Project2: Proxy Server and Network Address Translation (NAT)

M2608.001200 Introduction to Data Communication Networks (2021 Fall)

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TAs: Kyungmin Bin, Taekyung Han

Due date: Dec. 04, 2021, 11:59 pm.

Notes:

- Be aware of plagiarism. You are allowed to use the eTL for QnAs, but do **NOT** discuss with your classmates **directly**.
- **Grading**: 100 pts
- In case you find out bugs, typos or issues in the given code, please report to the TAs by posting on the eTL. We will look into them and fix as soon as possible. Once fixed, we will upload the new version on the eTL by naming proper version number for the code and make an announcement on the eTL. Please pay attention to it and make sure you are using the latest version before submission.
- If you do not want other students to see your questions, you can always make them private.

Objective

A proxy server is a server that clients use to access other computers. A client who requests some services connects to the proxy server. Then, the proxy server forwards the request to the different server that has available the requested service. There are many benefits of using a proxy server. The main advantage of proxy is anonymizing. The client can exchange data with the remote server without a direct connection. Therefore, it can hide the client's IP address from the remote server.

Network Address Translation (NAT) also can make the client anonymous. NAT is a method of mapping an IP address into another by modifying network address information in the IP header of packets while they are in transit across a traffic routing device. It is usually used to translate private IP to public IP to protect the private network.

The goal of this project is to implement a simple HTTP proxy server and create NAT rules. With this project, you can understand how proxy and NAT work and the difference between proxy and NAT.

1. Implementation of a Simple HTTP Proxy Server

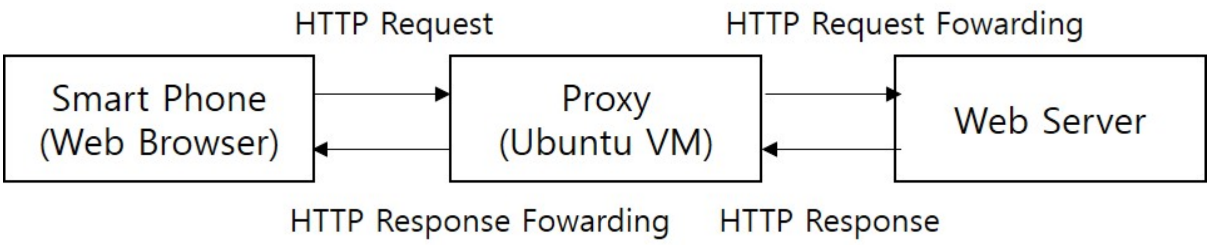
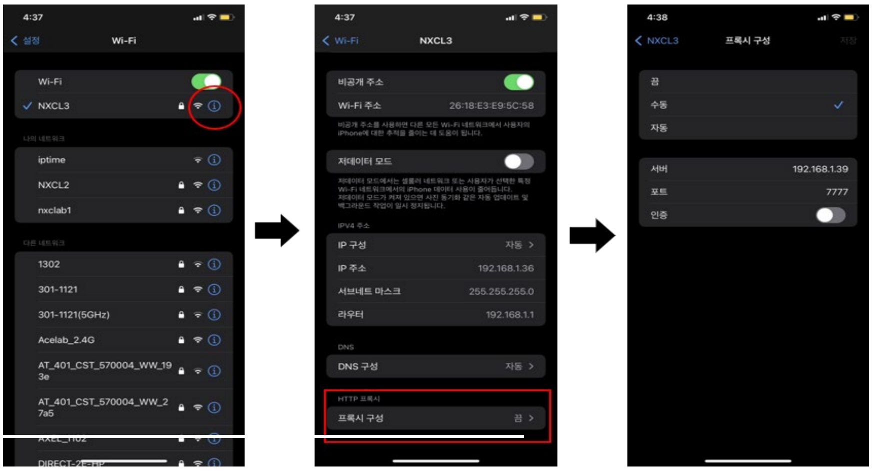


Figure 1: Overview of HTTP proxy server

1) Preparation

a) Connect VM and smartphone to the same AP (e.g., kt_SNU)

b) When you connect the smartphone to the AP, activate the advanced proxy option in WiFi menu.

