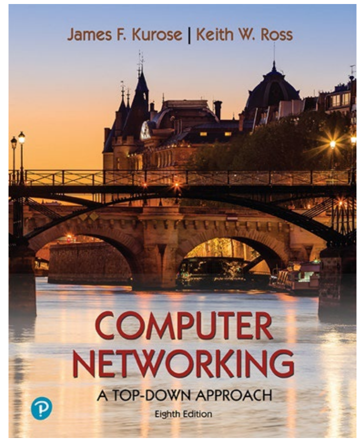
Wireshark Lab: TCP v8.1

Supplement to *Computer Networking: A Top-Down Approach, 8th ed.,* J.F. Kurose and K.W. Ross



"Tell me and I forget. Show me and I remember. Involve me and I understand." Chinese proverb

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You should work on this lab individually or in teams of up to 3 members (highly recommended). One submission per team.

0. **Academic integrity** – Print the following statement: "I (We) have read and understood the course academic integrity policy." **Your submission will NOT be graded without this statement.**

Important: When answering each question in this and all the following LABs, you should print out the captured packets/messages (see the introductory Wireshark lab for an explanation of how to do this) or take screenshots and indicate where in the message you have found the information that answers each question. Questions that are not accompanied by a screenshot or packet print with the answers CLEARLY marked will not be graded.

In this lab, we'll investigate the behavior of the celebrated TCP protocol in detail. We'll do so by analyzing a trace of the TCP segments sent and received in transferring a 150KB file (containing the text of Lewis Carrol's *Alice's Adventures in Wonderland*) from your computer to a remote server. We'll study TCP's use of sequence and acknowledgement numbers for providing reliable data transfer; we'll see TCP's congestion control algorithm – slow start and congestion avoidance – in action; and we'll look at TCP's receiver-advertised flow control mechanism. We'll also briefly consider TCP connection setup and we'll investigate the performance (throughput and round-trip time) of the TCP connection between your computer and the server.

Before beginning this lab, you'll probably want to review sections 3.5 and 3.7 in the text[1].

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[1] References to figures and sections are for the 8th edition of our text, *Computer Networks, A Top-down Approach, 8th ed., J.F. Kurose and K.W. Ross, Addison-Wesley/Pearson, 2020.*

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

Before beginning our exploration of TCP, we'll need to use Wireshark to obtain a packet trace of the TCP transfer of a file from your computer to a remote server. You'll do so by accessing a Web page that will allow you to enter the name of a file stored on your computer (which contains the ASCII text of *Alice in Wonderland*), and then transfer the file to a Web server using the HTTP POST method (see section 2.2.3 in the text). We're using the POST method rather than the GET method as we'd like to transfer a large amount of data *from* your computer to another computer. Of course, we'll be running Wireshark during this time to obtain the trace of the TCP segments sent and received from your computer.

Do the following:

- Start up your web browser. Go the http://gaia.cs.umass.edu/wireshark-labs/alice.txt and retrieve an ASCII copy of *Alice in Wonderland.* Store this as a .txt file somewhere on your computer.
- Next go to http://gaia.cs.umass.edu/wireshark-labs/TCP-wireshark-file1.html.
- You should see a screen that looks like Figure 1.

