Ethereal Lab: TCP

In this lab, we'll investigate the behavior of TCP 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 a 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 the client computer and the server.

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

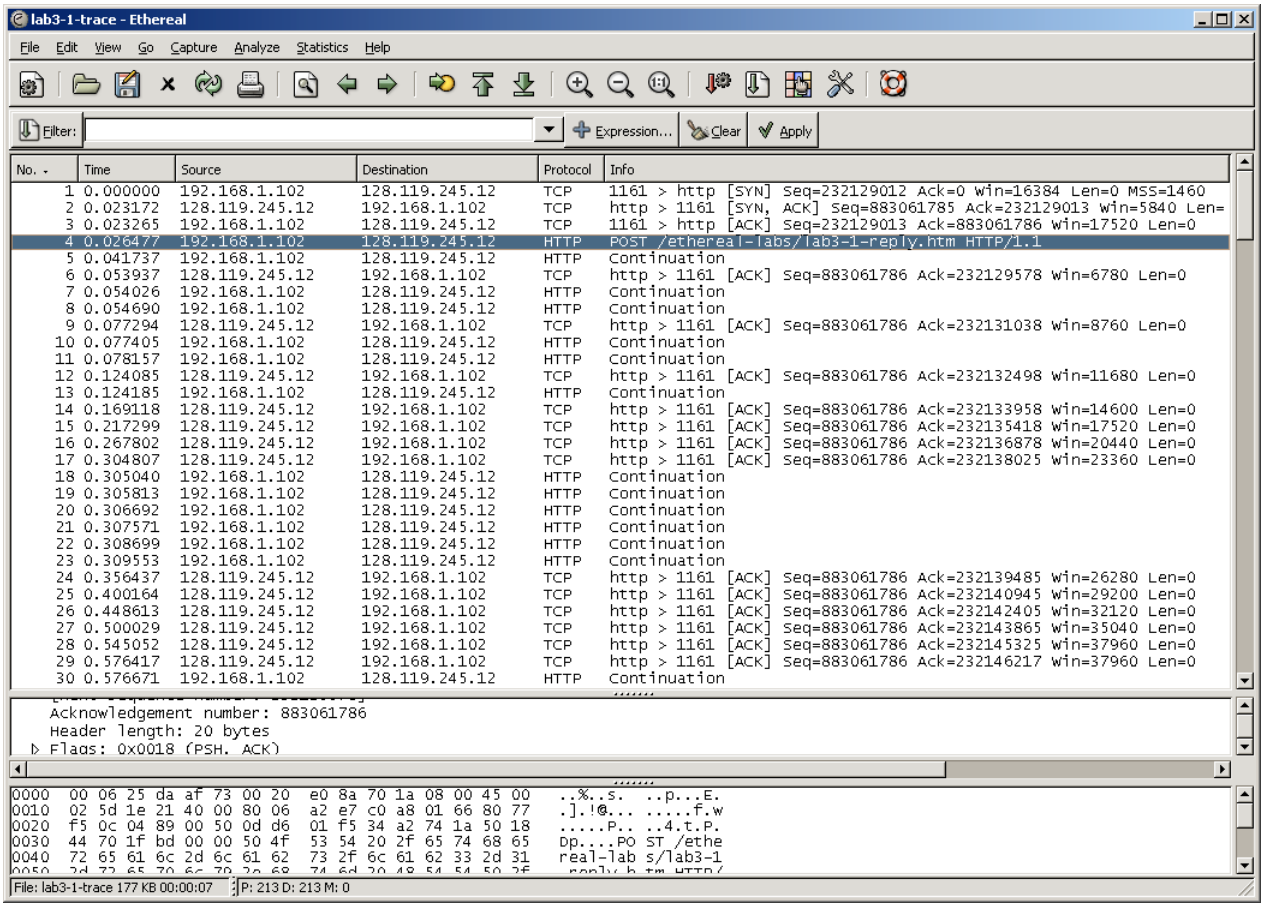
1. Capturing a bulk TCP transfer from the client computer to a remote server

To allow you to investigate TCP's behavior, Ethereal was used to obtain a packet trace of the TCP transfer of a file from a client computer to a remote server. The trace was created by accessing a Web page that will allowed the user to enter the name of a file stored on the client 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). The POST method was used rather than the GET method because we'd like to transfer a large amount of data *from* the client computer to another computer. During the transfer, Ethereal was running to obtain the trace of the TCP segments sent and received from the client computer.

