

# Department of Electrical and Information Technology

## ETSF10 – Internet Protocols

### Home / Laboratory Project II

# TCP

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The aim of this lab is to guide you while you familiarise yourselves with some of the basic TCP concepts you encounter during the lectures. For this purpose, you are going to analyse the packet capture file of a client-server communication, i.e. communication between two end points in a real IP network such as the Internet. The data you will analyse is stored in advance to PCAP files, i.e. they are the outcome of a real communication session but they are not 'live'. What you need to do is to perform the tasks defined later in this document, analyse and interpret your observations as requested, and write a report summarising your findings.

**Enjoy!**

**The deadline is found on the course web page.**  
**The language of the report is English.**

## 1. Lab Setup

For the analysis, you need a software called 'packet analyser'. There are a number of packet analysers you can actually use for this lab; and you're free to pick the one you like most. Your lecturers, on the other hand, will only assume Wireshark knowledge when they answer possible questions from you.

You will have the opportunity to complete the lab on your personal computers, if you prefer, or use the department's computer laboratory facilities as usual. In the latter case, you can use one of the common computer laboratories in E-huset's basement (varg, val, falk, hacke, panter, lo, venus, mars and jupiter). Please keep in mind that, in the laboratories, you will only be able to work with Wireshark on Linux machines.

It is recommended to familiarise yourselves with the tool you'll work with before getting started. In case you opt for Wireshark but haven't used it before, download (<http://www.wireshark.org/download.html>) and install it, or go to one of the laboratories in the basement. Play along with the user preferences, capture some network traffic – only if you are working from home, as the department's network security policy won't let you do this in the laboratories, download, open and investigate some previously captured files (<http://wiki.wireshark.org/SampleCaptures>), etc. Also, check the Wireshark user documentation (<http://www.wireshark.org/docs>, esp. sections 1.2, 2.5, 2.8, 3, 4.3, 4.5, 4.10, 4.11, 5.2, 5.7, and 6).

## 2. Groups

You will work in groups of two. The groups you have established for the routing lab will also be valid for the TCP lab unless you specifically point out that you'd like to form a new group with someone else. In the latter case, one partner from each group needs to register the group by sending an e-mail to Eduardo Medeiros ([eduardo.medeiros@eit.lth.se](mailto:eduardo.medeiros@eit.lth.se)) with the subject "ETSF10 - tcp lab group", and putting the other partner to CC.

### 3. Timeline

This year's lab is scheduled to take place during the second section of the course. Always check the course's web pages for current deadline dates. You are free to decide when to start with the lab and how much time to spend on it; but we strongly recommend you to not postpone it until the last minute.

### 4. Report

When writing your report, always keep in mind that your answers must be clear, complete and self-contained. In other words, you must not assume that the lecturers already know the answers or what's going on your minds. You need to describe your approach, i.e. how you found what you found, as well as your findings during the tasks. Whenever necessary, include in the report the relevant information from the PCAP file, e.g. screenshots or printouts from Wireshark showing the packet header(s) or the data where you got your answer from. A chapter with your own reflections and comments on the lab assignment concludes the report.

The report must be of reasonable length, written **in your own words** in English. You need to decide for yourselves what the reasonable length is but, based on previous years' experience, you can assume **8 pages** to be the maximum limit, with **10pt** minimum font size, and including everything (e.g. cover page, all figures and the appendix mentioned below). Apart from these requirements, the report is free-style, i.e. you are going to have to decide for yourselves the best way to present your results.

Please include as an appendix to your report your personal comments and suggestions on the lab as well as any errors found in this document or any bugs regarding the lab in general. We would also like to know the amount of time you spent with (a) your analysis and (b) the report.

Submit your report in PDF form via the course moodle (<http://moodle.eit.lth.se>) before the deadline. When submitting, write your group number (from the routing lab) and individual LTH ID on the cover.

### 5. Assessment

Your lab report will be reviewed and marked as **'passed'** or **'failed'**. Failed reports will be returned to their authors, who will then have the opportunity to revise them according to the received comments, and resubmit.

