Homework 2 - System Monitoring and VM Networking

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Listings

1 Kessler Paper

1.1 ARP and Types of Addressing

The Address Resolution Protocol (ARP) is a method for determining the MAC address correlated with an IP address it needs.

A machine address differs from a network address in that it is used on a lower logical layer of the network stack. MAC addresses are used to refer to a specific interface on a specific machine, whereas a network address like an IP address is used for the more general concept of finding and addressing machines between different networks.

1.2 DHCP

The Dynamic Host Configuration Protocol (DHCP) was created to provide a way to assign IP addresses to host on a network in an automated fashion. This is useful for two reasons:

- Users don't have to manually choose an IP address.
- Administrators don't have to keep IP addresses reserved for longer than necessary.

To make things even simpler, DHCP is useful for networks that change Internet Service Providers and subsequently changing their IP address. Without DHCP, admins would need to reassign IP addresses on all their machines in this scenario.

At a high level, DHCP works by the following steps:

1. Send a broadcast message asking for an available DHCP server.
2. Receive responses from candidate DHCP server(s).
3. Choose a DHCP server and ask it for an IP address.
4. DHCP server responds with an IP address that is good until end of lease.
5. When the lease ends, ask for a renewal.
6. Gracefully end the DHCP lease.

2 System Monitoring

I created the script discussed below and named it `hw2-Q2.sh`. Then, in order for cron to use it, I issued a `` `sudo crontab -e` `` to edit the crontab. Then, I placed the following line to get the program to run once a day at 5am:

```
0 5  *   *   *     cd /home/jared/Documents/code/udpecho; ./hw2-Q2.sh > /tmp/cron-hw2-$(date +\%F).log 2>&1
```

2.1 Config file

The config file in Listing 2 is read by the monitoring script in Listing 1. To make things simple, the config file is simply `sourced` by the script as if it were a bash file. Thus, the format for setting variables is the same as one would do in any bash script.

2.1.1 Variables

- `disk_max` (percent) - disk usage threshold.
- `bw_max` (kbits/s) - total bandwidth usage threshold per interface.

2.2 Disk Usage

This part of the script simply calls the UNIX program `du` and picks out the disk usage info for the root filesystem. If the percentage threshold specified in the config file is exceeded, the script will calculate and print the disk usage by each user's folder in the `/home` directory. Values are reported by percentage.

2.3 Authentication Failure Monitoring

Here, I decided to go a different route than parsing through `/var/log/auth.log`. My motivation for doing this is that there seems to be no standard searchable message for different authentication failures. For example, failing to authenticate to the root user when using `su` results in this log message:

```
Feb 27 21:42:56 hotdog su[4642]: pam_unix(su:auth): authentication failure; logname=jared uid=1000 euid=0 tty=/
    dev/pts/10 ruser=jared rho
st=  user=root
Feb 27 21:42:58 hotdog su[4642]: pam_authenticate: Authentication failure
Feb 27 21:42:58 hotdog su[4642]: FAILED su for root by jared
Feb 27 21:42:58 hotdog su[4642]: - /dev/pts/10 jared:root
```

While failing to authenticate using `sudo` results in a different message:

```
Feb 28 01:50:40 hotdog sudo:    jared : 1 incorrect password attempt ; TTY=pts/1 ; PWD=/home/jared/Documents/
    code/udpecho ; USER=root ; COMMAND=/bin/echo hi
```

So, I chose to install the program `auditd` and use one of its utility programs `aureport` to get more accurate authentication statistics. This program is available in the Ubuntu repositories. Some of its better features that I made use of were its ability to report just the authentication failures and its ability to filter only events within particular time ranges. In this case, the script outputs the number of failures over the past 24 hours.

2.4 Bandwidth Measurement

This was a more challenging part of the project mainly because of drawbacks with the particular network monitoring tool I chose to use, `vnstat`. This program is similarly available in the Ubuntu repositories. While it's a great program to use on the command line for getting a quick idea of what's going on with the network, it was more difficult to script against without mucking with its database.

