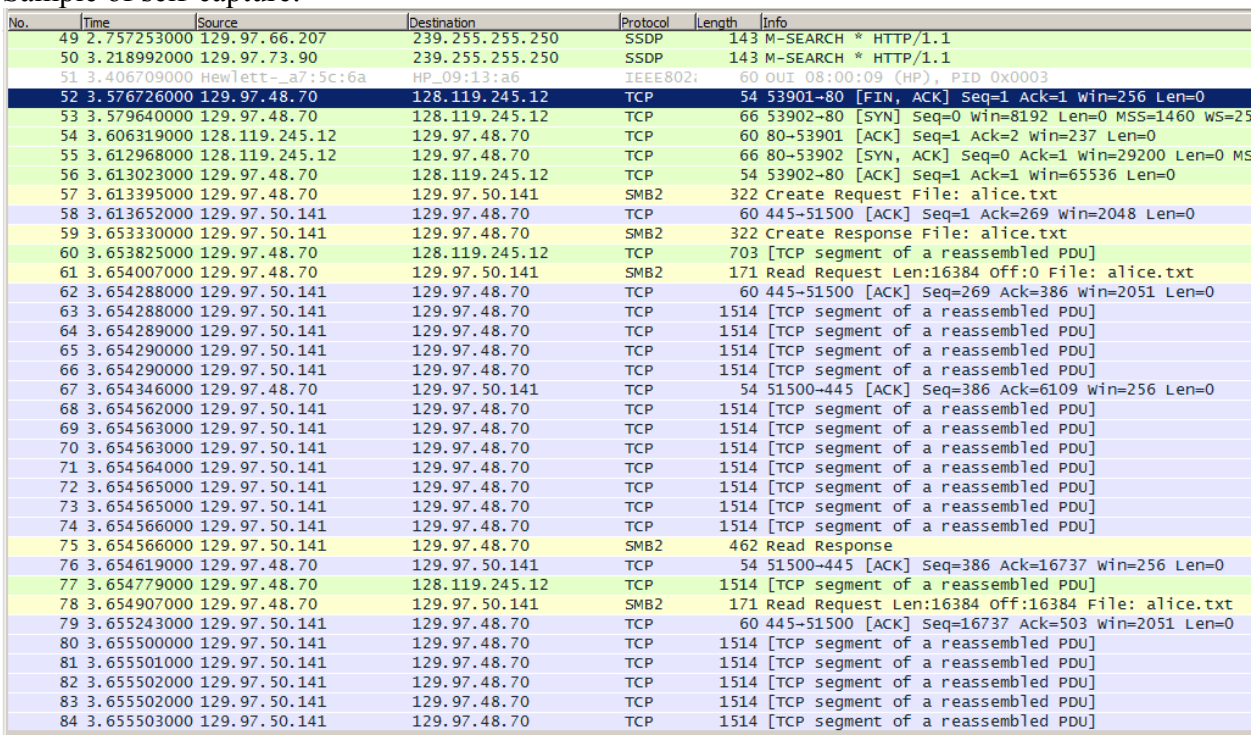
Sarah Watts – 20515933

## Overview

This assignment shows how TCP works from client to server. The concepts covered in this lab are 3 way handshakes, TCP slow start, congestion control and congestion avoidance. This lab was implemented by uploading the file alice.txt to the web server and capturing the packets using wire shark. All questions except 3 & 14 were answered using supplied wire shark traces.

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

Sample of self-capture:

