

四川大學

《计算机网络》实验报告（8）



Wireshark Lab: TCP v7.0

专业 软件工程

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成绩分数_____

二零二五年六月二日

Wireshark Lab: TCP v7.0

1. 将文件传输到 gaia.cs.umass.edu 的客户端计算机的 IP 地址和 TCP 端口号是多少?

客户端 IP: 192.168.1.102

端口号: 1161

2. gaia.cs.umass.edu 的 IP 地址是多少? 它在这个连接中使用哪个端口号发送和接收 TCP 段?

gaia.cs.umass.edu 的 IP 是 128.119.245.12

端口号: 80

```

> Frame 199: 104 bytes on wire (832 bits), 104 bytes captured (832 bits)
> Ethernet II, Src: ActiontecEle_8a:70:1a (00:20:e0:8a:70:1a), Dst: LinksysGroup_da:af:73 (00:06:
  < Internet Protocol Version 4, Src: 192.168.1.102, Dst: 128.119.245.12
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 90
    Identification: 0x1e9a (7834)
  > 010. .... = Flags: 0x2, Don't fragment
    ...0 0000 0000 0000 = Fragment Offset: 0
    Time to Live: 128
    Protocol: TCP (6)
    Header Checksum: 0xa471 [validation disabled]
    [Header checksum status: Unverified]
    Source Address: 192.168.1.102
    Destination Address: 128.119.245.12
    [Stream index: 0]
  < Transmission Control Protocol, Src Port: 1161, Dst Port: 80, Seq: 164041, Ack: 1, Len: 50
    Source Port: 1161
    Destination Port: 80
    [Stream index: 0]
    [Stream Packet Number: 196]
    [Conversation completeness: Incomplete, DATA (15)]
    [TCP Segment Len: 50]
    Sequence Number: 164041      (relative sequence number)
    Sequence Number (raw): 232293053
    [Next Sequence Number: 164091      (relative sequence number)]
    Acknowledgment Number: 1      (relative ack number)
    Acknowledgment number (raw): 883061786
    0101 .... = Header Length: 20 bytes (5)
    > Flags: 0x018 (PSH, ACK)
    . . . . .
  
```

Hex	Dec	ASCII
0000	00 06 25 da af 73 00 20	e0 8a 70 1a 08 00 45 00
0010	00 5a 1e 9a 40 00 80 06	a4 71 c0 a8 01 66 80 77
0020	f5 0c 04 89 00 50 0d d8	82 bd 34 a2 74 1a 50 18
0030	44 70 9f 0f 00 00 0d 0a	2d 2d 2d 2d 2d 2d 2d 2d
0040	2d 2d 2d 2d 2d 2d 2d 2d	2d 2d 2d 2d 2d 2d 2d 2d
0050	2d 2d 2d 2d 32 36 35	30 30 31 39 31 36 39 31
0060	35 37 32 34 2d 2d 0d 0a	-----265 00191691 5724----

3. 你的客户端计算机在将文件传输到 gaia.cs.umass.edu 时使用的 IP 地址和 TCP 端口号是多少?