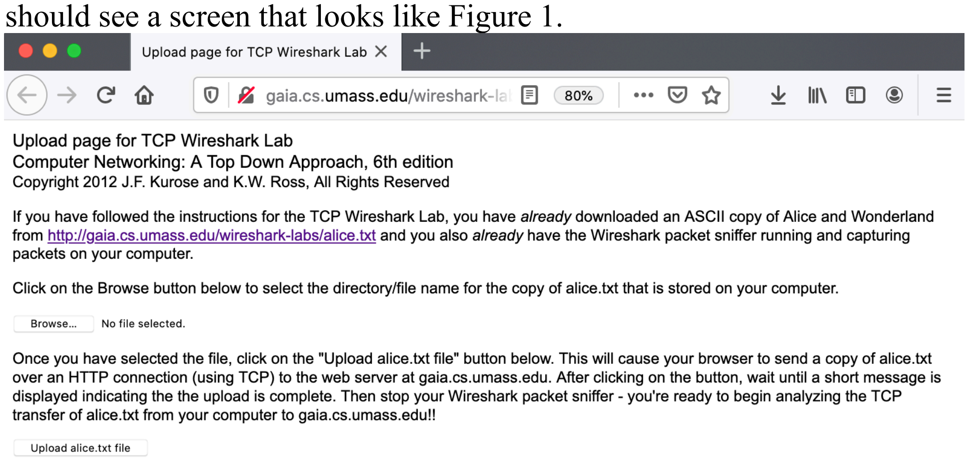

Figure 1: Page to upload the alice.txt file from your computer to gaia.cs.umass.edu

- Use the *Browse* button in this form to the file on your computer that you just created containing *Alice in Wonderland*. Don't press the "*Upload alice.txt file*" button yet.
- Now start up Wireshark and begin packet capture (see the earlier Wireshark labs if you need a refresher on how to do this).
- Returning to your browser, press the "*Upload alice.txt file*" button to upload the file to the gaia.cs.umass.edu server. Once the file has been uploaded, a short congratulations message will be displayed in your browser window.
- Stop Wireshark packet capture. Your Wireshark window should look similar to the window shown in Figure 2.

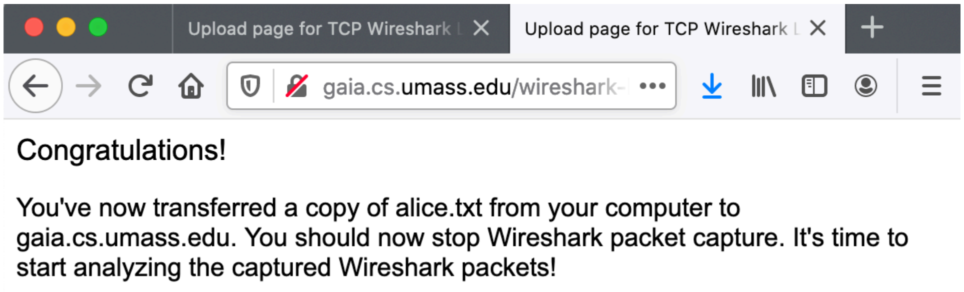

Figure 2: Success! You've uploaded a file to gaia.cs.umass.edu and have hopefully captured a Wireshark packet trace while doing so.

If you are unable to run Wireshark on a live network connection, you can download a packet trace that was captured while following the steps above on one of the author's computers. In addition, you may well find it valuable to download this trace even if you've captured your own trace and use it, as well as your own trace, when you explore the questions below.

2. A first look at the captured trace

Before analyzing the behavior of the TCP connection in detail, let's take a high-level view of the trace.

Let's start by looking at the HTTP POST message that uploaded the alice.txt file to gaia.cs.umass.edu from your computer. Find that file in your Wireshark trace and expand the HTTP message so we can take a look at the HTTP POST message more carefully. Your Wireshark screen should look something like Figure 3.

