
COM-407: TCP/IP NETWORKING

LAB EXERCISES (TP) 2

L2 v.s. L3, NAT, PHYSICAL CONNECTION, AND TROUBLESHOOTING

October 21st, 2021
Deadline: November 3rd, 2021 at 23.55 PM

Abstract

In this lab you will work with the virtual environment introduced in Lab 1. First you will see the different behaviors of networking devices that work on layer 2 and layer 3; then you will configure your virtual network to be able to access the Internet; and finally you will connect one physical machine to another one and use its Internet connection.

1 PREPARING THE LAB

1.1 LAB REPORT

Answer questions on Moodle.

The deadline is Wednesday, November 3rd, 23:55

1.2 SET UP

Copy the **lab2 resources** folder from Moodle into the shared folder of your VM before starting the lab.

2 LAYER 2 VS. LAYER 3 NETWORKING

The aim of this section is to illustrate the difference between networking devices that work at layer 2 and layer 3.

2.1 USING A SWITCH AS A NETWORKING DEVICE

ANALYZE and ANSWER: For this part, answer the quiz Lab2 - Part 1.1 on Moodle.

A switch is a MAC-layer device which expands a LAN by making forwarding decision based on destination MAC-address. In this section you will learn how they work.



Figure 1: Loop-free network configuration with three switches

Open a terminal in your VM and run the script `topol.py` as root (*password: lca2*), which should be located in the shared folder on the Desktop. If not, refer to Section 1.2.

```
# sudo python topol.py
```

This will create the network described in Figure 1, and redirect you to the Mininet Command Line. Additionally, one terminal will appear for each of the four hosts. The four new terminals will be labeled (`h1`, `h2`, `h3`, `h4`) for convenience. `h1`, `h2` and `h3` should be configured with the `10.0.0.0/24` subnet with the fourth byte of their IP address being 1, 2 and 3, respectively. Also, `h4` should have the IP address `10.0.0.4` with the subnet mask of `255.255.255.254`. Additionally, every host is automatically assigned an IPv6 address.



Q1/ Answer Question 1 in Lab2 Part 1.1 on Moodle.



Q2/ Answer Question 2 in Lab2 Part 1.1 on Moodle.

Now, let's test our configuration. Start Wireshark on all four hosts. It will be hard to keep track of which Wireshark window corresponds to which host. One way to do so would be to start Wireshark on the hosts in order, i.e. `h1`, then `h2`, then `h3`, and finally on `h4`. This way the Wireshark windows will be in this same order in the taskbar. Start capturing on all the `eth0` interfaces.

```
# wireshark &
```

Try to ping from each host to the others using its IPv6 address by executing the following command:

```
ping6 -I <interface name of host> <IPv6 address of destination>
```



Q3/ Answer Question 3 in Lab2 Part 1.1 on Moodle.

Now, from terminal of h1, ping h2 using its IPv4 address:

```
# ping <IPv4 address of h2>
```



Q4/ Answer Question 4 in Lab2 Part 1.1 on Moodle.

Now, ping from h1 to h3 using IPv4.



Q5/ Answer Question 5 in Lab2 Part 1.1 on Moodle.



Q6/ Answer Question 6 in Lab2 Part 1.1 on Moodle.



Q7/ Fix the configuration issue with host h4 ...
...and **Answer Question 7 in Lab2 Part 1.1** on Moodle.



Q8/ Answer Question 8 in Lab2 Part 1.1 on Moodle.

Exit Mininet and clean up the topology before going to next subsection:

```
mininet> exit
# mn -c
```

2.2 CONFIGURE A SWITCH TO HANDLE LOOPS

ANALYZE and ANSWER: For this part, answer the quiz **Lab2 - Part 1.2** on Moodle.

The goal of this subsection is to configure a LAN with loops. Similarly to the previous subsection, there are four hosts connected through three switches. The switches are forming a loop.

Run `topo2.py`. It creates the topology depicted in Figure 2.

