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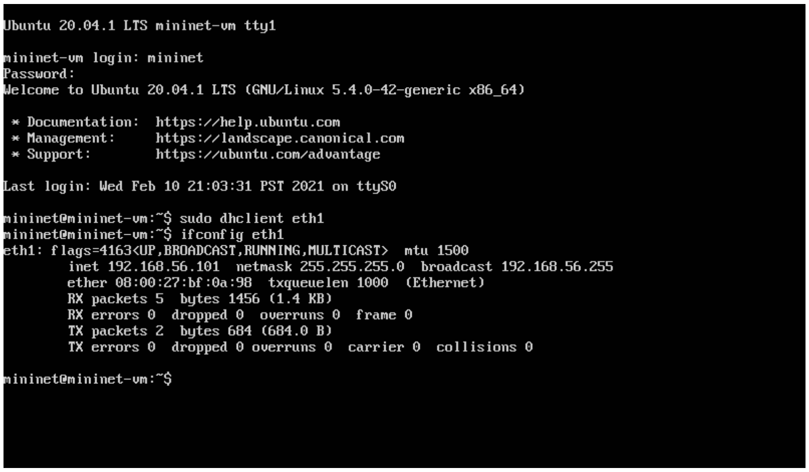
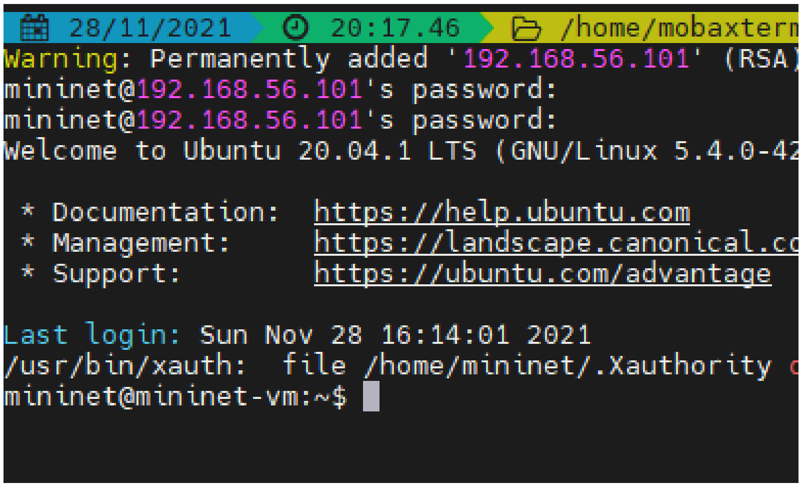
20121-12/03

ECE 4436A Lab 3: UDP and TCP

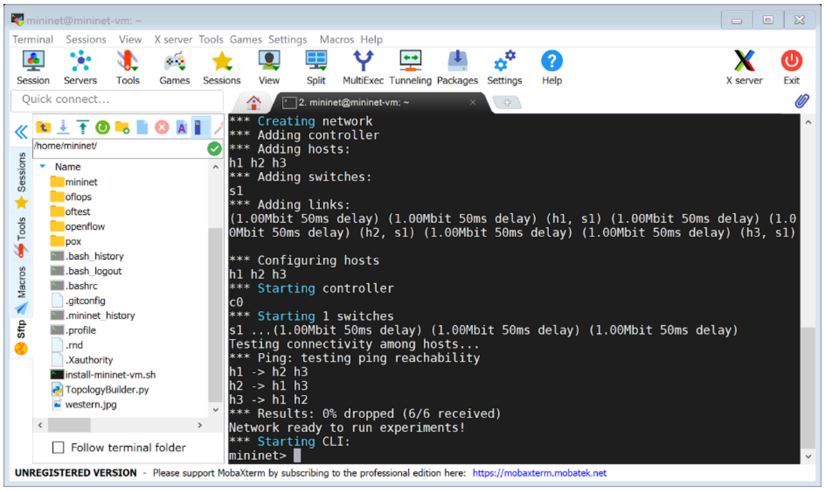
Task 1: Setting Up Network Emulation Environment



```
Ubuntu 20.04.1 LTS mininet-vm tty1

mininet-vm login: mininet
Password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

Last login: Wed Feb 10 21:03:31 PST 2021 on ttyS0

mininet@mininet-vm:~$ sudo dhclient eth1
mininet@mininet-vm:~$ ifconfig eth1
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.56.101  netmask 255.255.255.0  broadcast 192.168.56.255
        ether 08:00:27:bf:0a:98  txqueuelen 1000  (Ethernet)
        RX packets 5  bytes 1456 (1.4 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2  bytes 684 (684.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

mininet@mininet-vm:~$
```



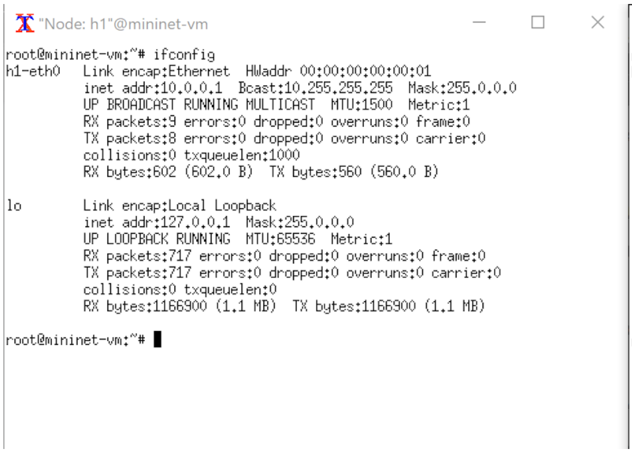
```
  28/11/2021    20:17.46    /home/mobaxterm
Warning: Permanently added '192.168.56.101' (RSA)
mininet@192.168.56.101's password:
mininet@192.168.56.101's password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.co
 * Support:        https://ubuntu.com/advantage

Last login: Sun Nov 28 16:14:01 2021
/usr/bin/xauth:  file /home/mininet/.Xauthority c
mininet@mininet-vm:~$
```