我的 IP: 10.14.40.236

端口号: 63428

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> Frame 2045: 503 bytes on wire (4024 bits), 503 bytes captured (4024 bits) on interface \Device\NPF_{7F7D
> Ethernet II, Src: Intel_78:8e:8a (74:13:ea:78:8e:8a), Dst: RuijieNetwor_4c:47:53 (58:69:6c:4c:47:53)
v Internet Protocol Version 4, Src: 10.134.40.236, Dst: 128.119.245.12
  0100 .... = Version: 4
  .... 0101 = Header Length: 20 bytes (5)
> Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
  Total Length: 489
  Identification: 0x91dd (37341)
> 010. .... = Flags: 0x2, Don't fragment
  ...0 0000 0000 0000 = Fragment Offset: 0
  Time to Live: 128
  Protocol: TCP (6)
  Header Checksum: 0xeb3b [validation disabled]
  [Header checksum status: Unverified]
  Source Address: 10.134.40.236
  Destination Address: 128.119.245.12
  [Stream index: 9]
v Transmission Control Protocol, Src Port: 63428, Dst Port: 80, Seq: 152532, Ack: 1, Len: 449
  Source Port: 63428
  Destination Port: 80
  [Stream index: 12]
  [Stream Packet Number: 150]
> [Conversation completeness: Incomplete, DATA (15)]
  [TCP Segment Len: 449]
  Sequence Number: 152532 (relative sequence number)
  Sequence Number (raw): 2754426023
  [Next Sequence Number: 152981 (relative sequence number)]
  Acknowledgment Number: 1 (relative ack number)
  Acknowledgment number (raw): 639813598
  0101 .... = Header Length: 20 bytes (5)
  > Flags: 0x018 (PSH, ACK)
    000. .... .... = Reserved: Not set
    ...0 .... .... = Accurate ECN: Not set
    .... 0... .... = Congestion Window Reduced: Not set
    .... .0. .... = ECN-Echo: Not set
  0010 01 e9 91 dd 40 00 80 06 be 3b 0a 86 28 ec 80 77 ....@... ;...(.w
  0020 f5 0c f7 c4 00 50 a4 2d 34 a7 26 22 c7 de 50 18 ....P - 4 &"..P.
  0030 00 ff 16 90 00 00 74 20 6f 66 20 68 65 72 20 63 .....t of her c
  0040 68 69 6c 64 68 6f 6f 64 3a 20 20 61 6e 64 20 68 hildhood : and h

```

4. 客户端计算机和 gaia.cs.umass.edu 建立 TCP 连接时所使用的 TCP SYN 段的序列号是多少？段中的哪一项标识这是一个 SYN 段？

序列号是 0

SYN 标志位是 1

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=14
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
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 L
5	0.041737	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520
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=0
8	0.054690	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=0
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=0
11	0.078157	192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len=0
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=1752
14	0.169118	128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len=0

```

v Transmission Control Protocol, Src Port: 1161, Dst Port: 80, Seq: 0, Len: 45
  Source Port: 1161
  Destination Port: 80
  [Stream index: 0]
  [Stream Packet Number: 1]
> [Conversation completeness: Incomplete, DATA (15)]
  [TCP Segment Len: 0]
  Sequence Number: 0 (relative sequence number)
  Sequence Number (raw): 232129612
  [Next Sequence Number: 1 (relative sequence number)]
  Acknowledgment Number: 0
  Acknowledgment number (raw): 0
  0111 .... = Header Length: 28 bytes (7)
  > Flags: 0x002 (SYN)
    000. .... .... = Reserved: Not set
    ...0 .... .... = Accurate ECN: Not set
    .... 0... .... = Congestion Window Reduced: Not set
    .... .0. .... = ECN-Echo: Not set
      .... - Unreset: Not set
  0000 00 06 25 da af 73 00 20 e0 8a 70 1a 08 00 45
  0010 00 30 1e 1d 40 00 80 06 a5 18 c0 a8 01 66 86
  0020 f5 0c 04 89 00 50 0d d6 01 f4 00 00 00 00 76
  0030 40 00 f6 e9 00 00 02 04 05 b4 01 01 04 02