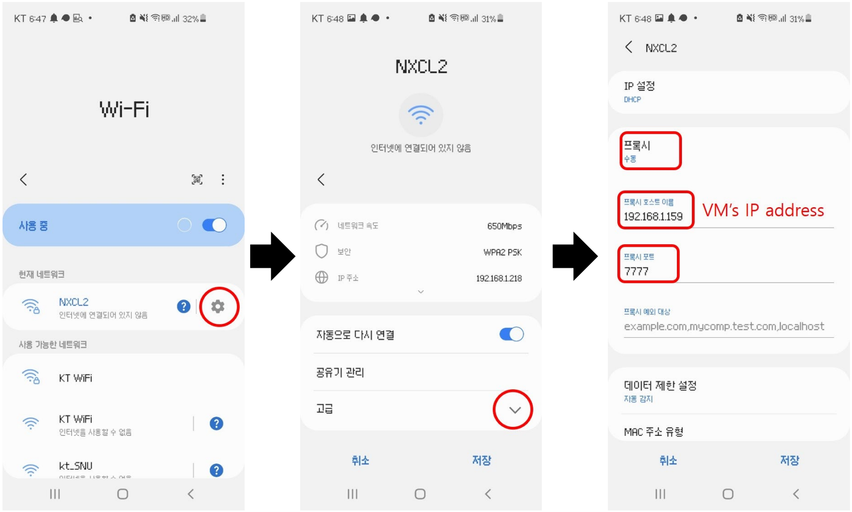


4:37
< 설정 Wi-Fi
Wi-Fi
✓ NXCL3
나의 네트워크
iptime
NXCL2
nxclab1
다른 네트워크
1302
301-1121
301-1121(5GHz)
Acelab_2.4G
AT_401_CST_570004_WW_193e
AT_401_CST_570004_WW_27a5
AXEL_1102
DIRECT-2E-HP

4:37
< Wi-Fi NXCL3
비공개 주소
Wi-Fi 주소 26:18:E3:E9:5C:58
비공개 주소를 사용하면 다른 모든 Wi-Fi 네트워크에서 사용자의 iPhone에 대한 추적을 줄이는 데 도움이 됩니다.
저데이터 모드
저데이터 모드에서는 셀룰러 네트워크 또는 사용자가 선택한 특정 Wi-Fi 네트워크에서의 iPhone 데이터 사용이 줄어듭니다. 저데이터 모드가 켜져 있으면 사진 동기화 같은 자동 업데이트 및 백그라운드 작업이 일시 정지됩니다.
IPV4 주소
IP 구성 자동 >
IP 주소 192.168.1.36
서브네트 마스크 255.255.255.0
라우터 192.168.1.1
DNS
DNS 구성 자동 >
HTTP 프록시
프록시 구성 끔 >

4:38
< NXCL3 프록시 구성 저장
끔
수동 ✓
자동
서버 192.168.1.39
포트 7777
인증

Figure 2: WiFi proxy setting in ios



KT 6:47 32%
Wi-Fi
사용 중
현재 네트워크
NXCL2
인터넷에 연결되어 있지 않음
사용 가능한 네트워크
KT WiFi
KT WiFi
인터넷을 사용할 수 없음
kt_SNU

KT 6:48 31%
NXCL2
인터넷에 연결되어 있지 않음
네트워크 속도 650Mbps
보안 WPA2 PSK
IP 주소 192.168.1.218
자동으로 다시 연결
공유기 관리
고급
취소 저장

KT 6:48 31%
< NXCL2
IP 설정
DHCP
프록시
수동
프록시 호스트 이름
192.168.1.159
VM's IP address
프록시 포트
7777
프록시 예외 대상
example.com,mycomp.test.com,localhost
데이터 제한 설정
자동 감지
MAC 주소 유형
취소 저장

Figure 3: WiFi proxy setting in Andorid

c) Run skeleton code

   i) Compile skeleton code (server.c) and run the proxy server.