Ultimately, I had the program list out the available `eth*` interfaces, then I measure the bandwidth usage on each interface for 5 seconds. Since `vnstat` only outputs separate send and receive measurements, I had to do some manual adjustments to add these two numbers together with correct units in order to get a picture of total bandwidth usage.

2.5 Sample output

```
Disk usage on /: 60%

Failed login attempts by user:
------------------------------
8 root
7 jared
```

```
7
8  Analyzing bandwidth usage by interface:
9  ---------------------------------------
10
11 Bandwidth used over 5 seconds on interface eth0...
12 24.00 kbits/s
13
14 Bandwidth used over 5 seconds on interface eth1...
15 20130.00 kbits/s
16 WARNING: bandwidth threshold 100 kbits/s exceeded!
```

3 VM Networking

The script shown in Listing 3 is a pretty straightforward implementation of the problem statement in the assignment document. A parameter valued 1 through 4 is provided to the script to identify which part of the question the script should perform. The first two parts simply run `iperf3` for 20 seconds, whereas the second pair of parts run `iperf3` while simultaneously running `UDPEchoClient` at varying rates.

Program output for parts 1 through 4 can be found in Listing 4 through Listing 11.

3.1 Discussion

The results of the first two parts (UDP and TCP `iperf3` executions) can largely be seen as controls for the experiments I performed in parts 3 and 4. The UDP execution saw a packet drop rate of roughly 0.25 percent, while the TCP execution window size had a mode of 130 KBytes.

In parts 3 and 4, I varied the interval delay by values 10^{-i}, where $i \in \{1, 2, 3, 4\}$. Most of the results in part 3 were unsurprising: in order of decreasing delay time, I saw packet losses of 1.6, 0.2, 1.2, and 2.4 percent. Most of these seemed to make sense, except for the 0.2 percent result attributed to the delay time of 0.1 s. Jitter was another interesting variable; in order of decreasing delay times I saw 0.099, 0.051, 0.456, and 0.114 ms jitter. Again, the 0.1 s delay time seemed to outperform the slower delay time of 1 s.

The results of part 4 were similarly difficult to predict. Some delay values resulted in large window sizes, while others led to smaller ones. There did not seem to be a strong correlation in any case.

4 Code

Listing 1: hw2-Q2.sh

```
1  #!/bin/bash
2
3  # read config file variables
4  source ./monitor.conf
5
6  root=($(df | awk '{ gsub(/%/, ""); if ($6 == "/") print $5 " " $3}'))
7  usage=${root[0]}
8  total=${root[1]}
9  echo "Disk usage on /: $usage%"
10
11 if [[ $usage -gt $disk_max ]]; then
12   echo "WARNING: disk usage threshold $disk_max exceeded!"
13   for user in /home/*; do
14     du -s $user | awk -v total=$total '{ printf("%.1f%% %s\n", 100*$1/total, $2) }'
15   done
16 fi
17
18
19 # The program aureport can be found in the 'auditd' package available
20 # in the standard Ubuntu repositories. It provides more comprehensive
21 # login attempt info than the difficult to analyze auth.log file.
22 echo
23 echo "Failed login attempts by user:"
24 echo "------------------------------"
25 sudo aureport -au -i --failed -ts yesterday $(date +%H:%M:%S) | tail -n+6 \
26   | awk '{arr[$4]++} END{for (i in arr) print arr[i] " " i}' | sort -nr
27
28
29 # vnstat can similarly be installed via apt-get package 'vnstat'
30 echo
31 echo "Analyzing bandwidth usage by interface:"
32 echo "---------------------------------------"
```

```
ifaces=($(vnstat --iflist | cut -d' ' -f3- | tr " " "\n\r" | grep "^eth"))
for iface in ${ifaces[@]}; do
  echo
  echo "Bandwidth used over 5 seconds on interface $iface..."

  vals=($(IFS=$'\n' vnstat -tr -i $iface | tail -n+4 | grep -v -e '^[[:space:]]*$' | awk '{print $2 $3}'))

  eq=
  for val in ${vals[@]}; do
    eq+=$(units $val 'bits/s' | awk 'NR==1{print $2}')
    eq+=" + "
  done
  eq+="0"
  eq=$(echo "$eq" | sed -e 's/e+*/\*10\^/g')

  result=$(echo "scale=2; ($eq) / 1000" | bc -l)
  echo "$result kbits/s"

  if [[ $(echo $result '>' $bw_max | bc) -eq 1 ]]; then
    echo "WARNING: bandwidth threshold $bw_max kbits/s exceeded!"
  fi
done
```

