ITS 413 Internet Technologies and Applications

Assignment: Final Report

By

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Date

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By submitting this report all members of the group listed above agree that each member has contributed approximately equal amounts to designing and performing experiments, as well as to preparing this report. All members agree that this report accurately reflects the experiments conducted by the group members, and is their own work (not works of other groups).

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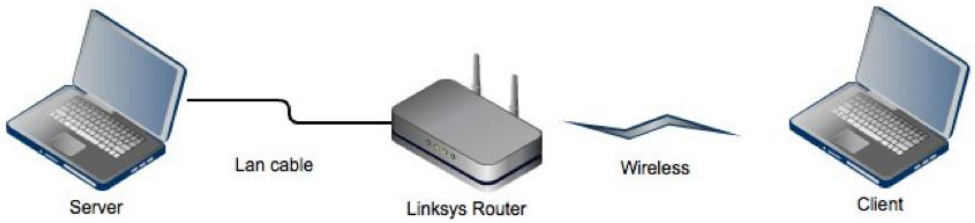
Table of content

Aim

- To understand how internet 5-layer work with UPD and TCP.
- To understand how bottleneck occurs when using wireless link and wired link.
- To understand how to use iperf.
- To know advantages of TCP and UDP.
- To be able to compare TCP and UDP.

Phase2

Network Diagram



For the first experiment

We use LAN cable to connect between server with router and client connects with wireless. And we try to send data from client to sever and record the throughput that server return back. We send 1MB to 40MB increment with 1MB and 40MB to 100MB increment with 10 MB (send 3 times).

	Server	Client	Router
Model	Dell studio14	Compaq presario	Linksys
OS	Linux Ubuntu 11.10	Linux Ubuntu 11.10	OpenWRT
CPU	Intel(R) Core(TM) 2 duo CPU 2.0 GHz	Intel(R) Core(TM) 2 duo CPU 2.0 GHz	Broad BCM5352 @ 200 MHz
RAM	4.00 GB DDR 2	3GB DDR 2	16 MB
Network interface	Broadcom NetLink (Gigabit) Ethanet	Intel(R) WiFi Link 5100 AGN	Data Link Protocol: Ethernet, Fast Ethernet, IEEE 802.11b, IEEE 802.11g

Parameters

- **Sending data size** (1Mb - 100Mb.

Methods

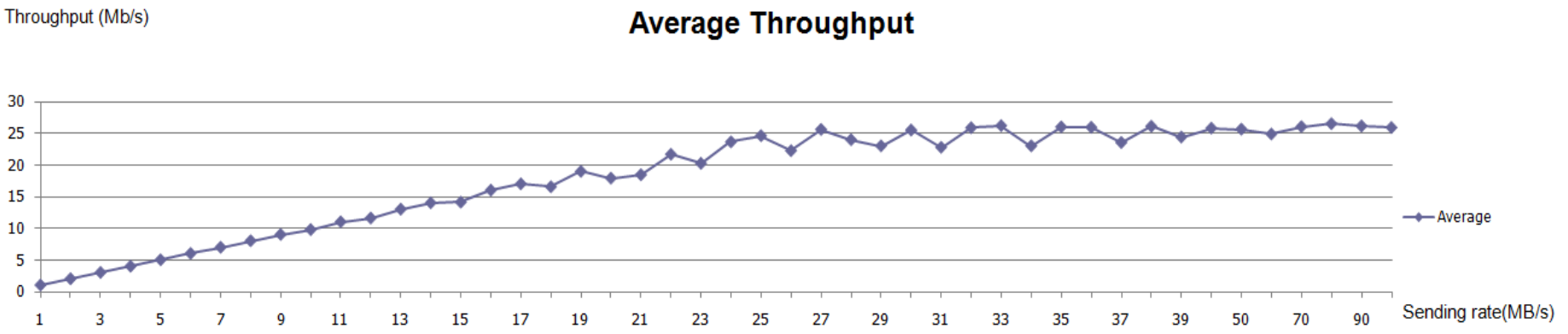
For the method that we use to implement in this experiment is shell script to using iperf command. Shell script is a command that we can code it and use the For loop like Java language.

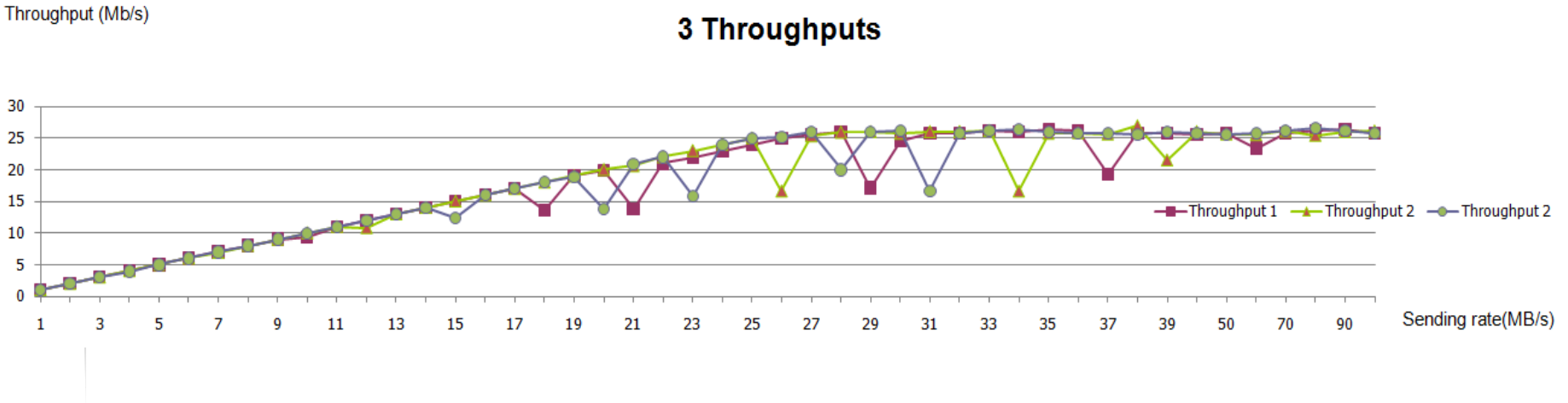
Example of shell script wired LAN

```
for i in {1..100}
do
      for j in {1..3}
      do
            echo +++++++++++++++Sending data "$i" MB
with "$j" round+++++++++++++++
            iperf -c 192.168.1.218 -u -b "$i"M
            sleep 5s
      done
done
```

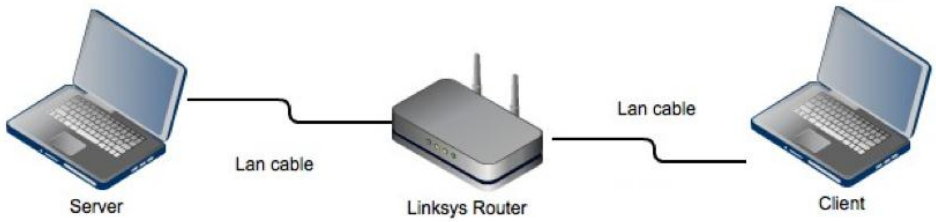
In this experiment we try to send a multiple values of data from client to server and record the throughput that archive from links. After we finish experiment, we represent our records in form of a graph.

The Maximum throughput is 26.9


Throughput (Mb/s)
Average Throughput
30
25
20
15
10
5
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
50
70
90
Average
Sending rate(MB/s)


Throughput (Mb/s)
3 Throughputs
30
25
20
15
10
5
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
50
70
90
Throughput 1
Throughput 2
Throughput 2
Sending rate(MB/s)

Network Diagram



For the second experiment

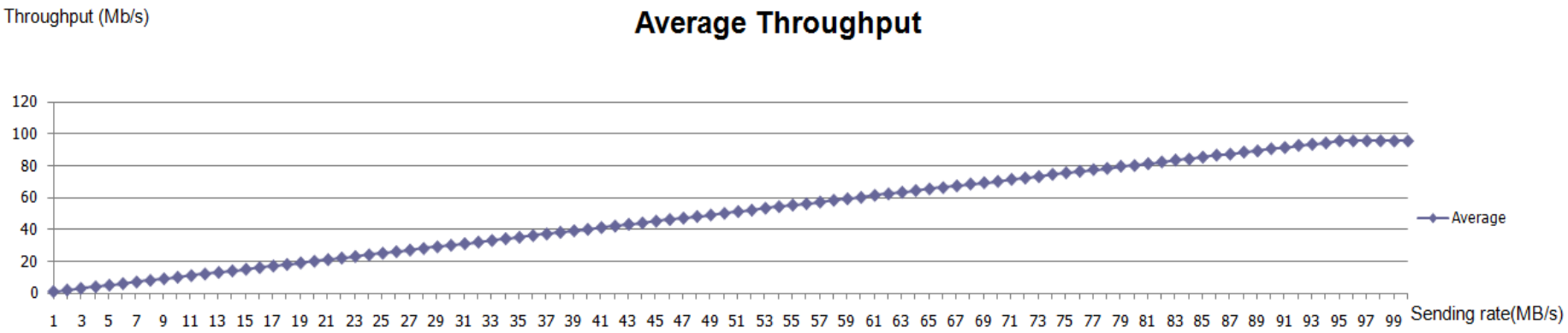
We use LAN cable to connect between server with router and client with router. And we try to send data from client to sever and record the throughput that server return back. We send 1MB to 100MB increment with 1MB (every 1MB increment send 3 times).

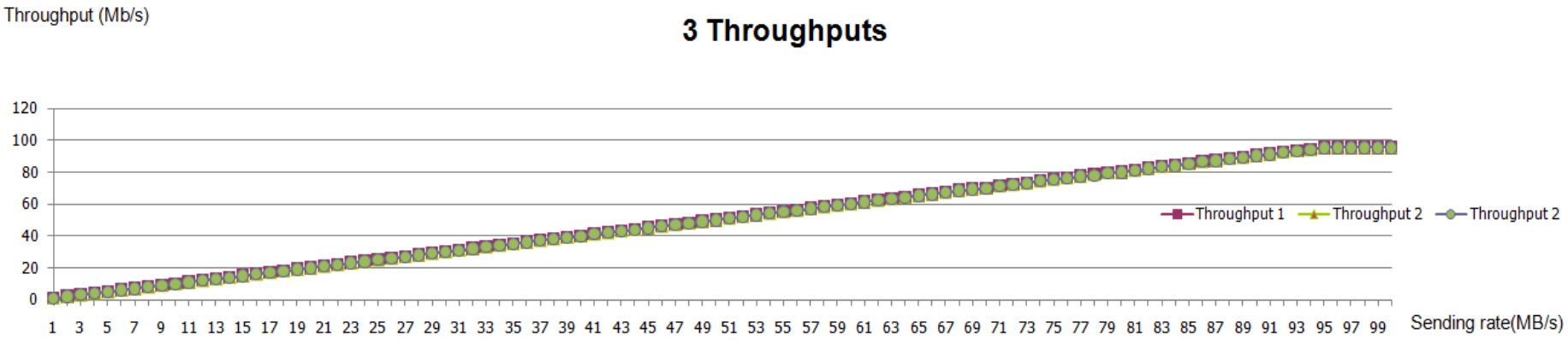
Method

For the method that we use to implement in this experiment is shell script to using iperf command. Shell script is a command that we can code it and use the For loop like Java language.