### 6. Help

Help will be available throughout the project timeline. The preferred method for asking questions is e-mail to the project supervisor. Check the office hours on the course's home page.

### 7. Further Reading

- <http://tools.ietf.org/html/rfc793> on TCP
- <http://tools.ietf.org/html/rfc2581> on TCP congestion control
- <http://en.wikipedia.org/wiki/Pcap> on packet capture
- [http://en.wikipedia.org/wiki/Packet\\_analyzer](http://en.wikipedia.org/wiki/Packet_analyzer) on packet analysers
- [http://en.wikipedia.org/wiki/Comparison\\_of\\_packet\\_analyzers](http://en.wikipedia.org/wiki/Comparison_of_packet_analyzers) on a list of available tools
- <http://www.wireshark.org> on our favorite tool

## 8. Tasks

To complete the following tasks, download the necessary PCAP file from the TCP Lab section of the course's project page.

Then, run the packet analyser of your choice (e.g. Wireshark) and open the PCAP file you downloaded. To answer the questions, it is sufficient to look into the listing of the captured packets (in Wireshark, the colourful lines usually in the upper half of the application window) and the details of the selected packet header (the middle part in Wireshark), unless specified otherwise. You won't need to go into the details of packet contents.

When answering the questions which require you to draw figures, keep in mind that you don't need to create exact replicas of the figures below. Just make sure you have represented clearly the answer to the question in graphical form, leaving no room for possible confusion for the reviewer of your report.

**You are now investigating the message exchange log of a file transfer between two nodes on the Internet. The node requesting the file is the CLIENT, whereas the one sending it is the SERVER.**

### 8.1. Connection Establishment

Investigate the packets exchanged for connection establishment and find the answers to the following questions. (Refer to Stallings chapter 15, if you need to refresh your memory.)

- 8.1.1. **[2 points]** Who's the client, who's the server? Identify with IP addresses.
- 8.1.2. **[4 points]** How many packets are exchanged to establish the connection? Which ones? Give index numbers. How do you identify these packets? What do we call this connection establishment process?
- 8.1.3. **[6 points]** For each packet you identify as a connection establishment packet, identify also the TCP header fields. Prepare a table representing the TCP header and fill it in with actual data you read from each packet. In your report, use tables like the one shown in Figure 1. Use decimal numbers instead of binary except for the 1-bit flags where you only can enter 1s and 0s. You do not need to fill in the "checksum", "urgent pointer", and "options and padding" fields.