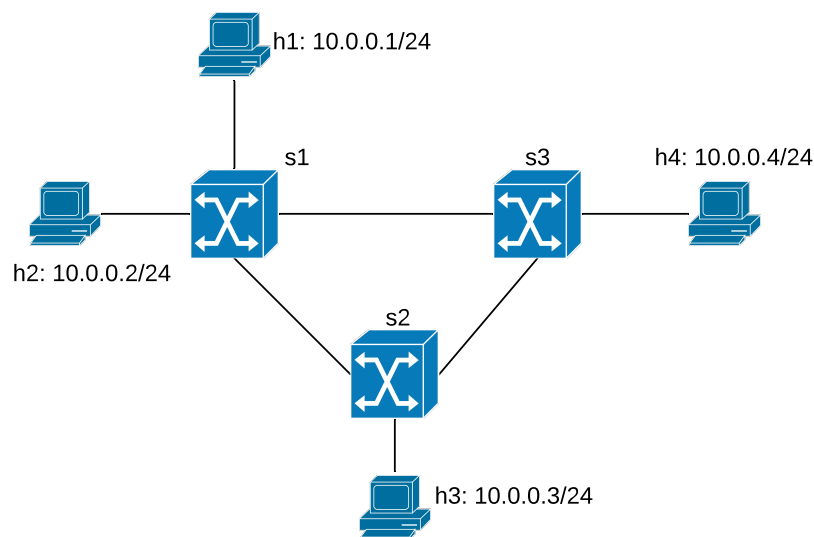


Figure 2: Network configuration with switches forming a loop

Now, perform a reachability test in Mininet using IPv4. A reachability test is a test to determine which hosts can 'reach' one another. This is performed by having each host ping all other hosts using its IPv4 address. A quick way to do this test in Mininet is by running the following command:

```
mininet> pingall
```



Q9/ Answer **Question 1 in Lab2 Part 1.2** on Moodle.

Try to ping h4 from host h1 using their IPv6 address.



Q10/ Answer **Question 2 in Lab2 Part 1.2** on Moodle.

The standard solution to this problem is to enable the Spanning Tree Protocol (STP) at every switch.



Q11/ Answer Question 3 in Lab2 Part 1.2 on Moodle.

The following command enables STP at the switch `s1`.

```
mininet > sh ovs-vsctl set bridge s1 stp-enable=true
```

Enable STP for all other switches in the network; then perform a reachability test again and verify the connectivity of all hosts.

Let's check how STP effects the network of Figure 2. First, we open a terminal from Mininet:

```
mininet > xterm s1
```

Then, open a Wireshark from the terminal. You should be able to see all the interfaces for every switch in the network (not only switch `s1`). You can see the volume of traffic beside each interface.

Execute the ping command for the following pairs of hosts.

- From `h1` to `h3`
- From `h3` to `h4`
- From `h2` to `h4`

You can get the status of links by using:

```
# ip link show
```



Q12/ Answer Question 4 in Lab2 Part 1.2 on Moodle.



Q13/ Answer Question 5 in Lab2 Part 1.2 on Moodle.

Shut down one of the active links between two switches but NOT the link `s1-s3`, namely `si` and `sj`, using the following command Mininet:

```
mininet > link <si> <sj> down
```

Now take a break and come back in 5 minutes.

Use the Ping command to check the connectivity of the hosts.



Q14/ Answer Question 6 in Lab2 Part 1.2 on Moodle.



Q15/ Answer Question 7 in Lab2 Part 1.2 on Moodle.

Exit Mininet and clean up the topology before going to next subsection:

```
mininet> exit
# mn -c
```

2.3 USING A ROUTER AS A NETWORKING DEVICE

ANALYZE and ANSWER: For this part, answer the quiz **Lab2 - Part 1.3** on Moodle.

We have already configured a router in Lab 1, but we did not address how it worked. In this section we learn

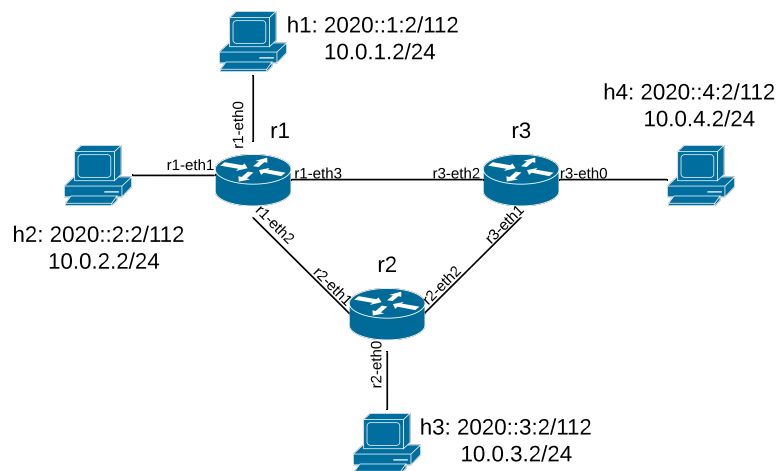


Figure 3: Network configuration with routers

about the process of routing a packet. To do so, run the script `topo3.py`. It creates the network topology with four hosts and three routers as shown in Figure 3.