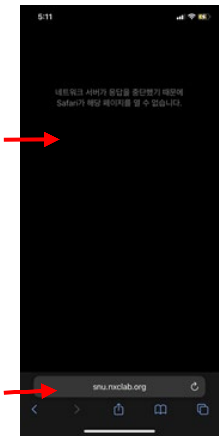
      (1) Type *make* in terminal

      (2) Type *./server* to run server.

   ii) Type in server address ("http://snu.nxclab.org:9000") in the web browser and check that the HTTP proxy server receives request successfully from the browser. (**※ test with "http://" request not "https://" because you need to implement complicated functionality for https requests**)

   iii) You can check that the proxy server shows requests from the browser.

Browser cannot show the page yet because forwarding is not implemented in the skeleton code.



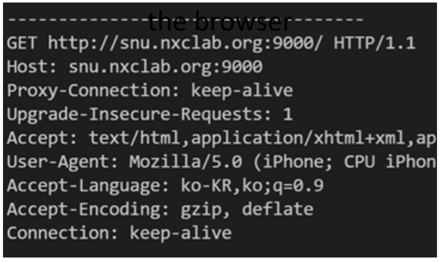
5:11

네트워크 서버가 응답을 중단했기 때문에
Safari가 해당 페이지를 열 수 없습니다.

snu.nxclab.org

Send request to http://snu.nxclab.org:9000

Result shows http request from the browser



```
--------------------------------
GET http://snu.nxclab.org:9000/ HTTP/1.1
Host: snu.nxclab.org:9000
Proxy-Connection: keep-alive
Upgrade-Insecure-Requests: 1
Accept: text/html,application/xhtml+xml,ap
User-Agent: Mozilla/5.0 (iPhone; CPU iPhon
Accept-Language: ko-KR,ko;q=0.9
Accept-Encoding: gzip, deflate
Connection: keep-alive
```

Figure 4: Example of sending a request to the web server via skeleton proxy server.

2) Implementation of request and response forwarding

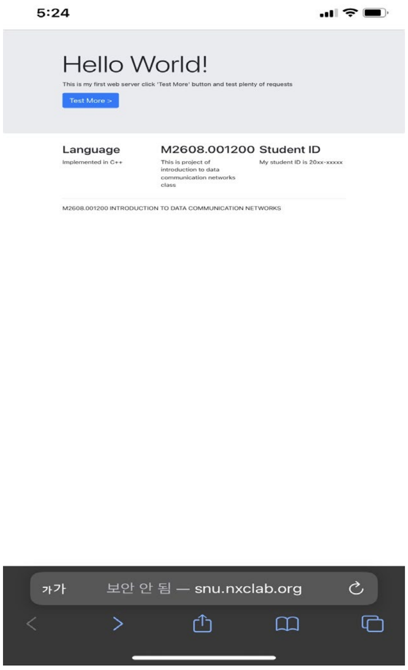
a) Forward received HTTP reques to the web server (test with http://snu.nxclab.org:9000)

   i) HInt1: The HTTP request has a hostname in the path. Take the IP address with the hostname and open a socket with the address. (use gethostbyname() function)

   ii) Hint 2: You should modify the path of the request header before forwarding it to a web server.
   ex) "GET http://snu.nxclab.org:9000/ HTTP 1.1"
   -> "GET / HTTP/1.1"

b) Receive responses from the web server and forward them to the browser.

c) If you implement all of these functionalities well, the smartphone browser will show the web page. (Please check if the browser receives images and JS/CSS files correctly. It is essential for your grade)



5:24

Hello World!

