Institute of Telecommunications
Warsaw University of Technology
May 2019

EINTE LAB EXERCISES

EINTE TCP LAB

INTRODUCTION

LEARNING TCP

Before starting the exercise, you should refresh your knowledge related to TCP. You are advised to study the following aspects: congestion control, flow control, RTO parameter estimation, conditions that may influence TCP efficiency.

To extend the knowledge of TCP you may study the following source documents:

- RFC 793: "Transmission Control Protocol"
- RFC 1122: "Requirements for Internet Hosts - Communication Layers"
- RFC 2581: "TCP Congestion Control" – TCP Reno
- RFC 2988: "Computing TCP's Retransmission Timer"
- RFC 3782: "The NewReno Modification to TCP's Fast Recovery Algorithm"
- RFC 6349: "Framework for TCP Throughput Testing"

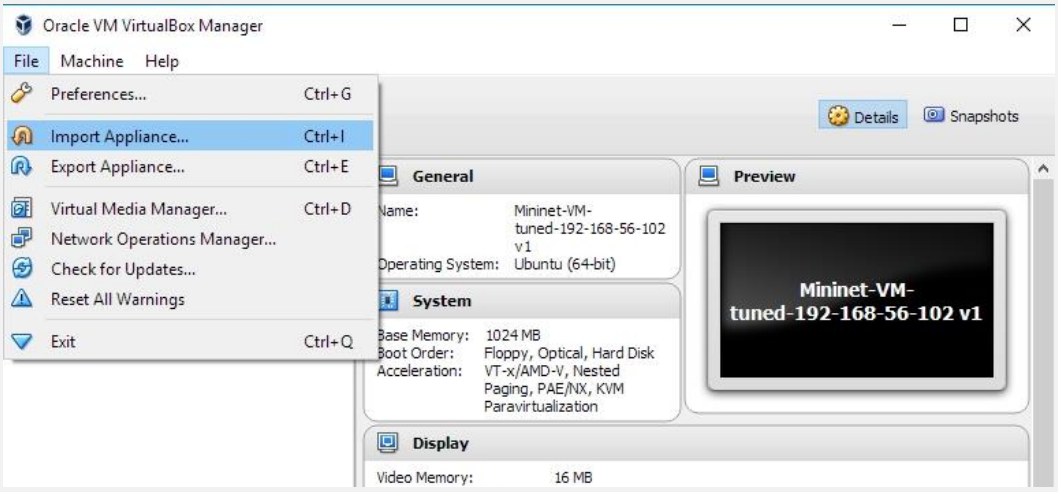
VIRTUAL MACHINE

The simulations required for the exercise are executed using ns2 (Network Simulator) software, running in VirtualBox virtual machine (VM) with Debian linux operating system. The VM is available for download from the course web page.

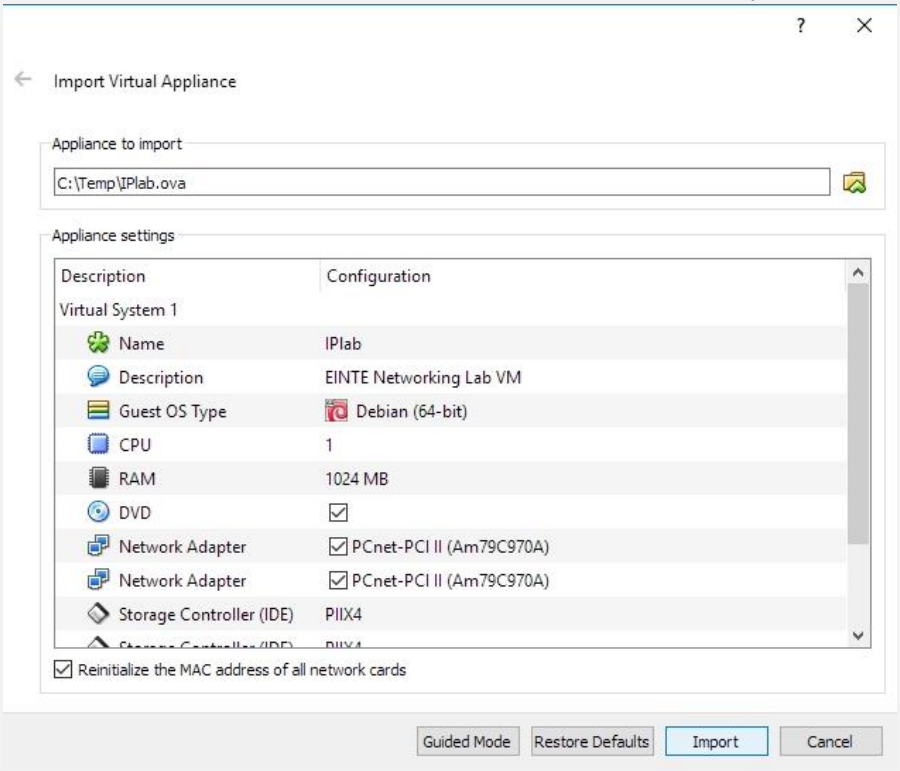
To execute the lab you need to download and install the free MobaXTerm terminal for Windows, available at https://mobaxterm.mobatek.net/download-home-edition.html.