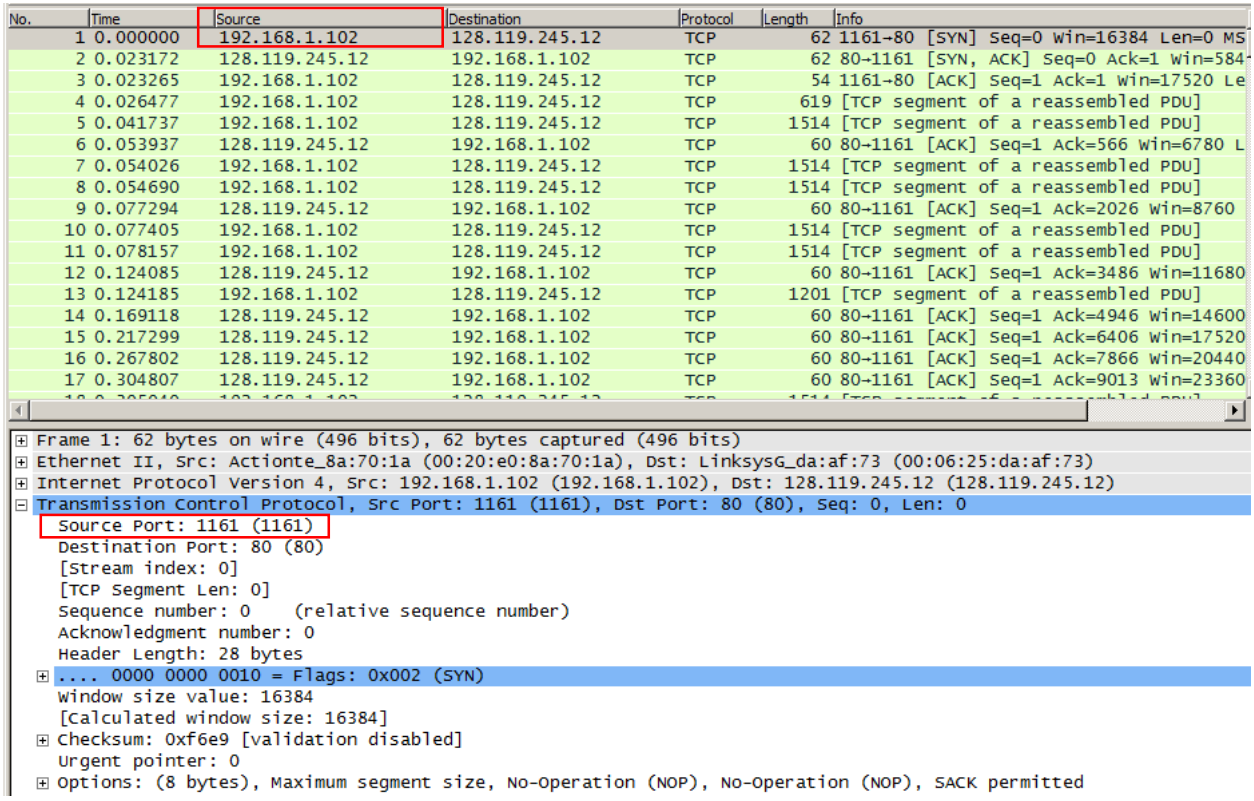


| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 49 | 2.757253000 | 129.97.66.207 | 239.255.255.250 | SSDP | 143 | M-SEARCH * HTTP/1.1 |
| 50 | 3.218992000 | 129.97.73.90 | 239.255.255.250 | SSDP | 143 | M-SEARCH * HTTP/1.1 |
| 51 | 3.406709000 | Hewlett-_a7:5c:6a | HP_09:13:a6 | IEEE802; | 60 | OUI 08:00:09 (HP), PID 0x0003 |
| 52 | 3.576726000 | 129.97.48.70 | 128.119.245.12 | TCP | 54 | 53901→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 53 | 3.579640000 | 129.97.48.70 | 128.119.245.12 | TCP | 66 | 53902→80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=25 |
| 54 | 3.606319000 | 128.119.245.12 | 129.97.48.70 | TCP | 60 | 80→53901 [ACK] Seq=1 Ack=2 Win=237 Len=0 |
| 55 | 3.612968000 | 128.119.245.12 | 129.97.48.70 | TCP | 66 | 80→53902 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MS |
| 56 | 3.613023000 | 129.97.48.70 | 128.119.245.12 | TCP | 54 | 53902→80 [ACK] Seq=1 Ack=1 Win=65536 Len=0 |
| 57 | 3.613395000 | 129.97.48.70 | 129.97.50.141 | SMB2 | 322 | Create Request File: alice.txt |
| 58 | 3.613652000 | 129.97.50.141 | 129.97.48.70 | TCP | 60 | 445→51500 [ACK] Seq=1 Ack=269 Win=2048 Len=0 |
| 59 | 3.653330000 | 129.97.50.141 | 129.97.48.70 | SMB2 | 322 | Create Response File: alice.txt |
| 60 | 3.653825000 | 129.97.48.70 | 128.119.245.12 | TCP | 703 | [TCP segment of a reassembled PDU] |
| 61 | 3.654007000 | 129.97.48.70 | 129.97.50.141 | SMB2 | 171 | Read Request Len:16384 Off:0 File: alice.txt |
| 62 | 3.654288000 | 129.97.50.141 | 129.97.48.70 | TCP | 60 | 445→51500 [ACK] Seq=269 Ack=386 Win=2051 Len=0 |
| 63 | 3.654288000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 64 | 3.654289000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 65 | 3.654290000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 66 | 3.654290000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 67 | 3.654346000 | 129.97.48.70 | 129.97.50.141 | TCP | 54 | 51500→445 [ACK] Seq=386 Ack=6109 Win=256 Len=0 |
| 68 | 3.654562000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 69 | 3.654563000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 70 | 3.654563000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 71 | 3.654564000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 72 | 3.654565000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 73 | 3.654565000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 74 | 3.654566000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 75 | 3.654566000 | 129.97.50.141 | 129.97.48.70 | SMB2 | 462 | Read Response |
| 76 | 3.654619000 | 129.97.48.70 | 129.97.50.141 | TCP | 54 | 51500→445 [ACK] Seq=386 Ack=16737 Win=256 Len=0 |
| 77 | 3.654779000 | 129.97.48.70 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 78 | 3.654907000 | 129.97.48.70 | 129.97.50.141 | SMB2 | 171 | Read Request Len:16384 Off:16384 File: alice.txt |
| 79 | 3.655243000 | 129.97.50.141 | 129.97.48.70 | TCP | 60 | 445→51500 [ACK] Seq=16737 Ack=503 Win=2051 Len=0 |
| 80 | 3.655500000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 81 | 3.655501000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 82 | 3.655502000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 83 | 3.655502000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 84 | 3.655503000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |

## 2. A first look at the captured trace

### Question 1

The IP address of the source computer is 192.168.1.102 and the TCP port number is 1161.