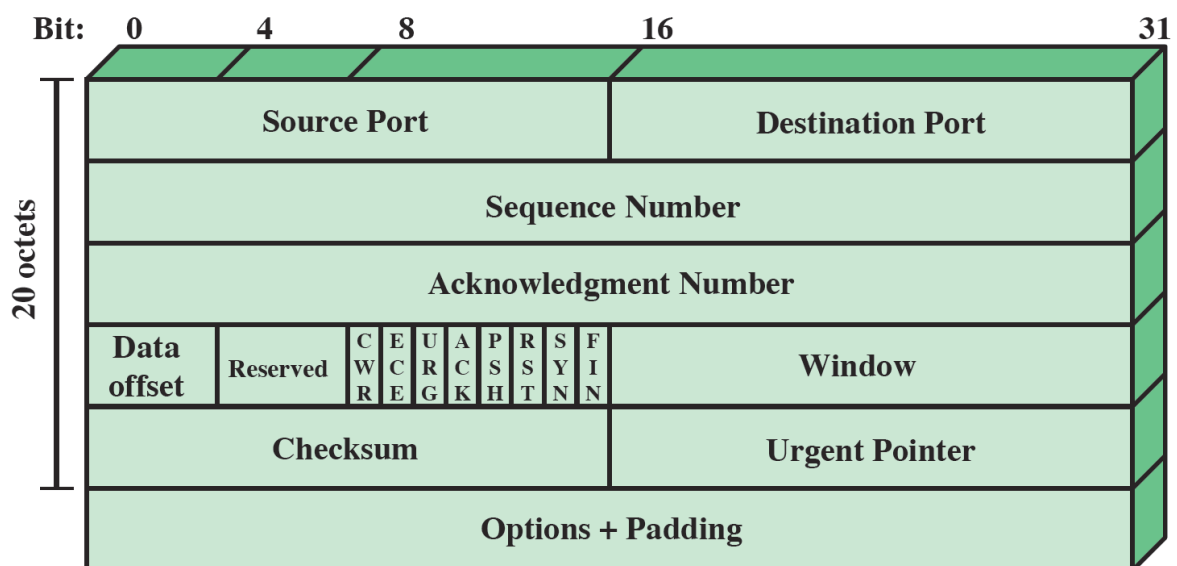


Figure 1: TCP segment header format – reprinted from Stallings, Figure 15.10.

- 8.1.4. [3 points] At the end of connection establishment, what are the values for the maximum segments size (MSS) and receiver-advertised window (RWND) agreed upon, both for the client as well as for the server?

## 8.2. Data Transfer

Once a connection is established, the actual data transfer can begin. So, now, investigate this second phase in our TCP session and answer the following questions.

- 8.2.1. [2 points] By now, you should know about the essential data networking concepts such as the OSI layered network architecture and the corresponding TCP/IP suite. So, you know that TCP is activated, at least in our lab, by an application layer protocol. Which one is it? Where do you read that information from?
- 8.2.2. [2 points] The application layer protocol on the client side uses a method to request a video from the server. What is this method called? ~~What is the title of the video being requested? How do you find that out?~~ (Note: Depending on your Wireshark version, it might be impossible to export the packets and watch the video, therefore I remove this part of the question.)
- 8.2.3. [4 points] When does the actual data transfer start? (We count the time starting from the beginning of the capture. In other words, the very first packet should have a timestamp showing 0 s. You can easily set the relative time in Wireshark Menu\View\ Time Display Format\Seconds Since Beginning of Capture.) Which one is the first packet carrying actual data? Why?
- 8.2.4. [6 points] Starting from the first packet carrying data bytes, show visually the packets being exchanged between the client and the server for the first three rounds, i.e. until the 3. ACK is sent by the client. For visualisation, use a flow graph style similar to that of Figure 2. Give sequence and acknowledgement numbers (the real numbers as used in the packet headers) as well as the number of the first and last data bytes contained in each packet. Skip the information on the flags' status.

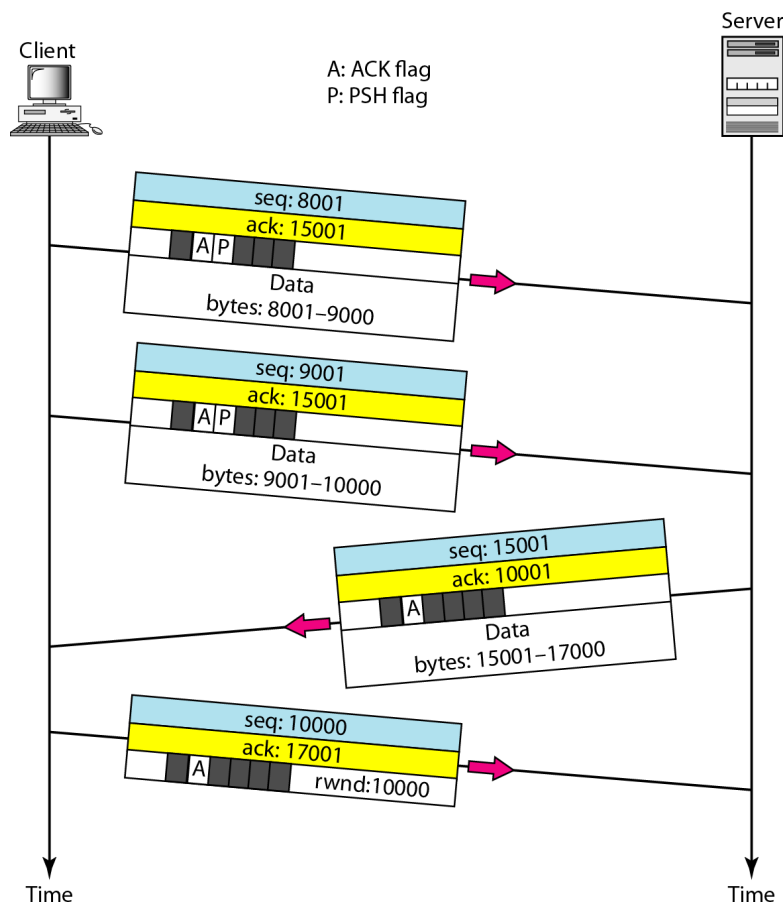


Figure 2: Data transfer example – reprinted from Forouzan “Data Communications and Networking”