The following steps are necessary to run and use the virtual router lab environment.

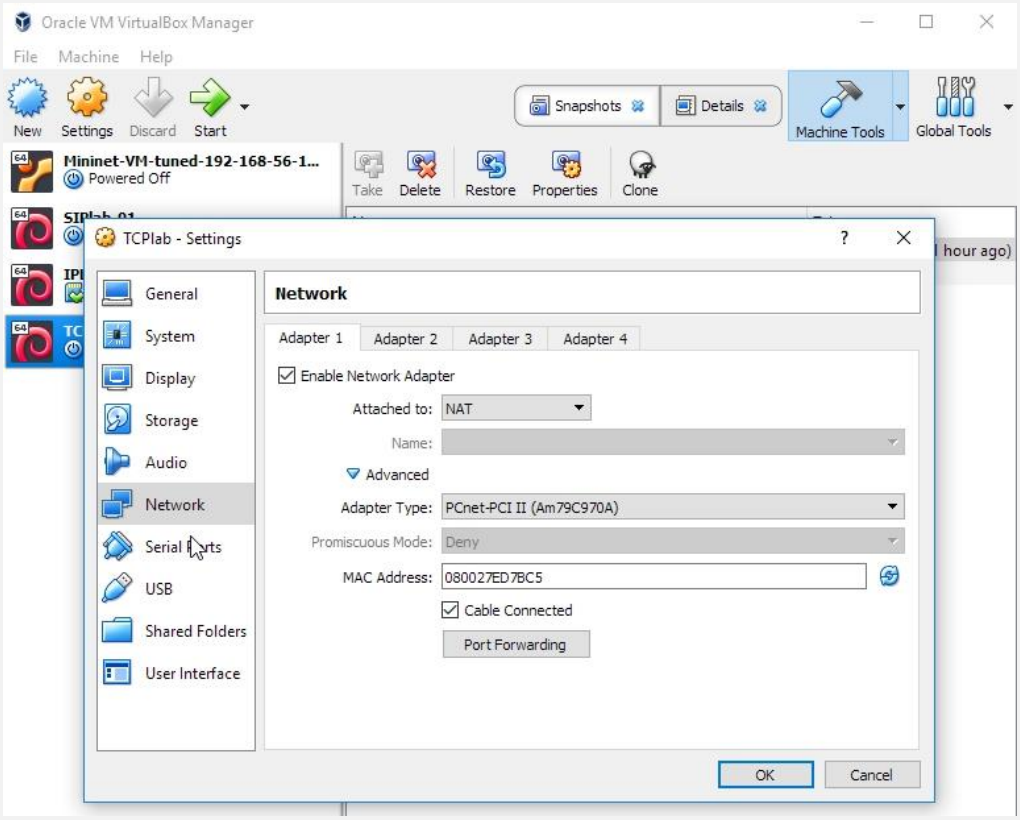
1. Run the VirtualBox and select "*File/Import Appliance*" from the main menu



2. Select the downloaded EINTE IP Lab virtual machine (in example below the name is IPlab.ova), check the "*Reinitialize the MAC address of all network cards*" checkbox and click the "*Import*" button.