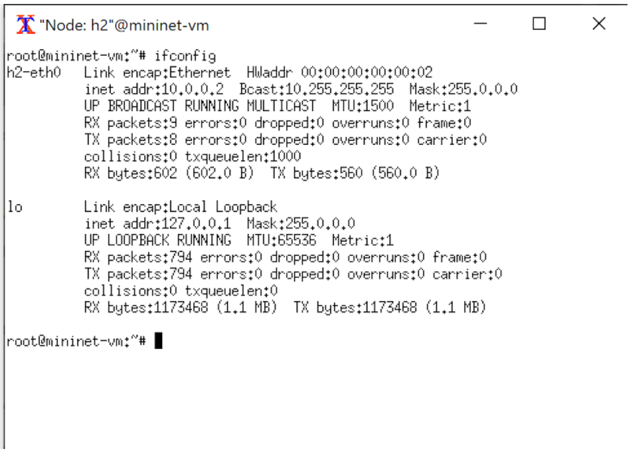
```
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3
*** Adding switches:
s1
*** Adding links:
(1.00Mbit 50ms delay) (1.00Mbit 50ms delay) (h1, s1) (1.00Mbit 50ms delay) (1.0
0Mbit 50ms delay) (h2, s1) (1.00Mbit 50ms delay) (1.00Mbit 50ms delay) (h3, s1)

*** Configuring hosts
h1 h2 h3
*** Starting controller
c0
*** Starting 1 switches
s1 ...(1.00Mbit 50ms delay) (1.00Mbit 50ms delay) (1.00Mbit 50ms delay)
Testing connectivity among hosts...
*** Ping: testing ping reachability
h1 -> h2 h3
h2 -> h1 h3
h3 -> h1 h2
*** Results: 0% dropped (6/6 received)
Network ready to run experiments!
*** Starting CLI:
mininet>
```

UNREGISTERED VERSION - Please support MobaXterm by subscribing to the professional edition here: https://mobaxterm.mobatek.net

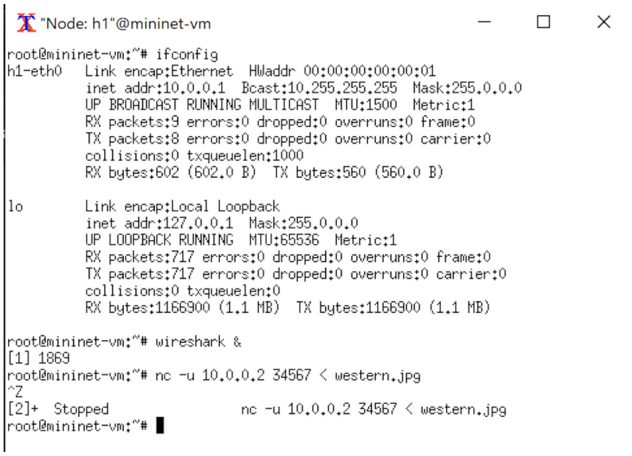
Task 2: Transmitting Packets Using UDP Protocol



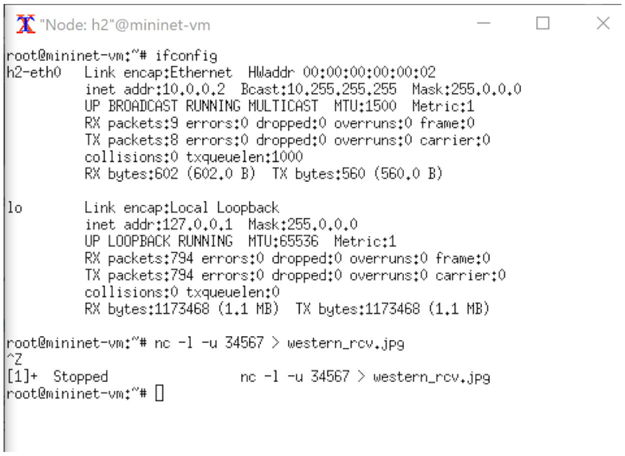
```
root@mininet-vm:~# ifconfig
h1-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:01
          inet addr:10.0.0.1  Bcast:10.255.255.255  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:602 (602.0 B)  TX bytes:560 (560.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:717 errors:0 dropped:0 overruns:0 frame:0
          TX packets:717 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:1166900 (1.1 MB)  TX bytes:1166900 (1.1 MB)

root@mininet-vm:~# █
```



```
root@mininet-vm:~# ifconfig
h2-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:02
          inet addr:10.0.0.2  Bcast:10.255.255.255  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:602 (602.0 B)  TX bytes:560 (560.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:794 errors:0 dropped:0 overruns:0 frame:0
          TX packets:794 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:1173468 (1.1 MB)  TX bytes:1173468 (1.1 MB)

root@mininet-vm:~# █
```



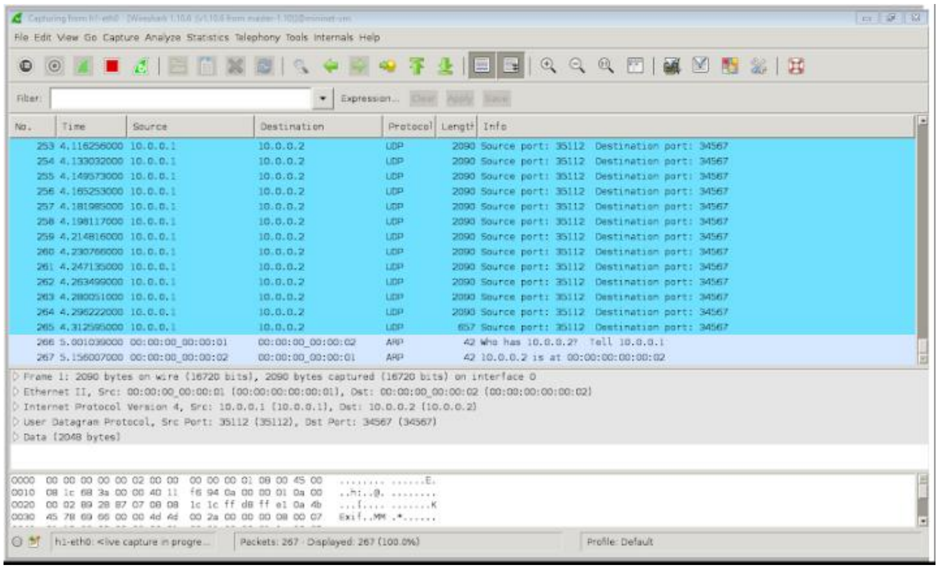
```
root@mininet-vm:~# ifconfig
h1-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:01
          inet addr:10.0.0.1  Bcast:10.255.255.255  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:602 (602.0 B)  TX bytes:560 (560.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:717 errors:0 dropped:0 overruns:0 frame:0
          TX packets:717 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:1166900 (1.1 MB)  TX bytes:1166900 (1.1 MB)

root@mininet-vm:~# wireshark &
[1] 1869
root@mininet-vm:~# nc -u 10.0.0.2 34567 < western.jpg
^Z
[2]+  Stopped                 nc -u 10.0.0.2 34567 < western.jpg
root@mininet-vm:~# █
```



```
root@mininet-vm:~# ifconfig
h2-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:02
          inet addr:10.0.0.2  Bcast:10.255.255.255  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:602 (602.0 B)  TX bytes:560 (560.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:794 errors:0 dropped:0 overruns:0 frame:0
          TX packets:794 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:1173468 (1.1 MB)  TX bytes:1173468 (1.1 MB)

root@mininet-vm:~# nc -l -u 34567 > western_rcv.jpg
^Z
[1]+  Stopped                 nc -l -u 34567 > western_rcv.jpg
root@mininet-vm:~# □
```