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.... .0.... = Acknowledgment: Not set
.... .0... = Push: Not set
.... .0.. = Reset: Not set
> .... .0...1. = Syn: Set
.... .0... = Fin: Not set
[TCP Flags: .....A-S-]
Window: 16384
[Calculated window size: 16384]
Checksum: 0x6e69 [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
> Options: (8 bytes), Maximum segment size, No-Operation (NOP), No-Open
> [Timestamps]

```

5. gaia.cs.umass.edu 回复 SYN 时发送的 SYNACK 段的序列号是多少？该段的确认号是多少？gaia.cs.umass.edu 是如何确定这个确认号的？段中的哪一项标识这是一个 SYNACK 段？

序列号为 0

确认号为 1

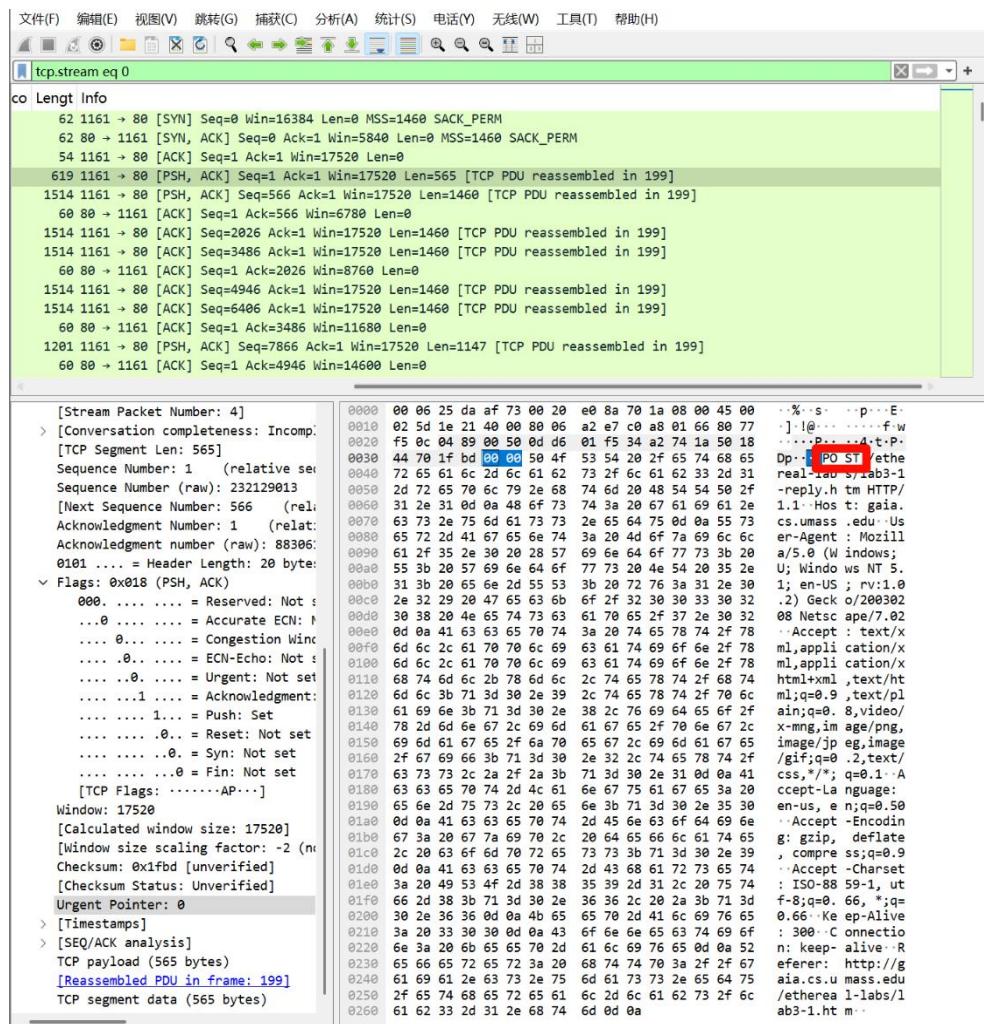
gaia.cs.umass.edu 通过对收到的序列号为 0 的 SYN 请求的 SEQ 加 1 确定 ACK 的值，SYN、ACK 标志位都为 1

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=14
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
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 L
5 0.041737		192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520
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 0.054926		192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=2026 Ack=1 Win=17520 Len
8 0.054690		192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len
9 0.077294		128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=2026 Win=8760 Len=
10 0.077405		192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=4946 Ack=1 Win=17520 Len
11 0.078157		192.168.1.102	128.119.245.12	TCP	1514	1161 → 80 [ACK] Seq=6406 Ack=1 Win=17520 Len
12 0.124085		128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=3486 Win=11680 Len
13 0.124185		192.168.1.102	128.119.245.12	TCP	1201	1161 → 80 [PSH, ACK] Seq=7866 Ack=1 Win=1752
14 0.169118		128.119.245.12	192.168.1.102	TCP	60	80 → 1161 [ACK] Seq=1 Ack=4946 Win=14600 Len