This is my first web server click 'Test More' button and test plenty of requests

Test More >

Language
Implemented in C++

M2608.001200
This is project of introduction to data communication networks class

Student ID
My student ID is 20xx-xxxxx

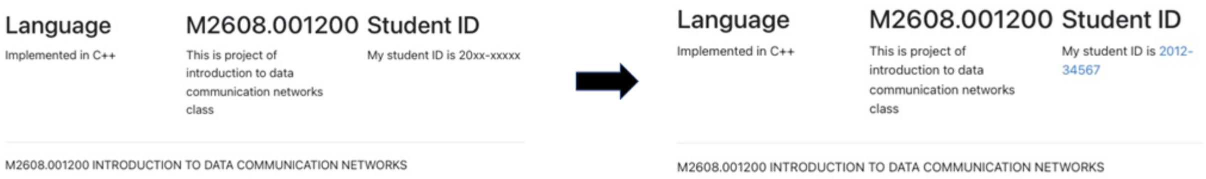
M2608.001200 INTRODUCTION TO DATA COMMUNICATION NETWORKS

가가 보안 안 됨 — snu.nxclab.org

Figure 5: Successfully rendered page in web browser.

3) Implementation of content modification in the proxy server

a) Modify HTML file before request forwarding. Then, the web browser in your smartphone shows the modified content. Replace the student id 20xx-xxxxx to your student id.



Language

Implemented in C++

M2608.001200 Student ID

This is project of introduction to data communication networks class

My student ID is 20xx-xxxxx

M2608.001200 INTRODUCTION TO DATA COMMUNICATION NETWORKS

Language

Implemented in C++

M2608.001200 Student ID

This is project of introduction to data communication networks class

My student ID is 2012-34567

M2608.001200 INTRODUCTION TO DATA COMMUNICATION NETWORKS

Figure 6: Example of content modification in proxy server.

2. Network Address Translation (NAT)

The concept of widely known NAT in a router, which we learned in the class, assigns a random port to a public address to manage private IP. But NAT in this project changes network address to the other literally. It just modifies the destination, the source address, or the port number of the packets from the client and delivers them to the server. By Figure 1, you can understand the mechanism of this simple proxy more easily. You will set up your own Ubuntu as an NAT proxy and send a request through your proxy for receiving web page by your smartphone. You will capture the packets in your proxy and report how this proxy modifies the packets and discuss the impact of this proxy.

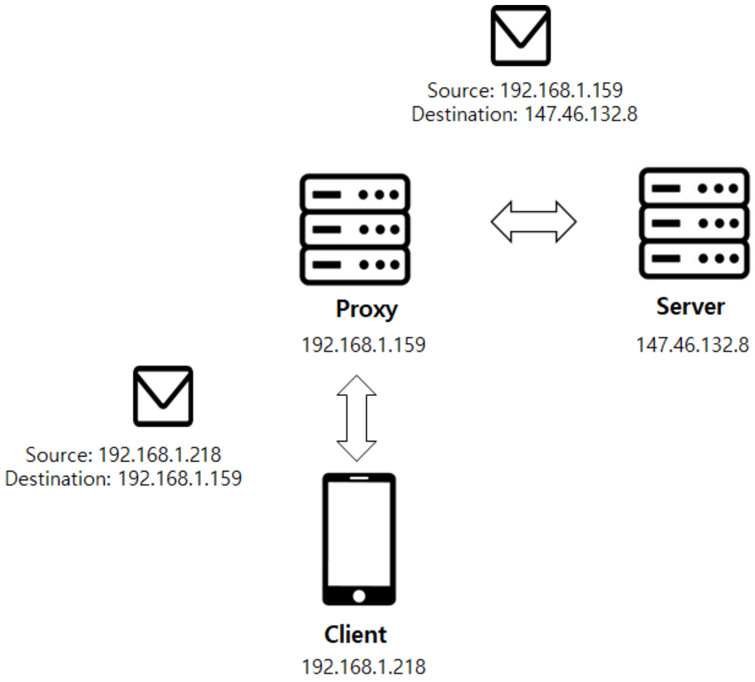


Figure 7: Client sends a packet to a proxy and the proxy modifies source and destination of packets. Then deliver the packet to server. Then, with this proxy server, the client and the server do not need to know their IP address each other. Therefore, this proxy hides the server from the client.