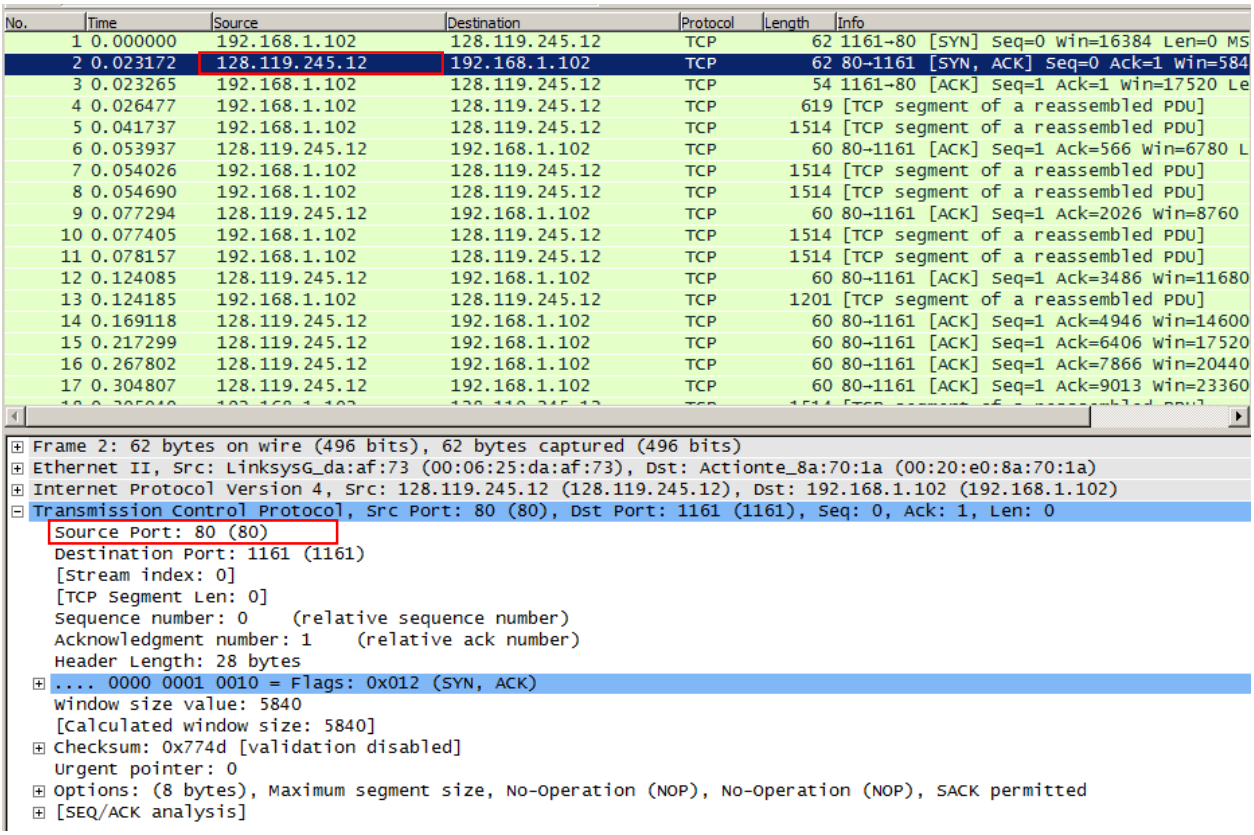


| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 1 | 0.000000 | 192.168.1.102 | 128.119.245.12 | TCP | 62 | 1161→80 [SYN] Seq=0 Win=16384 Len=0 MS |
| 2 | 0.023172 | 128.119.245.12 | 192.168.1.102 | TCP | 62 | 80→1161 [SYN, ACK] Seq=0 Ack=1 Win=584 |
| 3 | 0.023265 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161→80 [ACK] Seq=1 Ack=1 Win=17520 Le |
| 4 | 0.026477 | 192.168.1.102 | 128.119.245.12 | TCP | 619 | [TCP segment of a reassembled PDU] |
| 5 | 0.041737 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 6 | 0.053937 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=566 Win=6780 L |
| 7 | 0.054026 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 8 | 0.054690 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 9 | 0.077294 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=2026 Win=8760 |
| 10 | 0.077405 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 11 | 0.078157 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 12 | 0.124085 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=3486 Win=11680 |
| 13 | 0.124185 | 192.168.1.102 | 128.119.245.12 | TCP | 1201 | [TCP segment of a reassembled PDU] |
| 14 | 0.169118 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=4946 Win=14600 |
| 15 | 0.217299 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=6406 Win=17520 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 |
| 17 | 0.304807 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=9013 Win=23360 |

```
⊞ 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 (192.168.1.102), Dst: 128.119.245.12 (128.119.245.12)
⊟ Transmission Control Protocol, Src Port: 1161 (1161), Dst Port: 80 (80), Seq: 0, Len: 0
    Source Port: 1161 (1161)
    Destination Port: 80 (80)
    [Stream index: 0]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    Acknowledgment number: 0
    Header Length: 28 bytes
  ⊞ .... 0000 0000 0010 = Flags: 0x002 (SYN)
    Window size value: 16384
    [Calculated window size: 16384]
  ⊞ Checksum: 0xf6e9 [validation disabled]
    Urgent pointer: 0
  ⊞ Options: (8 bytes), Maximum segment size, No-Operation (NOP), No-Operation (NOP), SACK permitted
```

## Question 2

The IP address of gaia.cs.umass.edu is 128.119.245.12 and the TCP port number is 80.

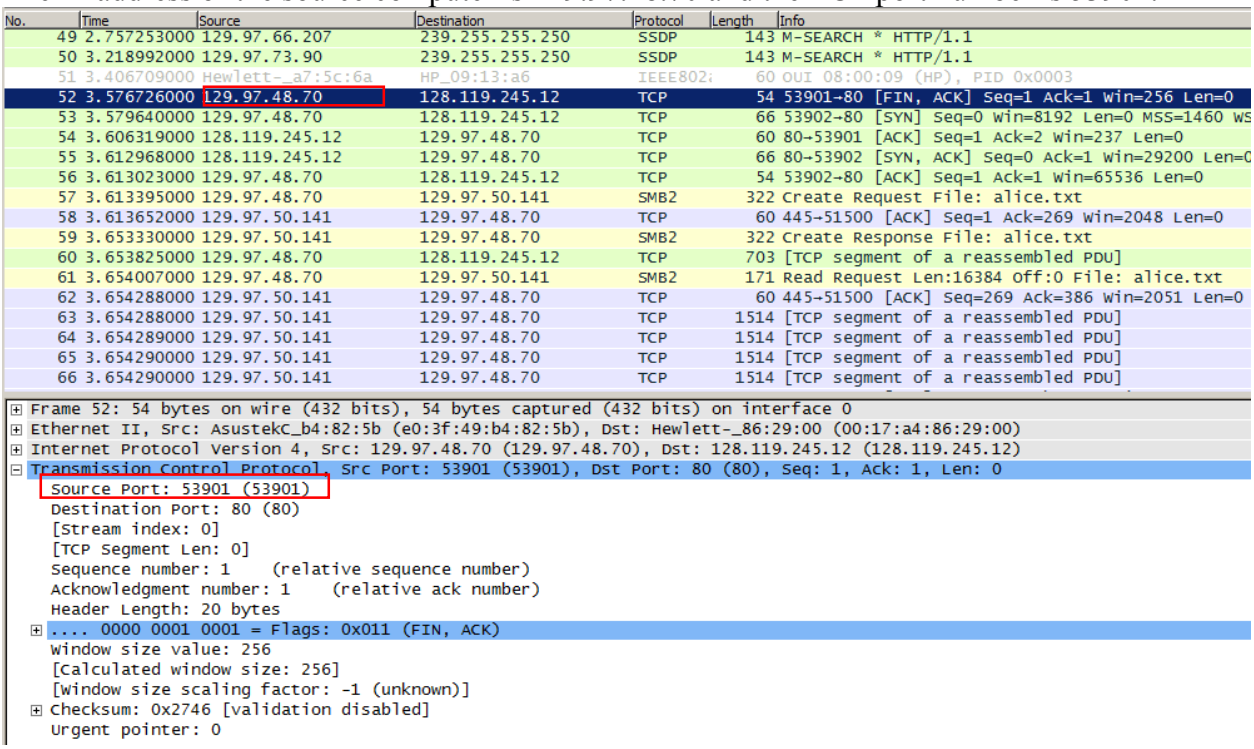


| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 1 | 0.000000 | 192.168.1.102 | 128.119.245.12 | TCP | 62 | 1161→80 [SYN] Seq=0 Win=16384 Len=0 MS |
| 2 | 0.023172 | 128.119.245.12 | 192.168.1.102 | TCP | 62 | 80→1161 [SYN, ACK] Seq=0 Ack=1 Win=584 |
| 3 | 0.023265 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161→80 [ACK] Seq=1 Ack=1 Win=17520 Le |
| 4 | 0.026477 | 192.168.1.102 | 128.119.245.12 | TCP | 619 | [TCP segment of a reassembled PDU] |
| 5 | 0.041737 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 6 | 0.053937 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=566 Win=6780 L |
| 7 | 0.054026 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 8 | 0.054690 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 9 | 0.077294 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=2026 Win=8760 |
| 10 | 0.077405 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 11 | 0.078157 | 192.168.1.102 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 12 | 0.124085 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=3486 Win=11680 |
| 13 | 0.124185 | 192.168.1.102 | 128.119.245.12 | TCP | 1201 | [TCP segment of a reassembled PDU] |
| 14 | 0.169118 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=4946 Win=14600 |
| 15 | 0.217299 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=6406 Win=17520 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 |
| 17 | 0.304807 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=9013 Win=23360 |



## Question 3

The IP address of the source computer is 129.97.48.70 and the TCP port number is 53901.