- 8.2.5. **[4 points]** Why is 192.168.0.105 acknowledging (ACK) every other data packet (DATA) and not every single one? Is that normal? If so, what is this behaviour called? How is the value of the ACK selected? What does it tell to the sender?
- 8.2.6. **[3 points]** Match the 3 acknowledgements with their corresponding data packets. Show in tabular format the times for DATA, its ACK, and the round trip time (RTT). (Look at the very bottom of the packet header details, you'll find some help under [SEQ/ACK analysis].) This is the actual RTT experienced by the network and is calculated as the difference of DATA and ACK. This is how you can validate your results.
- 8.2.7. **[6 points]** Calculate the estimated RTT for the end of this 3-segment sequence. Note that you need to do it step-by-step, i.e. after the reception of each ACK. So, assume the estimated RTT (old) to be equal to 0.035 ms for the first step (i=1). Then, use the following formula for each step (i=1,2,3):

$$\text{EstimatedRTT}(\text{new}) = 0.875 * \text{EstimatedRTT}(\text{old}) + 0.125 * \text{SampleRTT}(i++)$$

- 8.2.8. **[3 points]** Starting from packet #20, node 192.168.0.105 starts decrementing its receiver-advertised window (RWND). Let's try to understand what happens to the other node's sliding window, i.e. that of 208.117.253.88, from this point on. We know that both nodes start with a congestion window (CWND) of 1 MSS. We also know from the connection establishment phase the size of MSS. Let's assume that TCP is still in "slow start: exponential increase" phase. As of the time of packet #20, 208.117.253.88 has received 6 ACKs, so its CWND has become 7 MSS. Now, given the updates on RWND in the ACK packets #20, #23, and #26, all coming from 192.168.0.105, show how the sizes of RWND, CWND and of the sliding window change in bytes after each of these 3 packets. Remember that the sliding window's size is calculated as follows:

$$\text{WindowSize} = \min(\text{RWND}, \text{CWND})$$

- 8.2.9. **[10 points]** Now, go to packet #238. Starting from this packet, you shall draw a flow graph similar to that of Figure 3, for the packet exchange between the client and the server. The last packet on this graph should be #253. For the packets sent from the server to the client, identify the packets by their sequence numbers in the header. For the packets from the client to the server, identify them by their acknowledgement numbers. Show the lost segment(s) from the server to the client, too. On the server side, also note the number of bytes in flight for each DATA segment sent to the client. (Look at the very bottom of the packet header details, you'll find some help under [SEQ/ACK analysis].) Ignore the receiver buffer on the right side of the figure.

