

CSE 421

Lab 2: Introduction to Packet Analysis and Network Simulation

ID: _____

Introduction:

In real life, network monitoring and packet analysis is of great importance to observe the network state and identify any anomalous network event. Wireshark is a tool that can be used to monitor our network and also analysis traces of past network events. In this lab, we will get familiar with the wireshark interface and learn basic packet analysis.

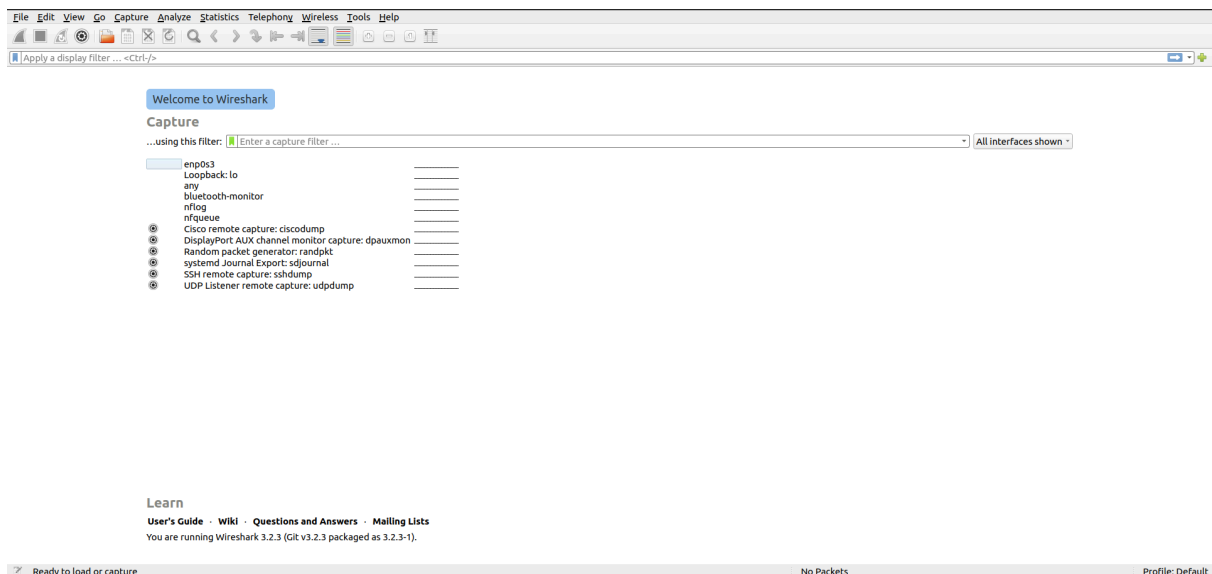
In networking research and protocol testing, simulating a network is one of the core works. We can try out existing networking protocols and measure their performance. Also, we can devise our own modified protocol and test its performance against the existing ones. In this lab, we will also get familiar with an open source network simulator, ns3. We will learn how to install the simulator and run a basic simulation.

Objectives:

1. Getting familiar with wireshark
 - a. Learn about basic wireshark interface
 - b. Basic filtering of packets
 - c. Explore a simple **HTTP** stream
2. Getting familiar with network simulation
 - a. Installing and running ns3
 - b. Understanding a simple simulation script
 - c. Visualizing our simulation
 - d. Collecting network traces and observing the events

Task 1: Using Wireshark **[Do this task in Windows]**

1. Step 1: Download and install wireshark
 - a. Go to <https://www.wireshark.org/>
 - b. Download and install the tool for the operating system you are using
2. Open wireshark if it is installed
 - a. You will see a window like the following



- Ethernet II**, Src: PoCompu, ca:08:0e:00:27:ca:08:6e, Dst: RealtekU, 12:35:02 (52:54:00:12:35:02)