Listing 2: monitor.conf

```
disk_max=90
bw_max=100
```

Listing 3: hw2-Q3.sh

```
#!/bin/bash

if [[ $# -ne 3 ]] && [[ $# -ne 4 ]]; then
  echo "Invalid parameters"
  echo "Syntax: $0 experiment_number host_ip host_port [echo_port]"
  exit 1
fi

case "$1" in
  1) #UDP
    iperf3 -p $3 -c $2 -b 20m -u -i 1 -t 20
    ;;
  2) #TCP
    iperf3 -p $3 -c $2 -b 20m -i 1 -t 20
    ;;
  3) #UDP with echo program running
    if [[ $# -ne 4 ]]; then
      echo "Invalid parameters"
      echo "Syntax: $0 experiment_number host_ip host_port echo_port"
      exit 1
    fi
    for i in '1' '0.1' '0.01' '0.001'; do
      # modified client to output ping info to stderr
      ./client $2 $4 $i 1024 2>/dev/null &
      client=$!
      iperf3 -p $3 -c $2 -b 20m -u -i 1 -t 20
      kill -INT $client
    done
    ;;
  4) #TCP with echo program running
    if [[ $# -ne 4 ]]; then
      echo "Invalid parameters"
      echo "Syntax: $0 experiment_number host_ip host_port echo_port"
      exit 1
    fi
    for i in '1' '0.1' '0.01' '0.001'; do
      # modified client to output ping info to stderr
      ./client $2 $4 $i 1024 2>/dev/null &
      client=$!
      iperf3 -p $3 -c $2 -b 20m -i 1 -t 20
      kill -INT $client
    done
    ;;
  *)
    echo "Invalid experiment number"
```

```
    echo "Syntax: $0 experiment_number host_ip host_port [echo_port]"
    exit 1
esac
```

Listing 4: q3p1.log

```
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 33676 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec  2.17 MBytes  18.2 Mbits/sec  278
[  4]   1.00-2.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   2.00-3.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   5.00-6.00   sec  2.40 MBytes  20.1 Mbits/sec  307
[  4]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]   7.00-8.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   8.00-9.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  11.00-12.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  12.00-13.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  14.00-15.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  15.00-16.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]  17.00-18.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  18.00-19.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  19.00-20.00  sec  2.38 MBytes  20.0 Mbits/sec  305
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec  0.128 ms  15/6076 (0.25%)
[  4] Sent 6076 datagrams

iperf Done.
```

Listing 5: q3p1-server.log

```
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42917
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 33676
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  2.17 MBytes  18.2 Mbits/sec  0.194 ms  0/278 (0%)
[  5]   1.00-2.00   sec  2.38 MBytes  20.0 Mbits/sec  0.133 ms  0/305 (0%)
[  5]   2.00-3.00   sec  2.38 MBytes  20.0 Mbits/sec  0.077 ms  0/305 (0%)
[  5]   3.00-4.00   sec  2.35 MBytes  19.7 Mbits/sec  0.278 ms  4/305 (1.3%)
[  5]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  0.091 ms  0/305 (0%)
[  5]   5.00-6.00   sec  2.40 MBytes  20.1 Mbits/sec  0.408 ms  0/307 (0%)
[  5]   6.00-7.00   sec  2.29 MBytes  19.2 Mbits/sec  0.206 ms  11/304 (3.6%)
[  5]   7.00-8.00   sec  2.38 MBytes  20.0 Mbits/sec  0.167 ms  0/305 (0%)
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec  0.119 ms  0/304 (0%)
[  5]   9.00-10.00  sec  2.39 MBytes  20.0 Mbits/sec  0.092 ms  0/306 (0%)
[  5]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  0.102 ms  0/305 (0%)
[  5]  11.00-12.00  sec  2.39 MBytes  20.1 Mbits/sec  0.133 ms  0/306 (0%)
[  5]  12.00-13.00  sec  2.38 MBytes  20.0 Mbits/sec  0.104 ms  0/305 (0%)
[  5]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  0.127 ms  0/305 (0%)
[  5]  14.00-15.00  sec  2.38 MBytes  20.0 Mbits/sec  0.161 ms  0/305 (0%)
[  5]  15.00-16.00  sec  2.39 MBytes  20.1 Mbits/sec  1.447 ms  0/306 (0%)
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec  0.085 ms  0/304 (0%)
[  5]  17.00-18.00  sec  2.39 MBytes  20.0 Mbits/sec  0.140 ms  0/306 (0%)
[  5]  18.00-19.00  sec  2.38 MBytes  20.0 Mbits/sec  0.070 ms  0/305 (0%)
[  5]  19.00-20.00  sec  2.38 MBytes  20.0 Mbits/sec  0.128 ms  0/305 (0%)
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.128 ms  0/0 (0%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.128 ms  15/6076 (0.25%)
```