Transmission Control Protocol, Src Port: 80, Dst Port: 1161, Seq: 0, Ack: 0000 00 20 e0 8a 70 1a 00 06 25 da af 73 08 00 45
Source Port: 80 0010 00 30 00 00 40 00 37 06 0c 36 80 77 f5 0c c6
Destination Port: 1161 0020 01 66 00 50 04 89 34 a2 74 19 0d d6 01 f5 76
[Stream index: 0] 0030 16 d0 77 4d 00 00 02 04 05 b4 01 01 04 02
[Stream Packet Number: 2]
[Conversation completeness: Incomplete, DATA (15)]
[TCP Segment Len: 0]
Sequence Number: 0 (relative sequence number)
Sequence Number (raw): 883061785
[Next Sequence Number: 1 (relative sequence number)]
Acknowledgment Number: 1 (relative ack number)
Acknowledgment number (raw): 232129013
0111 = Header Length: 28 bytes (7)
Flags: 0x012 (SYN, ACK)
000. = Reserved: Not set
...0. = Accurate ECN: Not set
.... 0.... = Congestion Window Reduced: Not set
.... .0.... = ECN-Echo: Not set
.... .0.... = Urgent: Not set
.... ..1.... = Acknowledgment: Set
.... ...0.... = Push: Not set
.... ...0.... = Reset: Not set
>0...1. = Syn: Set
.... .0... = Fin: Not set
[TCP Flags:A-S-]
Window: 5840
[Calculated window size: 5840]
Checksum: 0x774d [unverified]
[Checksum Status: Unverified]
Urgent Pointer: 0
> Options: (8 bytes), Maximum segment size, No-Operation (NOP), No-Open
> [Timestamps]

6. 包含 HTTP POST 命令的 TCP 段的序列号是多少？请注意，为了找到 POST 命令，你需要深入查看 Wireshark 窗口底部的数据包内容字段，查找其 DATA 字段中包含“POST”的段。

序列号为 1 (标注如图中红框所示)



7. 将包含 HTTP POST 命令的 TCP 段视为该 TCP 连接中的第一个段，前六个 TCP 段（包括包含 HTTP POST 的那个）的序列号分别是多少？每个段是在什么时候发送的？每个段的 ACK 是在什么时候收到的？根据每个 TCP 段发送时间与其确认 ACK 的接收时间之间的差值，计算每个段的往返时间 (RTT)。然后，根据课本第 3.5.3 节第 242 页中的 EstimatedRTT 公式，计算在收到每个 ACK 后的 EstimatedRTT 值。假设第一个段的 EstimatedRTT 值等于测得的 RTT 值，之后使用公式计算。