No.	Time	Source	Destination	Protocol	Length	Info
2861	19.396882640	10.0.2.15	172.217.31.196	TCP	54	48384 -> 443 [ACK] Seq=15141 Ack=605160 Win=27292 Len=0
2862	19.397838713	34.149.144.151	10.0.2.15	TCP	60	443 -> 44330 [FIN, ACK] Seq=19679 Ack=996 Min=6535 Len=0
2863	19.397850153	10.0.2.15	34.149.144.151	TCP	54	44330 -> 443 [Seq=696 Ack=16000 Win=4000 Len=0]
2864	19.397859953	34.117.65.55	10.0.2.15	TCP	60	443 -> 34740 [FIN, ACK] Seq=5847 Ack=1083 Min=6535 Len=0
2865	19.398141800	10.0.2.15	34.117.65.55	TCP	54	34740 -> 443 [Seq=1043 Ack=5548 Win=4000 Len=0]
2866	19.397859953	34.149.144.209	10.0.2.15	TCP	60	443 -> 39022 [FIN, ACK] Seq=79799 Ack=184 Min=6535 Len=0
2867	19.398487292	10.0.2.15	34.149.100.209	TCP	54	39022 -> 443 [Ack=1614 Ack=28000 Win=40800 Len=0]
2868	19.397859953	142.250.193.38	10.0.2.15	TCP	60	443 -> 48660 [FIN, ACK] Seq=7783 Ack=184 Min=6535 Len=0
2869	19.396838329	10.0.2.15	142.250.193.98	TCP	54	39600 -> 443 [Ack] Seq=1609 Ack=5784 Min=40800 Len=0
2870	19.478208645	142.250.193.38	10.0.2.15	TCP	60	443 -> 48700 [FIN, ACK] Seq=1843 Ack=184 Min=6535 Len=0
2871	19.478163661	10.0.2.15	3.160.188.15	TCP	54	39768 -> 443 [ACK] Seq=1541 Ack=10301 Min=40800 Len=0
2872	19.601259641	142.250.196.35	10.0.2.15	TCP	60	80 -> 44340 [FIN, ACK] Seq=703 Ack=429 Min=6535 Len=0
2873	19.601285140	10.0.2.15	142.250.196.35	TCP	54	44348 -> 80 [ACK] Seq=429 Ack=704 Min=42100 Len=0
2874	19.616341158	142.250.196.35	10.0.2.15	TCP	60	80 -> 44350 [FIN, ACK] Seq=4210 Ack=2961 Min=6535 Len=0
2875	19.616361807	10.0.2.15	142.250.196.35	TCP	54	44350 -> 80 [ACK] Seq=561 Ack=4211 Min=42100 Len=0
2876	19.653061448	152.195.38.76	10.0.2.15	TCP	60	80 -> 40660 [FIN, ACK] Seq=738 Ack=426 Min=6535 Len=0
2877	19.653029579	10.0.2.15	152.195.38.76	TCP	54	40660 -> 80 [ACK] Seq=426 Ack=739 Min=42000 Len=0

* Frame 1: 95 bytes on wire (760 bits), 95 bytes captured (760 bits) on interface empo3, id 0
 * Ethernet II, Src: PoCompu, ca:08:0e:00:27:ca:08:6e, Dst: RealtekU, 12:35:02 (52:54:00:12:35:02)
 * Internet Protocol Version 4, Src: 10.0.2.15, Dst: 192.168.0.1
 * User Datagram Protocol, Src Port: 43631, Dst Port: 53
 * Domain Name System (query)

```

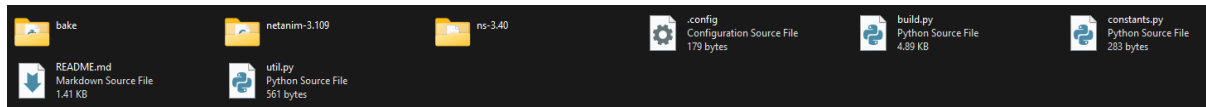
0000  52 54 00 12 35 02 08 0e 00 27 ca 08 6e 00 00 45 80   RT: 5, n: E
0010  00 51 d0 74 40 00 00 11 22 6a 0a 00 02 0f c0 a8    OKQ>0 "j...
0020  00 01 aa 50 00 35 00 3d c0 09 61 0e 01 00 00 01    ...[ s = An...
0030  00 00 00 00 00 01 05 64 65 74 65 63 74 70 70 72    ...d etector
0040  74 61 67 0f 86 69 72 65 66 6f 78 63 63 6f 6d 00   tal fire tex com
0050  00 01 00 01 00 00 29 02 00 00 00 00 00 00 00 00   )
```

c. We can observe that there are a lot of things going on. That means, our device is interacting through the network interface. We can focus on things by filtering out packets that are of our interest. For example, if we want to filter out http data, we can type 'http' on the text box on top and press enter. Only the http packets will be shown and other packets will be filtered out.