The ethereal packet trace was captured using the following steps:

- The user visited the URL http://gaia.cs.umass.edu/ethereal-labs/TCP-ethereal-file1.html
- The user entered the name of the file containing the text of *Alice in Wonderland*.
- Before pressing the Upload button, the packet capture with Ethereal was started.
- Then the user pressed the "*Upload alice.txt file*" button to upload the file to the gaia.cs.umass.edu server. Once the file had been uploaded, a short congratulations message was be displayed in the browser window.
- Ethereal packet capture was then stopped.

- If you load the ethereal_tcp_trace file into Ethereal, your Ethereal window should look like the window shown below.



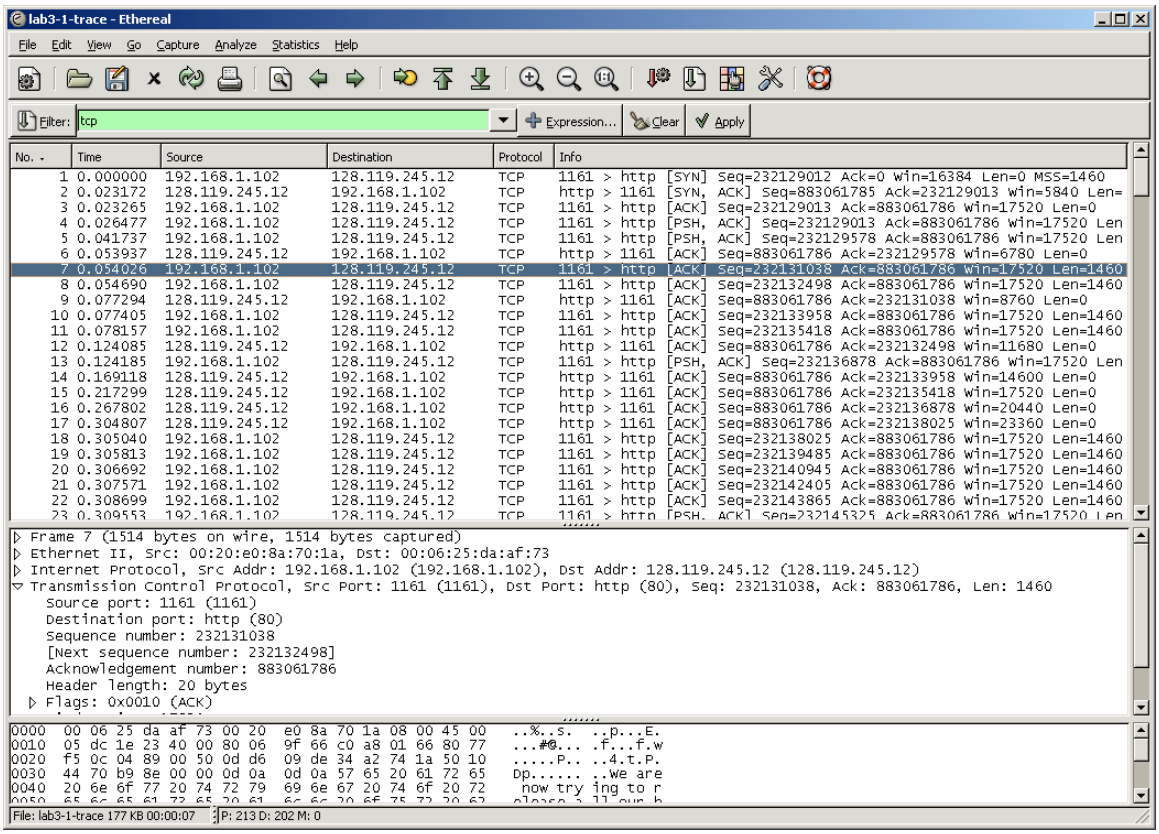
2. A first look at the captured trace

Before analyzing the behavior of the TCP connection in detail, let's take a high level view of the trace. First, filter the packets displayed in the Ethereal window by entering "tcp" into the display filter specification window towards the top of the Ethereal window.