Background Knowledge : iptables

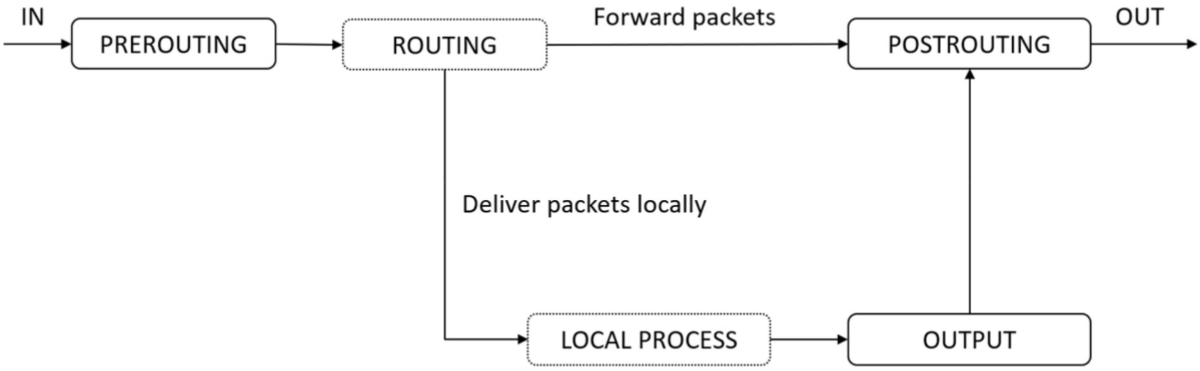


Figure 8: Overview of iptables. PREROUTING chain is responsible for packets that just arrived at the network interface. If you append a rule at PREROUTING, the rule applies to packets before being routed. After the packets are routed, they pass the POSTROUTING chain and then leaves through the network interface. Therefore, if you append a rule at POSTROUTING, the rule applied to packets after being routed.

You will use command utility ‘iptables’ to create NAT rules in the ‘nat’ table. This table has three predefined chains: PREROUTING, OUTPUT, and POSTROUTING, as in Figure 2. In this project, you will use PREROUTING and POSTROUTING chains.

- How to set rules

-t nat **- select table ‘nat’ for configuration NAT rules.**
-A [chain] **- append a rule to the corresponding chain.**
-i [network interface] **- select network interface for input packets.**
-o [network interface] **- select network interface for output packets.**
-j [action] **- set action for packets.**
--to-destination [IP address] **- set destination IP address.**
--to-source [IP address] **- set source IP address.**

Ex) Modify destination of packets to 1.2.3.4

```
Iptables -t nat -A PREROUTING -j DNAT –to-destination 1.2.3.4 Ex)
```

Ex) Modify the source of packets to 1.2.3.4

```
Iptables -t nat -A POSTROUTING -o wlp3s0 -j SNAT –to-source 1.2.3.4
```

*** DNAT (Destination Network Address Translation): Modify destination of the packets.**
*** SNAT (Source Network Address Translation): Modify the source of the packets.**

1) Enabling IP Forwarding on Ubuntu

To set up your Ubuntu as an NAT proxy, you should enable IP forwarding.

One line command

```
sudo sysctl -w net.ipv4.ip_forward=1
```

or

```
sudo echo 1 > /proc/sys/net/ipv4/ip_forward
```

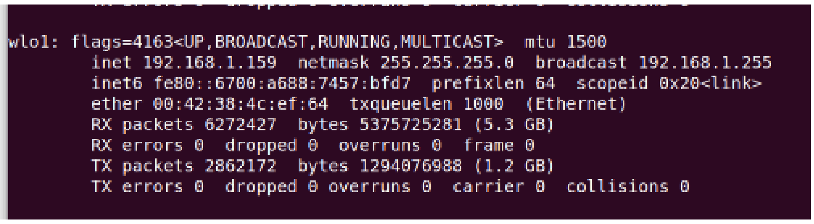
- **Reset your iptables**

```
sudo iptables -F

sudo iptables -X

sudo iptables -t nat -F

sudo iptables -t nat -X

sudo iptables -t mangle -F

sudo iptables -t mangle -X

sudo iptables -P INPUT ACCEPT

sudo iptables -P FORWARD ACCEPT

sudo iptables -P OUTPUT ACCEPT
```

2) Set Forwarding Rules on your Proxy

- Connect your proxy (Ubuntu VM) and smartphone to same WIFI network.