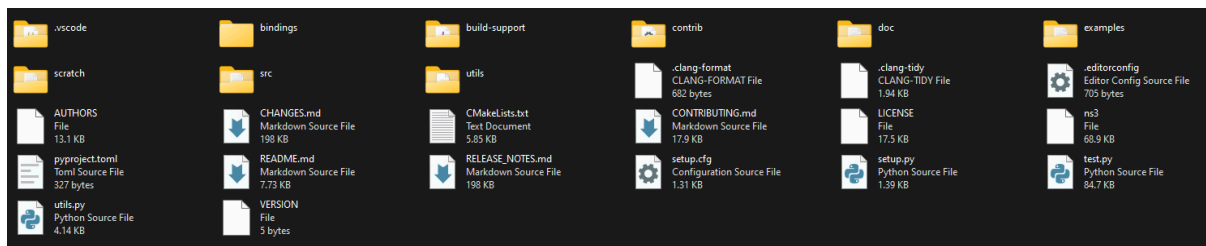
Visit any http website while monitoring the network traffic. Now filter only the http packets. Observe the headers of any http request and response packet and explain how the layers are operating in this case.

Task 2: Using NS-3 [Do this task in Ubuntu 22.04 (Jellyfish)]

1. Download NS3
 - a. Go to [ns-3.40 | ns-3](#) and download the exact version of ns3
 - i. If the above link does not work, try from [here](#)
 - b. Extract the contents and you will see the contents like this:



- c. Move inside ns-3.40 directory. The contents will look like this:



2. Install the necessary packages
 - a. **sudo apt install g++ python3 cmake ninja-build git**
 - i. If you find any error giving this command, update and upgrade your apps first and then try the above command. To update and upgrade give command,
 - **sudo apt update**
 - **sudo apt upgrade**
 - **sudo apt install g++ python3 cmake ninja-build git**
 - b. **python3 -m pip install --user cppy==2.4.1**
 - i. If you see that pip is not installed, first install pip and then try the above command. To install pip give command,
 - **sudo apt install python3-pip**
 - **python3 -m pip install --user cppy==2.4.1**
3. Configure ns3 with python support
 - a. First go to ns-allinone-3.40/ns-3.40 directory in terminal and then command,
 - i. **./ns3 configure --enable-python-bindings**
4. Build ns3
 - a. **./ns3 build**
5. Run your first script
 - a. **./ns3 shell**
 - b. **python3 examples/tutorial/first.py**
6. Try to understand our first simulation script
 - a. Create nodes/devices and connect them
 - i. Creating nodes:

```
nodes = ns.network.NodeContainer()
nodes.Create(2)
```

We create a NodeContainer and create multiple nodes inside that NodeContainer so that we can manage all the nodes at once through the NodeContainer

- ii. Create channel and set attributes:

```
pointToPoint = ns.point_to_point.PointToPointHelper()
pointToPoint.SetDeviceAttribute("DataRate", ns.core.StringValue("5Mbps"))
pointToPoint.SetChannelAttribute("Delay", ns.core.StringValue("2ms"))
```

We need to create a channel that will be used for the communication. In this case, we are using a point to point channel by getting a `PointToPointHelper` object. This `PointToPointHelper` will manage all the low level transmission related works.

Then we set some attributes of this channel. Here we are setting the `DataRate` of our channel as 5Mbps and the delay of the channel as 2ms.

- iii. Connect the created nodes using the point-to-point channel:

```
devices = pointToPoint.Install(nodes)
```

Installing the channel to the nodes gives us the `NetDevice` that is used for network communication.

- b. Install the internet stack on the nodes:

```
stack = ns.internet.InternetStackHelper()  
stack.Install(nodes)
```

We need to install the network stack on the nodes so that the nodes follow the common network layering and protocols. The `InternetStackHelper` does the necessary works to install the network stack on the nodes.