Experiment

In this experiment we try to send a multiple values of data from client to server and record the throughput that archive from links. After we finish experiment, we represent our records in form of a graph. The maximum Throughput is 95.4.


Throughput (Mb/s)
Average Throughput
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Sending rate(MB/s)
Average


Throughput (Mb/s)
3 Throughputs
120
100
80
60
40
20
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Sending rate(MB/s)
Throughput 1
Throughput 2
Throughput 2

Conclusion

UDP on wireless network we do this experiment by increasing the parameter that is size of sending data. We get the highest throughput is 26.9. As we know that UDP just receive packets from application layer and attached with header then send to destination. UDP does not have other services such as three-way handshake. So UDP does not care about correctness of data, only focus on sending speed. In practice we should get the maximum 54Mb/s but in reality we cannot reach 54Mb/s because we have at least noise or channel interfere or obstacle. Also the main point is DFC Error control and RTS/CTS that prevent data collision. The best case for 802.11g(54Mb/s) is 35.93Mb/s. Including RTS/CTS the best case is 33.61Mb/s. UDP on wired network In the wired connection, we also increasing the size of data. We get very stable and constant increasing throughput. In practice we should get 100Mb/s through the switch but we only get 95.4Mb/s. Because the LAN cable that we use may not get full 100% transmission rate, there may be some signal interfere or age of cable that affect with transmission.

Phase 3

Equipment Specifications

	Server	Client	Router
Model	Dell studio14	Compaq presario	Linksys
OS	Linux Ubuntu 11.10	Linux Ubuntu 11.10	OpenWRT
CPU	Intel(R) Core(TM) 2 duo CPU 2.0 GHz	Intel(R) Core(TM) 2 duo CPU 2.0 GHz	Broad BCM5352 @ 200 MHz
RAM	4.00 GB DDR 2	3GB DDR 2	16 MB
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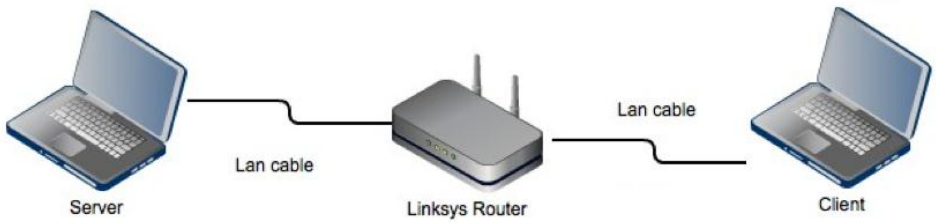
Network Diagram



TCP vs. UDP

For this task, we send one TCP session and one UDP session at different time by using wired connection. After that we record throughput and discuss about this task.

Method

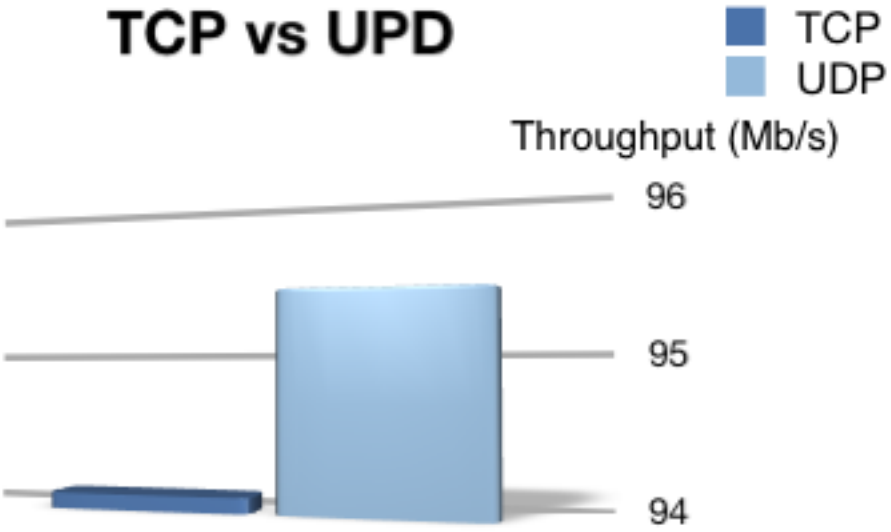
Command for Client

```
iperf -c DestAddress -u -b 100M     #Client's command to test UDP.

iperf -c DestAddress                #Client's command to test TCP.
```

Command for server

```
iperf -s -u                         #Server's command for UDP.

iperf -s                            #Server's command for TCP.


-c means client.
-s means server.
-u means UDP.
-b means declare the sending rate.
DestAddress is server IP address.
We use 100Mb for UDP because we know that the throughput will not
lager than 100Mb/s from phase II.
```

Experiments and Results



TCP gets 94.1 Mb/s throughput and UDP gets 95.4Mb/s throughput.

Discussion and conclusion

UDP gets throughput more than TCP because TCP has some features that make it lower than UDP. Normally UDP takes packets from application layer and combine with UDP header then send to destination. UDP does not care about reliable, lost, arrive out of order and duplicated packet. On the other words TCP has more features that make it become reliable. For example error control, congestion control and reliability (three-way handshake). In this experiment we think three-way handshake is the main thing that makes the TCP throughput is lower. Because same sending data time 60 seconds, UPD just sent the packets from client to server but TCP has to establish connection with 3 packets before sending real data and TCP has to send acknowledgment for ensure that receiver finish getting data. So TCP has more overhead that make throughput lower.

In summary, in term of speed UDP is better. But In term of reliable TCP is better.

Multiple TCP Session

For this experiment

We use LAN cable to connect between server with router and client with router. And we try to send data from client to sever and record the throughput that server return back. We run Multiple TCP session concurrently start on 1 TCP session and increase number of TCP increment by one up to 30 session.

(**For example** 1 TCP session,2 TCP session ,3 TCP session, …,30 TCP session)

Method

Example of shell script Multiple 3 TCP session

```
for  I  in  {1..3}
        do
                gnome-terminal --tab -e "iperf -c 192.168.1.124"
                --tab -e "iperf -c 192.168.1.124  "
                --tab -e "iperf -c 192.168.1.124  "
                sleep 15s
        done
```

Can add more TCP session by add --tab -e "iperf -c 192.168.1.124"

Parameters

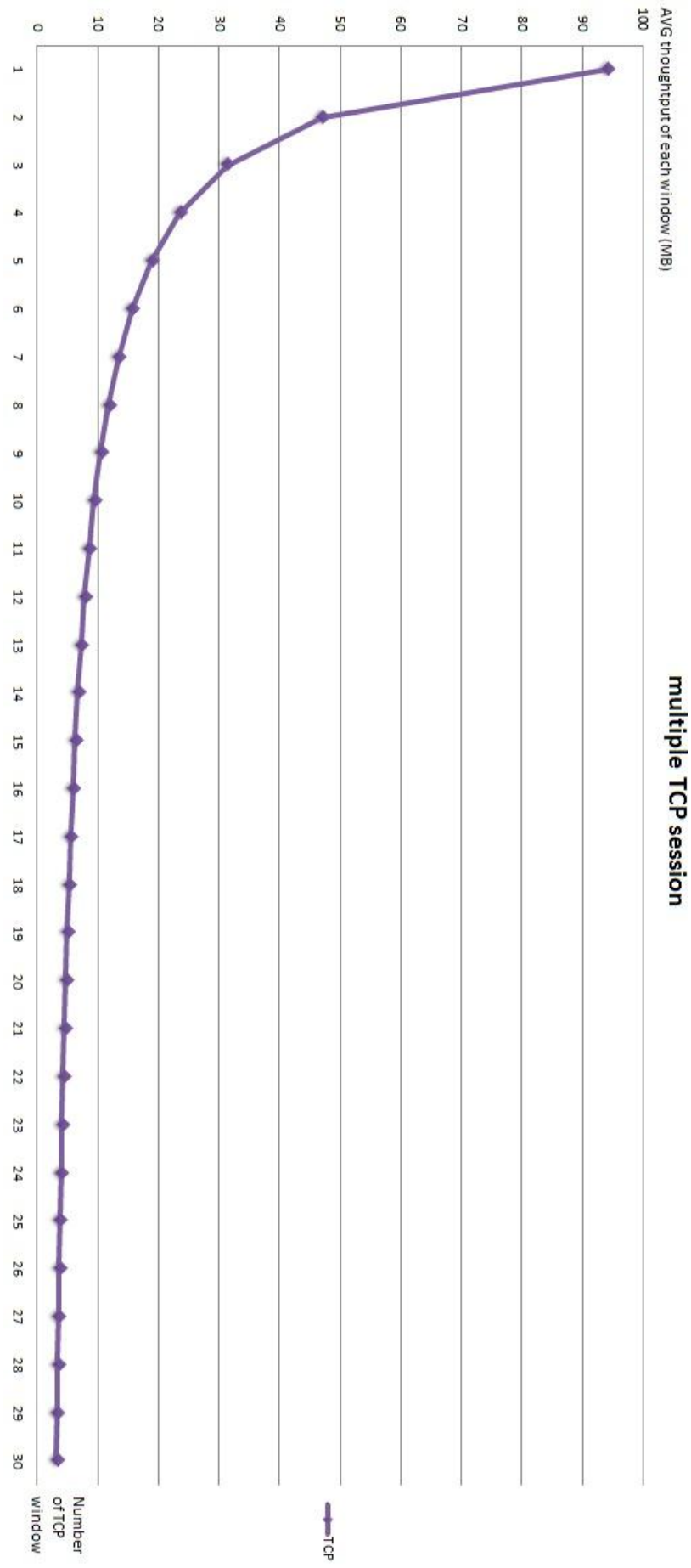
- **Number of session** 1TCP-30TCP.

Experiments and Results

We test this experiment 3 times each for measure the average throughput and use the average throughput plot the graph and this following is our result.

Conclusion

In this experiment, we run multiple TCP session up to 1-30 windows concurrently and the result show that throughput sum of every number TCP windows all are equal to 94.1 and we found that TPC mechanism try to divide throughput to each TCP session equally but in fact it is not 100% fairness.



TCP & UDP Session

For this experiment

We use LAN cable to connect between server with router and client with router. And we try to send data from client to sever and record the throughput that server return back. We send TCP and UDP at the same time by increase number of TCP and UDP increment by one

(**for example** 1TCP:1UDP, 1TCP:2UDP, …,1TCP:5UDP , 2TCP:1UDP, 2TCP:2UDP,…, 2TCP:5UDP,…,5TCP:5UDP)

Method

" gnome-terminal " is a command that open new terminal window .