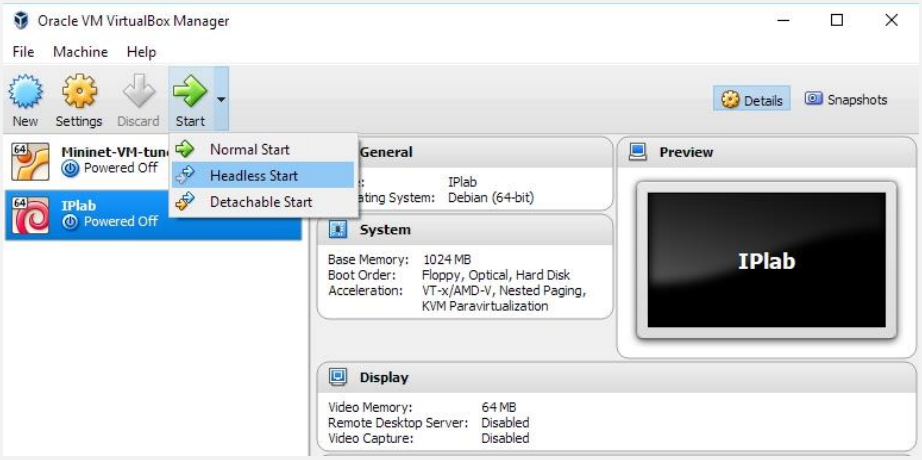
3. Select the VM on the panel, click "*Settings*" and then "*Network*". On "*Adapter 1*" tab click "*Advanced*" and then click the "*Port Forwarding*" button.



4. Make sure that the port forwarding rules contain the following entry:

If not, add the entry using the green + button on the right.

5. Select the TCPlab VM on the panel, click the right side of the "*Start*" button and select "*Headless Start*" from the drop-down menu.



The VM is based on Debian linux without any graphical interface.

6. Start the MobaXTerm software and click the "*Start local terminal*" button – this will open the terminal first tab. In terminal window, run the following command: `ssh -p 2222 einte@localhost`
7. Log in to the VM using password `einte`. The ns-2 simulator is already installed on the VM.

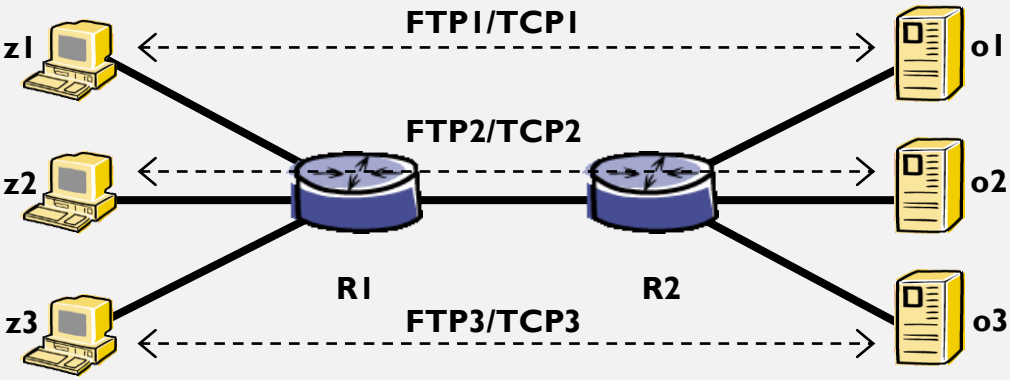
LAB EXERCISE - SIMULATIONS

Simulations for the exercise are done using the popular public-domain network simulation software **ns-2.** After logging in to the VM, in the *einte* user home directory you should find a **tcp.tcl** script, describing the simulated network. The simulation parameters can be modified within the script to adjust them to requirements of subsequent tasks, defined for this exercise. You can edit the script using the *pico* text editor (*pico tcp.tcl*). To run the simulation, you need to issue the **ns tcp.tcl** command.

Please ignore the following notification displayed after starting the simulation.

```
When configured, ns found the right version of tclsh in /home/dukat/ns-allinone-
2.28/tcl8.4.5/unix/tclsh but it doesn't seem to be there anymore, so ns will fall back on
running the first tclsh in your path. The wrong version of tclsh may break the test suites.
Reconfigure and rebuild ns if this is a problem.
```

The simulated network consists of two routers (nodes R1, R2). The hosts attached to the routers represent TCP sources (z1, z2, z3) and receivers (o1, o2, o3), respectively. There are TCP connections set up between each source-receiver pair (z1-o1, etc.). These connections are used by FTP applications.