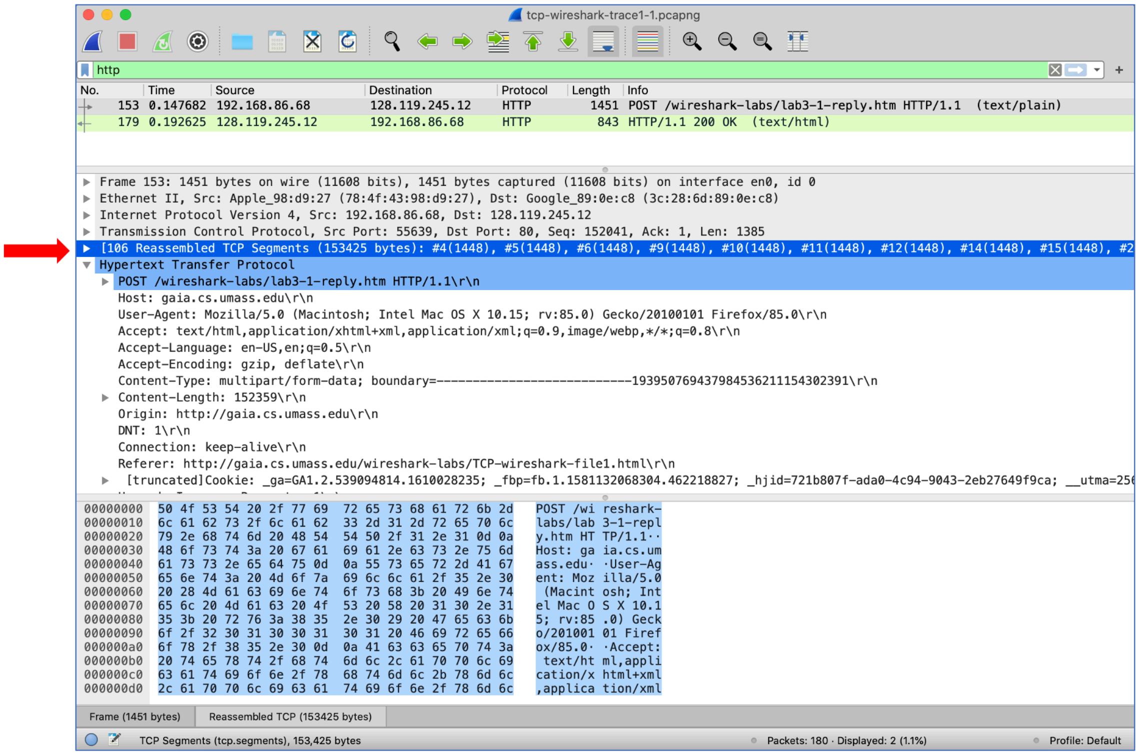

Figure 3: expanding the HTTP POST message that uploaded alice.txt from your computer to gaia.cs.umass.edu

There are a few things to note here:

- The body of your application-layer HTTP POST message contains the contents of the file alice.txt, which is a large file of more than 152K bytes. OK – it's not *that* large, but it's going to be too large for this one HTTP POST message to be contained in just one TCP segment!
- In fact, as shown in the Wireshark window in Figure 3, we see that the HTTP POST message was spread across 106 TCP segments. This is shown where the red arrow is placed in Figure 3 [Aside: Wireshark doesn't have a red arrow like that; we added it to the figure to be helpful ☺]. If you look even more carefully there, you can see that Wireshark is being really helpful to you as well, telling you that the first TCP segment containing the beginning of the POST message is packet #4 in the particular trace for the example in Figure 3, which is the trace *tcp-wireshark-trace1-1* noted in footnote 2. The second TCP segment containing the POST message in packet #5 in the trace, and so on.

Let's now "get our hands dirty" by looking at some TCP segments.

- First, filter the packets displayed in the Wireshark window by entering "tcp" (lowercase, no quotes, and don't forget to press return after entering!) into the display filter specification window towards the top of the Wireshark window. Your Wireshark display should look something like Figure 4. In Figure 4, we've noted the TCP segment that has its SYN bit set – this is the first TCP message in the three-way handshake that sets up the TCP connection to gaia.cs.umass.edu that will eventually carry the HTTP POST message and the alice.txt file. We've also noted the SYNACK segment (the second step in TCP three-way handshake), as well as the TCP segment (packet #4, as discussed above) that carries the POST message and the beginning of the alice.txt file. Of course, if you're taking your own trace file, the packet numbers will be different, but you should see similar behavior to that shown in Figures 3 and 4.