" --tab " is a command that will open tab in terminal.

" –e " is a command that will execute following command.

We use " gnome-terminal --tab –e "command" " for make sure that we can run the command at the same time.

Example of shell script TCP & UDP Session

```
for I in {1..3}
    do
        gnome-terminal --tab -e "iperf -c 192.168.1.124"
        --tab -e "iperf -c 192.168.1.124 -u -b 10M"
        sleep 15s
    done
```

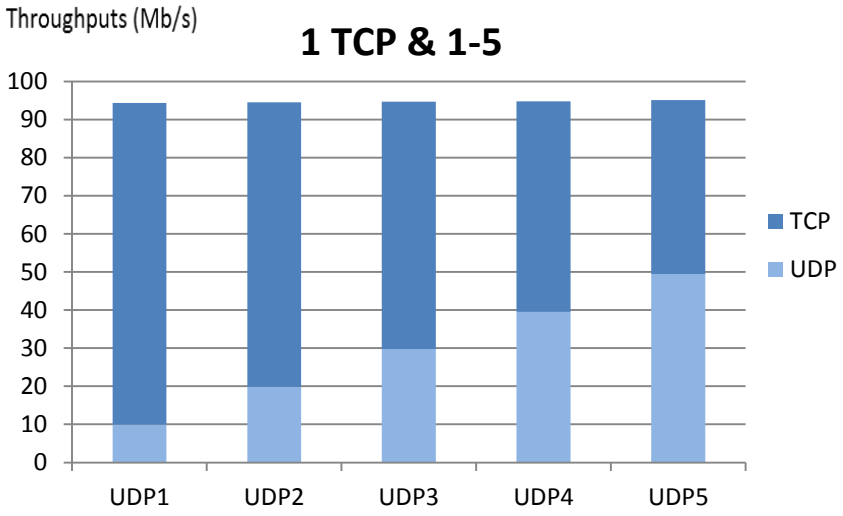
Can add more TCP session by add --tab -e "iperf -c 192.168.1.124" and add more UDP session by add --tab -e "iperf -c 192.168.1.124 -u -b 10M" into script command.

Parameters

- **Number of session** 1TCP-5TCP & 1UDP-5UDP.
- **Size of data** 10 Mb.

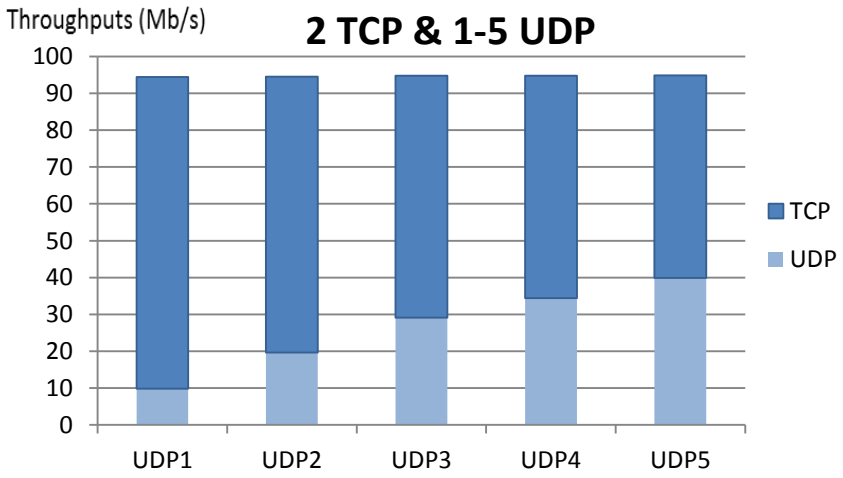
Experiments and Results

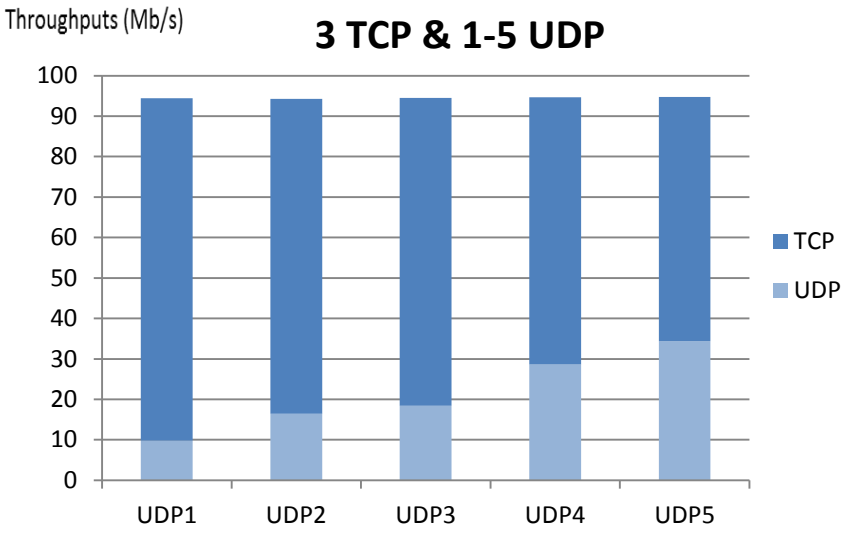
We test this experiment 3 times each for measure the average throughput and use the average throughput plot the graph and this following is our result.

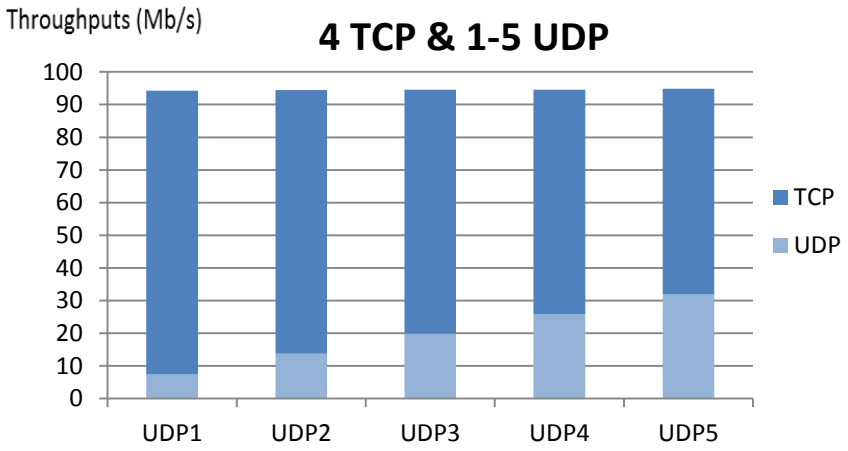


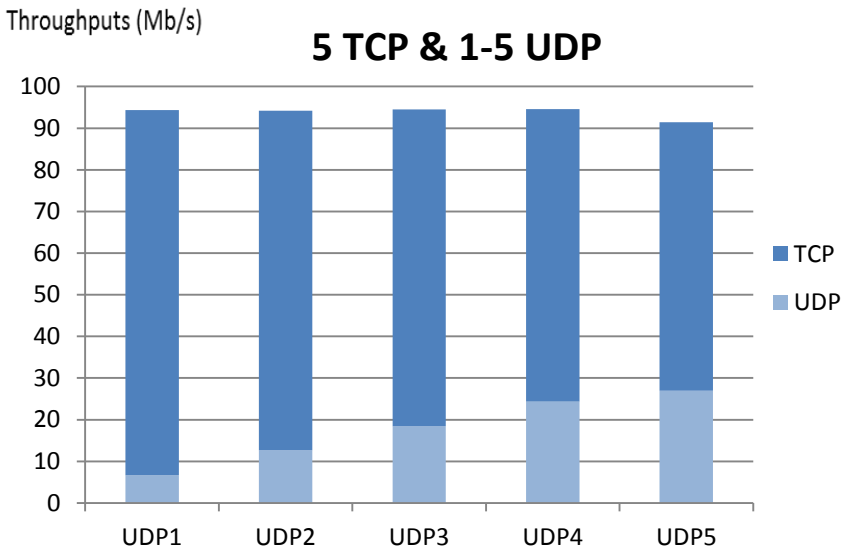
UDP send 10 Mb for each session so

You can see that at 5UDP throughput is around 50Mb/s because TCP cannot fix size so less of throughput will be assign to TCP



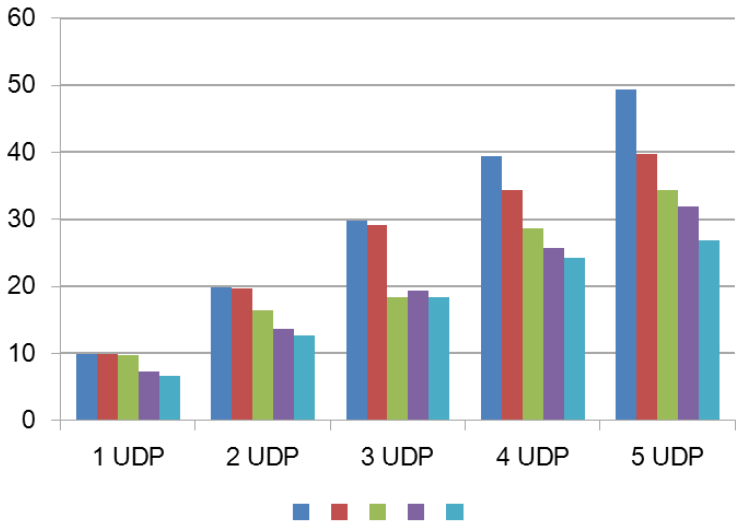






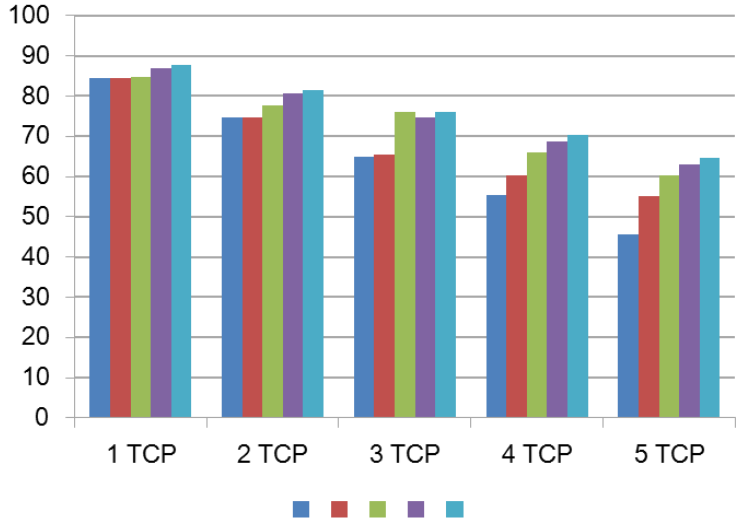
Although UDP send 10Mb each but have 5 session of TCP so that mean UDP cannot get 50 Mb/s throughputs because all TCP will send maximum otherwise if UDP send maximum UDP will get more throughput than TCP for sure. Because UDP will focus on transmission speed but TCP will focus on correctness of data.