Q1: Explore the capture information to answer: How long did it take to transfer the file? Are there UDP packets in both directions, i.e. from h1 to h2 and from h2 to h1? Justify your answers. [10 marks]

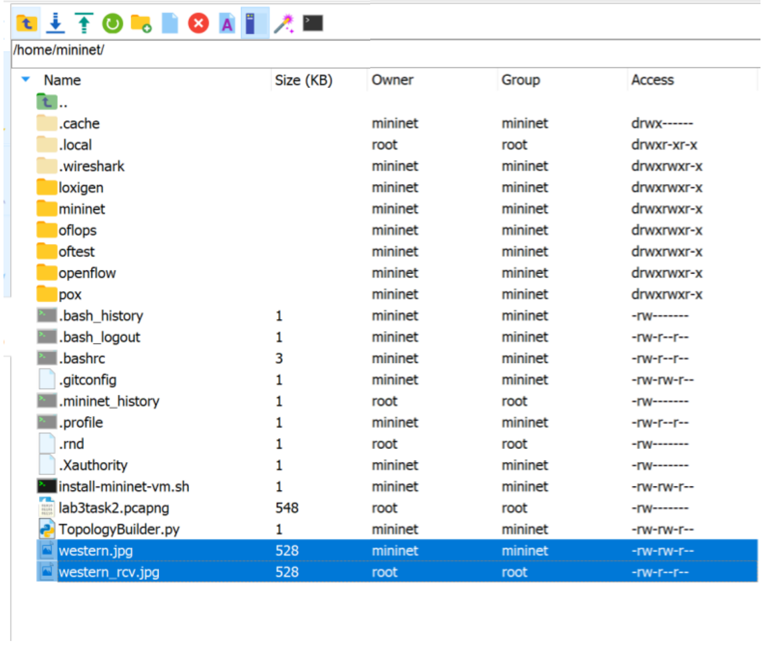
It took approx. 4.312596ms to transfer the file from h1 to h2. h1 does not need a response from h2 using the UDP protocol as UDP packets are only sent in one direction (h1 to h2).


File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression...
Clear
Apply
Save

```
No.   Time         Source               Destination          Protocol Length Info
  253 4.116256000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  254 4.133032000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  255 4.149573000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  256 4.165253000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  257 4.181985000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  258 4.198117000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  259 4.214816000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  260 4.230766000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  261 4.247135000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  262 4.263499000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  263 4.280051000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  264 4.296222000  10.0.0.1             10.0.0.2             UDP      2090 Source port: 35112  Destination port: 34567
  265 4.312595000  10.0.0.1             10.0.0.2             UDP       657 Source port: 35112  Destination port: 34567
  266 5.001039000  00:00:00_00:00:01    00:00:00_00:00:02    ARP         42 Who has 10.0.0.2?  Tell 10.0.0.1
  267 5.156007000  00:00:00_00:00:02    00:00:00_00:00:01    ARP         42 10.0.0.2 is at 00:00:00:00:00:02

▷ Frame 1: 2090 bytes on wire (16720 bits), 2090 bytes captured (16720 bits) on interface 0
▷ Ethernet II, Src: 00:00:00_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00_00:00:02 (00:00:00:00:00:02)
▷ Internet Protocol Version 4, Src: 10.0.0.1 (10.0.0.1), Dst: 10.0.0.2 (10.0.0.2)
▷ User Datagram Protocol, Src Port: 35112 (35112), Dst Port: 34567 (34567)
▷ Data (2048 bytes)

0000  00 00 00 00 00 02 00 00  00 00 00 01 08 00 45 00   ........ ......E.
0010  08 1c 68 3a 00 00 40 11  f6 94 0a 00 00 01 0a 00   ..h:..@. ........
0020  00 02 89 28 87 07 08 08  1c 1c ff d8 ff e1 0a 4b   ...(.... .......K
0030  45 78 69 66 00 00 4d 4d  00 2a 00 00 00 08 00 07   Exif..MM .*......

h1-eth0: <live capture in progre...   Packets: 267 · Displayed: 267 (100.0%)   Profile: Default
```

Q2: Is the received image same as the original test file? Do they have the same size? Include screenshots in your answer sheet.

The received image is the same as the sent image, exact same file and size. Since the transfer was over a virtual network within the host, there was no loss of data during transfer

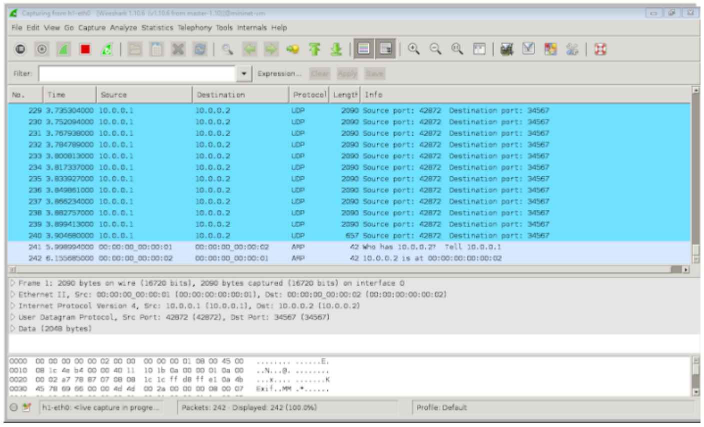


/home/mininet/

Name	Size (KB)	Owner	Group	Access
..				
.cache		mininet	mininet	drwx------
.local		root	root	drwxr-xr-x
.wireshark		mininet	mininet	drwxrwxr-x
loxigen		mininet	mininet	drwxrwxr-x
mininet		mininet	mininet	drwxrwxr-x
oflops		mininet	mininet	drwxrwxr-x
oftest		mininet	mininet	drwxrwxr-x
openflow		mininet	mininet	drwxrwxr-x
pox		mininet	mininet	drwxrwxr-x
.bash_history	1	mininet	mininet	-rw-------
.bash_logout	1	mininet	mininet	-rw-r--r--
.bashrc	3	mininet	mininet	-rw-r--r--
.gitconfig	1	mininet	mininet	-rw-rw-r--
.mininet_history	1	root	root	-rw-------
.profile	1	mininet	mininet	-rw-r--r--
.rnd	1	root	root	-rw-------
.Xauthority	1	mininet	mininet	-rw-------
install-mininet-vm.sh	1	mininet	mininet	-rw-rw-r--
lab3task2.pcapng	548	root	root	-rw-------
TopologyBuilder.py	1	mininet	mininet	-rw-rw-r--
western.jpg	528	mininet	mininet	-rw-rw-r--
western_rcv.jpg	528	root	root	-rw-r--r--

Q3: Did you find any significant difference in Q1 and Q2? Justify your answers.