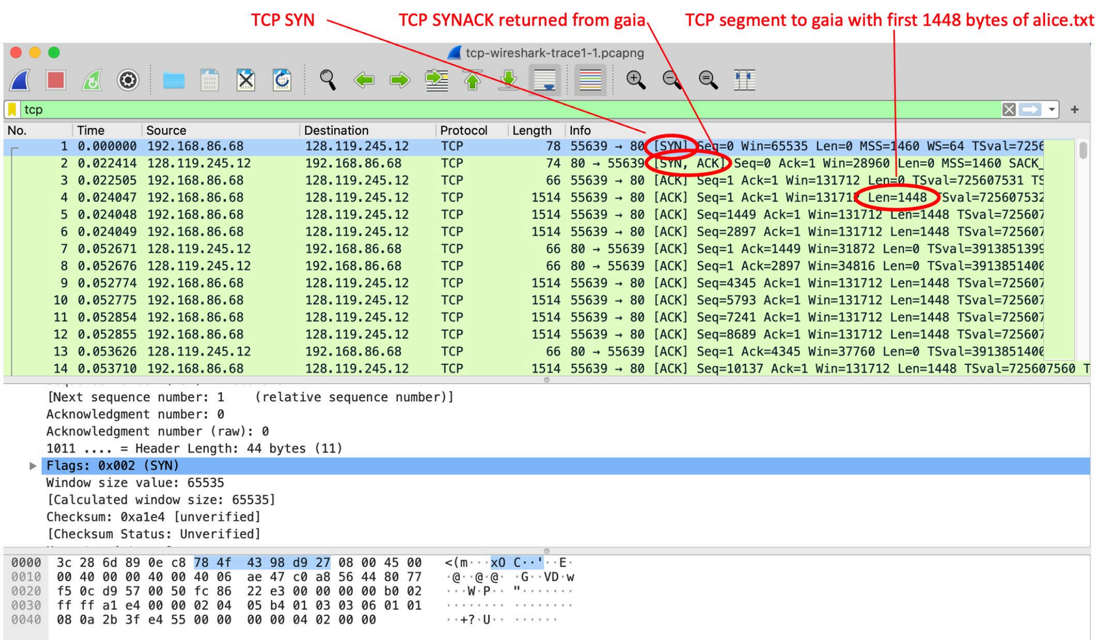

Figure 4: TCP segments involved in sending the HTTP POST message (including the file alice.txt) to gaia.cs.umass.edu

Answer the following questions, either from your own live trace, or by opening the Wireshark captured packet file *tcp-wireshark-trace1-1* in http://gaia.cs.umass.edu/wireshark-labs/wireshark-traces-8.1.zip

1. What is the IP address and TCP port number used by the client computer (source) that is transferring the alice.txt file to gaia.cs.umass.edu? To answer this question, it's probably easiest to select an HTTP message and explore the details of the TCP packet used to carry this HTTP message, using the "details of the selected packet header window" (refer to Figure 2 in the "Getting Started with Wireshark" Lab if you're uncertain about the Wireshark windows). (**4 points)**
2. What is the IP address of gaia.cs.umass.edu? On what port number is it sending and receiving TCP segments for this connection? (**4 points)**

Since this lab is about TCP rather than HTTP, now change Wireshark's "listing of captured packets" window so that it shows information about the TCP segments containing the HTTP messages, rather than about the HTTP messages, as in Figure 4 above. This is what we're looking for–a series of TCP segments sent between your computer and gaia.cs.umass.edu!

3. TCP Basics

Answer the following questions for the TCP segments:

3. What is the *sequence number* of the TCP SYN segment that is used to initiate the TCP connection between the client computer and gaia.cs.umass.edu? (Note: this is the "raw" sequence number carried in the TCP segment itself; it is *NOT* the packet # in the "No." column in the Wireshark window. Remember there is no such thing as a "packet number" in TCP or UDP; as you know, there *are* sequence numbers in TCP and that's what we're after here. Also note that this is not the relative sequence number with respect to the starting sequence number of this TCP session.). What is it in this TCP segment that identifies the segment as a SYN segment? (**4 points)**
4. What is the *sequence number* of the SYNACK segment sent by gaia.cs.umass.edu to the client computer in reply to the SYN? What is it in the segment that identifies the segment as a SYNACK segment? What is the value of the Acknowledgement field in the SYNACK segment? How did gaia.cs.umass.edu determine that value? (**8 points)**
5. What is the sequence number of the TCP segment containing the header of the HTTP POST command? Note that in order to find the POST message header, you'll need to dig into the packet content field at the bottom of the Wireshark window, *looking for a segment with the ASCII text "POST" within its DATA field*[2,3]. (**2 points**)
6. Consider the TCP segment containing the HTTP "POST" as the first segment in the data transfer part of the TCP connection.
   - At what time was the first segment (the one containing the HTTP POST) in the data-transfer part of the TCP connection sent? (**2 points**)
   - At what time was the ACK for this first data-containing segment received? (**2 points**)
   - What is the RTT for this first data-containing segment? (**3 points**)
   - What is the RTT value between the second data-carrying TCP segment and its ACK? (**3 points**)
   - What is the `EstimatedRTT` value (see Section 3.5.3, in the text) after the ACK for the second data-carrying segment is received? Assume that in

[2] *Hint:* this TCP segment is sent by the client soon (but not always immediately) after the SYNACK segment is received from the server.