Throughput (Mb/s)



Sum of all UDP with different number session of TCP (1 TCP – 5 TCP)

Throughput (Mb/s)



Sum of all TCP with different number session of UDP (1 UDP – 5 UDP)

Conclusion

With increase a number of sessions of TCP&UDP. TCP has Three-way handshake that means the data that server will guarantee arrive in orders, also retransmit but UDP has only send to server it does not care about retransmit or not guarantee arrive in order so the overhead of UDP will less than TCP and about TCP fairness TCP can achieve fairness when same size segment, same RTT and no other traffic but we sent both TCP and UDP to server so TCP does not fairness in this case. For 5 session of UDP and 5 session of TCP. UDP cannot get 50 Mb/s throughputs because all TCP will send maximum that mean if maximum is 100Mb/s TCP will send 500Mb but UDP send only 50Mb so impossible that UDP will get 50Mb/s of throughput. On the other hand if UDP send maximum UDP will get more throughput than TCP for sure. Because UDP will focus on transmission speed but TCP will focus on correctness of data.

TCP & UDP Session: (Experiment 2)

This part is 1-TCP session VS 1-UDP session, we run both of iperf command concurrently by use gnome command and run it 100 time each time has different size of UDP (1-100 MB).

(**For example** 1-TCP vs. 1-UDP with size 1M, 1-TCP vs. 1-UDP with size 2M, 1-TCP vs. 1-UDP with size 3M, . . ., 1-TCP vs. 1-UDP with size 100M)

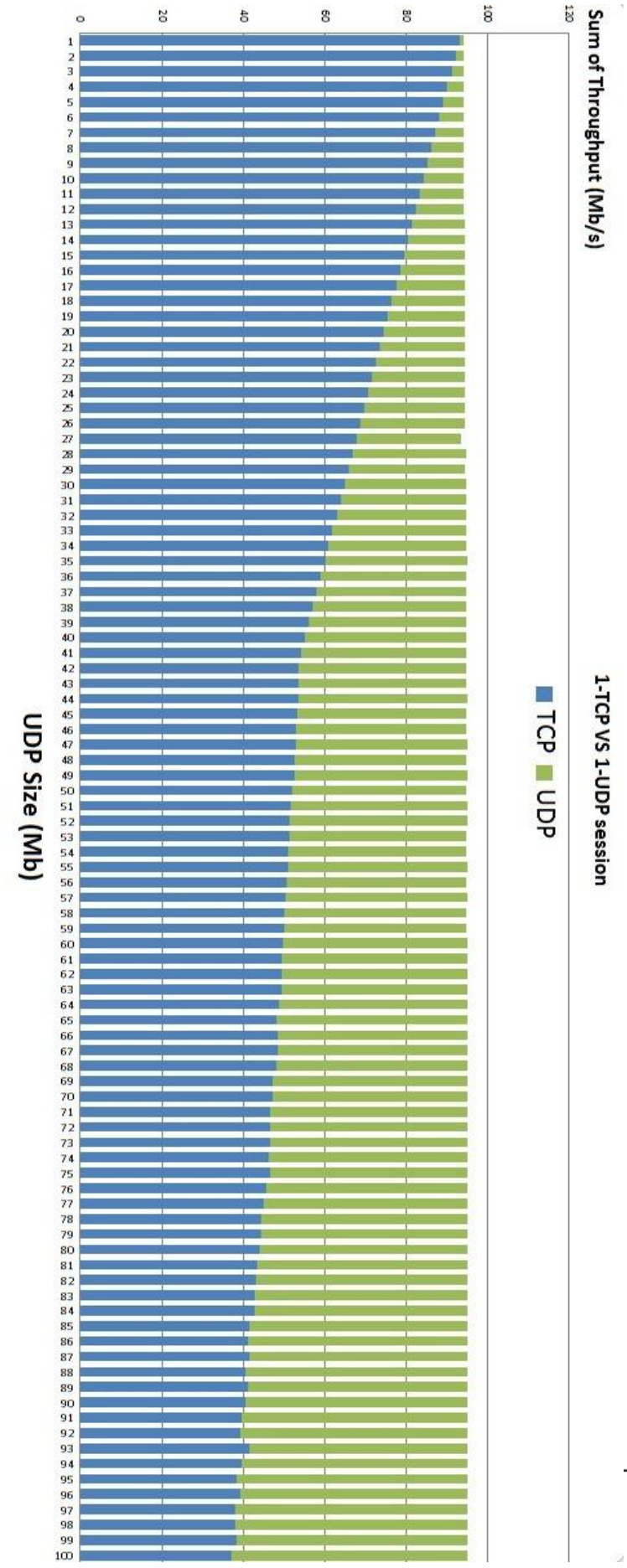
Method

Example of shell script TCP & UDP Session

```
for  i  in  {1..100}
do
for  j  in  {1..3}
        do
                gnome-terminal --tab -e "iperf -c 192.168.1.124"
                --tab -e "iperf -c 192.168.1.124 -u –b "$i"  M"
                sleep 15s
        do
```

Parameters

- **Number of session** 1TCP& 1UDP.
- **UDP Size of data** 1Mb-100Mb.



Experiments and Results

We test this experiment 3 times each for measure the average throughput and use the average throughput plot the graph and this following is our result.

Conclusion

Note: that TCP cannot select the size but TCP will try as much as possible that it can.

The result show that the sums of Throughput (TCP+UDP) all are nearby (94.1-95.26MB). At size of UDP 1-40) UDP got throughput close to t(he size of request, after that at the size of UDP (41-100) the increasing of UDP throughput much slower from previous and if the size of UDP increases the sum will be increases a little bit.

At the size of UDP is 100 MB this is the maximum possible throughput of our network diagram, the result show that UDP got 58.222 MB, TCP got 37 MB and sum is 95.2333 MB.

So we can say that UDP got higher throughput than TCP, because of UDP got lower overhead than TCP.

TCP sessions over varying duration.

For this task, we send 2 TCP sessions in different duration and different interval. We run command that shown below. For that command, we can assign the duration, starting port. After that we record throughputs from client and server (see in Appendix).

Method

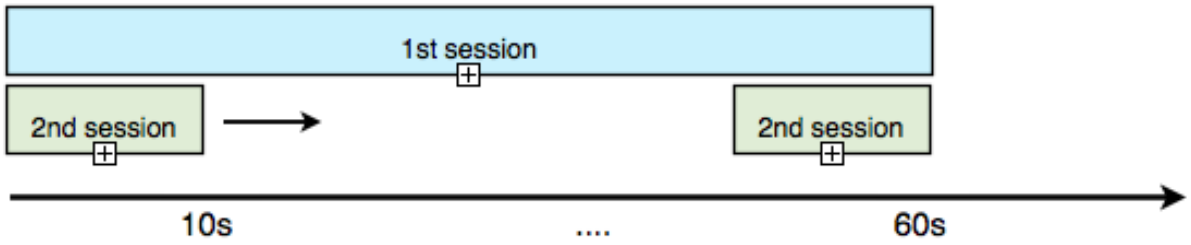
```
At Client
iperf -c DestAddress -t X1s -p Z1&
sleep Ys;
iperf -c DestAddress -t X2s -p Z2;

At server
iperf -s -p Z1
iperf -s -p Z2

DestAddress is server IP address.
X1 is Duration of first TCP session.
X2 is Duration of second TCP session.
Z1,Z2 are port that we can assign.
Y is time that 2nd command will execute after 1st command execute.
```

Parameter

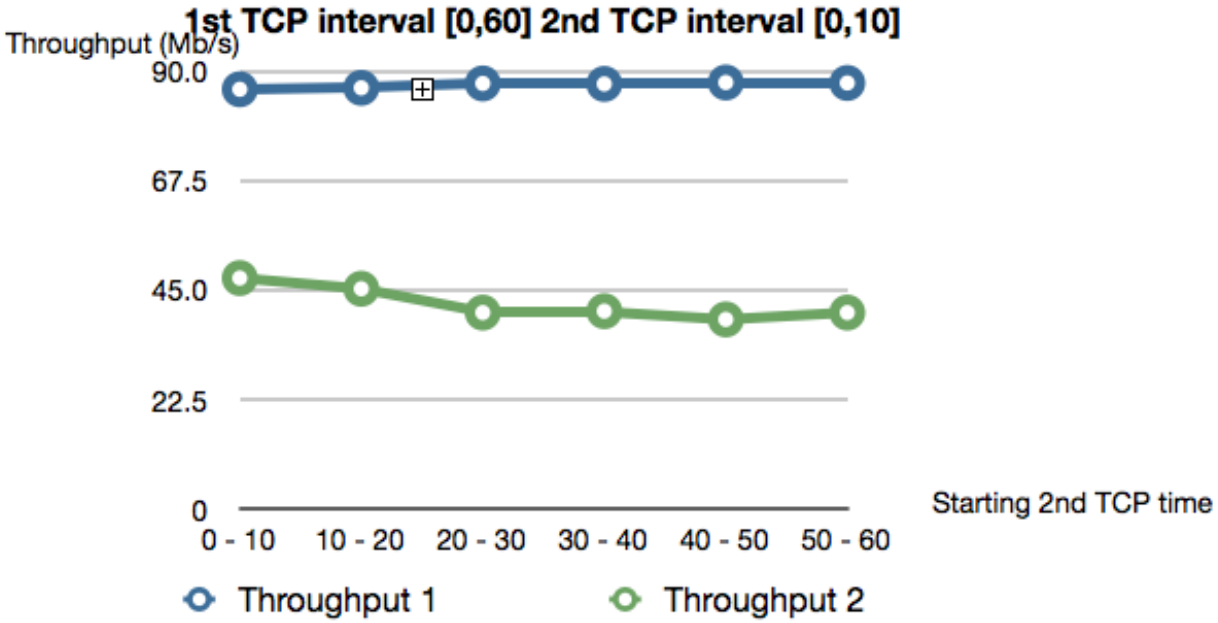
- **Starting time** 0,10,20,30,40,50 seconds
- **Time interval** 0-10, 0-20, 0-30, 0-40, 0-50 and 0-60 seconds

First round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 10]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline



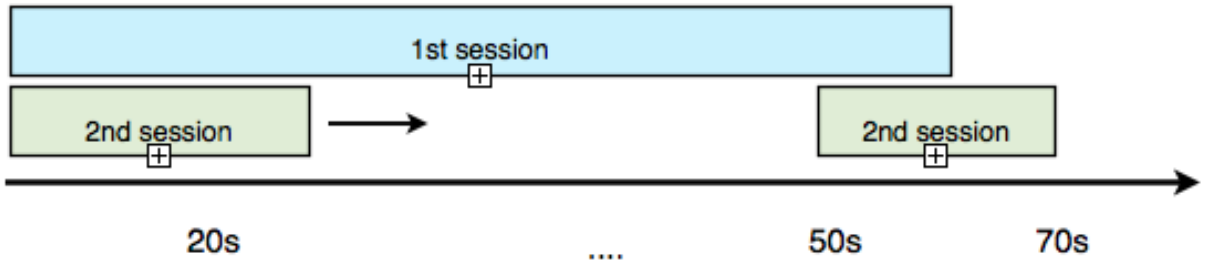
Result



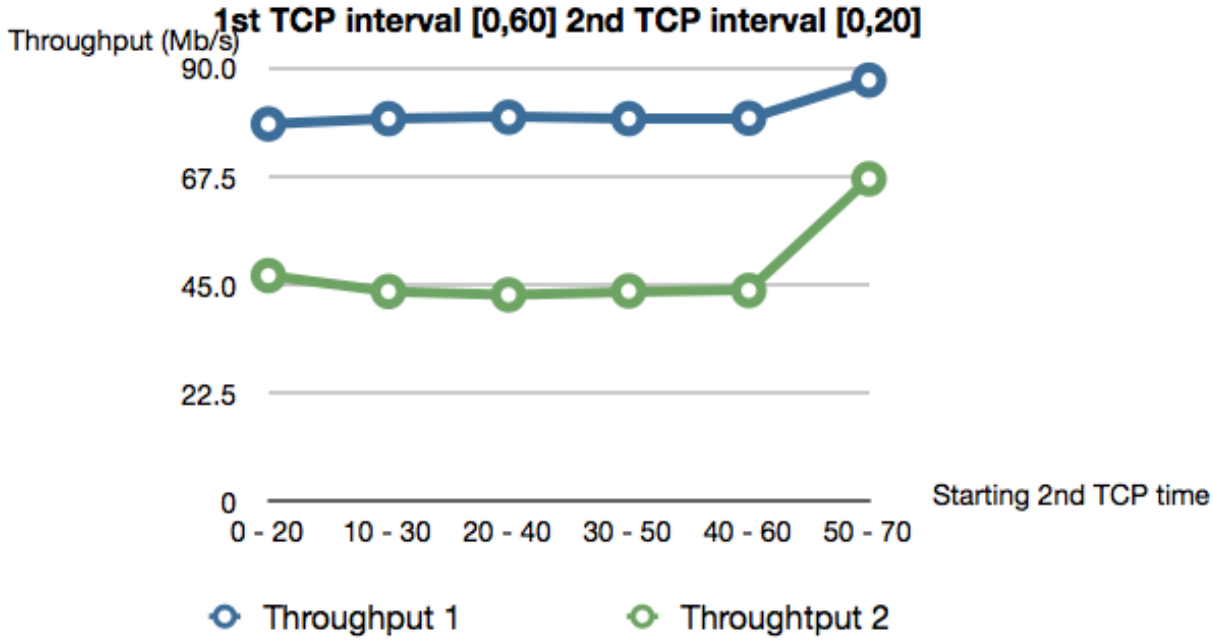
So, we get higher throughput at 1st TCP that interval time is [0, 60]. And lower throughput at 2 TCP that interval time is [0, 10]. The first throughputs look stable but second throughput is start at high then drop a little bit and become stable.

Second round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 20]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline



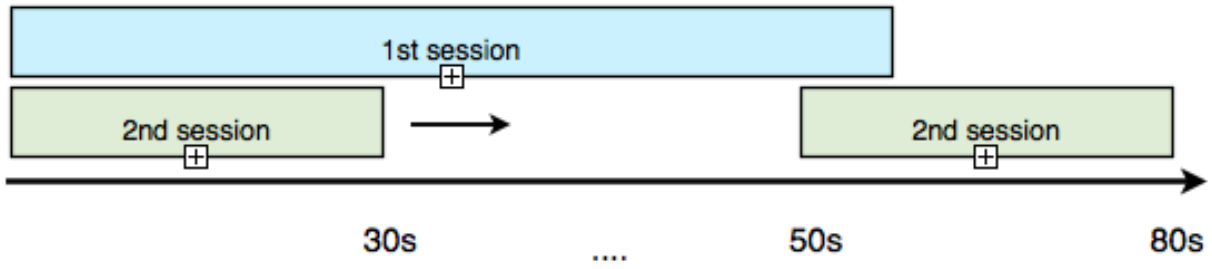
Result



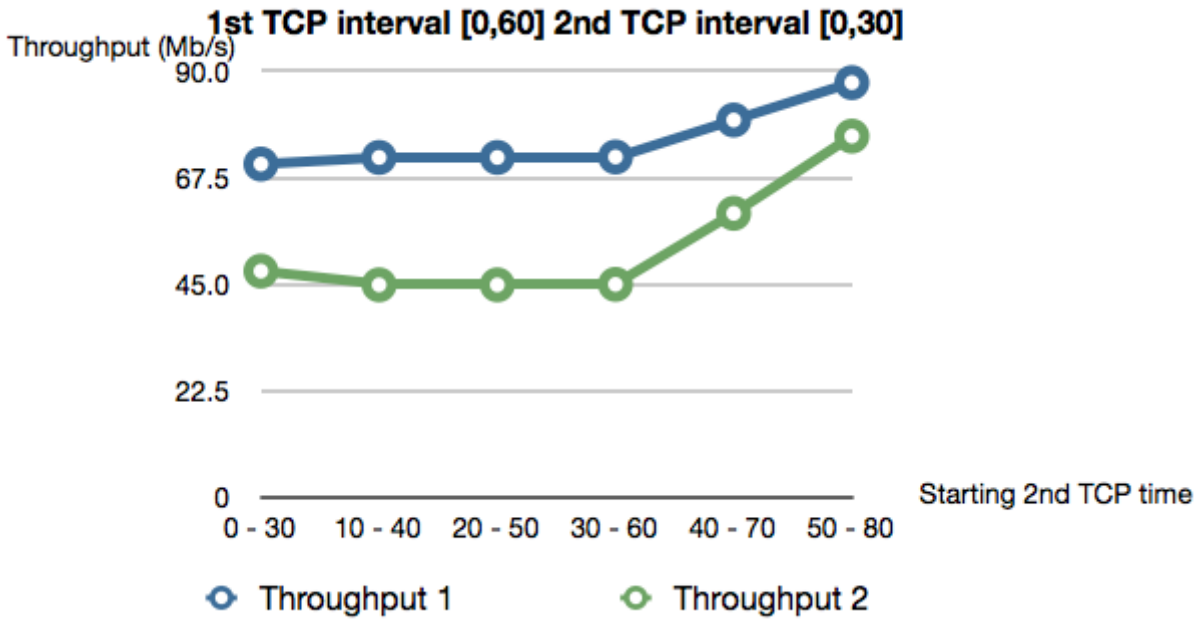
In second round, we get higher throughput at 1st TCP but the values a little lower than first round. 2nd TCP in this round time interval is [0,20] and we get the throughput around 45 MB/s. And range between (40-60) - (50-70) the throughput will increase because the 2nd TCP session will take time longer than 60s. First TCP session will take throughput at start and end within 60s. and second TCP session will take 10s after first session end. So two throughput values increase.

Third round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 30]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline



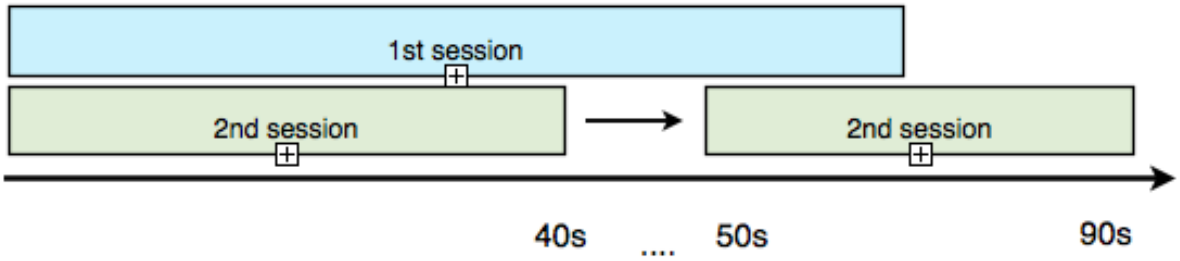
Result



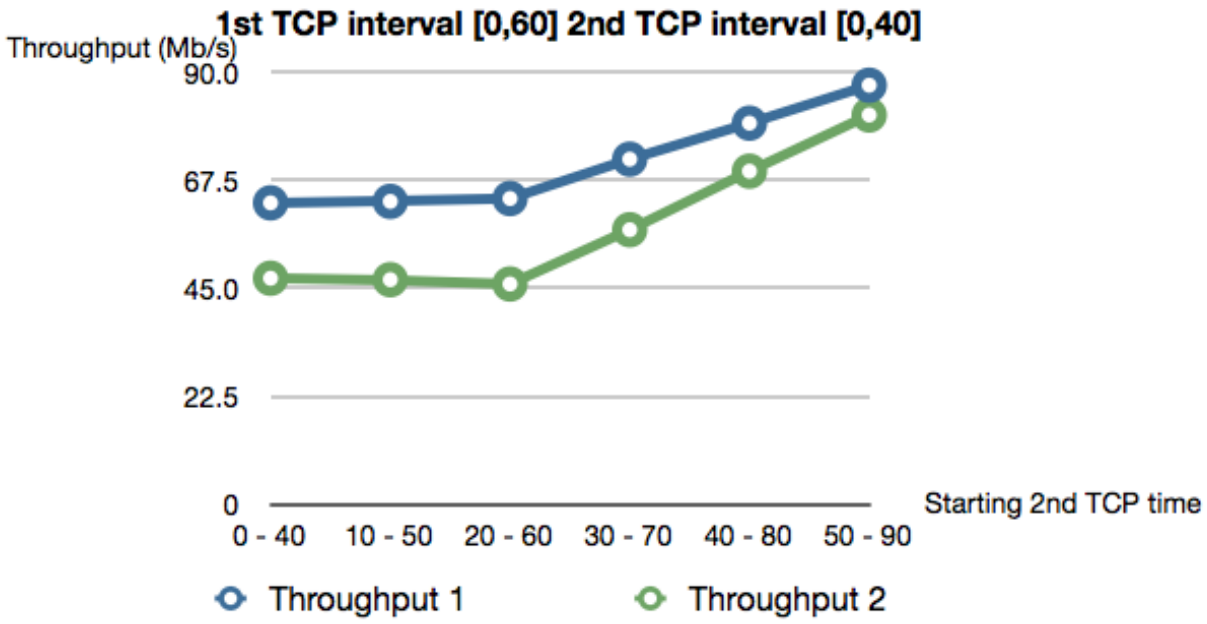
In third round, we still remain get higher throughput at 1st TCP session but the value is decreased. At the start 2nd TCP (30-60) throughput will increase because the same reason that I explained in previous round.