At the beginning of the tcp.tcl script there's a section where the simulation parameters are defined:

sim_time	- total simulation time [s]
ini_time	- simulation startup time [s]
interwal	- sampling interval [s]
enable_tcp1	- enable/disable TCP source 1 [1 - on, 0 - off]
enable_tcp2	- enable/disable TCP source 2 [1 - on, 0 - off]
enable_tcp3	- enable/disable TCP source 3 [1 - on, 0 - off]
window_tcp1	- max. TCP window size of source 1 [segments]
window_tcp2	- max. TCP window size of source 2 [segments]
window_tcp3	- max. TCP window size of source 3 [segments]
delay_R1R2	- delay on R1-R2 link (propagation time) [ms, e.g. 10ms]
capacity_R1R2	- R1-R2 link capacity [Mbps, e.g. 10Mb]
buffer_R1R2	- R1-R2 link buffer size [packets]
segment_size	- TCP segment size [bytes]

The values of these parameters have to be set according to the content of each subtask.

When the simulation ends, the program displays the throughput of TCP connections. For each connection, two values are displayed: mean throughput for the total simulation time (Average Throughput) and mean throughput calculated for the period excluding the simulation startup time (Stable Throughput). You should write down these values.

Other simulation results are written to **out.csv** file (the file will be created in *einte* home directory, the same that hosts the tcp.tcl script). The following data is written to the output file:

Time	– sampling time
cwnd1	– TCP1 window size [bytes]
cwnd2	– TCP2 window size [bytes]
cwnd3	– TCP3 window size [bytes]]
rtt1	– rtt for TCP1 [s]
rtt2	– rtt for TCP2 [s]
rtt3	– rtt for TCP3 [s]
bytes1	– bytes received over TCP1
bytes2	– bytes received over TCP2
bytes3	– bytes received over TCP3

This file must be downloaded from the VM for further analysis using a spreadsheet software (e.g. Microsoft Excel, or any freeware equivalent). Note that after each simulation the old file will be overwritten if you don't change its name in the simulation script. Therefore, you can either download the file after each simulation and

rename it such that you can recognize to which simulation/task the results belong, or you can modify the name of the output file in the tcp.tcl before each simulation.

To download the output files from the VM to your host PC you need to establish the sftp session with the VM. Using MobaXTerm, you need to click the "*Session*" button and then "*SFTP*". In the "*Remote host*" field enter *localhost*, the user name is *einte* (the password is *einte* as well), the port number should be set to 2222.

TASK 1

The goal of task 1 is to investigate how the window size influences TCP effectiveness. The simulations should be run using the following parameters:

- R1-R2 link delay: 50ms,
- R1-R2 link capacity: 10 Mbps,
- R1-R2 link buffer: 5 packets.

TCP window size should be changed in range of one segment to the value that corresponds to full network utilization (i.e. the optimal window size). You should write in the report how this value is calculated. Simulations should be run for a single TCP connection. The report should contain the plot showing the mean TCP connection throughput as a function of window size.

NOTE: the mean TCP throughput should be calculated for a period when the TCP connection works stable, i.e. neglecting the simulation „startup" period. The simulation time should be set such that it covers at least a few periods of TCP connection being in a *congestion avoidance* phase.

The report should also contain the plots (prepared from the simulation with optimal window size, from the data logged in the output file) showing how the following parameters change in time:

- cwnd size
- rtt,
- TCP momentary throughput (calculated for 1s periods)
- TCP momentary throughput estimated od the base of cwnd and rtt.

TASK 2

The goal of task 2 is to investigate the influence of network buffers on TCP efficiency. The simulation should be run using the following parameters:

- R1-R2 link delay: 50ms,
- R1-R2 link capacity: 10 Mbps,
- max. TCP window size: 5000 packets.

Simulations should be done for a single TCP connection.

The report should contain a plot of TCP connection throughput as a function of buffer size on R1-R2 link. The buffer size should be changed in range from 5 packets to the value that assures maximum TCP efficiency (close to the link capacity).

The report should also contain the plots showing how the following parameters change in time (for two simulations done for the lowest and optimal buffer size):

- cwnd size
- rtt,
- TCP momentary throughput (calculated for 1s periods)
- TCP momentary throughput estimated od the base of cwnd and rtt.

On the base of the results explain how the buffer size influences the TCP efficiency.

TASK 3

Investigate how the buffer size influences TCP efficiency for optimal TCP window size, calculated in Task 1. Simulations should be run with the following parameters:

- R1-R2 link delay: 50ms,
- R1-R2 link capacity: 10 Mbps.

Compare the results with results obtained in Task 2 and explain the differences.

FINAL REPORT

The final report should be prepared in pdf format, archived together with other required files. The report should contain printscreens with simulation results (one printscreen for each task). The archive should also contain the simulation output files for each simulation (for tasks 1 and 2 only files related to simulations with optimal values of the window size and buffer size are required).