In Q2 there is 10% less packets to transfer, thus packets were transferred 0.407915ms quicker than in Q1. The received image is not the same as the sent image, because a 10% chunk of data is missing thus the file size decreased by 10%.



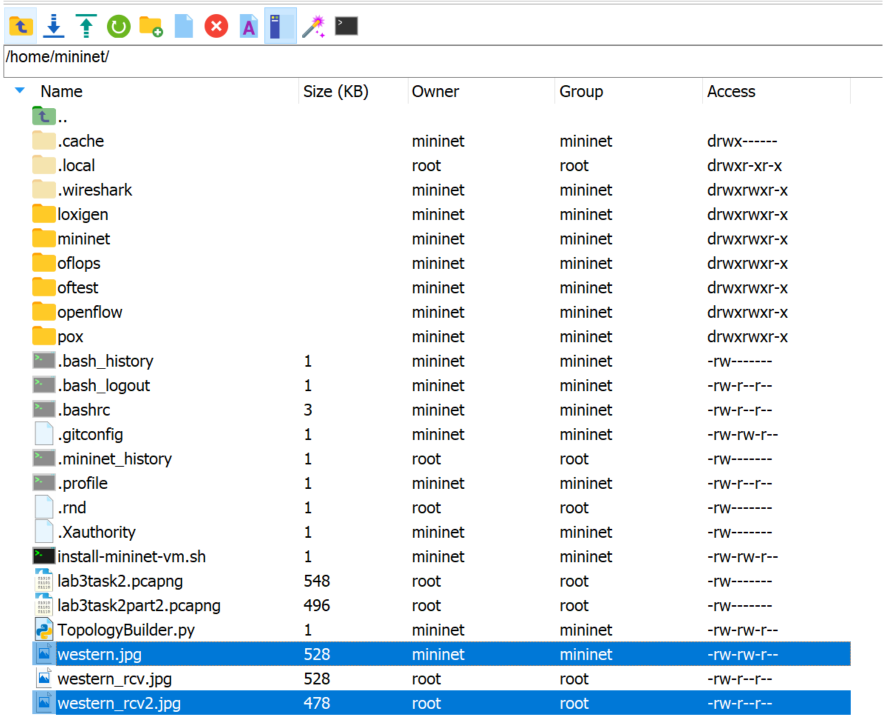
Capturing from h1-eth0 [Wireshark 1.10.6 (v1.10.6 from master-1.10)]@mininet-vm
File Edit View Go Capture Analyze Statistics Telephony Internals Help
Filter:
Expression...
Clear
Apply
Save

No.	Time	Source	Destination	Protocol	Length	Info
229	3.735304000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
230	3.752094000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
231	3.767938000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
232	3.784789000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
233	3.800813000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
234	3.817337000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
235	3.833927000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
236	3.849861000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
237	3.866234000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
238	3.882757000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
239	3.899413000	10.0.0.1	10.0.0.2	UDP	2090	Source port: 42872 Destination port: 34567
240	3.904680000	10.0.0.1	10.0.0.2	UDP	657	Source port: 42872 Destination port: 34567
241	5.998994000	00:00:00_00:00:01	00:00:00_00:00:02	ARP	42	Who has 10.0.0.2? Tell 10.0.0.1
242	6.155685000	00:00:00_00:00:02	00:00:00_00:00:01	ARP	42	10.0.0.2 is at 00:00:00:00:00:02

```
▷ Frame 1: 2090 bytes on wire (16720 bits), 2090 bytes captured (16720 bits) on interface 0
▷ Ethernet II, Src: 00:00:00_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00_00:00:02 (00:00:00:00:00:02)
▷ Internet Protocol Version 4, Src: 10.0.0.1 (10.0.0.1), Dst: 10.0.0.2 (10.0.0.2)
▷ User Datagram Protocol, Src Port: 42872 (42872), Dst Port: 34567 (34567)
▷ Data (2048 bytes)
```

```
0000  00 00 00 00 00 02 00 00  00 00 00 01 08 00 45 00   ........ ......E.
0010  08 1c 4e b4 00 00 40 11  10 1b 0a 00 00 01 0a 00   ..N...@. ........
0020  00 02 a7 78 87 07 08 08  1c 1c ff d8 ff e1 0a 4b   ...x.... .......K
0030  45 78 69 66 00 00 4d 4d  00 2a 00 00 00 08 00 07   Exif..MM .*......
```

h1-eth0: <live capture in progre... | Packets: 242 · Displayed: 242 (100.0%) | Profile: Default