  - Take the IP address and network interface name (e.g. wlo1 or wlp3s0) of your proxy with “ifconfig” command line.



```
wlo1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.159  netmask 255.255.255.0  broadcast 192.168.1.255
        inet6 fe80::6700:a688:7457:bfd7  prefixlen 64  scopeid 0x20<link>
        ether 00:42:38:4c:ef:64  txqueuelen 1000  (Ethernet)
        RX packets 6272427  bytes 5375725281 (5.3 GB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2862172  bytes 1294076988 (1.2 GB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

- **(Rule1) Append DNAT rule to the PREROUTING Table**

```
sudo iptables -t nat -A PREROUTING -j DNAT -p tcp --to-destination 147.46.132.8:9000
```

*** 147.46.132.8 : web page address (use this for testing)**

- **(Rule2) Append SNAT rule to the POSTROUTING Table**

```
sudo iptables -t nat -A POSTROUTING -j SNAT -o eth0 --to-source 192.168.1.159
```

*** 192.168.1.159 : change this IP to your VM's IP.**

- **Check that you appended two rules correctly**

```
sudo iptables -t nat --list
```

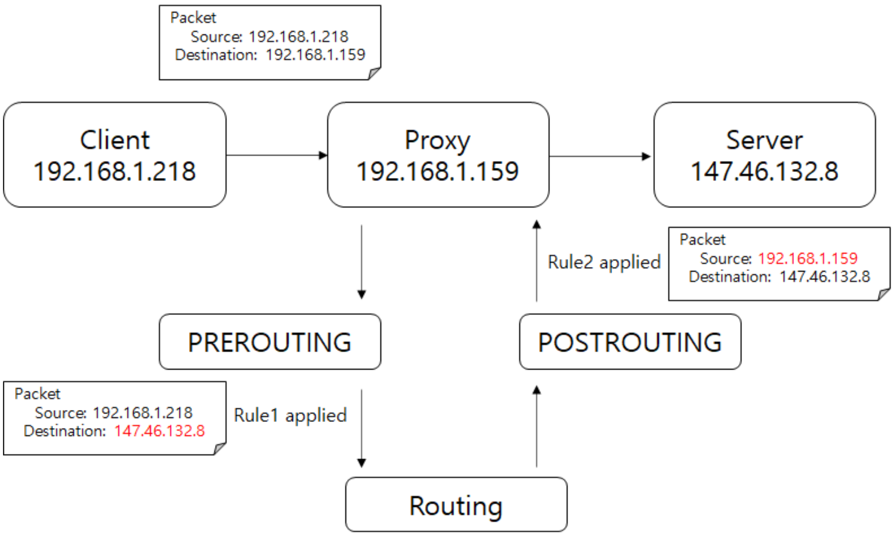


Figure 9: Overview of iptables operation.

3) Packet capture with tcpdump & wireshark

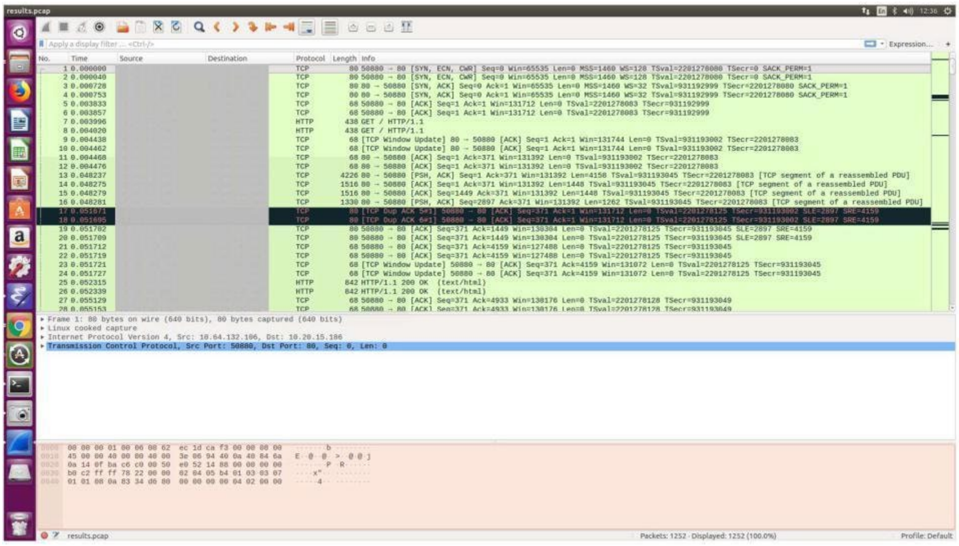
In this project, you should report how this proxy server works with capturing packets on the proxy. You can capture packets which pass through network interface with 'tcpdump' and show the results with 'wireshark.'

After setting up the rules, execute 'tcpdump' with following command line and request to proxy by your smartphone browser.