Q16/ Answer Question 1 in Lab2 Part 1.3 on Moodle.

We will now attempt to fix the problem. First, open the `topo3.py` script and inspect it.



Q17/ Answer Question 2 in Lab2 Part 1.3 on Moodle.



Q18/ Answer Question 3 in Lab2 Part 1.3 on Moodle.

Solve the issue at `r1`.



Q19/ Answer Question 4 in Lab2 Part 1.3 on Moodle.

Try again to ping hosts from each other with IPv4 and IPv6 addresses.



Q20/ Answer Question 5 in Lab2 Part 1.3 on Moodle.

Now solve the issue concerning `h2`.



Q21/ Answer Question 6 in Lab2 Part 1.3 on Moodle.



Q22/ Answer Question 7 in Lab2 Part 1.3 on Moodle.

You can check the routing table on router `r2` using the following command for IPv4 and IPv6, respectively:

```
ip route show  
ip -6 route show
```



Q23/ Answer Question 8 in Lab2 Part 1.3 on Moodle.



Q24/ Answer Question 9 in Lab2 Part 1.3 on Moodle.



Q25/ Answer Question 10 in Lab2 Part 1.3 on Moodle.

Ping again each host from another one using both IPv4 and IPv6 addresses, and confirm that your fix solves the problem.

Based on your observations, conclude this section by comparing switches and routers in a network.



Q26/ Answer Question 11 in Lab2 Part 1.3 on Moodle.



Q27/ Answer Question 12 in Lab2 Part 1.3 on Moodle.



Q28/ Answer Question 13 in Lab2 Part 1.3 on Moodle.

Now, exit Mininet and clean up the topology before going to next section:

```
mininet> exit  
# mn -c
```


3 CONNECTING VIRTUAL ENVIRONMENT TO THE REAL WORLD USING NETWORK ADDRESS TRANSLATION (NAT)

ANALYZE and ANSWER: For this part, answer the quiz **Lab2 - Part 2** on Moodle.

In this section we will use what we learned from Lab1 about manipulating the `iptables` filter. The purpose of the section is to connect an isolated virtual network that we have deployed so far, to the Internet.

Look at the Figure 4. The NAT in the box "Physical Machine" is the one created by VirtualBox. It connects the network interface of "LCA2 VM" to the physical interface of your laptop (**Note that in the network setting of the VM, there should be one Network Adapter which is set to "NAT"**).

As soon as you turn on the VM, remove the IP configuration of the interface connected to the NAT, as it is going to be used by Mininet. Get the list of interfaces in the VM and use the following command to flush the interface of the VM connected to NAT:

```
# sudo ip addr flush dev <interface name of VM connected to NAT>
```

Remember that the root password is `lca2`. Run the script `topo4.py`. This creates the network described in the box "Network in Mininet" shown in Figure 4. In this network, `h1` and `h2` are hosts, `r1` is also a host but configured to act as a perimeter router where we will have our connection to the real world. The goal of the switch `s3` is connecting `r1-eth1` to the network interface of the LCA2 VM. However, we know that LCA2 VM interface is used by the virtual machine itself. Therefore, we add a port to `s3` and connect it the network interface of LCA2 VM.