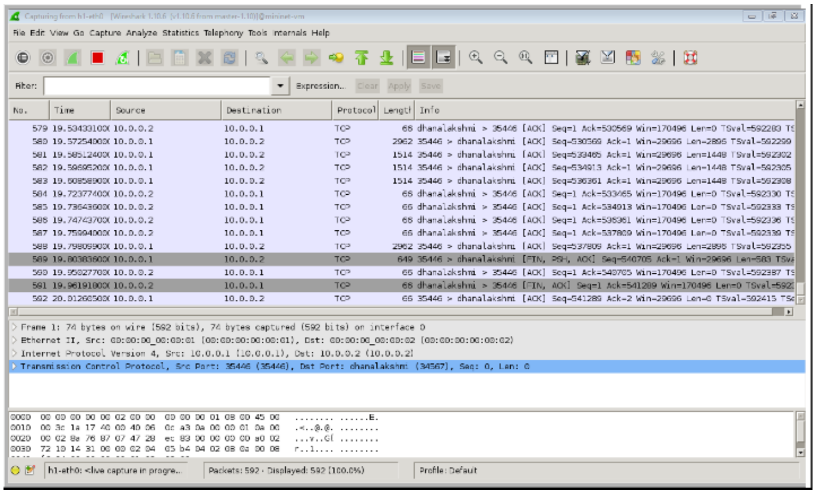
/home/mininet/

Name	Size (KB)	Owner	Group	Access
..				
.cache		mininet	mininet	drwx------
.local		root	root	drwxr-xr-x
.wireshark		mininet	mininet	drwxrwxr-x
loxigen		mininet	mininet	drwxrwxr-x
mininet		mininet	mininet	drwxrwxr-x
oflops		mininet	mininet	drwxrwxr-x
oftest		mininet	mininet	drwxrwxr-x
openflow		mininet	mininet	drwxrwxr-x
pox		mininet	mininet	drwxrwxr-x
.bash_history	1	mininet	mininet	-rw-------
.bash_logout	1	mininet	mininet	-rw-r--r--
.bashrc	3	mininet	mininet	-rw-r--r--
.gitconfig	1	mininet	mininet	-rw-rw-r--
.mininet_history	1	root	root	-rw-------
.profile	1	mininet	mininet	-rw-r--r--
.rnd	1	root	root	-rw-------
.Xauthority	1	mininet	mininet	-rw-------
install-mininet-vm.sh	1	mininet	mininet	-rw-rw-r--
lab3task2.pcapng	548	root	root	-rw-------
lab3task2part2.pcapng	496	root	root	-rw-------
TopologyBuilder.py	1	mininet	mininet	-rw-rw-r--
western.jpg	528	mininet	mininet	-rw-rw-r--
western_rcv.jpg	528	root	root	-rw-r--r--
western_rcv2.jpg	478	root	root	-rw-r--r--

Task 3: Transmitting Packets Using TCP Protocol

Q4: Explore the capture information to answer: How long did it take to transfer the file? Are there TCP packets in both directions, i.e. from h1 to h2 and from h2 to h1? Justify your answers.

It took approx. 20ms to transfer the file, longer than UDP protocol. The TCP packets are present in both directions, since h2 must be ACK/NACK when receiving packets to ensure reliable data transfer.

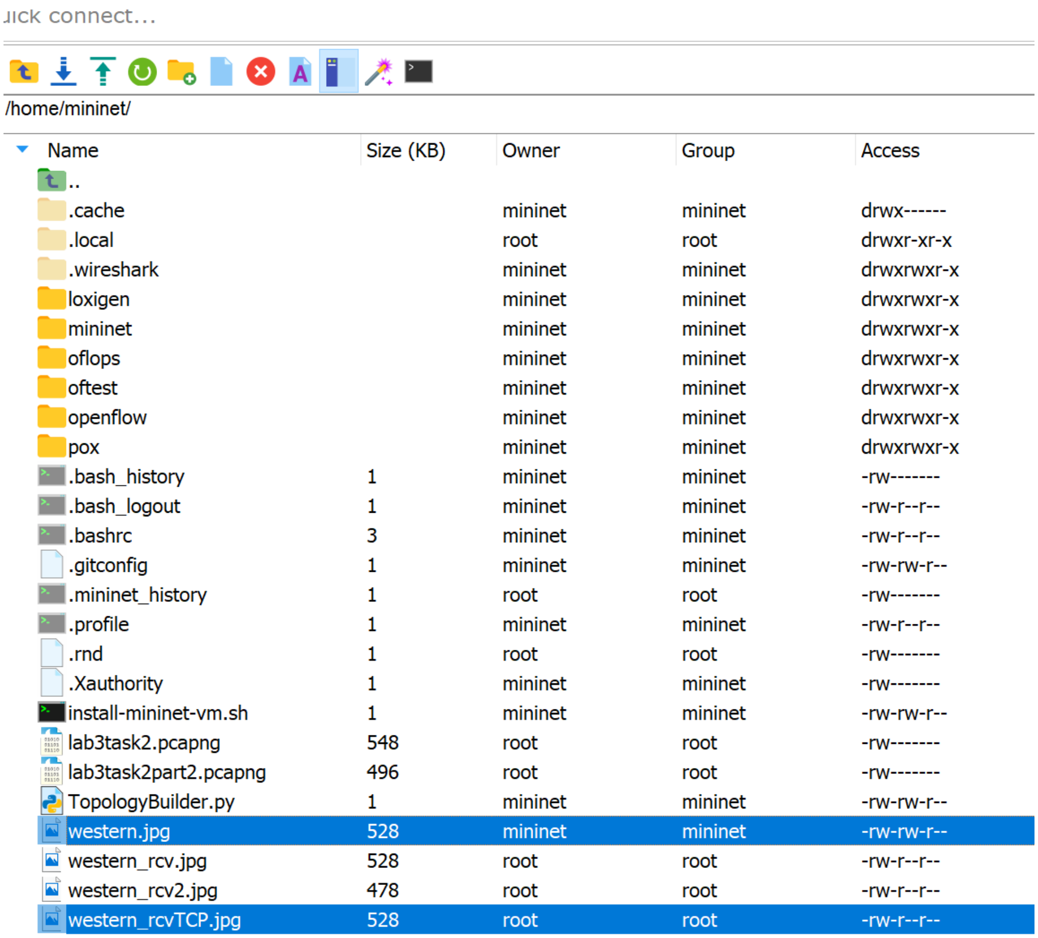


Capturing from h1-eth0 [Wireshark 1.10.6 (v1.10.6 from master-1.10)]@mininet-vm
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save

```
No.  Time          Source    Destination  Protocol Length Info
 579 19.534331000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=530569 Win=170496 Len=0 TSval=592283 TS
 580 19.572540000  10.0.0.1  10.0.0.2     TCP      2962 35446 > dhanalakshmi [ACK] Seq=530569 Ack=1 Win=29696 Len=2896 TSval=592299
 581 19.585124000  10.0.0.1  10.0.0.2     TCP      1514 35446 > dhanalakshmi [ACK] Seq=533465 Ack=1 Win=29696 Len=1448 TSval=592302
 582 19.596952000  10.0.0.1  10.0.0.2     TCP      1514 35446 > dhanalakshmi [ACK] Seq=534913 Ack=1 Win=29696 Len=1448 TSval=592305
 583 19.608589000  10.0.0.1  10.0.0.2     TCP      1514 35446 > dhanalakshmi [ACK] Seq=536361 Ack=1 Win=29696 Len=1448 TSval=592308
 584 19.723774000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=533465 Win=170496 Len=0 TSval=592330 TS
 585 19.735436000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=534913 Win=170496 Len=0 TSval=592333 TS
 586 19.747437000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=536361 Win=170496 Len=0 TSval=592336 TS
 587 19.759940000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=537809 Win=170496 Len=0 TSval=592339 TS
 588 19.798059000  10.0.0.1  10.0.0.2     TCP      2962 35446 > dhanalakshmi [ACK] Seq=537809 Ack=1 Win=29696 Len=2896 TSval=592355
 589 19.803836000  10.0.0.1  10.0.0.2     TCP       649 35446 > dhanalakshmi [FIN, PSH, ACK] Seq=540705 Ack=1 Win=29696 Len=583 TSva
 590 19.950277000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [ACK] Seq=1 Ack=540705 Win=170496 Len=0 TSval=592387 TS
 591 19.961918000  10.0.0.2  10.0.0.1     TCP        66 dhanalakshmi > 35446 [FIN, ACK] Seq=1 Ack=541289 Win=170496 Len=0 TSval=592
 592 20.012685000  10.0.0.1  10.0.0.2     TCP        66 35446 > dhanalakshmi [ACK] Seq=541289 Ack=2 Win=29696 Len=0 TSval=592415 TSe

> Frame 1: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
> Ethernet II, Src: 00:00:00_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00_00:00:02 (00:00:00:00:00:02)
> Internet Protocol Version 4, Src: 10.0.0.1 (10.0.0.1), Dst: 10.0.0.2 (10.0.0.2)
> Transmission Control Protocol, Src Port: 35446 (35446), Dst Port: dhanalakshmi (34567), Seq: 0, Len: 0

0000  00 00 00 00 00 02 00 00  00 00 00 01 08 00 45 00   ........ ......E.
0010  00 3c 1a 17 40 00 40 06  0c a3 0a 00 00 01 0a 00   .<..@.@. ........
0020  00 02 8a 76 87 07 47 28  ec 83 00 00 00 00 a0 02   ...v..G( ........
0030  72 10 14 31 00 00 02 04  05 b4 04 02 08 0a 00 08   r..1.... ........

h1-eth0: <live capture in progre...   Packets: 592 · Displayed: 592 (100.0%)   Profile: Default
```