```
sudo tcpdump -i eth0 tcp port 9000 -w results_1.pcap
```

```
sudo tcpdump -i eth1 tcp port 9000 -w results_2.pcap
```

If your browser show web page successfully, stop ‘tcpdump’(press Ctrl+C).
Drag results.pcap to Wireshark in Windows/MAC



```
No.  Time      Source  Destination  Protocol Length Info
   1 0.000000                       TCP        80 50880 → 80 [SYN, ECN, CWR] Seq=0 Win=65535 Len=0 MSS=1460 WS=128 TSval=2201278080 TSecr=0 SACK_PERM=1
   2 0.000040                       TCP        80 50880 → 80 [SYN, ECN, CWR] Seq=0 Win=65535 Len=0 MSS=1460 WS=128 TSval=2201278080 TSecr=0 SACK_PERM=1
   3 0.000728                       TCP        80 80 → 50880 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460 WS=32 TSval=931192999 TSecr=2201278080 SACK_PERM=1
   4 0.000753                       TCP        80 80 → 50880 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460 WS=32 TSval=931192999 TSecr=2201278080 SACK_PERM=1
   5 0.003833                       TCP        68 50880 → 80 [ACK] Seq=1 Ack=1 Win=131712 Len=0 TSval=2201278083 TSecr=931192999
   6 0.003857                       TCP        68 50880 → 80 [ACK] Seq=1 Ack=1 Win=131712 Len=0 TSval=2201278083 TSecr=931192999
   7 0.003996                       HTTP      438 GET / HTTP/1.1
   8 0.004020                       HTTP      438 GET / HTTP/1.1
   9 0.004438                       TCP        68 [TCP Window Update] 80 → 50880 [ACK] Seq=1 Ack=1 Win=131744 Len=0 TSval=931193002 TSecr=2201278083
  10 0.004462                       TCP        68 [TCP Window Update] 80 → 50880 [ACK] Seq=1 Ack=1 Win=131744 Len=0 TSval=931193002 TSecr=2201278083
  11 0.004468                       TCP        68 80 → 50880 [ACK] Seq=1 Ack=371 Win=131392 Len=0 TSval=931193002 TSecr=2201278083
  12 0.004476                       TCP        68 80 → 50880 [ACK] Seq=1 Ack=371 Win=131392 Len=0 TSval=931193002 TSecr=2201278083
  13 0.048237                       TCP      4226 80 → 50880 [PSH, ACK] Seq=1 Ack=371 Win=131392 Len=4158 TSval=931193045 TSecr=2201278083 [TCP segment of a reassembled PDU]
  14 0.048275                       TCP      1516 80 → 50880 [ACK] Seq=1 Ack=371 Win=131392 Len=1448 TSval=931193045 TSecr=2201278083 [TCP segment of a reassembled PDU]
  15 0.048279                       TCP      1516 80 → 50880 [ACK] Seq=1449 Ack=371 Win=131392 Len=1448 TSval=931193045 TSecr=2201278083 [TCP segment of a reassembled PDU]
  16 0.048281                       TCP      1330 80 → 50880 [PSH, ACK] Seq=2897 Ack=371 Win=131392 Len=1262 TSval=931193045 TSecr=2201278083 [TCP segment of a reassembled PDU]
  17 0.051671                       TCP        80 [TCP Dup ACK 5#1] 50880 → 80 [ACK] Seq=371 Ack=1 Win=131712 Len=0 TSval=2201278125 TSecr=931193002 SLE=2897 SRE=4159
  18 0.051695                       TCP        80 [TCP Dup ACK 6#1] 50880 → 80 [ACK] Seq=371 Ack=1 Win=131712 Len=0 TSval=2201278125 TSecr=931193002 SLE=2897 SRE=4159
  19 0.051702                       TCP        80 50880 → 80 [ACK] Seq=371 Ack=1449 Win=130304 Len=0 TSval=2201278125 TSecr=931193045 SLE=2897 SRE=4159
  20 0.051709                       TCP        80 50880 → 80 [ACK] Seq=371 Ack=1449 Win=130304 Len=0 TSval=2201278125 TSecr=931193045 SLE=2897 SRE=4159
  21 0.051712                       TCP        68 50880 → 80 [ACK] Seq=371 Ack=4159 Win=127488 Len=0 TSval=2201278125 TSecr=931193045
  22 0.051719                       TCP        68 50880 → 80 [ACK] Seq=371 Ack=4159 Win=127488 Len=0 TSval=2201278125 TSecr=931193045
  23 0.051721                       TCP        68 [TCP Window Update] 50880 → 80 [ACK] Seq=371 Ack=4159 Win=131072 Len=0 TSval=2201278125 TSecr=931193045
  24 0.051727                       TCP        68 [TCP Window Update] 50880 → 80 [ACK] Seq=371 Ack=4159 Win=131072 Len=0 TSval=2201278125 TSecr=931193045
  25 0.052315                       HTTP      842 HTTP/1.1 200 OK  (text/html)
  26 0.052339                       HTTP      842 HTTP/1.1 200 OK  (text/html)
  27 0.055129                       TCP        68 50880 → 80 [ACK] Seq=371 Ack=4933 Win=130176 Len=0 TSval=2201278128 TSecr=931193049
  28 0.055153                       TCP        68 50880 → 80 [ACK] Seq=371 Ack=4933 Win=130176 Len=0 TSval=2201278128 TSecr=931193049
```