- c. Assign IP addresses to devices:

```
address = ns.internet.Ipv4AddressHelper()  
address.SetBase(ns.network.Ipv4Address("10.1.1.0"),  
               ns.network.Ipv4Mask("255.255.255.0"))  
  
interfaces = address.Assign(devices)
```

We need to uniquely identify the devices in the network for communication. For this reason, we need to assign IP addresses to each devices. So, we first create a network with a network address and subnet mask. Then, we assign IP addresses to each devices. The `Ipv4AddressHelper` does all the necessary works to do that.

- d. Creating server and client application:

- i. Configuring the server:

```
echoServer = ns.applications.UdpEchoServerHelper(9)  
  
serverApps = echoServer.Install(nodes.Get(1))  
serverApps.Start(ns.core.Seconds(1.0))  
serverApps.Stop(ns.core.Seconds(10.0))
```

We first create a server application that listens on its port number 9 and accepts connections from any host. Then we install the server application on the second node (`nodes.Get(1)`, indexing starts from 0). Then we define when the server application will start and when it will stop.

- ii. Configuring the client:

```
address = interfaces.GetAddress(1).ConvertTo()  
echoClient = ns.applications.UdpEchoClientHelper(address, 9)  
echoClient.SetAttribute("MaxPackets", ns.core.UintegerValue(1))  
echoClient.SetAttribute("Interval", ns.core.TimeValue(ns.core.Seconds(1.0)))  
echoClient.SetAttribute("PacketSize", ns.core.UintegerValue(1024))
```

We have to configure the client application and define what it will do. In this case, it tries to connect to the server by first fetching the address of the server. Then we are creating a client application by telling it to connect to the server address with port number 9. Then we define some attributes of the client application. We set the **MaxPacket** to fix how many packets the client will send the server. Then, we set the **Interval** to fix the delay between successive packet sending. Then, we set the **PacketSize** and tell the client application to send 1024 bytes of data to the server.

- iii. Install the client application:

```
clientApps = echoClient.Install(nodes.Get(0))
clientApps.Start(ns.core.Seconds(2.0))
clientApps.Stop(ns.core.Seconds(10.0))
```

We now install the client application on the first node and set the start and stop time of the client application.

- e. Running the simulation:

```
ns.core.Simulator.Run()
ns.core.Simulator.Destroy()
```

7. Observing the output:

```
At time +2s client sent 1024 bytes to 10.1.1.2 port 9
At time +2.00369s server received 1024 bytes from 10.1.1.1 port 49153
At time +2.00369s server sent 1024 bytes to 10.1.1.1 port 49153
At time +2.00737s client received 1024 bytes from 10.1.1.2 port 9
```

Here we can see the traces of the network events that are performed by the server and client. We can see that 1024 bytes of data is being sent and received. Also, port 9 is used by the server as we had configured. We can also see the time in the simulation when the events happened. The transmission started at 2s because we configured the client to start at 2s.

8. Visualizing the simulation:

- a. Installing NetAnim:

NetAnim is a simulation visualization tool that comes bundled with ns3. To use NetAnim, we need to perform some steps.