What you should see is series of TCP and HTTP messages between the client computer and gaia.cs.umass.edu. You should see the initial three-way handshake containing a SYN message. You should see an HTTP POST message and a series of "HTTP Continuation" messages being sent from the client computer to gaia.cs.umass.edu. Note that there is no such thing as an HTTP Continuation message – this is Ethereal's way of indicating that there are multiple TCP segments being used to carry a single HTTP message. You should also see TCP ACK segments being returned from gaia.cs.umass.edu to the client computer.

Whenever possible, when answering a question you should hand in a printout of the packet(s) within the trace that you used to answer the question asked. Annotate the printout to explain your answer. To print a packet, use *File->Print*, choose *Selected packet only*, choose *Packet summary line*, and select the minimum amount of packet detail that you need to answer the question.

Since this lab is about TCP rather than HTTP, let's change Ethereal'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. To have Ethereal do this, select *Analyze->Enabled Protocols.* Then uncheck the HTTP box and select *OK*. Also, in this lab we would like to see TCP's sequence numbers (and not the relative sequence numbers that Ethereal may instead display). To see the sequence numbers, go to Edit>Preferences>Protocols>IP and uncheck "relative sequence numbers". You should now see an Ethereal window that looks like:



This is what we're looking for - a series of TCP segments sent between the client computer and gaia.cs.umass.edu. We will use the packet trace to study TCP behavior in the rest of this lab.

3. TCP Basics

Answer the following questions for the TCP segments:

1. What is the IP address and TCP port number used by the client computer (source) to transfer the file to gaia.cs.umass.edu? What is the IP address and port number used by gaia.cs.umass.edu to receive the file?
2. 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? What is it in the segment that identifies the segment as a SYN segment?
3. 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 the value of the ACKnowledgement field in the SYNACK segment? How did gaia.cs.umass.edu determine that value? What is it in the segment that identifies the segment as a SYNACK segment?
4. What is the sequence number of the TCP segment containing the HTTP POST command? Note that in order to find the POST command, you'll need to dig into the packet content field at the bottom of the Ethereal window, looking for a segment with a "POST" within its DATA field.
5. Consider the TCP segment containing the HTTP POST as the first segment in the TCP connection. What are the sequence numbers of the first six segments in the TCP connection (including the segment containing the HTTP POST)? At what time was each segment sent? When was the ACK for each segment received? Given the difference between when each TCP segment was sent, and when its acknowledgement was received, what is the RTT value for each of the six segments? What is the `EstimatedRTT` value (see page 237 in text) after the receipt of each ACK? Assume that the value of the `EstimatedRTT` is equal to the measured RTT for the first segment, and then is computed using the `EstimatedRTT` equation on page 237 for all subsequent segments.

   Note: Ethereal 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.*
6. What is the length of each of the first six TCP segments?[1]
7. What is the minimum amount of available buffer space advertised at the received for the entire trace? Does the lack of receiver buffer space ever throttle the sender?
8. Are there any retransmitted segments in the trace file? What did you check for (in the trace) in order to answer this question?
9. How much data does the receiver typically acknowledge in an ACK? Can you identify cases where the receiver is ACKing every other received segment (see Table 3.2 on page 245 in the text).
10. What is the throughput (bytes transferred per unit time) for the TCP connection? Explain how you calculated this value.