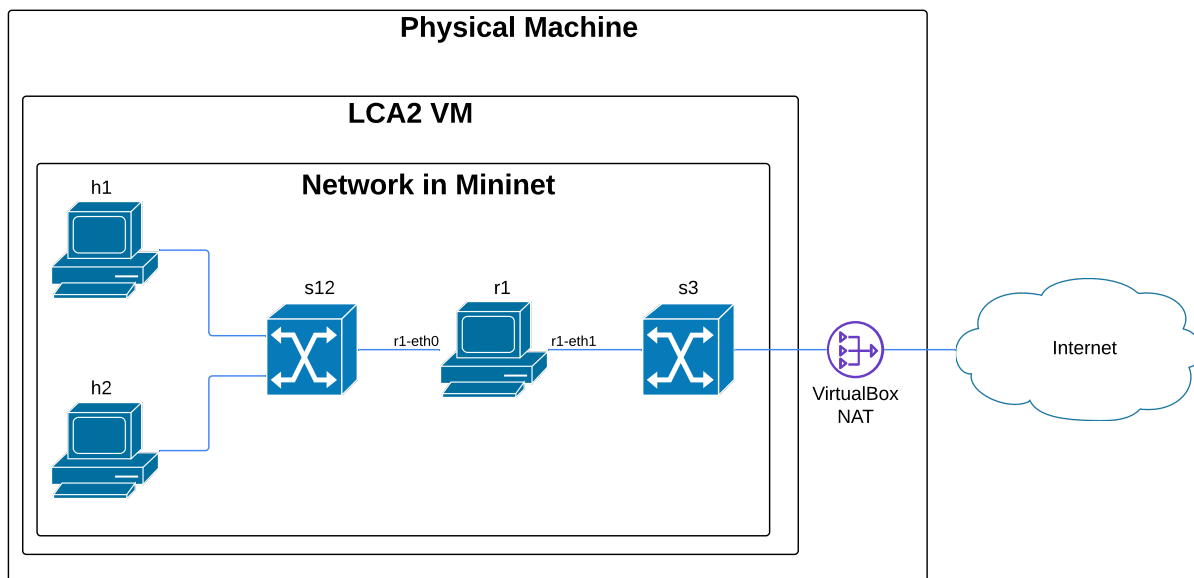


Figure 4: Network configuration with a connection to the real world

3.1 CONNECTING THE PERIMETER ROUTER TO THE INTERNET

The goal of this section is to connect `r1` to the Internet. To perform the bridging between physical and virtual network-adapters, execute the following command from Mininet terminal to connect the interface of VM to the switch `s3`.

```
mininet> sh ovs-vsctl add-port s3 <interface name of VM connected to NAT>
```

Replace `<interfacename>` with the interface that accesses the Internet in your VM.

The next step is to assign an appropriate IP address to the `r1-eth1` interface of `r1`. The address should be in the same subnet as `<interface name of VM connected to NAT>` because both are connected by a switch and are thus in the same subnet. In a physical network, address allocation can be done manually or using a DHCP server. The same holds in the VM, as VirtualBox also provides a DHCP server. We use DHCP in order to avoid conflict with IP addresses that the VM might have allocated to other interfaces in the same subnet as the interface of the VM connected to the VirtualBox NAT. You can ask the DHCP server of VirtualBox to provide a valid IP address by using the following command in the terminal of `r1`:

```
# dhclient r1-eth1
```

This automatically sets a usable IPv4 address to the `eth1` interface of `r1`, allowing it to access the internet through the bridge we just set up. Test the configuration by pinging `8.8.8.8`.



Q29/ Answer Question 1 in Lab2 Part 2 on Moodle.

3.2 PROVIDING INTERNET ACCESS TO MININET HOSTS

The goal of this subsection is to provide Internet access to hosts `h1` and `h2`, via `r1`.



Q30/ Answer Question 2 in Lab2 Part 2 on Moodle.

In order to give Internet access to `h1` and `h2` we will configure `r1` as a NAT. Indeed, the situation is the same as if `r1` would be connected to an ADSL modem at home: `r1` receives a single IP address from its provider (here: VirtualBox) and we want to use it to connect more devices (here: `h1` and `h2`).



Q31/ Answer Question 3 in Lab2 Part 2 on Moodle.

Test from `h1` and `h2` that you have Internet connectivity by pinging `8.8.8.8`. Next, let's explore in detail the result of our configuration.

Do `traceroute` to `8.8.8.8` from `h2` and then from `r1`, while capturing `eth0` and `eth1` traffic on `r1` using Wireshark. Explore the difference in the traffic on both cases.



Q32/ Answer Question 4 in Lab2 Part 2 on Moodle.



Q33/ Answer Question 5 in Lab2 Part 2 on Moodle.



Q34/ Answer Question 6 in Lab2 Part 2 on Moodle.