[3] Note that if you filter to only show "http" messages, you'll see that the TCP segment that Wireshark associates with the HTTP POST message is the *last* TCP segment in the connection (which contains the text at the *end* of alice.txt: "THE END") and *not* the first data-carrying segment in the connection. Students (and teachers!) often find this unexpected and/or confusing.

making this calculation after the received of the ACK for the second segment, that the initial value of `EstimatedRTT` is equal to the measured RTT for the first segment, and then is computed using the `EstimatedRTT` equation on page 242, and a value of $\alpha = 0.125$. (**3 points**)

Note: Wireshark has a nice feature that allows you to plot the RTT for each of the TCP segments sent. Select a TCP segment in the "listing of captured packets" window that is being sent from the client to the gaia.cs.umass.edu server. Then select: *Statistics->TCP Stream Graph->Round Trip Time Graph.*

7. What is the length (header plus payload) of each of the first four data-carrying TCP segments? (**5 points**)
8. What is the minimum amount of available buffer space advertised to the client by gaia.cs.umass.edu among these first four data-carrying TCP segments[4]? Does the lack of receiver buffer space ever throttle the sender for these first four data-carrying segments? (**5 points**)
9. Are there any retransmitted segments in the trace file? What did you check for (in the trace) in order to answer this question? (**5 points**)
10. How much data does the receiver typically acknowledge in an ACK among the first ten data-carrying segments sent from the client to gaia.cs.umass.edu? Can you identify cases where the receiver is ACKing every other received segment (see Table 3.2 in the text) among these first ten data-carrying segments? (**5 points**)
11. What is the throughput (bytes transferred per unit time) for the TCP connection? Explain how you calculated this value. (**5 points**)

4. TCP congestion control in action

Let's now examine the amount of data sent per unit time from the client to the server. Rather than (tediously!) calculating this from the raw data in the Wireshark window, we'll use one of Wireshark's TCP graphing utilities–*Time-Sequence-Graph(Stevens)*–to plot out data.

- Select a client-sent TCP segment in the Wireshark's "listing of captured-packets" window corresponding to the transfer of alice.txt from the client to gaia.cs.umass.edu. Then select the menu: *Statistics->TCP Stream Graph-> Time-Sequence-Graph(Stevens*[5]). You should see a plot that looks similar to the plot in Figure 5, which was created from the captured packets in the packet trace *tcp-wireshark-trace1-1*. You may have to expand, shrink, and fiddle around with the intervals shown in the axes in order to get your graph to look like Figure 5.

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[4] Give the Wireshark-reported value for "Window Size Value" which must then be multiplied by the Window Scaling Factor to give the actual number of buffer bytes available at gaia.cs.umass.edu for this connection.

[5] William Stevens wrote the "bible" book on TCP, known as [*TCP Illustrated*](#).