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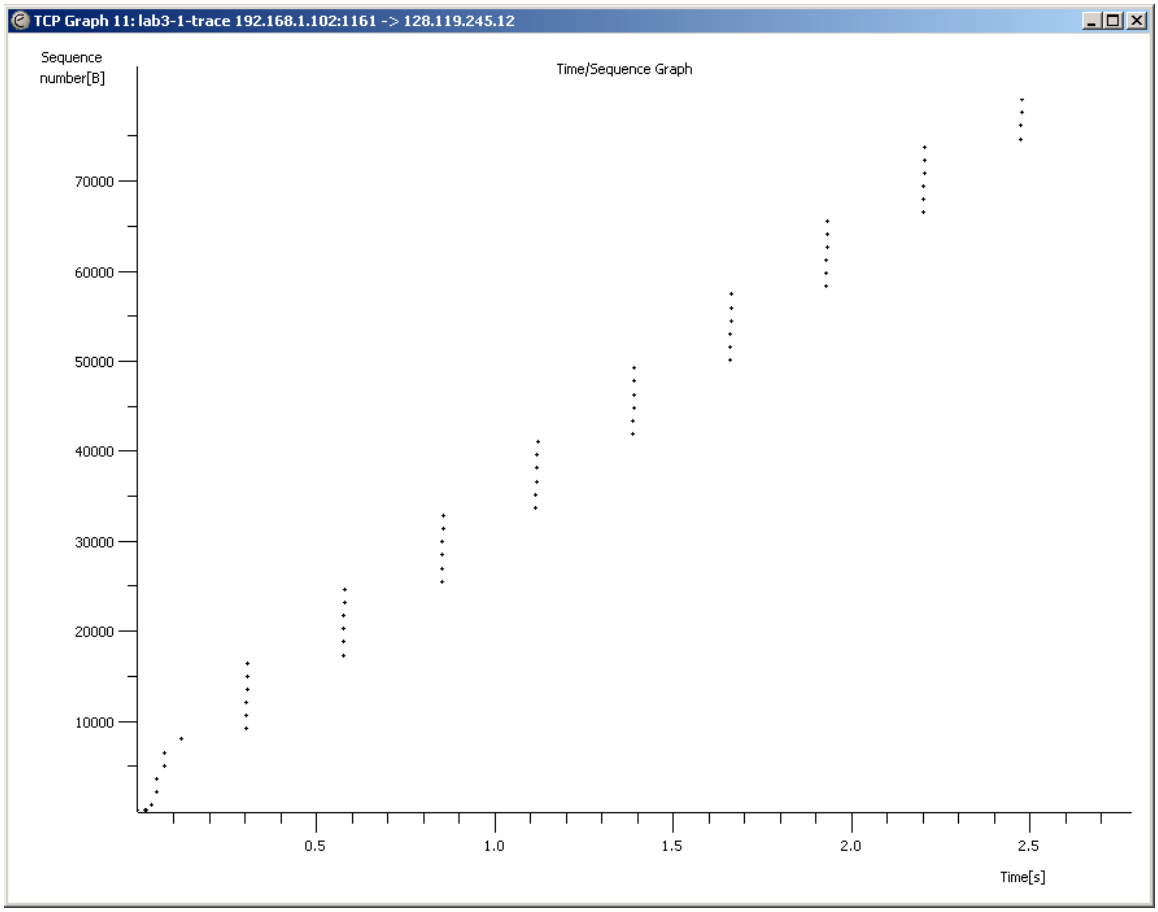
[1] The TCP segments in the tcp-ethereal-trace-1 trace file are all less that 1460 bytes. This is because the computer on which the trace was gathered has an Ethernet card that limits the length of the maximum IP packet to 1500 bytes (40 bytes of TCP/IP header data and 1460 bytes of TCP payload). This 1500 byte value is the standard maximum length allowed by Ethernet.

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 Ethereal window, we'll use one of Ethereal's TCP graphing utilities - *Time-Sequence-Graph(Stevens*) - to plot out data.

- Select a TCP segment in the Ethereal's "listing of captured-packets" window. Then select the menu : *Statistics->TCP Stream Graph-> Time-Sequence-Graph(Stevens*). You should see a plot that looks similar to the following plot:



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 that were sent back-to-back by the sender.

Answer the following questions:

11. 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. Can you identify where TCP's slowstart phase begins

and ends, and where congestion avoidance takes over? Note that in this "real-world" trace, not everything is quite as neat and clean as in Figure 3.51 (also note that the y-axis labels for the *Time-Sequence-Graph(Stevens*) plotting tool and Figure 3.51 are different).

12. Comment on ways in which the measured data differs from the idealized behavior of TCP that we've studied in the text.