Fourth round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 40]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline



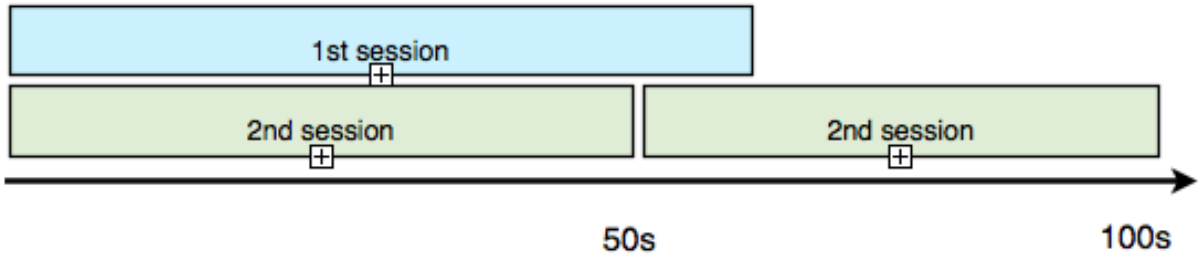
Result



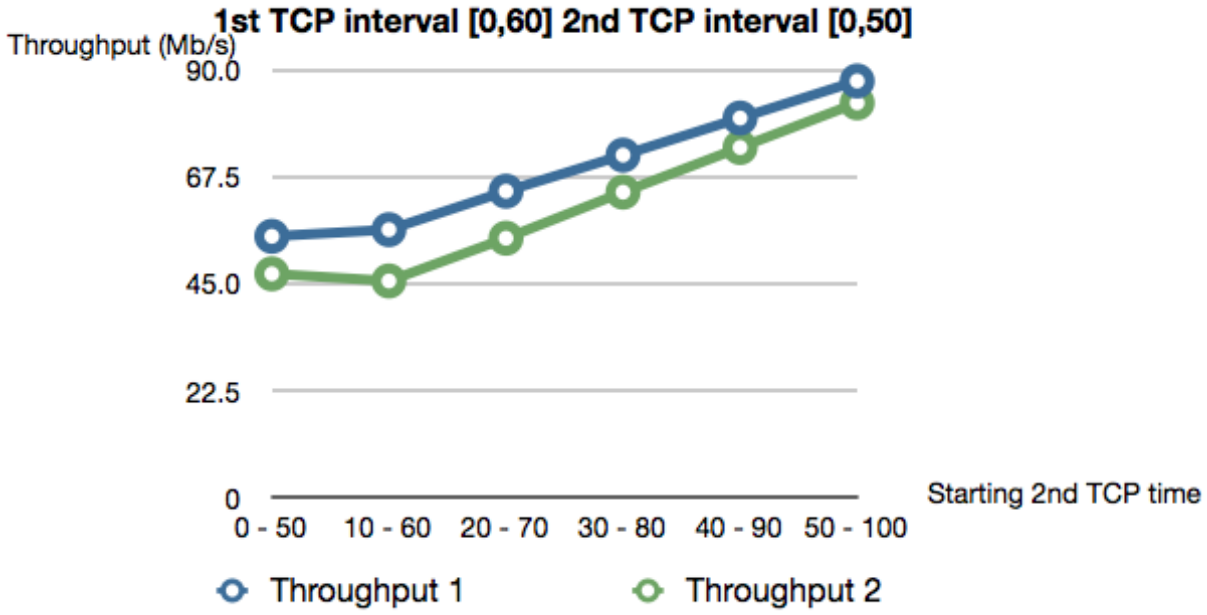
In fourth round, we still remain get higher throughput at 1st TCP session but the value is decreased. At the start 2nd TCP (20-60) throughput will increase because the same reason that I explained in second round.

Fifth round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 50]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline



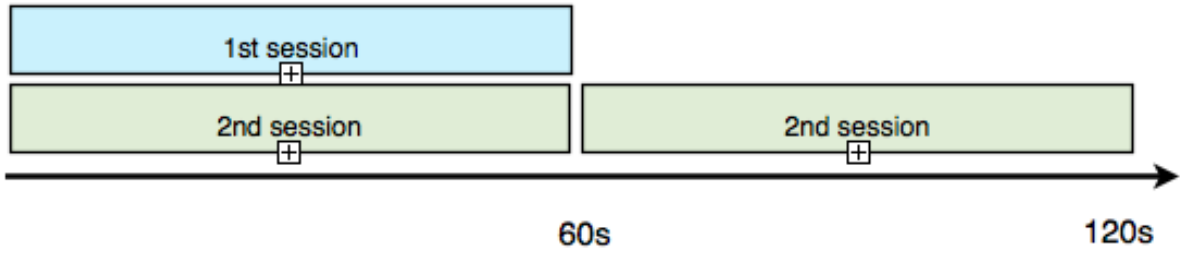
Result



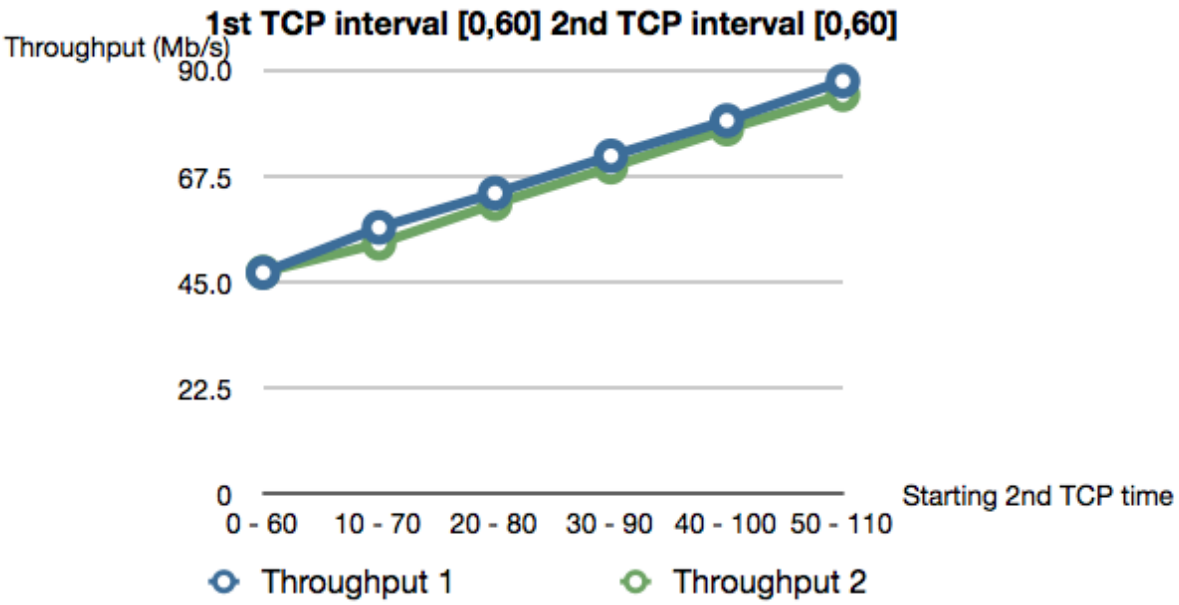
In fifth round, 1st TCP throughputs become closer with 2nd TCP throughput because the two TCP time intervals become closer.

Sixth round, Time interval of 1st TCP session is [0, 60] and 2nd is [0, 60]. We increase the waiting 2nd command execution time by increment every 10 seconds.

Timeline

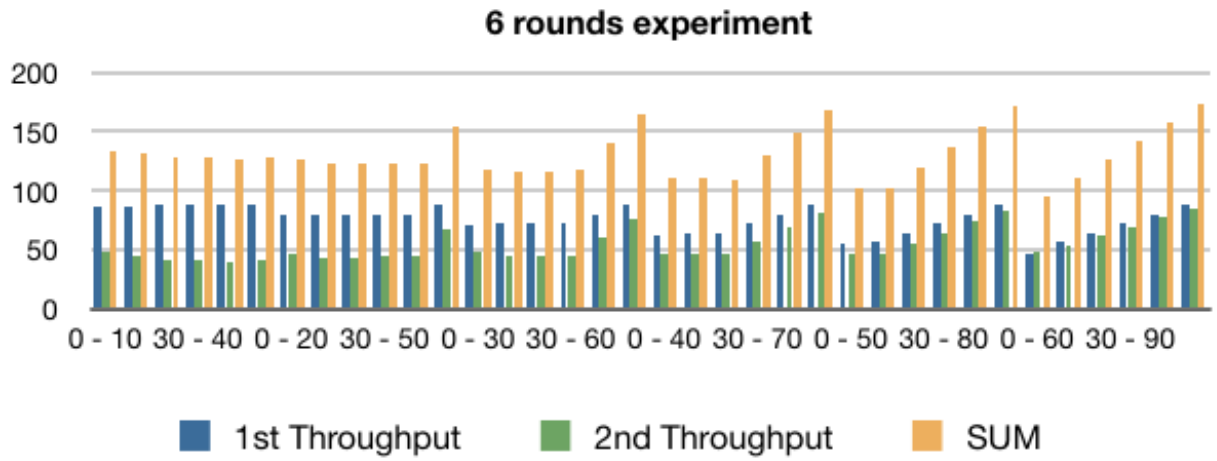


Result



In sixth round, two TCP throughputs become very close and constant increasing. But the TCP session that run first get a little higher throughput than second session.

Conclusion



Above is a graph of 6 rounds experiment. From every round, With 2 TCP sessions run different duration the highest throughput is 87.8 Mb/s and the lowest is 39.0. As we know if same link, size sized segment, with other traffic then the fairness of TCP is achieved. We can conclude that if we have 2 TCP sessions run in different duration, the one that take longer time will take higher throughput more than the other one. And if 2 sessions take same duration time, the one that starting first will get more a little bit throughput that the other one. In this take we do not assign the sending rate then TCP will send data as much as it can. So the duration time is the main factor that is affected with throughput.