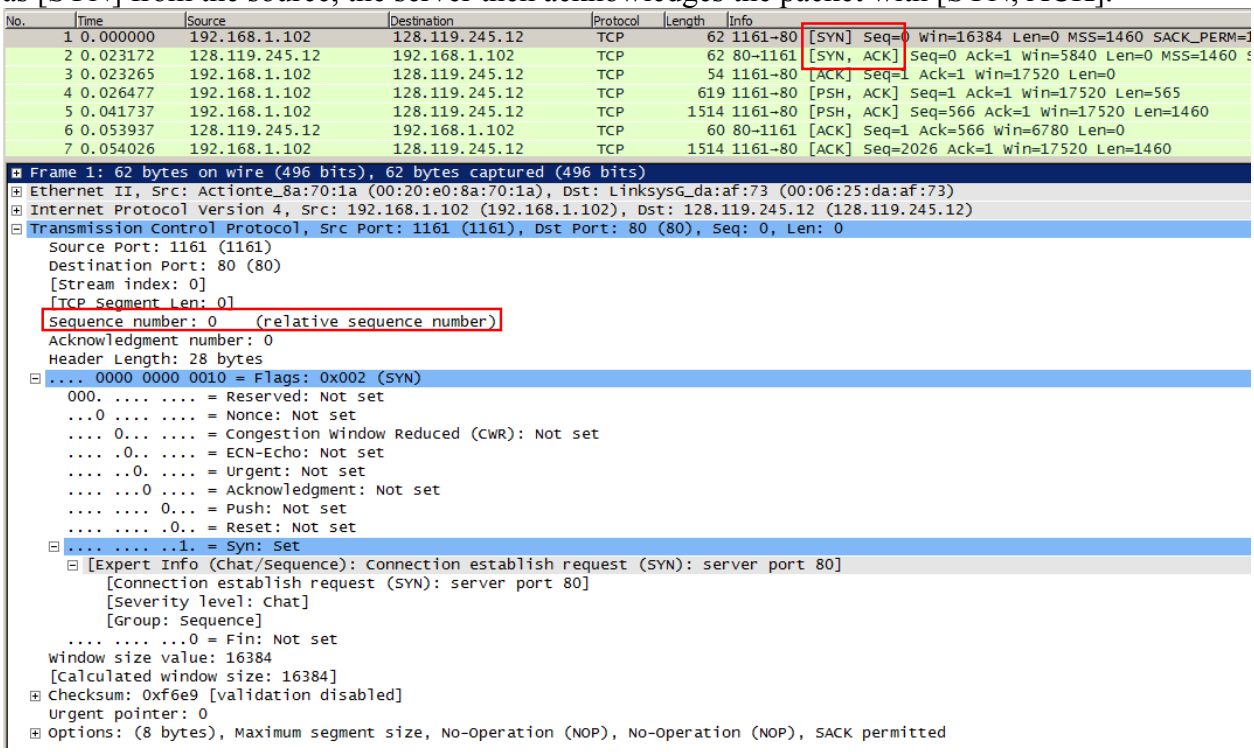


| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 49 | 2.757253000 | 129.97.66.207 | 239.255.255.250 | SSDP | 143 | M-SEARCH * HTTP/1.1 |
| 50 | 3.218992000 | 129.97.73.90 | 239.255.255.250 | SSDP | 143 | M-SEARCH * HTTP/1.1 |
| 51 | 3.406709000 | Hewlett-_a7:5c:6a | HP_09:13:a6 | IEEE802; | 60 | OUI 08:00:09 (HP), PID 0x0003 |
| 52 | 3.576726000 | 129.97.48.70 | 128.119.245.12 | TCP | 54 | 53901→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 53 | 3.579640000 | 129.97.48.70 | 128.119.245.12 | TCP | 66 | 53902→80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS |
| 54 | 3.606319000 | 128.119.245.12 | 129.97.48.70 | TCP | 60 | 80→53901 [ACK] Seq=1 Ack=2 Win=237 Len=0 |
| 55 | 3.612968000 | 128.119.245.12 | 129.97.48.70 | TCP | 66 | 80→53902 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 |
| 56 | 3.613023000 | 129.97.48.70 | 128.119.245.12 | TCP | 54 | 53902→80 [ACK] Seq=1 Ack=1 Win=65536 Len=0 |
| 57 | 3.613395000 | 129.97.48.70 | 129.97.50.141 | SMB2 | 322 | Create Request File: alice.txt |
| 58 | 3.613652000 | 129.97.50.141 | 129.97.48.70 | TCP | 60 | 445→51500 [ACK] Seq=1 Ack=269 Win=2048 Len=0 |
| 59 | 3.653330000 | 129.97.50.141 | 129.97.48.70 | SMB2 | 322 | Create Response File: alice.txt |
| 60 | 3.653825000 | 129.97.48.70 | 128.119.245.12 | TCP | 703 | [TCP segment of a reassembled PDU] |
| 61 | 3.654007000 | 129.97.48.70 | 129.97.50.141 | SMB2 | 171 | Read Request Len:16384 Off:0 File: alice.txt |
| 62 | 3.654288000 | 129.97.50.141 | 129.97.48.70 | TCP | 60 | 445→51500 [ACK] Seq=269 Ack=386 Win=2051 Len=0 |
| 63 | 3.654288000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 64 | 3.654289000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 65 | 3.654290000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 66 | 3.654290000 | 129.97.50.141 | 129.97.48.70 | TCP | 1514 | [TCP segment of a reassembled PDU] |

# 3. TCP Basics

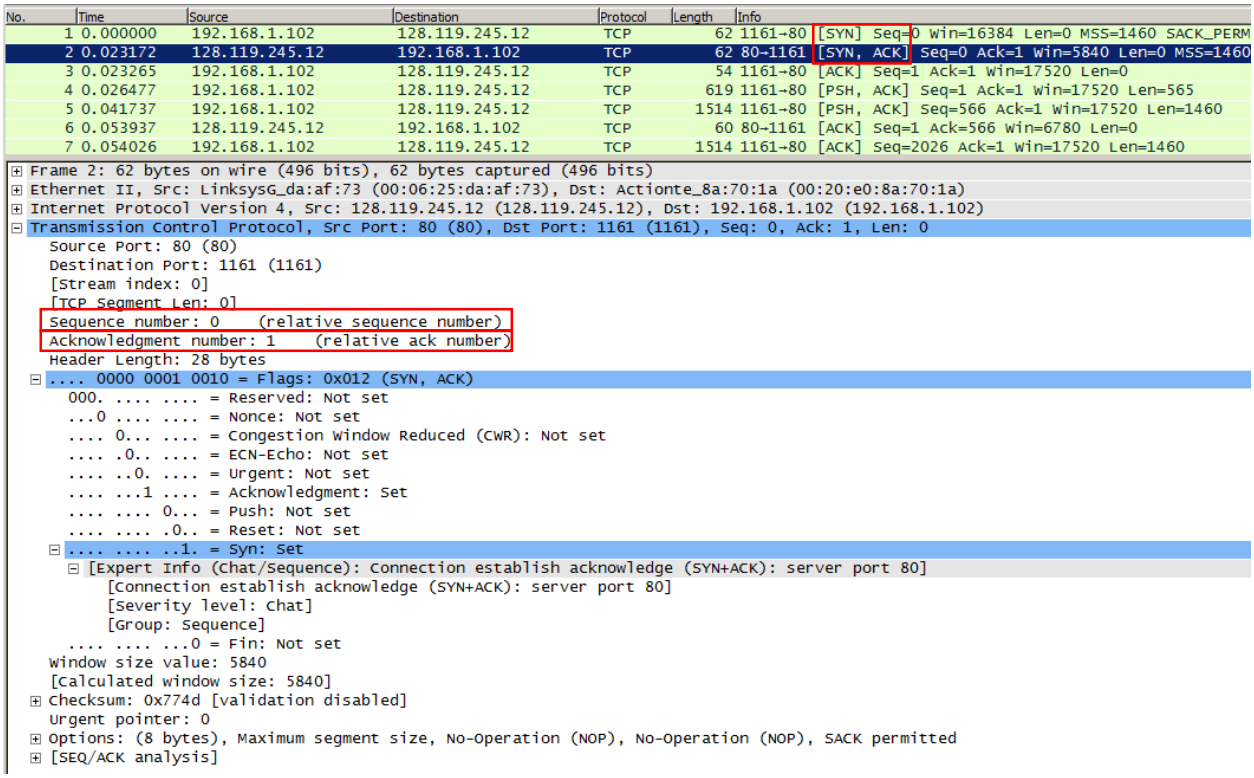
## Question 4

The sequence number of the TCP SYN segment is 0. In the “Info” field, the packet is identified as [SYN] from the source, the server then acknowledges the packet with [SYN, ACK].