```
▸ Frame 1: 80 bytes on wire (640 bits), 80 bytes captured (640 bits)
▸ Linux cooked capture
▸ Internet Protocol Version 4, Src: 10.64.132.106, Dst: 10.20.15.106
▸ Transmission Control Protocol, Src Port: 50880, Dst Port: 80, Seq: 0, Len: 0
```

```
0000  00 00 00 01 00 06 00 62  ec 1d ca f3 00 00 00 00   .......b ........
0010  45 00 00 40 00 00 40 00  3e 06 94 40 0a 40 84 6a   E..@..@. >..@.@.j
0020  0a 14 0f ba c6 c0 00 50  e0 52 14 88 00 00 00 00   .......P .R......
0030  b0 c2 ff ff 78 22 00 00  02 04 05 b4 01 03 03 07   ....x".. ........
0040  01 01 08 0a 83 34 d6 80  00 00 00 00 04 02 00 00   .....4.. ........
```

results.pcap   Packets: 1252 · Displayed: 1252 (100.0%)   Profile: Default

Figure 10: Example of Wireshark

4) Report

So far, you have implemented a simple HTTP proxy server and NAT rules. In the report, you should explain how you implemented them in details. Note that you must include ‘wireshark’ screenshot in your report. Then, you should list the pros and cons of proxy and NAT and compare them. Finally, you need to suggest a simple web page caching HTTP proxy with a pseudocode. If you have implemented HTTP proxy and NAT, you can understand them enough to write your report.

4. Grading Policy

- **[HTTP Proxy Server] Forwarding: 30%**
- **[HTTP Proxy Server] Content Modification: 30%**
- **[NAT] Report: 40%**

5. Submission

- Make a directory “**proxyserver_<student_id>**” and compress to a zip file.
- A zip file should contain the report and your codes.
- Submit the zip file to eTL.