Appendix

Phase2 Experiments and Results (wireless)

Data	Throughput 1	Throughput 2	Throughput 3	Avg.
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	3.95	3.98
5	5	5	5	5
6	6	6	6	6
7	7	6.92	7	6.97
8	8	8	8	8
9	9	9	9.01	9
10	9.32	10	10	9.77
11	11	11	11	11
12	12	10.8	12	11.6
13	13	13	13	13
14	14	14	14	14
15	15	15	12.3	14.1
16	16	16	16	16
17	17	17	17	17
18	13.6	18	18	16.5
19	19	19	18.9	19
20	19.9	20	13.8	17.9
21	13.8	20.6	20.9	18.4
22	21	22	22	21.7
23	21.9	23	15.8	20.2
24	23	24	23.9	23.6
25	23.9	25	24.9	24.6
26	24.9	16.6	25.2	22.2
27	25.6	25.3	25.9	25.6
28	26	25.9	20	24
29	17.1	26	25.9	23
30	24.6	25.7	26.2	25.5
31	25.7	26	16.6	22.8
32	25.8	26	25.8	25.9
33	26.2	26.2	26.2	26.2
34	26	16.6	26.4	23
35	26.4	25.7	25.9	26
36	26.2	25.8	25.8	25.9
37	19.2	25.6	25.8	23.5
38	25.8	26.9	25.6	26.1
39	25.7	21.5	26	24.4
40	25.6	26	25.8	25.8
50	25.8	25.6	25.5	25.6
60	23.4	25.5	25.7	24.9
70	25.8	26.1	26.2	26
80	26.1	25.4	26.5	26.5
90	26.3	26	26.1	26.1
100	25.8	26.1	25.8	25.9
MAX	26.4	26.9	26.5	26.5

Experiments and Results (wired LAN)

Data	Throughput 2	Throughput 2	Throughput 3	AVG
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9
10	10	10	10	10
11	11	11	11	11
12	12	12	12	12
13	13	13	13	13
14	14	14	14	14
15	15	15	15	15
16	16	16	16	16
17	17	17	17	17
18	18	18	18	18
19	19	19	19	19
20	20	20	20	20
21	21	21	21	21
22	22	22	22	22
23	23	23	23	23
24	24	24	24	24
25	25	25	25	25
26	26	26	26	26
27	27	27	27	27
28	28	28	28	28

29	29	29	29	29
30	30	30	30	30
31	31	31	31	31
32	32	32	32	32
33	33	33	33	33
34	34.1	34.1	34.1	34.1
35	35	35	35	35
36	36.1	36.1	36.1	36.1
37	37.1	37.1	37.1	37.1
38	38.1	38.1	38.1	38.1
39	39.1	39.1	39.1	39.1
40	40	40	40	40
41	41.1	41.1	41.1	41.1
42	42	42	42	42
43	43.1	43.1	43.1	43.1
44	44	44	44	44
45	45.1	45.1	45.1	45.1
46	46.1	46.1	46.1	46.1
47	47	47	47	47
48	48	48	48	48
49	49	49	49	49
50	50	50	50	50
51	51.1	51.1	51.1	51.1
52	52	52	52	52
53	53.2	53.2	53.2	53.2
54	54.2	54.2	54.2	54.2
55	55.2	55.2	55.2	55.2
56	56	56	56	56
57	57.1	57.1	57.1	57.1
58	58.2	58.2	58.2	58.2
59	59.1	59.1	59.1	59.1
60	60	60	60	60
61	61.3	61.3	61.3	61.3
62	62.2	62.2	62.2	62.2
63	63.2	63.2	63.2	63.2
64	64.3	64.3	64.3	64.3
65	65.3	65.3	65.3	65.3
66	66.1	66.1	66.1	66.1
67	67.2	67.2	67.2	67.2
68	68.4	68.4	68.4	68.4
69	69.2	69.2	69.2	69.2
70	70	70	70	70
71	71.3	71.3	71.3	71.3
72	72.1	72.1	72.1	72.1
73	73	73	73	73
74	74.4	74.4	74.4	74.4
75	75.4	75.4	75.4	75.4

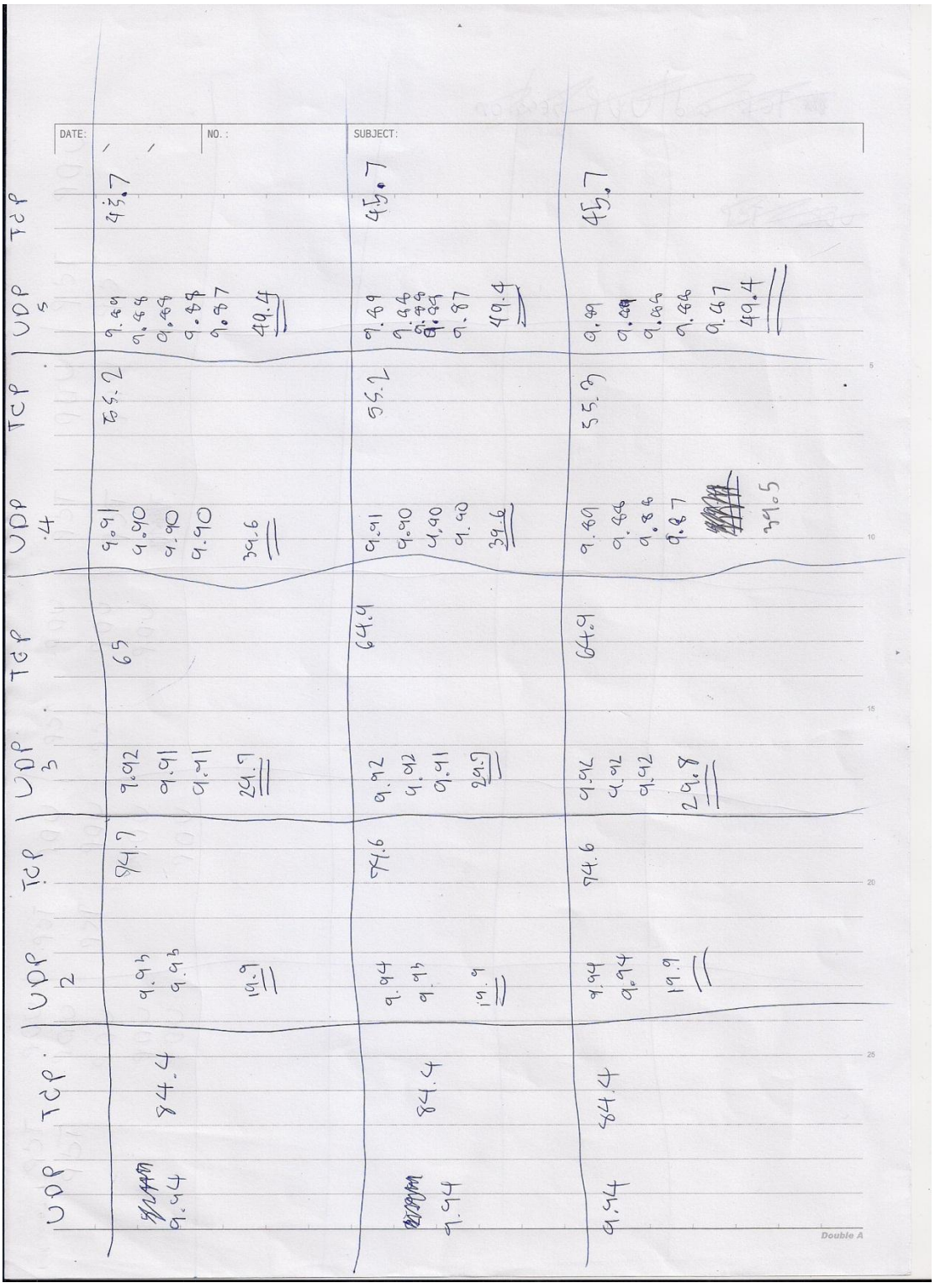
76	76.4	76.3	76.4	76.36667
77	77.4	77.4	77.4	77.4
78	78.4	78.4	77.7	78.16667
79	79.5	79.5	79.5	79.5
80	79.9	80	80	79.96667
81	81.1	81.1	81.1	81.1
82	82.2	82.2	82.2	82.2
83	83.4	83.4	83.4	83.4
84	84	84	84	84
85	85.2	85.2	85.2	85.2
86	86.5	86.4	86.5	86.46667
87	87.1	87.1	87.1	87.1
88	88.4	88.4	88.4	88.4
89	89.1	89.1	89.1	89.1
90	90.4	90.5	90.5	90.46667
91	91.2	91.2	91.2	91.2
92	92.6	92.5	92.6	92.56667
93	93.3	93.3	93.3	93.3
94	94.1	94	94.1	94.06667
95	95.4	95.4	95.4	95.4
96	95.4	95.3	95.4	95.36667
97	95.4	95.4	95.4	95.4
98	95.4	95.4	95.4	95.4
99	95.3	95.3	95.3	95.3
100	95.3	95.3	95.4	95.33333
Max	**95.4**	**95.4**	**95.4**	**95.4**