Do ping to Google from `h1` and `r1`, while capturing the traffic on `r1` (both on `eth0` and `eth1`) using Wireshark. Explore the difference in the traffic in both cases.



Q35/ Answer Question 7 in Lab2 Part 2 on Moodle.



Q36/ Answer Question 8 in Lab2 Part 2 on Moodle.

RESEARCH EXERCISES (OPTIONAL)

4 POINT-TO-POINT WIRED CONNECTION OF TWO PHYSICAL MACHINES

ANALYZE and ANSWER: For this part, answer the quiz **Lab2 - Bonus - Part 1** on Moodle.

In this section, you will connect two physical machines via an Ethernet cable. The goal of this section is to give you a feel about the communication between physical machines.

To accomplish this section, you are required to have access over two physical machines, e.g. your laptop and your friend's, and an Ethernet cable. If you need an Ethernet cable or a USB-to-Ethernet adapter, you can borrow one INF015.



Figure 5: Point-to-point wired connection of two physical machines

4.1 SETTING UP THE CONNECTION

The goal of this subsection is to make a point-to-point connection between two physical machines, namely M1 and M2, via cable. To avoid any complication in the process, please turn off the Wi-Fi connection of the machines (or set it to flight mode). Now, physically connect the two machines by plugging in one port of an Ethernet cable to M1 and the other port to M2.



Q37/ Answer Question 1 in Lab2 Bonus Part 1 on Moodle.

If you are using Windows, turn off the Windows Firewall now, as it may block traffic between interfaces, for security reasons.



Q38/ Answer Question 2 in Lab2 Bonus Part 1 on Moodle.



Q39/ Answer Question 3 in Lab2 Bonus Part 1 on Moodle.

We now set up a private IPv4 network between M1 and M2, using private but routable addresses.



Q40/ Answer Question 4 in Lab2 Bonus Part 1 on Moodle.

Verify the connection of the machines by executing the ping command again with IPv4 on M1 and M2.

4.2 MEASURING THE BANDWIDTH OF THE COMMUNICATION LINK

So far, you have built a point-2-point IPv4/v6 network between two physical machines via an Ethernet cable. The goal of this subsection is to find out the practical bandwidth of the Ethernet cable.

In Lab1, you worked with `iperf` and how to measure the physical bandwidth of a communication link. In this subsection, you want to measure the bandwidth of the Ethernet cable connecting M1 and M2.

Run `iperf` as server in M2.



Q41/ Answer Question 5 in Lab2 Bonus Part 1 on Moodle.

Now run the `iperf` client in M1.



Q42/ Answer Question 6 in Lab2 Bonus Part 1 on Moodle.



Q43/ Answer Question 7 in Lab2 Bonus Part 1 on Moodle.

4.3 SHARING INTERNET ACCESS

ANALYZE and ANSWER: For this part, answer either the quiz **Lab2 - Bonus - Part 2 for Linux** or **Lab2 - Bonus - Part 2 for Windows/Mac**, depending on your operating system, on Moodle.

The goal of this subsection is to allow M1 to access the Internet via M2. This is similar to “tethering”, when you share a mobile phone’s internet access with other devices that do not have Internet access.

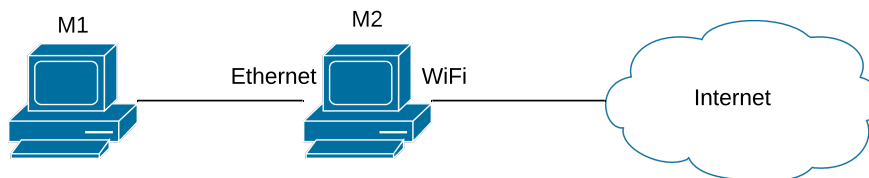


Figure 6: Sharing Internet with a friend!

Assume the configuration is as in Figure 6. We want to connect M1 via M2 to the Internet. We could setup M2 as a bridge, a router, or a NAT.



Q44/ Answer Question 1 in Lab2 Bonus Part 2 on Moodle.

Turn on the Wi-Fi interface of the physical machine M2 and check its connectivity by pinging `google.com`. Note that M1 still does not have Internet access.

4.3.1 SETTING UP M2 AS A NAT

If M2 is running Linux, then it can be setup as a NAT. If this is your case, continue with this section; otherwise jump to Section 4.3.2.