Listing 6: q3p2.log

```
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 42916 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
```

```
[  4]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec    0    107 KBytes
[  4]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec    0    130 KBytes
[  4]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec    0    130 KBytes
[  4]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  15.00-16.00  sec  2.38 MBytes  20.0 Mbits/sec    0    130 KBytes
[  4]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  17.00-18.00  sec  2.38 MBytes  20.0 Mbits/sec    0    130 KBytes
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
[  4]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec    0    130 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec    0             sender
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec                  receiver

iperf Done.
```

Listing 7: q3p2-server.log

```
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42915
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 42916
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec
[  5]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-20.04  sec  47.5 MBytes  19.9 Mbits/sec                  receiver
```

Listing 8: q3p3.log

```
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 58868 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec  2.16 MBytes  18.1 Mbits/sec  276
[  4]   1.00-2.00   sec  2.46 MBytes  20.6 Mbits/sec  315
[  4]   2.00-3.00   sec  2.33 MBytes  19.5 Mbits/sec  298
[  4]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec  304
[  4]   4.00-5.00   sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]   5.00-6.01   sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]   6.01-7.00   sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]   7.00-8.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   8.00-9.00   sec  2.38 MBytes  20.0 Mbits/sec  305
```

```
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]  11.00-12.00  sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  14.00-15.01  sec  2.40 MBytes  20.0 Mbits/sec  307
[  4]  15.01-16.01  sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]  16.01-17.00  sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]  17.00-18.00  sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]  19.00-20.00  sec  2.38 MBytes  20.0 Mbits/sec  304
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec  0.099 ms  98/6075 (1.6%)
[  4] Sent 6075 datagrams

iperf Done.

Avg Ping: 562 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 57397 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec  2.16 MBytes  18.1 Mbits/sec  276
[  4]   1.00-2.00   sec  2.40 MBytes  20.1 Mbits/sec  307
[  4]   2.00-3.00   sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]   6.00-7.00   sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]   7.00-8.00   sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]   8.00-9.01   sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]   9.01-10.00  sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  11.00-12.00  sec  2.40 MBytes  20.1 Mbits/sec  307
[  4]  12.00-13.01  sec  2.38 MBytes  19.8 Mbits/sec  304
[  4]  13.01-14.00  sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]  15.00-16.00  sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]  16.00-17.01  sec  2.39 MBytes  19.9 Mbits/sec  306
[  4]  17.01-18.00  sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]  19.00-20.00  sec  2.40 MBytes  20.1 Mbits/sec  307
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec  0.051 ms  12/6077 (0.2%)
[  4] Sent 6077 datagrams

iperf Done.

Avg Ping: 615 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 51071 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec  2.16 MBytes  18.1 Mbits/sec  277
[  4]   1.00-2.00   sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]   2.00-3.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   5.00-6.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   6.00-7.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   7.00-8.00   sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]   8.00-9.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  11.00-12.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  12.00-13.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  13.00-14.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  14.00-15.00  sec  2.40 MBytes  20.2 Mbits/sec  307
[  4]  15.00-16.00  sec  2.37 MBytes  19.8 Mbits/sec  303
[  4]  16.00-17.00  sec  2.40 MBytes  20.1 Mbits/sec  307
[  4]  17.00-18.00  sec  2.37 MBytes  19.9 Mbits/sec  303
[  4]  18.00-19.00  sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]  19.00-20.00  sec  2.38 MBytes  20.0 Mbits/sec  305
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec  0.456 ms  74/6076 (1.2%)
```

```
[  4] Sent 6076 datagrams

iperf Done.

Avg Ping: 614 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 48663 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Total Datagrams
[  4]   0.00-1.00   sec  2.16 MBytes  18.1 Mbits/sec  276
[  4]   1.00-2.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   2.00-3.00   sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]   3.00-4.00   sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   5.00-6.00   sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]   6.00-7.00   sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]   7.00-8.01   sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]   8.01-9.00   sec  2.38 MBytes  20.1 Mbits/sec  305
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  11.00-12.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  12.00-13.00  sec  2.39 MBytes  20.0 Mbits/sec  306
[  4]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec  304
[  4]  15.00-16.00  sec  2.38 MBytes  20.0 Mbits/sec  304
[  4]  16.00-17.00  sec  2.39 MBytes  20.1 Mbits/sec  306
[  4]  17.00-18.00  sec  2.38 MBytes  20.0 Mbits/sec  305
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec  305
[  4]  19.00-20.00  sec  2.39 MBytes  20.1 Mbits/sec  306
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec  0.114 ms  143/6076 (2.4%)
[  4] Sent 6076 datagrams

iperf Done.

Avg Ping: 737 microseconds Loss: 0 Percent
```