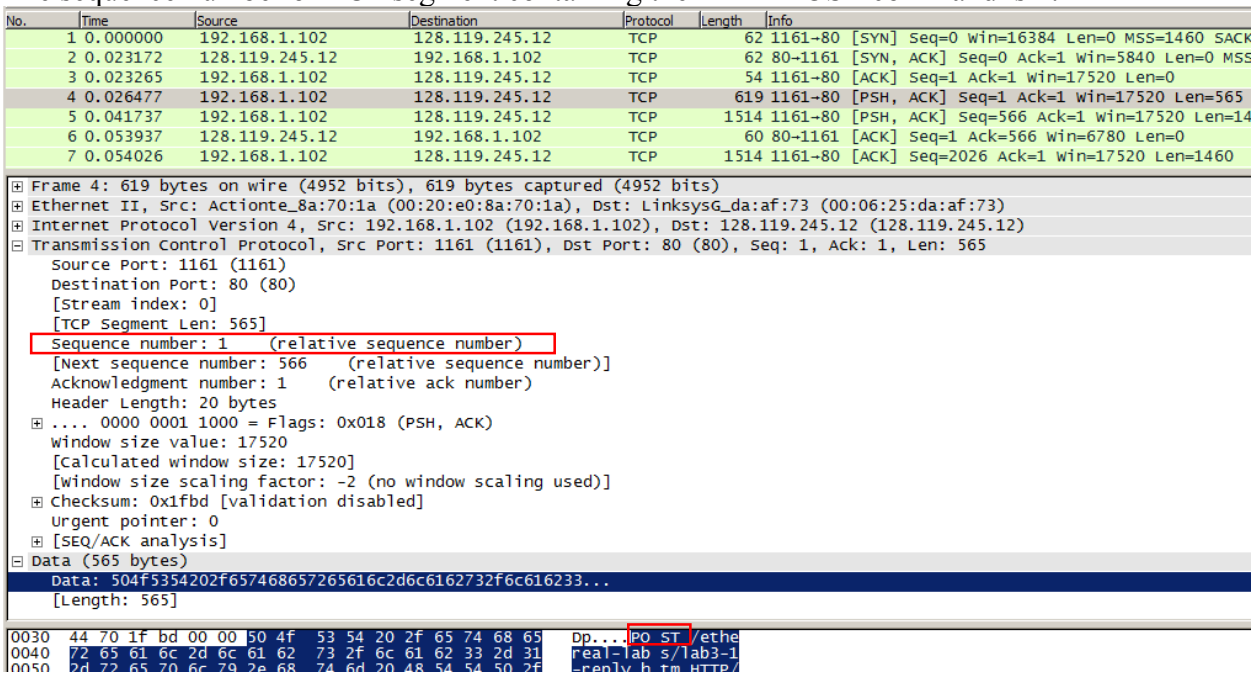

## Question 5

The sequence number of the SYNACK segment is 0. The ACK number is 1. This number was set to 1 to indicate the receipt of the SYN flag in the first packet. In the “Info” field, the packet is identified with [SYN, ACK].

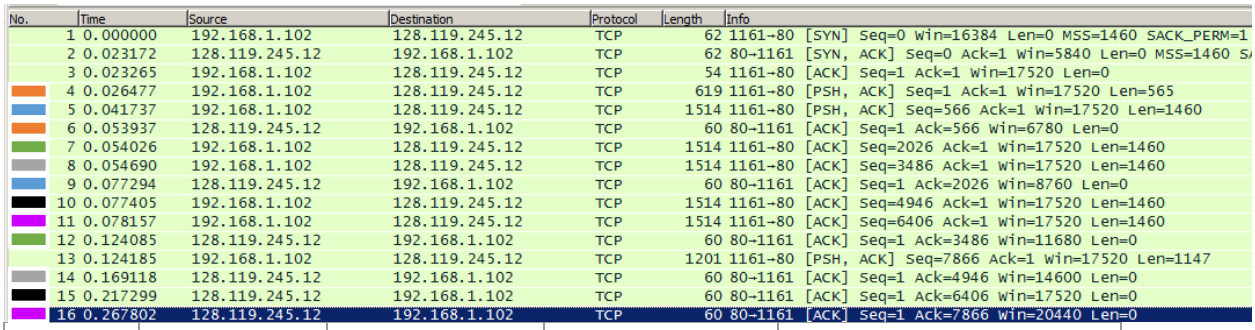



## Question 6

The sequence number of TCP segment containing the HTTP POST command is 1.



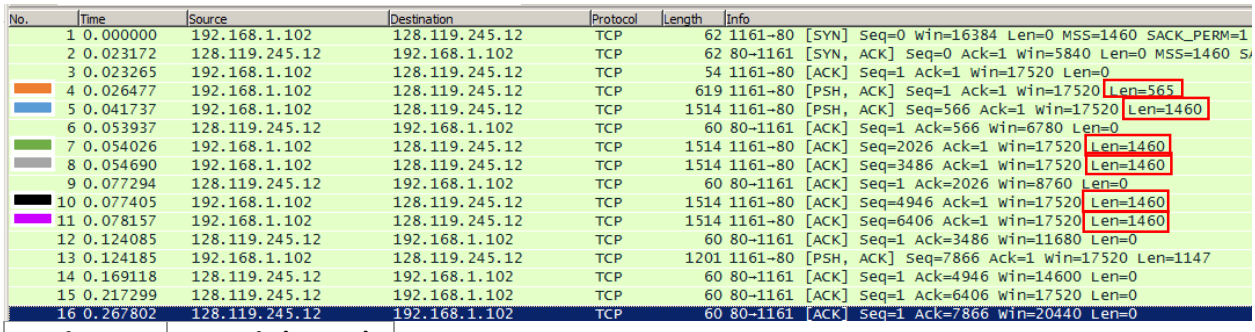
## Question 7



| 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 SA |
| 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 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0 |

| Packet | Sent Time | Received Time | RTT (seconds) | Equation |
|---|---|---|---|---|
| | 0.026477 | 0.053937 | 0.02746 | B2-A2 |
| | 0.041737 | 0.077294 | 0.028472125 | 0.875*C2+0.125*(B3-A3) |
| | 0.054026 | 0.124085 | 0.033670484 | 0.875*C3+0.125*(B4-A4) |
| | 0.05469 | 0.169118 | 0.043765174 | 0.875*C4+0.125*(B5-A5) |
| | 0.077405 | 0.217299 | 0.055781277 | 0.875*C5+0.125*(B6-A6) |
| | 0.078157 | 0.267802 | 0.072514242 | 0.875*C6+0.125*(B7-A7) |