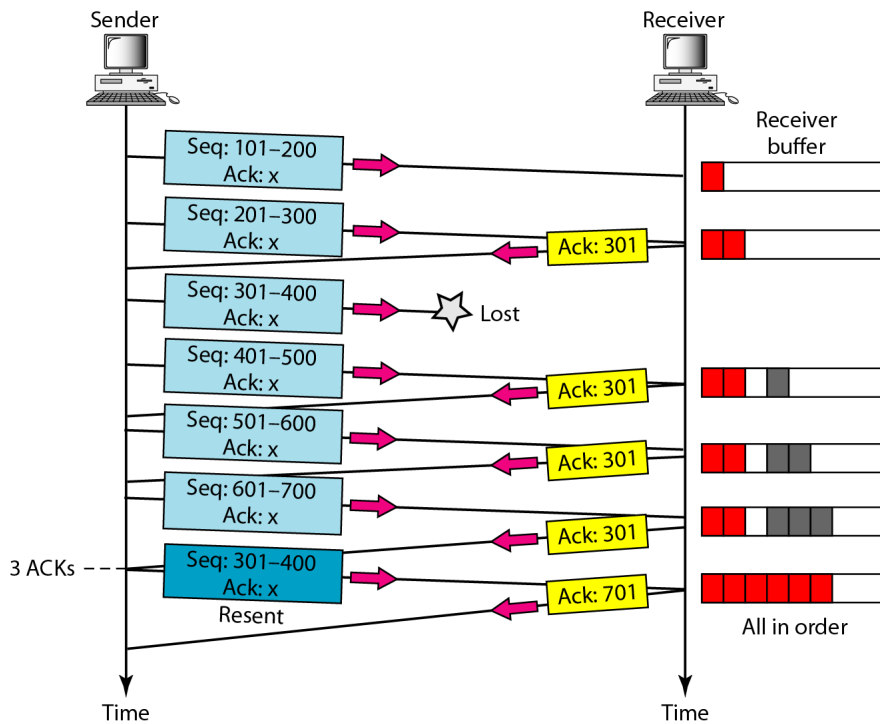


Figure 3: Fast retransmission example – reprinted from Forouzan “Data Communications and Networking”

8.2.10. [4 points] There is a sudden increase in the number of bytes in flight on the server side. Why? (Bytes in flight are those sent but not yet acknowledged. See Figure 4, but note that numbers are made up.)

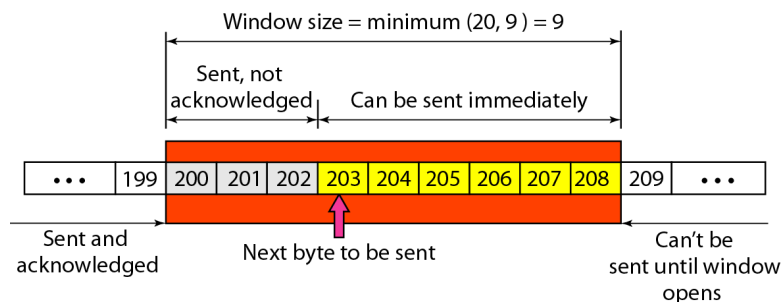


Figure 4: Sliding window example – reprinted from Forouzan “Data Communications and Networking”

### 8.3. Connection Termination

As you can guess, the last couple of packets are designated for connection termination. Look at them and find the answers to the following questions.

- 8.3.1. [3 points] How many packets are exchanged this time? How do you recognise them?
- 8.3.2. [3 points] Is the process similar to that of connection establishment? If not, what is different? There is a special name for this particular termination process. What is it?

### 8.4. Overall Assessment

We have seen a TCP connection being established, used for data transfer, and torn down. Now it is time to analyse from a holistic perspective the TCP session we’ve just closed. Answer the following questions.

- 8.4.1. [6 points] What is the average throughput for the whole duration of the TCP session? How do you calculate this value? Compare the result to the instantaneous throughput, which you can see by plotting the throughput graph under Wireshark Menu\Statistics\TCP Stream Graph\Throughput Graph. Remember that we’re interested in the throughput of the connection from the server towards

the client. So, make sure you have clicked on a packet which is sent in the right direction before plotting the graph.

- 8.4.2. **[2 points]** Following the same menu, also plot the graph for the round trip time. What is the maximum RTT experienced during the TCP session? When did it happen according to the graph?
- 8.4.3. **[3 points]** Finally, plot the Time/Sequence (Stevens's style) graph, which shows the sequence number of the segments received by the client versus time. (You can zoom in and out by clicking on a location on the graph.) What can you tell about the data flow in this TCP session by looking at this graph? What could be happening as the line goes diagonally upwards; what as it goes more or less horizontally?
- 8.4.4. **[4 points]** Can you identify where TCP's slow start phase begins and ends, and where congestion avoidance takes over? Justify your answer.

## 9. Final Remarks

Please don't forget to finish your report with a conclusion section summarising what you have learned, together with your own reflections and comments on the lab. Finally, try to keep track of time, for we would like to know the amount of time you spent with this lab.

**Congratulations! You've completed the TCP lab.**