Listing 9: q3p3-server.log

```
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42899
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 58868
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  2.13 MBytes  17.9 Mbits/sec  0.171 ms  0/273 (0%)
[  5]   1.00-2.00   sec  2.14 MBytes  17.9 Mbits/sec  0.126 ms  44/318 (14%)
[  5]   2.00-3.00   sec  2.16 MBytes  18.1 Mbits/sec  0.070 ms  22/298 (7.4%)
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec  0.060 ms  0/304 (0%)
[  5]   4.00-5.00   sec  2.39 MBytes  20.1 Mbits/sec  0.076 ms  0/306 (0%)
[  5]   5.00-6.00   sec  2.38 MBytes  20.0 Mbits/sec  1.714 ms  0/305 (0%)
[  5]   6.00-7.00   sec  2.38 MBytes  20.0 Mbits/sec  0.090 ms  0/305 (0%)
[  5]   7.00-8.00   sec  2.38 MBytes  20.0 Mbits/sec  0.139 ms  0/305 (0%)
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec  0.150 ms  1/305 (0.33%)
[  5]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  0.085 ms  0/305 (0%)
[  5]  10.00-11.00  sec  2.34 MBytes  19.6 Mbits/sec  0.112 ms  6/305 (2%)
[  5]  11.00-12.00  sec  2.33 MBytes  19.5 Mbits/sec  0.077 ms  8/306 (2.6%)
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec  0.080 ms  0/304 (0%)
[  5]  13.00-14.00  sec  2.29 MBytes  19.2 Mbits/sec  0.268 ms  7/300 (2.3%)
[  5]  14.00-15.00  sec  2.40 MBytes  20.1 Mbits/sec  0.101 ms  5/312 (1.6%)
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec  0.070 ms  0/304 (0%)
[  5]  16.00-17.00  sec  2.38 MBytes  20.0 Mbits/sec  0.118 ms  0/305 (0%)
[  5]  17.00-18.00  sec  2.39 MBytes  20.1 Mbits/sec  0.140 ms  0/306 (0%)
[  5]  18.00-19.00  sec  2.34 MBytes  19.7 Mbits/sec  0.142 ms  5/305 (1.6%)
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec  0.099 ms  0/304 (0%)
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.099 ms  0/0 (0%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.099 ms  98/6075 (1.6%)
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42900
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 57397
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
```

```
[  5]   0.00-1.00   sec  2.12 MBytes  17.7 Mbits/sec  0.122 ms  5/276 (1.8%)
[  5]   1.00-2.00   sec  2.40 MBytes  20.1 Mbits/sec  0.092 ms  0/307 (0%)
[  5]   2.00-3.00   sec  2.39 MBytes  20.1 Mbits/sec  0.078 ms  0/306 (0%)
[  5]   3.00-4.00   sec  2.38 MBytes  20.0 Mbits/sec  0.079 ms  0/305 (0%)
[  5]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  0.106 ms  0/305 (0%)
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec  0.110 ms  0/304 (0%)
[  5]   6.00-7.00   sec  2.38 MBytes  20.0 Mbits/sec  0.118 ms  0/305 (0%)
[  5]   7.00-8.00   sec  2.39 MBytes  20.1 Mbits/sec  0.128 ms  0/306 (0%)
[  5]   8.00-9.00   sec  2.36 MBytes  19.8 Mbits/sec  0.082 ms  3/305 (0.98%)
[  5]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  0.211 ms  0/305 (0%)
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec  0.195 ms  1/305 (0.33%)
[  5]  11.00-12.00  sec  2.40 MBytes  20.1 Mbits/sec  0.065 ms  0/307 (0%)
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec  0.106 ms  0/304 (0%)
[  5]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  0.081 ms  0/305 (0%)
[  5]  14.00-15.00  sec  2.38 MBytes  20.0 Mbits/sec  0.207 ms  0/305 (0%)
[  5]  15.00-16.00  sec  2.38 MBytes  20.0 Mbits/sec  0.062 ms  0/305 (0%)
[  5]  16.00-17.00  sec  2.39 MBytes  20.0 Mbits/sec  0.054 ms  0/306 (0%)
[  5]  17.00-18.00  sec  2.38 MBytes  20.0 Mbits/sec  0.079 ms  0/305 (0%)
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec  0.067 ms  0/304 (0%)
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec  0.051 ms  3/307 (0.98%)
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.051 ms  0/0 (0%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.051 ms  12/6077 (0.2%)