## Question 8



| 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 SA |
| 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 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0 |

| Packet | Length (Bytes) |
|---|---|
| | 565 |
| | 1460 |
| | 1460 |
| | 1460 |
| | 1460 |
| | 1460 |

## Question 9

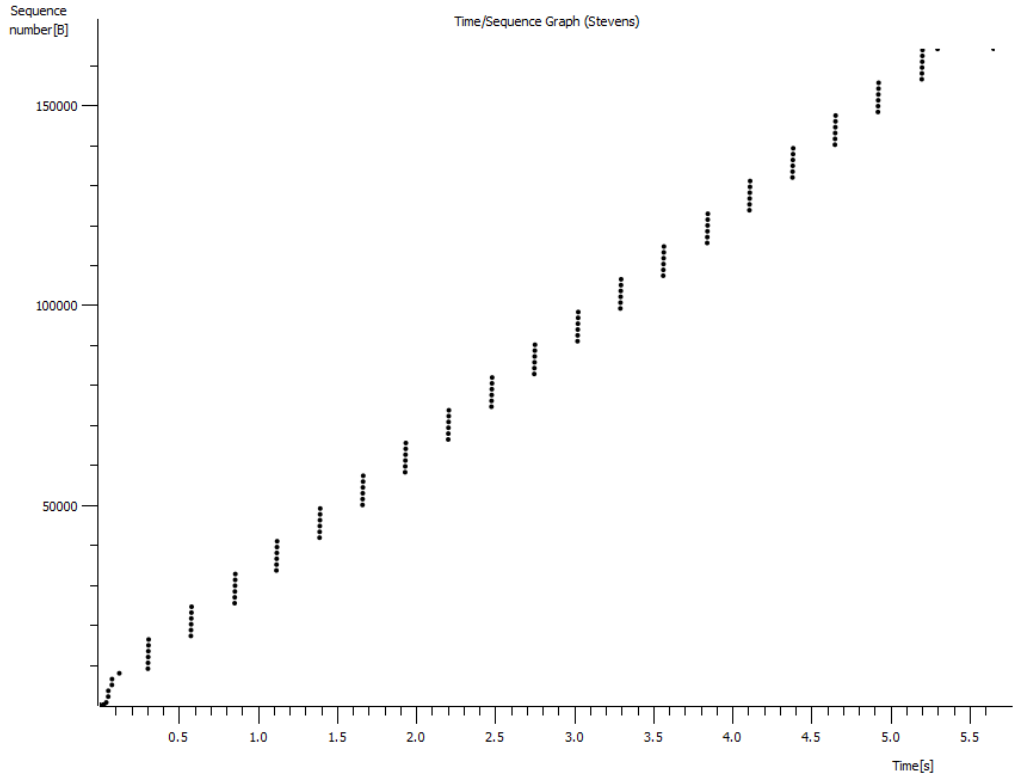
The minimum amount of available buffer space advertised at the received for the entire trace is 5840 bytes. The receiver buffer space continues to grow and never throttle the sender.

| 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 SACK_PERM=1 |
| 3 | 0.023265 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161→80 [ACK] Seq=1 Ack=1 Win=17520 Len=0 |
| 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 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0 |
| 17 | 0.304807 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=9013 Win=23360 Len=0 |

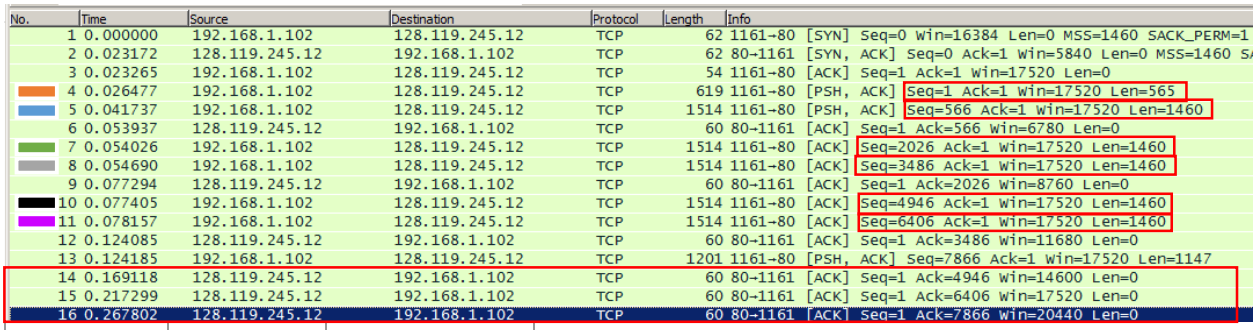
```
⊞ Frame 2: 62 bytes on wire (496 bits), 62 bytes captured (496 bits)
⊞ Ethernet II, Src: LinksysG_da:af:73 (00:06:25:da:af:73), Dst: Actionte_8a:70:1a (00:20:e0:8a:70:1a)
⊞ Internet Protocol Version 4, Src: 128.119.245.12 (128.119.245.12), Dst: 192.168.1.102 (192.168.1.102)
⊟ Transmission Control Protocol, Src Port: 80 (80), Dst Port: 1161 (1161), Seq: 0, Ack: 1, Len: 0
    Source Port: 80 (80)
    Destination Port: 1161 (1161)
    [Stream index: 0]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    Acknowledgment number: 1    (relative ack number)
    Header Length: 28 bytes
  ⊞ .... 0000 0001 0010 = Flags: 0x012 (SYN, ACK)
    Window size value: 5840
    [Calculated window size: 5840]
  ⊞ Checksum: 0x774d [validation disabled]
    Urgent pointer: 0
  ⊞ Options: (8 bytes), Maximum segment size, No-Operation (NOP), No-Operation (NOP), SACK permitted
  ⊞ [SEQ/ACK analysis]
```

## Question 10

The sequence numbers are increasing for time 0 to End of transmission, this means that no segments were retransmitted.