Q5: Is the received image same as the original test file? Do they have the same size?

Yes, the received image is the same as the original test file and also have the same size.

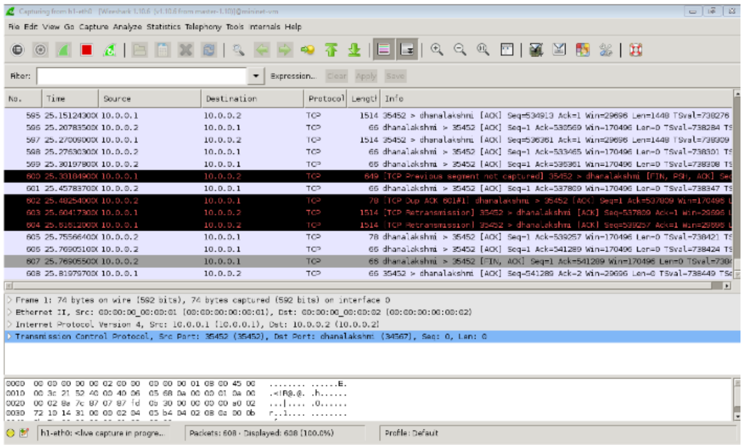


/home/mininet/

Name	Size (KB)	Owner	Group	Access
..				
.cache		mininet	mininet	drwx------
.local		root	root	drwxr-xr-x
.wireshark		mininet	mininet	drwxrwxr-x
loxigen		mininet	mininet	drwxrwxr-x
mininet		mininet	mininet	drwxrwxr-x
oflops		mininet	mininet	drwxrwxr-x
oftest		mininet	mininet	drwxrwxr-x
openflow		mininet	mininet	drwxrwxr-x
pox		mininet	mininet	drwxrwxr-x
.bash_history	1	mininet	mininet	-rw-------
.bash_logout	1	mininet	mininet	-rw-r--r--
.bashrc	3	mininet	mininet	-rw-r--r--
.gitconfig	1	mininet	mininet	-rw-rw-r--
.mininet_history	1	root	root	-rw-------
.profile	1	mininet	mininet	-rw-r--r--
.rnd	1	root	root	-rw-------
.Xauthority	1	mininet	mininet	-rw-------
install-mininet-vm.sh	1	mininet	mininet	-rw-rw-r--
lab3task2.pcapng	548	root	root	-rw-------
lab3task2part2.pcapng	496	root	root	-rw-------
TopologyBuilder.py	1	mininet	mininet	-rw-rw-r--
western.jpg	528	mininet	mininet	-rw-rw-r--
western_rcv.jpg	528	root	root	-rw-r--r--
western_rcv2.jpg	478	root	root	-rw-r--r--
western_rcvTCP.jpg	528	root	root	-rw-r--r--

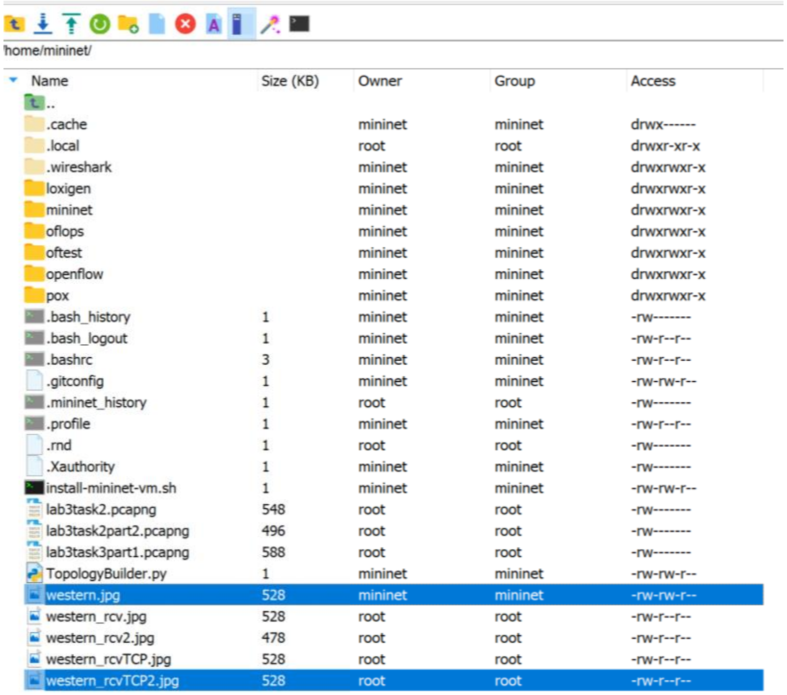
Q6: Did you find any significant difference in Q4 and Q5? Justify your answers.

The time to transfer the file was approx. 5ms longer, as lost packets needed to be resent. However, the final product is the same as TCP ensures reliable file transfer, every lost packet was resent to ensure complete file transfer.