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42901
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 51071
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  2.16 MBytes  18.1 Mbits/sec  0.065 ms  0/277 (0%)
[  5]   1.00-2.00   sec  2.39 MBytes  20.0 Mbits/sec  0.089 ms  0/306 (0%)
[  5]   2.00-3.00   sec  2.38 MBytes  20.0 Mbits/sec  0.109 ms  0/305 (0%)
[  5]   3.00-4.00   sec  2.33 MBytes  19.5 Mbits/sec  0.178 ms  7/305 (2.3%)
[  5]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec  0.069 ms  0/305 (0%)
[  5]   5.00-6.00   sec  2.38 MBytes  20.0 Mbits/sec  0.127 ms  0/305 (0%)
[  5]   6.00-7.00   sec  2.38 MBytes  20.0 Mbits/sec  0.738 ms  0/305 (0%)
[  5]   7.00-8.00   sec  2.39 MBytes  20.1 Mbits/sec  0.086 ms  0/306 (0%)
[  5]   8.00-9.00   sec  2.38 MBytes  20.0 Mbits/sec  0.200 ms  0/305 (0%)
[  5]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  0.102 ms  0/305 (0%)
[  5]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec  0.149 ms  0/305 (0%)
[  5]  11.00-12.00  sec  2.38 MBytes  20.0 Mbits/sec  0.059 ms  0/305 (0%)
[  5]  12.00-13.00  sec  2.30 MBytes  19.3 Mbits/sec  0.090 ms  10/305 (3.3%)
[  5]  13.00-14.00  sec  2.30 MBytes  19.3 Mbits/sec  0.113 ms  12/306 (3.9%)
[  5]  14.00-15.00  sec  2.32 MBytes  19.5 Mbits/sec  0.129 ms  10/307 (3.3%)
[  5]  15.00-16.00  sec  2.37 MBytes  19.9 Mbits/sec  0.160 ms  0/303 (0%)
[  5]  16.00-17.00  sec  2.35 MBytes  19.7 Mbits/sec  0.101 ms  6/307 (2%)
[  5]  17.00-18.00  sec  2.37 MBytes  19.9 Mbits/sec  0.128 ms  0/303 (0%)
[  5]  18.00-19.00  sec  2.32 MBytes  19.5 Mbits/sec  0.155 ms  9/306 (2.9%)
[  5]  19.00-20.00  sec  2.23 MBytes  18.7 Mbits/sec  0.456 ms  20/305 (6.6%)
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.456 ms  0/0 (0%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.456 ms  74/6076 (1.2%)
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42902
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 48663
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  1.98 MBytes  16.6 Mbits/sec  0.163 ms  11/265 (4.2%)
[  5]   1.00-2.00   sec  2.09 MBytes  17.6 Mbits/sec  0.160 ms  48/316 (15%)
[  5]   2.00-3.00   sec  2.30 MBytes  19.3 Mbits/sec  0.347 ms  1/295 (0.34%)
[  5]   3.00-4.00   sec  2.30 MBytes  19.3 Mbits/sec  0.085 ms  23/317 (7.3%)
[  5]   4.00-5.00   sec  2.28 MBytes  19.1 Mbits/sec  0.192 ms  13/305 (4.3%)
[  5]   5.00-6.00   sec  2.38 MBytes  20.0 Mbits/sec  0.238 ms  0/305 (0%)
[  5]   6.00-7.00   sec  2.33 MBytes  19.5 Mbits/sec  0.122 ms  8/306 (2.6%)
[  5]   7.00-8.00   sec  2.28 MBytes  19.1 Mbits/sec  0.297 ms  11/303 (3.6%)
[  5]   8.00-9.00   sec  2.37 MBytes  19.9 Mbits/sec  0.089 ms  4/307 (1.3%)
[  5]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec  0.187 ms  0/305 (0%)
[  5]  10.00-11.00  sec  2.30 MBytes  19.3 Mbits/sec  0.065 ms  11/305 (3.6%)
[  5]  11.00-12.00  sec  2.39 MBytes  20.1 Mbits/sec  0.244 ms  0/306 (0%)
[  5]  12.00-13.00  sec  2.39 MBytes  20.0 Mbits/sec  0.115 ms  0/306 (0%)
[  5]  13.00-14.00  sec  2.38 MBytes  20.0 Mbits/sec  0.288 ms  0/305 (0%)
[  5]  14.00-15.00  sec  2.35 MBytes  19.7 Mbits/sec  0.188 ms  3/304 (0.99%)
[  5]  15.00-16.00  sec  2.30 MBytes  19.3 Mbits/sec  0.250 ms  0/294 (0%)
```

```
[  5]  16.00-17.00  sec  2.39 MBytes  20.1 Mbits/sec  0.186 ms  10/316 (3.2%)
[  5]  17.00-18.00  sec  2.38 MBytes  20.0 Mbits/sec  0.149 ms  0/305 (0%)
[  5]  18.00-19.00  sec  2.38 MBytes  20.0 Mbits/sec  0.126 ms  0/305 (0%)
[  5]  19.00-20.00  sec  2.39 MBytes  20.1 Mbits/sec  0.114 ms  0/306 (0%)
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.114 ms  0/0 (0%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Jitter    Lost/Total Datagrams
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec  0.114 ms  143/6076 (2.4%)
```