- i. **Install prerequisite packages by running the following command:**

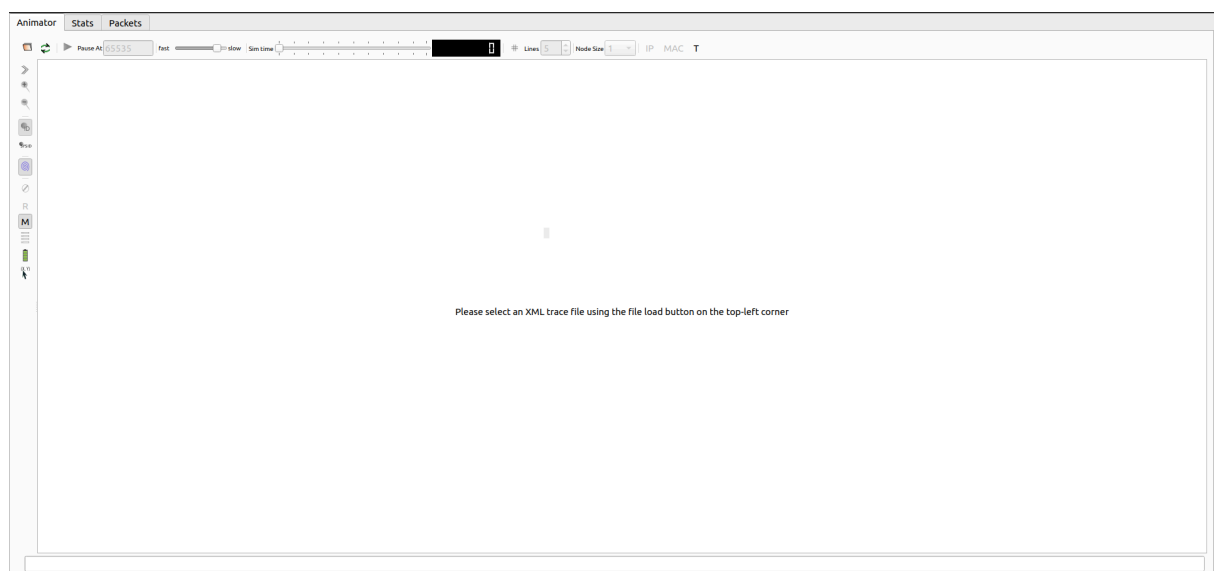
- `sudo apt install qtbase5-dev qtchooser qt5-qmake qtbase5-dev-tools`

- ii. Build NetAnim:

- Move inside the **netanim-3.109** directory.
- Run the following commands:
 - a. **qmake NetAnim.pro**
 - b. **make**

- iii. Run NetAnim:

- **./NetAnim**
- The interface should look like the following:



- b. Generating the visualization script:
 - i. Add the following line of code **before calling** the Run() method:
 - **anim = ns.netanim.AnimationInterface("first.xml")**
 - ii. This will generate a "first.xml" file after running the simulation. This file contains the necessary scripts to run the visualization of our simulation.
 - c. Open the "first.xml" file in NetAnim and play the simulation. You will see a visual representation of the network events happened in our simulation.
9. Collecting network trace:
- We can collect packet captures from all our nodes in the simulation. These packet captures can help to understand the network events and troubleshoot the network.
- a. Add the following line of code **before calling** the Run() method:
 - i. **pointToPoint.EnablePcapAll("first")**
 - b. This will generate a pcap file for every node in our simulation. As we had only two nodes in our simulation, we will get two pcap files after running the simulation.
 - c. Open the pcap files and observe the packets.
 - i. For this we have to install wireshark. So give command
 - **sudo apt install wireshark**
 - ii. Then double click on the pcap files.
10. Getting network metrics and flow statistics:
- a. Add the following code block instead of calling the Run() method:

```

flowmon_helper = ns.flow_monitor.FlowMonitorHelper()
monitor = flowmon_helper.InstallAll()
monitor = flowmon_helper.GetMonitor()

ns.core.Simulator.Stop(ns.core.Seconds(20.0))
ns.core.Simulator.Run()

def print_stats(st):
    print("Tx Bytes: ", st.txBytes)
    print("Rx Bytes: ", st.rxBytes)
    print("Tx Packets: ", st.txPackets)
    print("Rx Packets: ", st.rxPackets)
    print("Lost Packets: ", st.lostPackets)
    if st.rxPackets > 0:
        print("Mean Delay: ", (st.delaySum.GetSeconds() / st.rxPackets))
        print("Throughput: ", (st.rxBytes*8)/18)

monitor.CheckForLostPackets()
classifier = flowmon_helper.GetClassifier()

for flow_id, flow_stats in monitor.GetFlowStats():
    t = classifier.FindFlow(flow_id)
    proto = {6: 'TCP', 17: 'UDP'} [t.protocol]
    print ("FlowID: %i (%s %s/%s --> %s/%i)" % \
          (flow_id, proto, t.sourceAddress, t.sourcePort, t.destinationAddress,
t.destinationPort))
    print stats(flow_stats)

```

Home Task:

Now **vary the packet size and observe the metrics**. Take packet size [128,256,512,1024,2048] bytes and collect the throughputs for each of them. Plot the packet size vs Throughput in this case and explain the graph.