Capturing from h1-eth0 [Wireshark 1.10.6 (v1.10.6 from master-1.10)]@mininet-vm
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save

```
No.  Time          Source    Destination Protocol Length Info
 595 25.15124300( 10.0.0.1  10.0.0.2    TCP      1514 35452 > dhanalakshmi [ACK] Seq=534913 Ack=1 Win=29696 Len=1448 TSval=738276
 596 25.20783500( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [ACK] Seq=1 Ack=530569 Win=170496 Len=0 TSval=738284 TS
 597 25.27009000( 10.0.0.1  10.0.0.2    TCP      1514 35452 > dhanalakshmi [ACK] Seq=536361 Ack=1 Win=29696 Len=1448 TSval=738309
 598 25.27630300( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [ACK] Seq=1 Ack=533465 Win=170496 Len=0 TSval=738301 TS
 599 25.30197800( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [ACK] Seq=1 Ack=536361 Win=170496 Len=0 TSval=738308 TS
 600 25.33184900( 10.0.0.1  10.0.0.2    TCP       649 [TCP Previous segment not captured] 35452 > dhanalakshmi [FIN, PSH, ACK] Seq
 601 25.45783700( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [ACK] Seq=1 Ack=537809 Win=170496 Len=0 TSval=738347 TS
 602 25.48254000( 10.0.0.2  10.0.0.1    TCP        78 [TCP Dup ACK 601#1] dhanalakshmi > 35452 [ACK] Seq=1 Ack=537809 Win=170496 L
 603 25.60417300( 10.0.0.1  10.0.0.2    TCP      1514 [TCP Retransmission] 35452 > dhanalakshmi [ACK] Seq=537809 Ack=1 Win=29696 L
 604 25.61612000( 10.0.0.1  10.0.0.2    TCP      1514 [TCP Retransmission] 35452 > dhanalakshmi [ACK] Seq=539257 Ack=1 Win=29696 L
 605 25.75566400( 10.0.0.2  10.0.0.1    TCP        78 dhanalakshmi > 35452 [ACK] Seq=1 Ack=539257 Win=170496 Len=0 TSval=738421 TS
 606 25.76905100( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [ACK] Seq=1 Ack=541289 Win=170496 Len=0 TSval=738424 TS
 607 25.76905500( 10.0.0.2  10.0.0.1    TCP        66 dhanalakshmi > 35452 [FIN, ACK] Seq=1 Ack=541289 Win=170496 Len=0 TSval=738
 608 25.81979700( 10.0.0.1  10.0.0.2    TCP        66 35452 > dhanalakshmi [ACK] Seq=541289 Ack=2 Win=29696 Len=0 TSval=738449 TSe

> Frame 1: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
> Ethernet II, Src: 00:00:00_00:00:01 (00:00:00:00:00:01), Dst: 00:00:00_00:00:02 (00:00:00:00:00:02)
> Internet Protocol Version 4, Src: 10.0.0.1 (10.0.0.1), Dst: 10.0.0.2 (10.0.0.2)
> Transmission Control Protocol, Src Port: 35452 (35452), Dst Port: dhanalakshmi (34567), Seq: 0, Len: 0

0000  00 00 00 00 00 02 00 00  00 00 00 01 08 00 45 00   ........ ......E.
0010  00 3c 21 52 40 00 40 06  05 68 0a 00 00 01 0a 00   .<!R@.@. .h......
0020  00 02 8a 7c 87 07 87 fd  0b 30 00 00 00 00 a0 02   ...|.... .0......
0030  72 10 14 31 00 00 02 04  05 b4 04 02 08 0a 00 0b   r..1.... ........

h1-eth0: <live capture in progre...   Packets: 608 · Displayed: 608 (100.0%)   Profile: Default
```



/home/mininet/

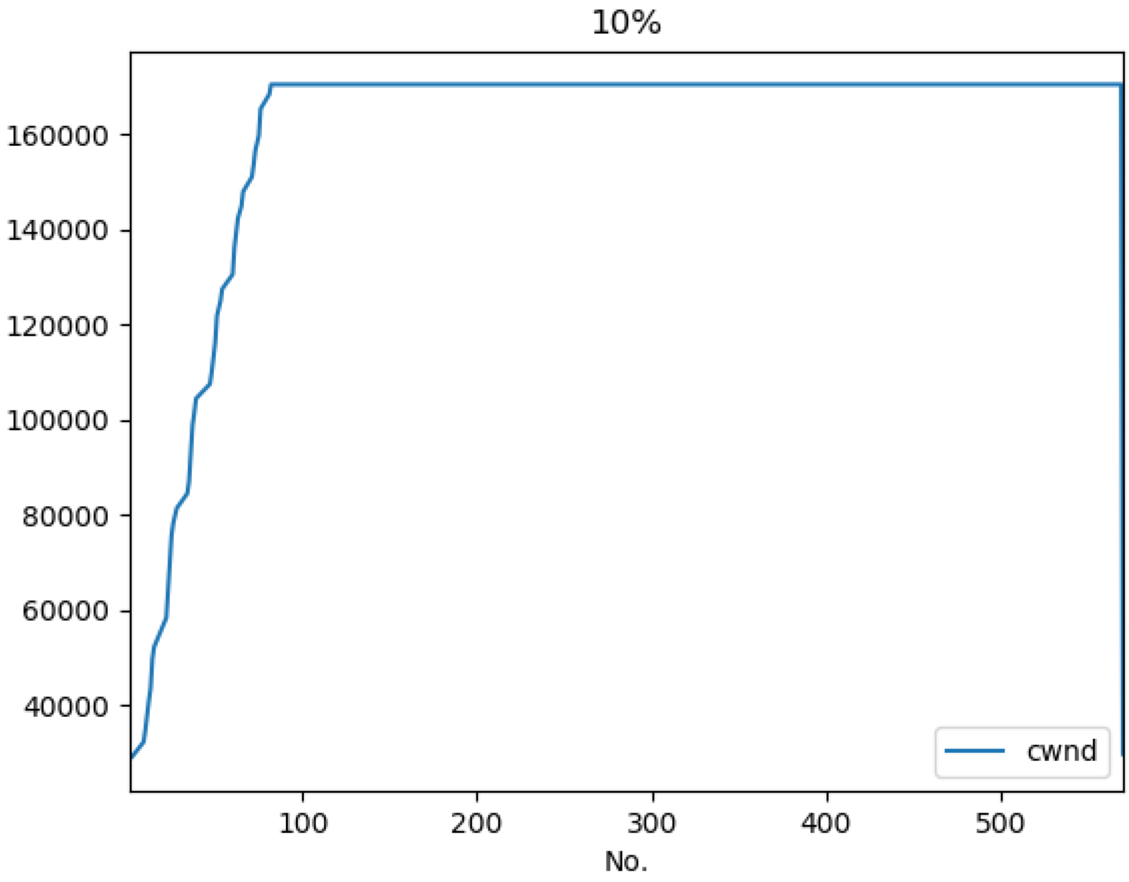
Name	Size (KB)	Owner	Group	Access
..				
.cache		mininet	mininet	drwx------
.local		root	root	drwxr-xr-x
.wireshark		mininet	mininet	drwxrwxr-x
loxigen		mininet	mininet	drwxrwxr-x
mininet		mininet	mininet	drwxrwxr-x
oflops		mininet	mininet	drwxrwxr-x
oftest		mininet	mininet	drwxrwxr-x
openflow		mininet	mininet	drwxrwxr-x
pox		mininet	mininet	drwxrwxr-x
.bash_history	1	mininet	mininet	-rw-------
.bash_logout	1	mininet	mininet	-rw-r--r--
.bashrc	3	mininet	mininet	-rw-r--r--
.gitconfig	1	mininet	mininet	-rw-rw-r--
.mininet_history	1	root	root	-rw-------
.profile	1	mininet	mininet	-rw-r--r--
.rnd	1	root	root	-rw-------
.Xauthority	1	mininet	mininet	-rw-------
install-mininet-vm.sh	1	mininet	mininet	-rw-rw-r--
lab3task2.pcapng	548	root	root	-rw-------
lab3task2part2.pcapng	496	root	root	-rw-------
lab3task3part1.pcapng	588	root	root	-rw-------
TopologyBuilder.py	1	mininet	mininet	-rw-rw-r--
western.jpg	528	mininet	mininet	-rw-rw-r--
western_rcv.jpg	528	root	root	-rw-r--r--
western_rcv2.jpg	478	root	root	-rw-r--r--
western_rcvTCP.jpg	528	root	root	-rw-r--r--
western_rcvTCP2.jpg	528	root	root	-rw-r--r--