序列号: 1、556、2026、3486、4946、6406

发送时间: 0.026477, 0.041737, 0.054026, 0.054690, 0.077405, 0.078157

ACK 时间: 0.053937, 0.077294, 0.124085, 0.169118, 0.217299, 0.267802

RTT: 0.02746, 0.035557, 0.070059, 0.11443, 0.13989, 0.18964

根据公式: $\text{EstimatedRTT} = (1 - a) \times \text{EstimatedRTT} + a \times \text{SampleRTT}$, $a = 0.125$

$$\text{EstimatedRTT}_1 = \text{SampleRTT}_1 = 0.02746$$

$$\text{EstimatedRTT}_2 = (1 - 0.125) \times 0.02746 + 0.125 \times 0.035557$$

$$= 0.875 \times 0.02746 + 0.125 \times 0.035557$$

$$= 0.0240275 + 0.004444625$$

$$= 0.028472125$$

$$\text{EstimatedRTT}_3 = 0.875 \times 0.028472125 + 0.125 \times 0.070059$$

$$= 0.024411109375 + 0.008757375$$

$$= 0.033168484375$$

$$\text{EstimatedRTT}_4 = 0.875 \times 0.033168484375 + 0.125 \times 0.11443$$

$$= 0.029521424 + 0.01430375$$

$$= 0.043825174375$$

$$\text{EstimatedRTT}_5 = 0.875 \times 0.043825174375 + 0.125 \times 0.13989$$

$$= 0.0383445276 + 0.01748625$$

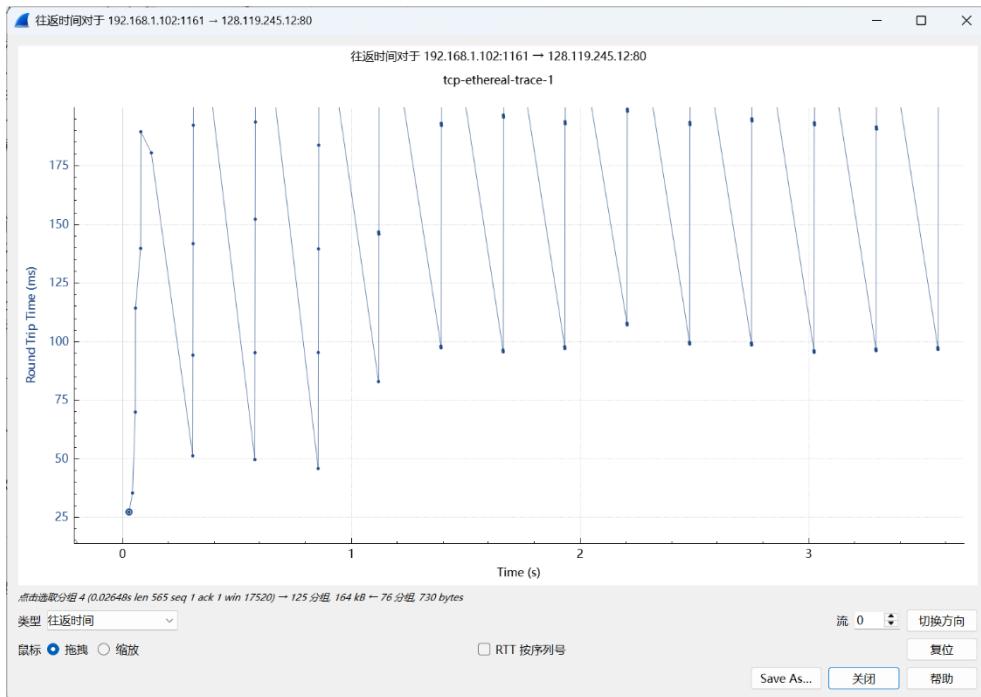
$$= 0.0558307776$$

$$\text{EstimatedRTT}_6 = 0.875 \times 0.0558307776 + 0.125 \times 0.18964$$

$$= 0.0488519309 + 0.023705$$

$$= 0.0725569309$$

EstimatedRTT: 0.02746, 0.02847, 0.03317, 0.04383, 0.05583, 0.07256



8. 前六个 TCP 段的长度分别是多少？

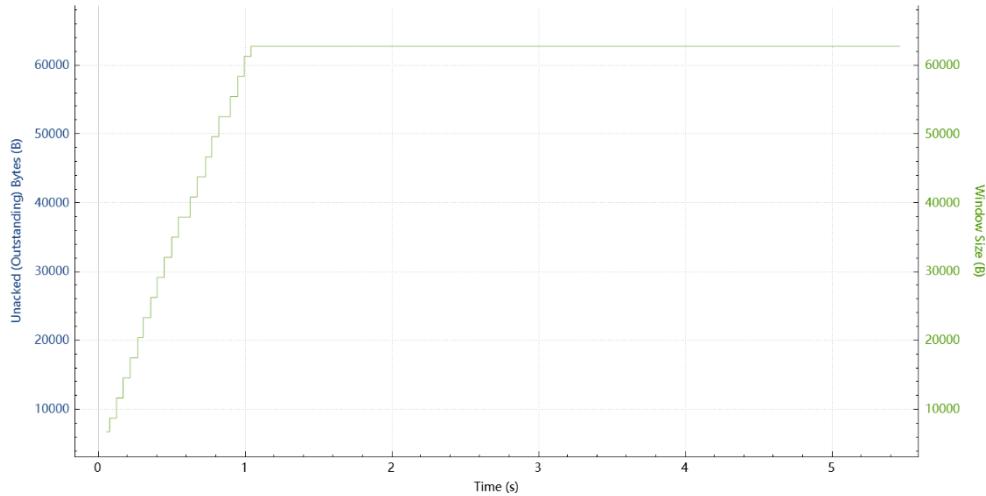
4 0.026477	192.168.1.102	128.119.245.12	TCP	619 1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=17520 Len=556 [TCP PDU reassembled in 199]
5 0.041737	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [PSH, ACK] Seq=566 Ack=1 Win=17520 Len=1460 [TCP PDU reassembled in 199]
6 0.053937	128.119.245.12	192.168.1.102	TCP	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 [TCP PDU reassembled in 199]