Listing 10: q3p4.log

```
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 42904 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec    0    103 KBytes
[  4]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec    0    132 KBytes
[  4]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  12.00-13.00  sec  2.38 MBytes  20.0 Mbits/sec    0    132 KBytes
[  4]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  14.00-15.00  sec  2.38 MBytes  20.0 Mbits/sec    0    132 KBytes
[  4]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  17.00-18.00  sec  2.38 MBytes  20.0 Mbits/sec    0    132 KBytes
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
[  4]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec    0    132 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec    0             sender
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec                  receiver

iperf Done.

Avg Ping: 605 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 42906 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec    0    112 KBytes
[  4]   1.00-2.00   sec  2.38 MBytes  20.0 Mbits/sec    0    173 KBytes
[  4]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec    0    247 KBytes
[  4]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]   7.00-8.00   sec  2.50 MBytes  20.9 Mbits/sec    0    257 KBytes
[  4]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  11.00-12.00  sec  2.38 MBytes  20.0 Mbits/sec    0    257 KBytes
[  4]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  16.00-17.00  sec  2.38 MBytes  20.0 Mbits/sec    0    257 KBytes
[  4]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
[  4]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec    0    257 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec    0             sender
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec                  receiver

iperf Done.

Avg Ping: 599 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 42908 connected to 192.168.56.104 port 5005
```

```
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec    0    140 KBytes
[  4]   1.00-2.00   sec  2.38 MBytes  20.0 Mbits/sec    0    140 KBytes
[  4]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec    0    140 KBytes
[  4]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec    0    140 KBytes
[  4]   4.00-5.00   sec  2.38 MBytes  20.0 Mbits/sec    0    140 KBytes
[  4]   5.00-6.00   sec  2.38 MBytes  19.8 Mbits/sec    0    140 KBytes
[  4]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]   7.00-8.01   sec  2.50 MBytes  20.9 Mbits/sec    0    280 KBytes
[  4]   8.01-9.00   sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
[  4]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]  11.00-12.00  sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
[  4]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]  13.00-14.01  sec  2.38 MBytes  19.8 Mbits/sec    0    280 KBytes
[  4]  14.01-15.00  sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
[  4]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]  16.00-17.00  sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
[  4]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec    0    280 KBytes
[  4]  19.00-20.00  sec  2.38 MBytes  20.0 Mbits/sec    0    280 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec    0             sender
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec                  receiver

iperf Done.

Avg Ping: 709 microseconds Loss: 0 Percent
Connecting to host 192.168.56.104, port 5005
[  4] local 192.168.56.105 port 42910 connected to 192.168.56.104 port 5005
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec    0    208 KBytes
[  4]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]   2.00-3.00   sec  2.38 MBytes  20.0 Mbits/sec    0    266 KBytes
[  4]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]   5.00-6.01   sec  2.38 MBytes  19.8 Mbits/sec    0    266 KBytes
[  4]   6.01-7.00   sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]   7.00-8.00   sec  2.50 MBytes  21.1 Mbits/sec    0    266 KBytes
[  4]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]   9.00-10.00  sec  2.38 MBytes  20.0 Mbits/sec    0    266 KBytes
[  4]  10.00-11.00  sec  2.38 MBytes  20.0 Mbits/sec    0    266 KBytes
[  4]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
[  4]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec    0    266 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec    0             sender
[  4]   0.00-20.00  sec  47.5 MBytes  19.9 Mbits/sec                  receiver

iperf Done.

Avg Ping: 592 microseconds Loss: 0 Percent
```