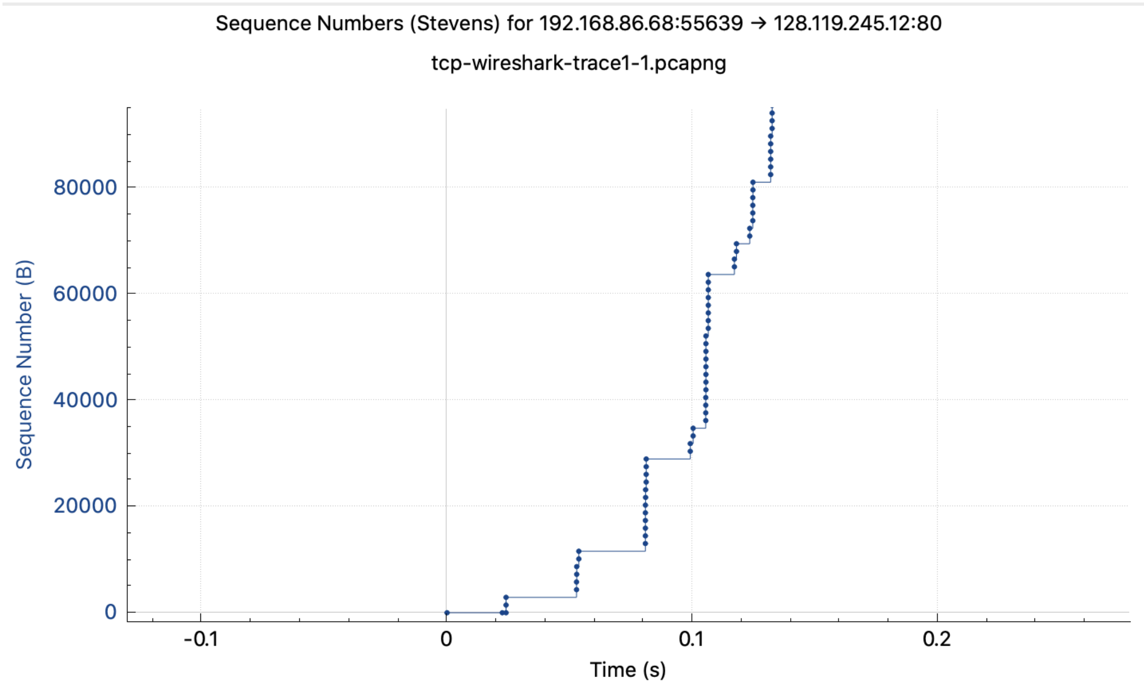

Figure 5: A sequence-number-versus-time plot (Stevens format) of TCP segments.

Here, each dot represents a TCP segment sent, plotting the sequence number of the segment versus the time at which it was sent. Note that a set of dots stacked above each other represents a series of packets (sometimes called a "fleet" of packets) that were sent back-to-back by the sender.

12. Consider the "fleets" of packets sent around $t = 0.025$, $t = 0.053$, $t = 0.082$ and $t = 0.1$ in Figure 5. Comment on whether this looks as if TCP is in its slow start phase, congestion avoidance phase or some other phase. Figure 6 shows a slightly different view of this data. (**10 points**)
13. Use the *Time-Sequence-Graph(Stevens)* plotting tool to view the sequence number versus time plot of segments being sent from the client to the gaia.cs.umass.edu server in the trace that you have gathered when you transferred a file from your computer to gaia.cs.umass.edu. Answer again question 12 for your trace. (**5 points**)