## Question 11



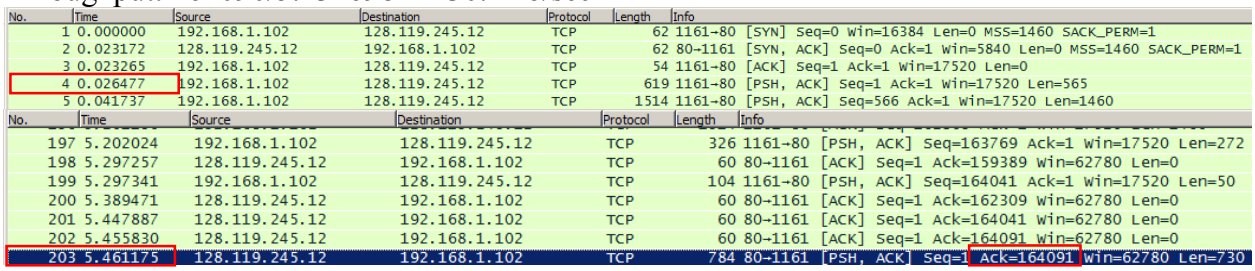
| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 1 | 0.000000 | 192.168.1.102 | 128.119.245.12 | TCP | 62 | 1161→80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1 |
| 2 | 0.023172 | 128.119.245.12 | 192.168.1.102 | TCP | 62 | 80→1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SA |
| 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 |
| 16 | 0.267802 | 128.119.245.12 | 192.168.1.102 | TCP | 60 | 80→1161 [ACK] Seq=1 Ack=7866 Win=20440 Len=0 |

| ACK | ACK data | ACK sequence |
|---|---|---|
| | 565 | 556 |
| | 1460 | 2026 |
| | 1460 | 3486 |
| | 1460 | 4946 |
| | 1460 | 6406 |
| | 1460 | 7866 |

No. 14, 15 and 16 shown above are examples where the receiver is accepting every other receipt segment.

## Question 12

Start Time (seconds): 0.026477
End Time (seconds): 5.461175
Total Data (bytes): 164091 – 1 = 164090
Throughput: 164090/5.434698 = ~30.2Kb/sec

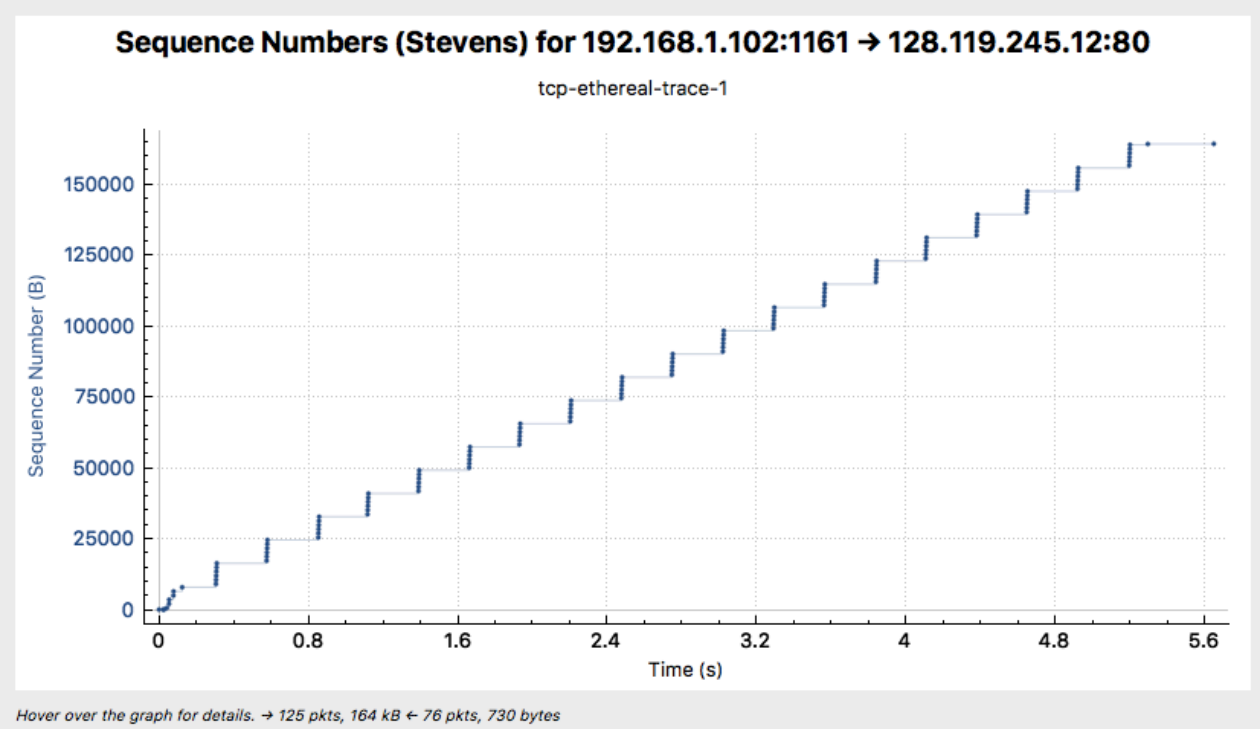


| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 1 | 0.000000 | 192.168.1.102 | 128.119.245.12 | TCP | 62 | 1161→80 [SYN] Seq=0 Win=16384 Len=0 MSS=1460 SACK_PERM=1 |
| 2 | 0.023172 | 128.119.245.12 | 192.168.1.102 | TCP | 62 | 80→1161 [SYN, ACK] Seq=0 Ack=1 Win=5840 Len=0 MSS=1460 SACK_PERM=1 |
| 3 | 0.023265 | 192.168.1.102 | 128.119.245.12 | TCP | 54 | 1161→80 [ACK] Seq=1 Ack=1 Win=17520 Len=0 |
| 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 |

| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 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 |
| 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 | TCP | 104 | 1161→80 [PSH, ACK] Seq=164041 Ack=1 Win=17520 Len=50 |
| 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 | TCP | 784 | 80→1161 [PSH, ACK] Seq=1 Ack=164091 Win=62780 Len=730 |

# 4. TCP congestion control in action

## Question 13




The TCP's slow start phase begins at time 0 until time 0.2 seconds. After the slow start phase, congestion avoidance takes over. The idealized behavior of TCP studied in the text is for the transmission to grow but instead the packets are sent in batches of 6.

## Question 14

Filter: tcp  Expression... Clear Apply Save

| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 13 | 1.38594600 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55635→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 14 | 1.38600900 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55632→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 15 | 1.38604800 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55634→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 16 | 1.38608900 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55633→80 [FIN, ACK] Seq=1 Ack=1 Win=256 Len=0 |
| 17 | 1.38714500 | 129.97.25.162 | 128.119.245.12 | TCP | 66 | 55644→80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=256 SACK_PERM=1 |
| 19 | 1.41968600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55635 [FIN, ACK] Seq=1 Ack=2 Win=229 Len=0 |
| 20 | 1.41968700 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55633 [ACK] Seq=1 Ack=2 Win=237 Len=0 |
| 21 | 1.41976700 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55635→80 [ACK] Seq=2 Ack=2 Win=256 Len=0 |
| 22 | 1.42528500 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55632 [FIN, ACK] Seq=1 Ack=2 Win=229 Len=0 |
| 23 | 1.42528600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55634 [FIN, ACK] Seq=1 Ack=2 Win=229 Len=0 |
| 24 | 1.42533700 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55632→80 [ACK] Seq=2 Ack=2 Win=256 Len=0 |
| 25 | 1.42537500 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55634→80 [ACK] Seq=2 Ack=2 Win=256 Len=0 |
| 26 | 1.42708400 | 128.119.245.12 | 129.97.25.162 | TCP | 66 | 80→55644 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460 SACK_PERM=1 WS=12 |
| 27 | 1.42716300 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55644→80 [ACK] Seq=1 Ack=1 Win=65536 Len=0 |
| 28 | 1.42756100 | 129.97.25.162 | 128.119.245.12 | TCP | 704 | [TCP segment of a reassembled PDU] |
| 29 | 1.42768100 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 30 | 1.42769000 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 31 | 1.42769500 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 32 | 1.42770000 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 33 | 1.42770600 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 34 | 1.42771200 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 35 | 1.42771800 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 36 | 1.42772400 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 37 | 1.42773000 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 38 | 1.46709700 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=651 Win=30592 Len=0 |