8 0.054690	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=3486 Ack=1 Win=17520 Len=1460 [TCP PDU reassembled in 199]
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 [TCP PDU reassembled in 199]
11 0.078157	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=6496 Ack=1 Win=17520 Len=1460 [TCP PDU reassembled in 199]
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 [TCP PDU reassembled in 199]
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=6496 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

(其中 No.4、5、7、8、10、11 为前 6 个报文段, No.6、9、12、14、15、16 为 ACK)

由上图 Len 可知除第一段长度为 556 字节，其他 5 段都是 1460 字节

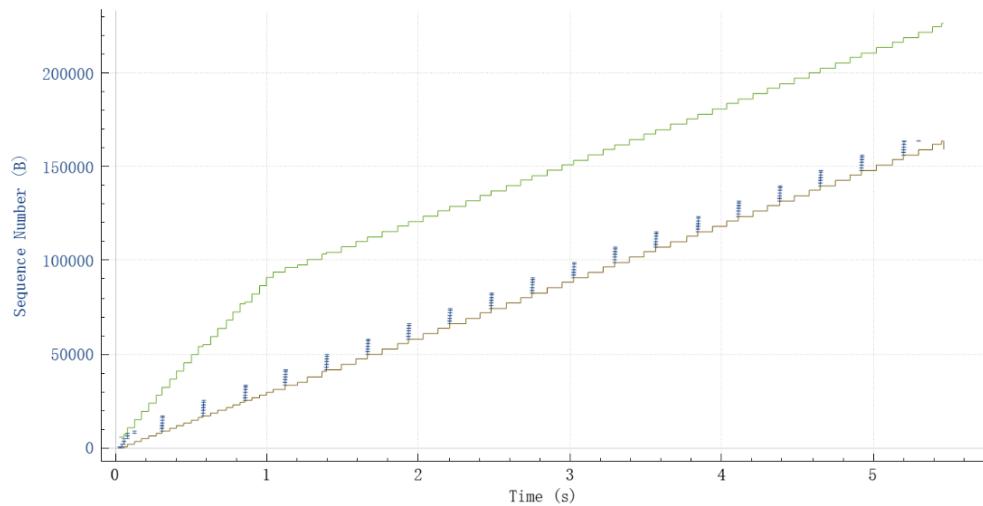
9. 整个抓包过程中，接收方通告的最小可用缓冲区空间是多少？接收方缓冲区空间不足是否曾经限制过发送方的发送速率？

最开始时接收端公布的可用缓冲空间最小, 为 5840 字节, 之后一直增大到 62780 字节, 说明这里不会因为缺少接收端缓存而限制发送端



10. 在抓包文件中是否有重传的段? 你是通过查看抓包中的哪些信息来回答这个问题的?

没有, 通过图表发现序列号随时间一直增加, 说明没有重传



11. 接收方通常在一个 ACK 中确认了多少数据? 你能否找到接收方每接收两个段才发送一个 ACK 的情况? (参考课本第 250 页的表 3.2)

有时每收到一个数据段就 ACK 一次, 第一次 ACK 确认 556 字节, 大多数时候每次确认 1460 字节, 有时是累计确认, 比如 NO.88 确认了两段, 确认的数据段长度为 2920 字节

4 0.026477	192.168.1.102	128.119.245.12	TCP	619 1161 → 80 [PSH, ACK] Seq=1 Ack=1 Win=6
5 0.041737	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [PSH, ACK] Seq=566 Ack=1
6 0.053937	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=566 Win=6
7 0.054026	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=2026 Ack=1 Win=6
8 0.054690	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=3486 Ack=1 Win=6
9 0.077294	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=2026 Win=6
10 0.077405	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=4946 Ack=1 Win=6