Task 4: Visualizing the TCP Congestion Control Mechanism [60 marks]

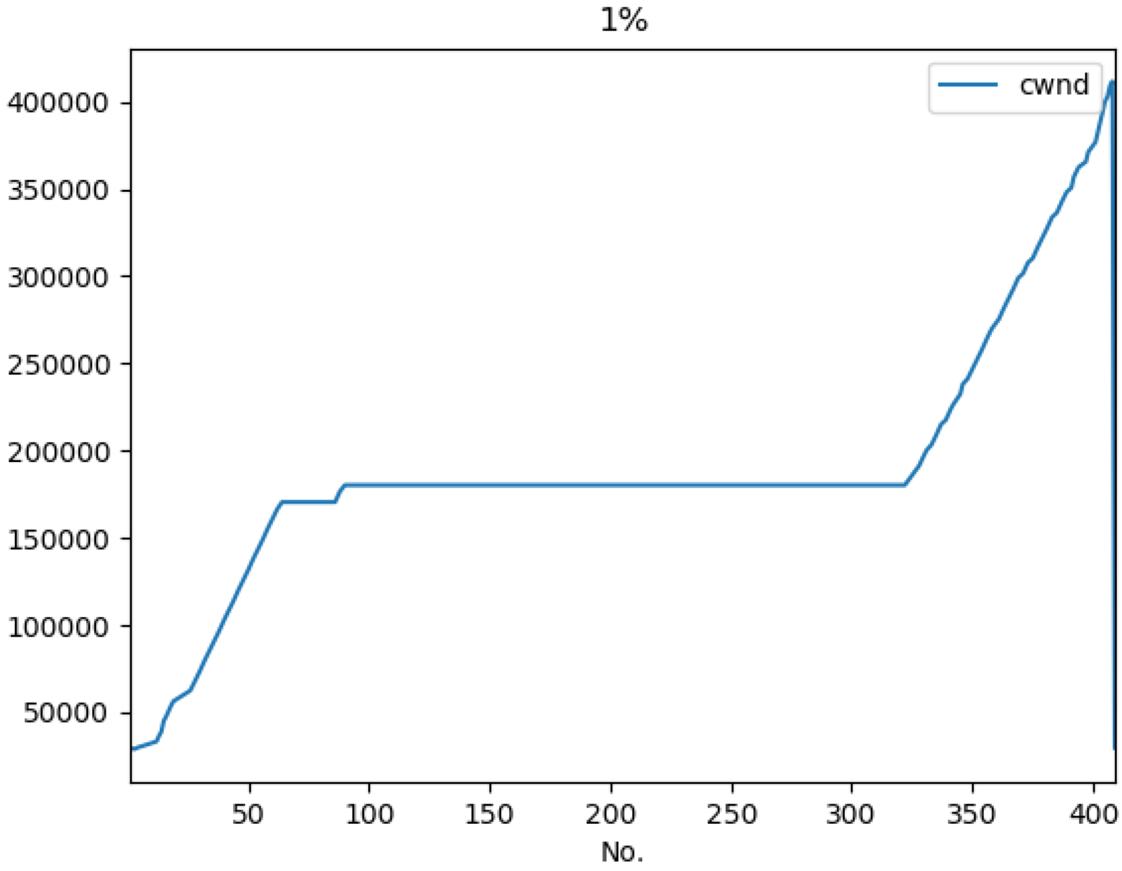
Q7: : Write a Python 3 program to visualize how the congestion window varies over time. Although the actual congestion window (CWND) is an internal variable on the sender side and it is not advertised by the TCP protocol, the Wireshark Protocol Analyzer provides a calculated window value, which is the "Win=XXXXX" data in the Info field. Then, from the CSV files extract the frame time and the window size value. The output of your program should be two plots of window size versus time (corresponding to h1 and h3 traffic). Include screenshots in your answer sheet.

NOTE: You may use different available Python 3 libraries for this part such as matplotlib, seaborn, numpy, and csv.

H1 Traffic (10% loss)



H3 Traffic (1% loss)



Q8: Explain how different the plots are. Why? [10 marks]

The plots differ evident when analyzing the shape of each graph. The H1 traffic begins with exponential growth for a short period of time, and for approx. 500 No. the window size remains constant. As opposed to the H3 traffic where the window size initially grows over No. remains at a constant size and at approx. 325 No. continues to grow. In both graphs there is a drop at the end of the the No. allotted to indicate the loss of size over time. H1 appears to be more 'stable' than H3, initially because the congestion window scale is less than H3, meaning H1 experiences more traffic. However, with 10% loss we can retract the idea that H1 is more stable. As, H3 only has a 1% congestion loss and reaches higher scales of congestion. Although, it does run for less No. than H1 to be fair and there are still losses in both graphs regardless.