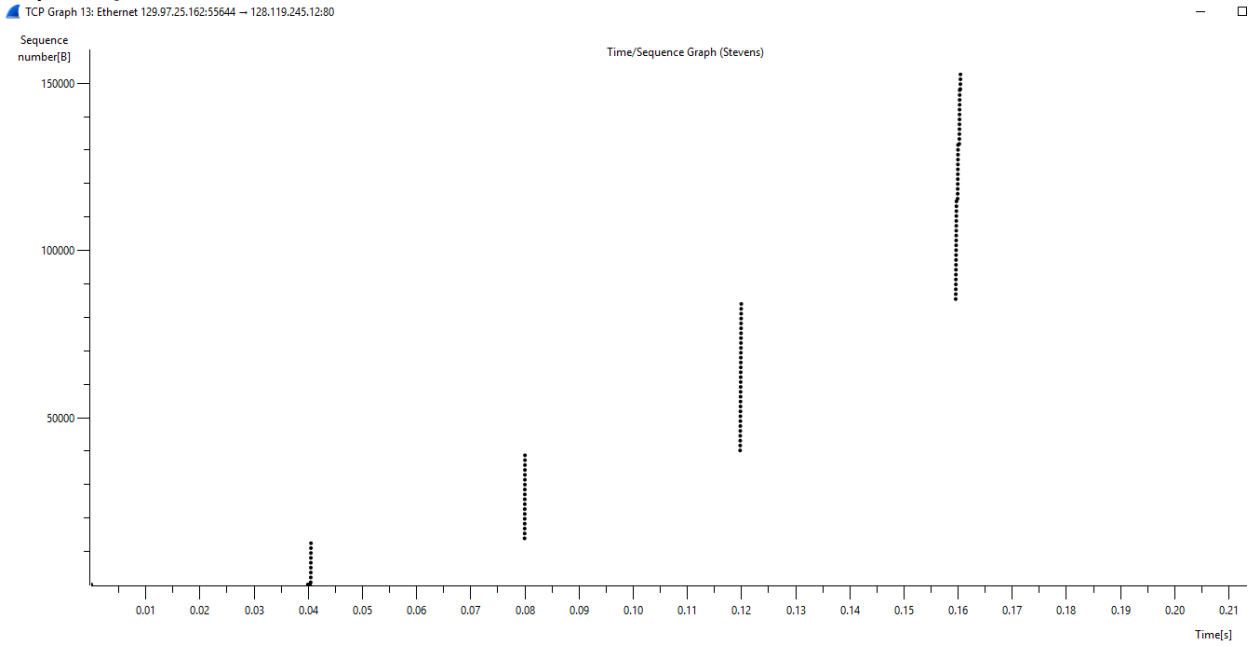
Filter: tcp Expression... Clear Apply Save

| No. | Time | Source | Destination | Protocol | Length | Info |
|---|---|---|---|---|---|---|
| 144 | 1.54747900 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 145 | 1.54748500 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 146 | 1.54749200 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 147 | 1.54749800 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 148 | 1.54750400 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 149 | 1.54751100 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 150 | 1.54751700 | 129.97.25.162 | 128.119.245.12 | TCP | 378 | [TCP segment of a reassembled PDU] |
| 151 | 1.54762800 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 152 | 1.54764200 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 153 | 1.54765200 | 129.97.25.162 | 128.119.245.12 | TCP | 1514 | [TCP segment of a reassembled PDU] |
| 154 | 1.54765900 | 129.97.25.162 | 128.119.245.12 | HTTP | 539 | POST /wireshark-labs/lab3-1-reply.htm HTTP/1.1 (text/plain) |
| 155 | 1.58650900 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=98471 Win=175616 Len=0 |
| 156 | 1.58651000 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=99931 Win=174592 Len=0 |
| 157 | 1.58651100 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=105771 Win=170624 Len=0 |
| 158 | 1.58651100 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=113071 Win=197888 Len=0 |
| 159 | 1.58651100 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=115339 Win=202368 Len=0 |
| 160 | 1.58651200 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=116799 Win=205312 Len=0 |
| 161 | 1.58651200 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=124099 Win=219904 Len=0 |
| 162 | 1.58669600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=131399 Win=224896 Len=0 |
| 163 | 1.58669600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=131723 Win=224640 Len=0 |
| 164 | 1.58709600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=139023 Win=224896 Len=0 |
| 165 | 1.58709600 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=146323 Win=219904 Len=0 |
| 166 | 1.58709700 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=148107 Win=218240 Len=0 |
| 167 | 1.58709700 | 128.119.245.12 | 129.97.25.162 | TCP | 60 | 80→55644 [ACK] Seq=1 Ack=152972 Win=214016 Len=0 |
| 168 | 1.58709700 | 128.119.245.12 | 129.97.25.162 | HTTP | 831 | HTTP/1.1 200 OK (text/html) |
| 169 | 1.60624000 | 129.97.25.162 | 128.119.245.12 | TCP | 54 | 55644→80 [ACK] Seq=152972 Ack=778 Win=64768 Len=0 |

```
⊞ Frame 169: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
⊞ Ethernet II, Src: AsustekC_06:34:13 (f4:6d:04:06:34:13), Dst: HewlettP_86:29:00 (00:17:a4:86:29:00)
⊞ Internet Protocol Version 4, Src: 129.97.25.162 (129.97.25.162), Dst: 128.119.245.12 (128.119.245.12)
⊟ Transmission Control Protocol, Src Port: 55644 (55644), Dst Port: 80 (80), Seq: 152972, Ack: 778, Len: 0
    Source Port: 55644 (55644)
    Destination Port: 80 (80)
    [Stream index: 4]
    [TCP Segment Len: 0]
    Sequence number: 152972    (relative sequence number)
    Acknowledgment number: 778    (relative ack number)
```

Repeat Question 12:
Start Time (seconds): 1.427
End Time (seconds): 1.606
Total Data (bytes): 152972 – 1 = 152971
Throughput: 152971/0.179 = ~855Kb/sec

Repeat Question 13:



The TCP's slow start phase begins at time 0.04 seconds. After the slow start, TCP's linear speed growth takes over. The idealized behavior of TCP studied in the text is seen as the packets are doubling each time.