11 0.078157	192.168.1.102	128.119.245.12	TCP	1514 1161 → 80 [ACK] Seq=6406 Ack=1 Win=6
12 0.124085	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=3486 Win=6
13 0.124185	192.168.1.102	128.119.245.12	TCP	1201 1161 → 80 [PSH, ACK] Seq=7866 Ack=1
14 0.169118	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=4946 Win=6
15 0.217299	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=6406 Win=6
16 0.267802	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=7866 Win=6
17 0.304807	128.119.245.12	192.168.1.102	TCP	60 80 → 1161 [ACK] Seq=1 Ack=9013 Win=6

12. 该 TCP 连接的吞吐量是多少（单位时间内传输的字节数）？请解释你是如何计算这个值的。

$$(1604091-1)/(5.455830-0.026477)=30.222\text{KB/s}$$

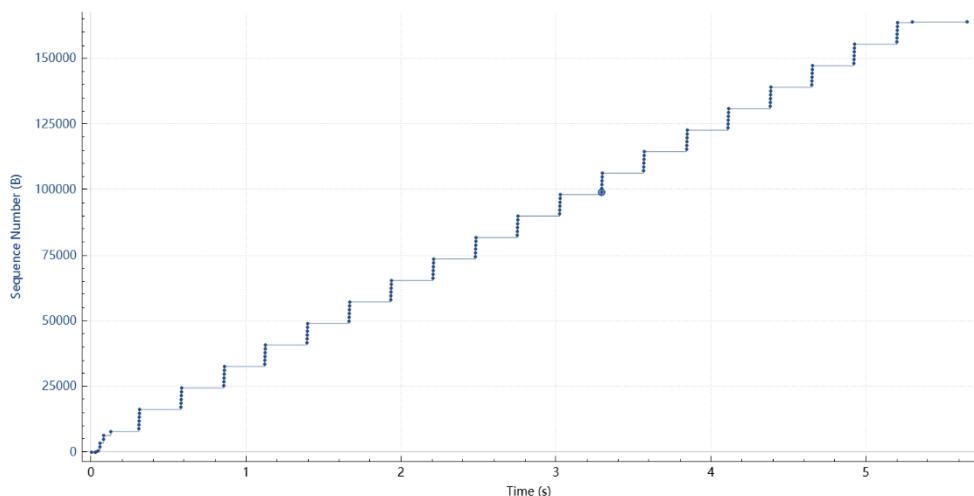
以握手后第一个 TCP 报文段为开始，到最后一个 ACK 结束，SEQ 差值即为数据总量，再除以它们的时间差值为吞吐量

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)

13. 使用 Time-Sequence-Graph (Stevens) 绘图工具查看从客户端发送到 gaia.cs.umass.edu 服务器的段的“序列号与时间”图。

你能否识别出 TCP 的慢启动 (slow start) 阶段是从哪里开始、到哪里结束？拥塞避免 (congestion avoidance) 阶段从哪里开始？

请对比测得的数据和我们在课本中学习的 TCP 理想行为，指出有哪些不同之处，并进行评论。



慢启动从发出了 HTTP POST 报文段后开始，但从图中并不能看出慢启动什么时候结束，拥塞避免是什么时候开始的

TCP 采用慢启动的目的是进行拥塞控制，但是在实际的网络通信中，对于一些数据量较小的小文件，在网络畅通的情况下发送非常快，甚至可能在慢启动结束之前就已经发送完毕。而这种情况下，采用慢启动方式反而来制约了文件的快速发送，从而影响通信的效率。

14. 对你在将文件从你的计算机传输到 gaia.cs.umass.edu 时收集到的抓包数据，回答以上两个问题

(1) TCP 的慢启动阶段从连接建立后第一个 HTTP POST 段发送时开始。虽然我们无法直接从时间-序列图中获取发送方的拥塞窗口大小，但可以通过未确认数据来估计拥塞窗口的下界。由于接收方缓冲区在本次实验中并未成为瓶颈，因此我们可以忽略其对窗口上限的影响，专注于通过未确认数据量近似反映拥塞窗口的增长。

(2) 理论上，TCP 理想状态下的发送方应始终保持尽可能活跃，以充分利用可用带宽，同时通过 AIMD 算法控制拥塞风险。然而实际中 TCP 的表现受应用层行为强烈影响。本次实验中，尽管网络未出现显著丢包或延迟，TCP 连接在慢启动阶段结束之前就完成了数据传输。这是因为 Web 应用中传输的对象体积非常小，发送方没有更多数据可以传输，导致连接在慢启动过程中即被终止。这种现象表明：对于短小的 Web 对象，TCP 慢启动机制可能

引发不必要的启动延迟，降低了小对象传输的效率。这也是为什么现代 Web 应用倾向于使用持久连接或优化 TCP 初始窗口大小的原因。