Listing 11: q3p4-server.log

```
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42903
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 42904
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec
[  5]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec
```

```
[  5]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-20.04  sec  47.5 MBytes  19.9 Mbits/sec                  receiver
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42905
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 42906
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec
[  5]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-20.04  sec  47.5 MBytes  19.9 Mbits/sec                  receiver
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42907
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 42908
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec
[  5]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec
```

```
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-20.04  sec  47.5 MBytes  19.9 Mbits/sec                  receiver
-----------------------------------------------------------
Server listening on 5005
-----------------------------------------------------------
Accepted connection from 192.168.56.105, port 42909
[  5] local 192.168.56.104 port 5005 connected to 192.168.56.105 port 42910
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-1.00   sec  2.21 MBytes  18.5 Mbits/sec
[  5]   1.00-2.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   2.00-3.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   3.00-4.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   4.00-5.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   5.00-6.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   6.00-7.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   7.00-8.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   8.00-9.00   sec  2.38 MBytes  19.9 Mbits/sec
[  5]   9.00-10.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  10.00-11.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  12.00-13.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  13.00-14.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  14.00-15.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  15.00-16.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  16.00-17.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  17.00-18.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  18.00-19.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  19.00-20.00  sec  2.38 MBytes  19.9 Mbits/sec
[  5]  20.00-20.04  sec  0.00 Bytes  0.00 bits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth
[  5]   0.00-20.04  sec  0.00 Bytes  0.00 bits/sec                  sender
[  5]   0.00-20.04  sec  47.5 MBytes  19.9 Mbits/sec                  receiver
```