Q45/ Answer Question 2 in Lab2 Bonus Part 2 for Linux on Moodle.

Now you may go directly to Section 4.3.3.

4.3.2 SETTING UP THE LCA2 VM IN M2 AS A NAT

If M2 cannot be natively configured as a NAT, we can use a VM inside M2 and configure it as a NAT, since we know how to do this. This involves two steps:

1. Connecting the VM to the Ethernet port
2. Setting up the VM as a NAT

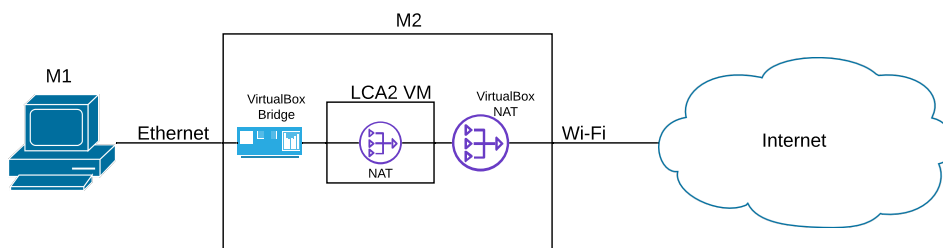


Figure 7: Sharing Internet with NAT in the VM

CONNECTING THE VM TO THE ETHERNET PORT As usual, the VM is connected to the Internet (i.e. to the WiFi interface) via a NAT. We could do the same to connect the VM to the Ethernet adapter, but since we have full control of all IP addresses allocated in this Ethernet LAN, we can do a simpler solution, i.e., use a bridge.

Set two network adapters (a NAT and a Bridge) in host M2. To do so, you have to open "Settings" of the VM, then select "Network", go to tab "Adapter 1" and set it to "NAT" and tab "Adapter 2" and set it to "Bridged adapter"; the name should be the Ethernet interface of your physical machine as it is used to connect M2 to M1.

Now power on the LCA2 virtual machine. Open a terminal in the VM and ping `epfl.ch`.



Q46/ Answer Question 2 in Lab2 Bonus Part 2 for Windows/Mac on Moodle.

We need to check the connectivity of the VM in `M2` to Internet via NAT (we already had it in Section 3) and set up its connection to `M1` via bridge.

The first step to achieve this goal is to assign a suitable IPv4 address to the bridge interface of the VM.



Q47/ Answer Question 3 in Lab2 Bonus Part 2 for Windows/Mac on Moodle.



Q48/ Answer Question 4 in Lab2 Bonus Part 2 for Windows/Mac on Moodle.

Now, ping `M1` from the VM and verify the connectivity of VM and `M1` through the bridge.

SETTING UP LCA2-VM AS A NAT So far, we have connected one interface of the VM in `M2` to the Internet via the VirtualBox NAT and WiFi connection, and the other interface of VM to `M1` via the VirtualBox bridge and Ethernet cable. The final step is to set up the LCA2-VM to work as a NAT.



Q49/ Answer Question 5 in Lab2 Bonus Part 2 for Windows/Mac on Moodle.

4.3.3 FINAL STEPS!



Q50/ Answer Question 6 in Lab2 Bonus Part 2 for Windows/Mac or Question 3 in Lab2 Bonus Part 2 for Linux on Moodle.

Verify the Internet connection of `M1` by pingging `8.8.8.8` as the Google DNS server.

Assume a router `r` is the next hop of `M2`. The host `M1` starts to ping `8.8.8.8`.



Q51/ Answer Question 7 in Lab2 Bonus Part 2 for Windows/Mac or Question 4 in Lab2 Bonus Part 2 for Linux on Moodle.

One application of such configuration is to share your own Internet access with other people who are not connected to the Internet. Suppose a friend of you visits Switzerland and would like to have Internet access; however, the cost of Roaming is too much for him/her. Therefore, you would like to do him/her a favor and share your own Internet with him/her. This can be done by the practical experience you have obtained in this section.

Disclaimer: You may think of sharing your EPFL Internet connection using your GASPARE credentials and give Internet access to your friend. We would like to warn you that this generous behavior is unfortunately forbidden.

Note: If you borrowed any Ethernet cable or USB-to-Ethernet adapter, please return them to INF015; as otherwise, your submission will not be graded.

Note: If you are using a Windows machine, turn on the Windows Firewall again.