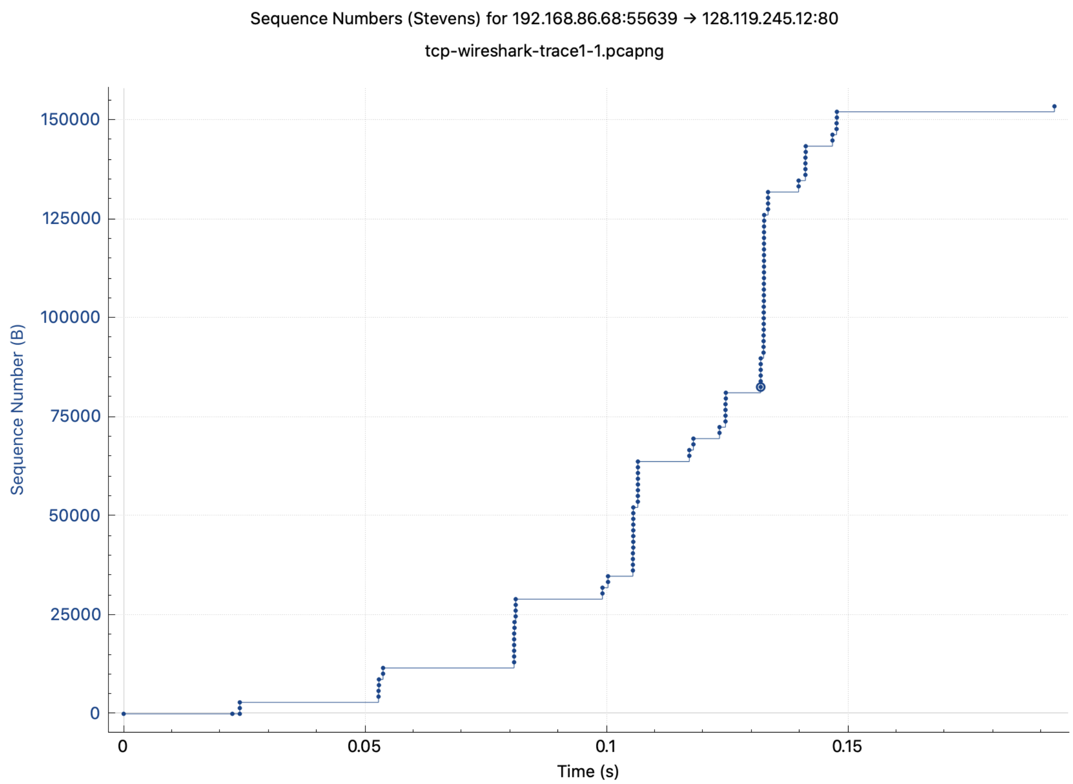

Figure 6: Another view of the same data as in Figure 5.

5. Measuring bandwidth with Iperf3

Iperf3 is a tool for measuring network performance, especially the maximum TCP/UDP bandwidth available. For more information about the tool, refer to its homepage https://iperf.fr/iperf-doc.php. To measure the available bandwidth, you run iperf3 on one host that acts as a server and another one that acts as a client. The client sends packets to the server as fast as it can and measures the network bandwidth. For more information regarding this, refer to iperf3 documentation pages https://iperf.fr/iperf-doc.php and http://software.es.net/iperf/invoking.html#iperf3-manual-page. For this problem, one of the two hosts will be your own personal computer (installation instructions are here https://iperf.fr/iperf-download.php) and the other one will be one of the public iperf3 servers listed here https://iperf.fr/iperf-servers.php. Since our goal in this problem is to measure the bandwidth from one of the public servers to your computer, ideally you should run the server on your computer and the client on the public server. However, if your computer is behind a NAT (this is most probably the case), then the public server cannot establish a connection to it. Hence, **you should always run the client on your computer and the server on the public server and use the –R option (reversed) to run iperf3 in reverse mode (servers sends, client receives).** For the following questions, try to use the two public servers in California whenever possible.

a) Start a 10-second TCP transfer from a public server to your computer. Use the –i option on the client to report the TCP throughput every 100 ms. Plot the TCP throughput on the client as a function of time. **(5 points)**

b) Start a 10-second UDP transfer from a public server to your computer. Use the –b option to set the sending rate to a very high value (higher than the downlink speed of your Internet connection – 200 Mbps should be sufficient). Use the –i option on the client to report the UDP throughput every 100 ms. Plot the UDP throughput on the client as a function of time. **(5 points)**

c) Compare the two graphs you plotted in (a) and (b) and write down your observations and possible causes for the observed performance, in case it differs from the expected one. (**5 points)**

d) Start a 10-second TCP transfer from a public server to your computer. After 3 seconds, start another 10-second TCP transfer from a different public server (this means that you will have to run two iperf3 clients on your computer). Use the –i option on the client to report the TCP throughput every 100 ms. Plot the TCP throughput of each connection as a function of time on the same graph. Comment on how the two TCP sessions share the bandwidth. (**5 points)**

e) Start a 10-second TCP transfer from a public server to your computer. After 3 seconds, start a 10-second UDP transfer from a different public server (this means that you will have to run two iperf3 clients on your computer). Use the –i option on the client to report the TCP and UDP throughput every 100 ms. Plot the TCP and UDP throughput as a function of time on the same graph. Comment on how a UDP and a TCP connection share the bandwidth. (**5 points)**