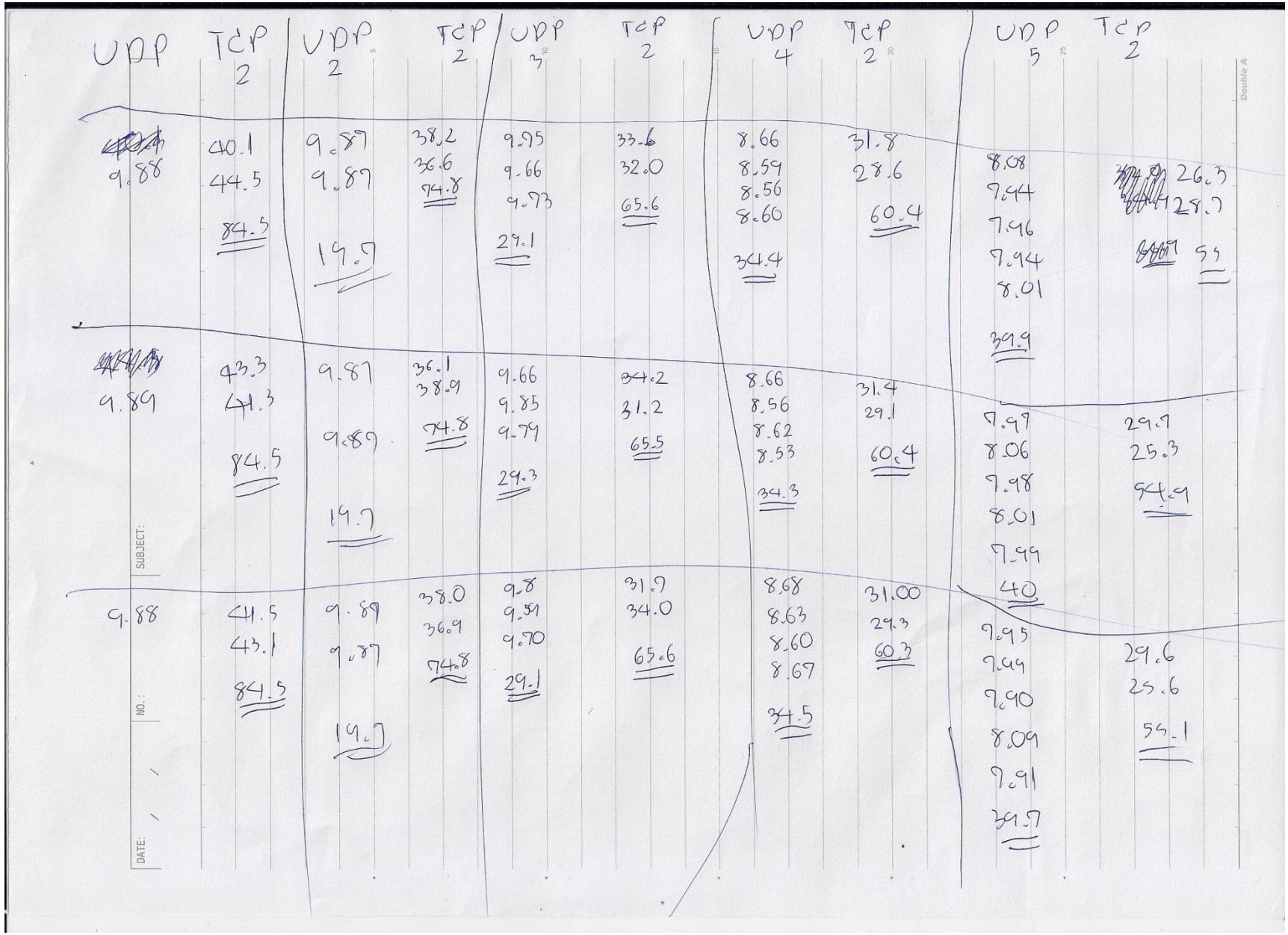
Phase3

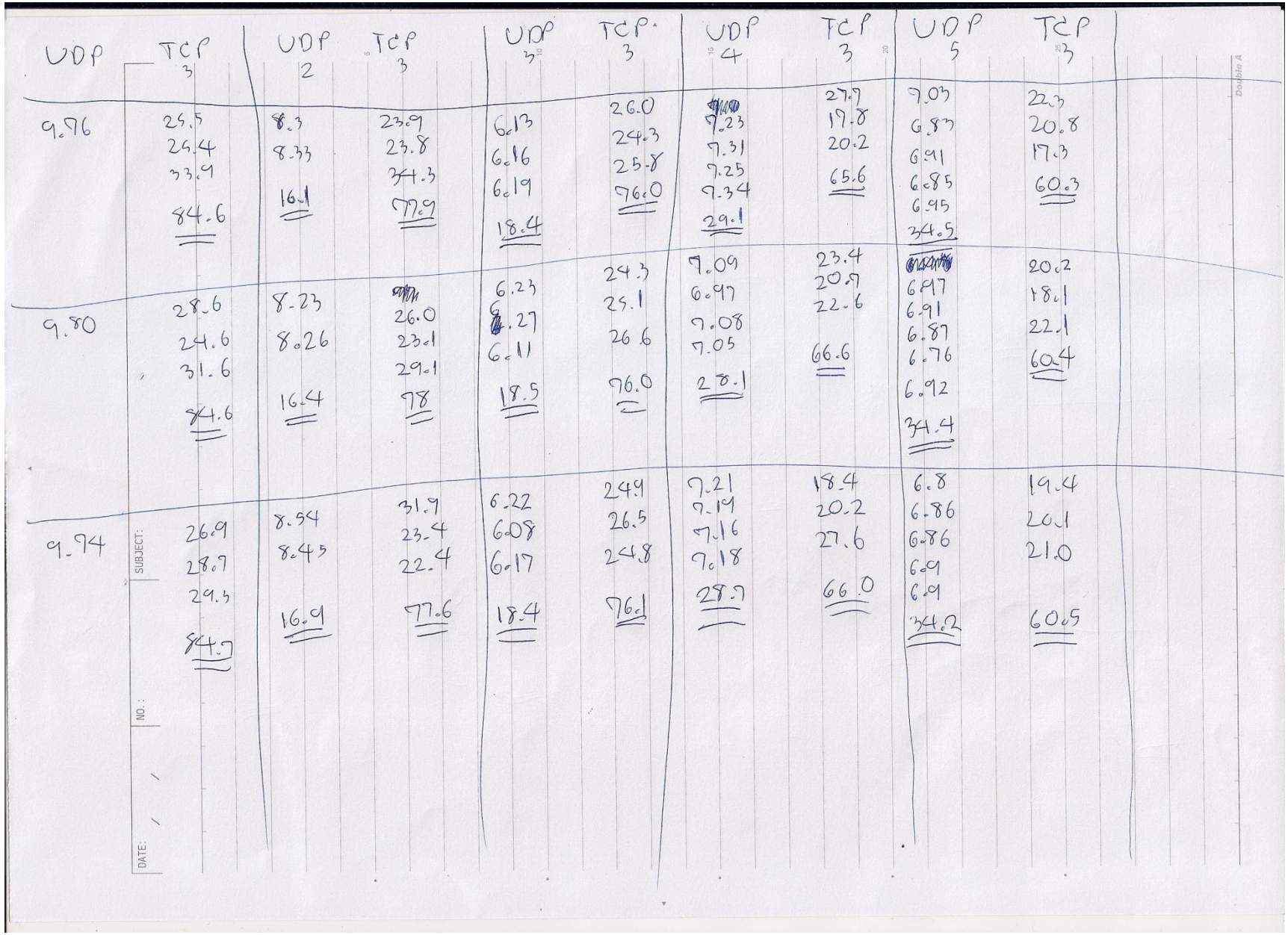
Multiple TCP Session

Numbers of TCP window	AVG of each window	SUM of throughput
1	94.1	94.1
2	47.05	94.1
3	31.36	94.1
4	23.52	94.1
5	18.82	94.1
6	15.68	94.1
7	13.44	94.1
8	11.762	94.1
9	10.455	94.1
10	9.41	94.1
11	8.554	94.1
12	7.841	94.1
13	7.238	94.1
14	6.721	94.1
15	6.27	94.1
16	5.88	94.1
17	5.53	94.1
18	5.3	94.1
19	4.95	94.1
20	4.705	94.1
21	4.4809	94.1
22	4.276	94.1
23	4.09	94.1
24	3.92	94.1
25	3.764	94.1
26	3.619	94.1
27	3.485	94.1
28	3.36	94.1
29	3.244	94.1
30	3.136	94.1

TCP&UDPSession.

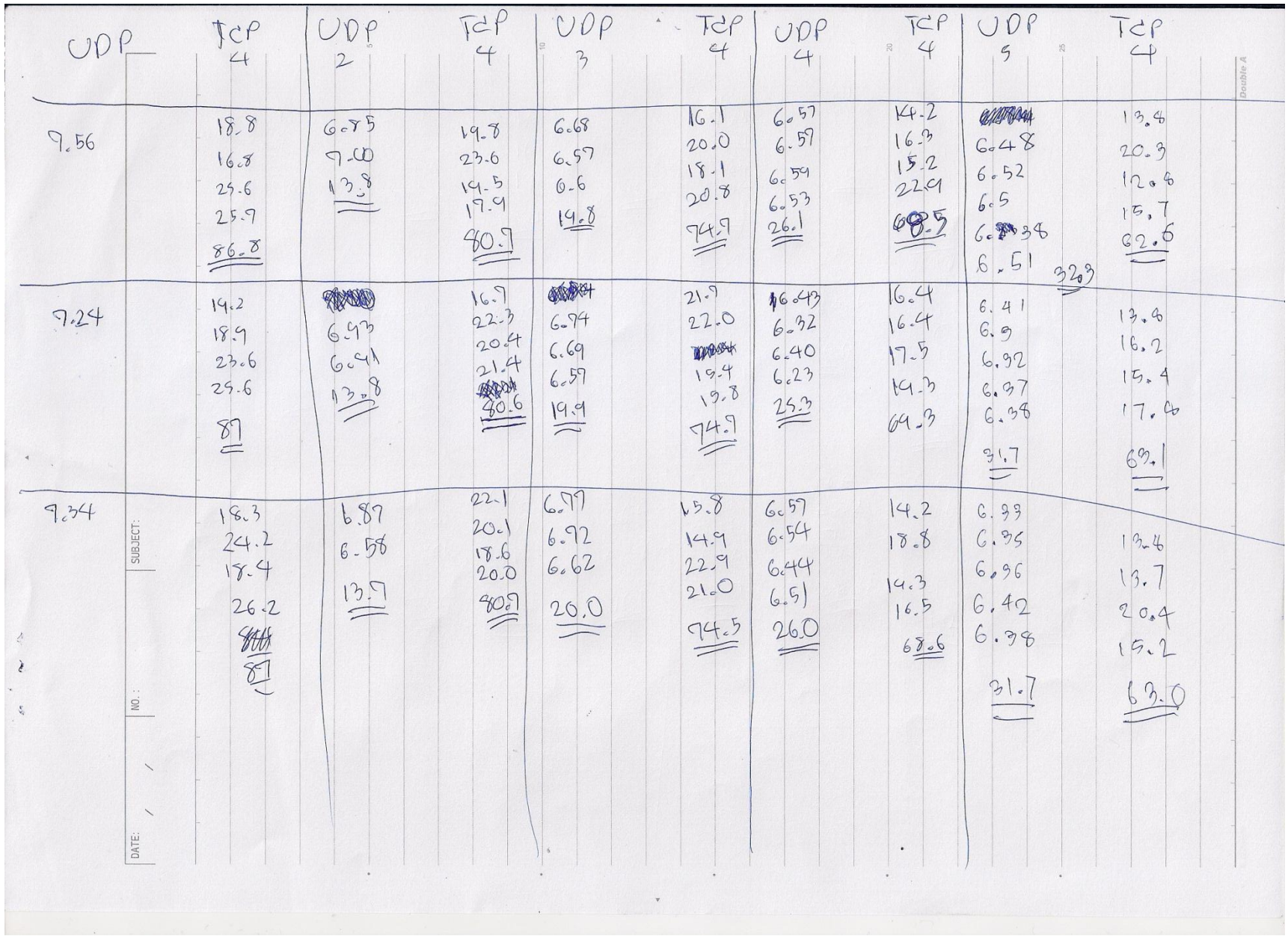



UDP
TCP
2
UDP
2
TCP
2
UDP
3
TCP
2
UDP
4
TCP
2
UDP
5
TCP
2
9.88
40.1
44.5
84.5
9.87
9.87
14.7
38.2
36.6
74.8
9.95
9.66
9.73
29.1
33.6
32.0
65.6
8.66
8.59
8.56
8.60
34.4
31.8
28.6
60.4
8.08
7.44
7.96
7.94
8.01
39.9
26.3
28.7
55
9.89
43.3
41.3
84.5
9.87
9.89
14.7
36.1
38.9
74.8
9.66
9.85
9.79
29.3
34.2
31.2
65.5
8.66
8.56
8.62
8.53
34.3
31.4
29.1
60.4
7.97
8.06
7.98
8.01
7.99
40
29.7
25.3
54.9
9.88
41.5
43.1
84.5
9.89
9.87
14.7
38.0
36.9
74.8
9.8
9.51
9.70
29.1
31.9
34.0
65.6
8.68
8.63
8.60
8.67
34.5
31.00
29.3
60.3
7.95
7.44
7.90
8.09
7.91
39.7
29.6
25.6
55.1
DATE:
NO.:
SUBJECT:
Double A



UDP	TCP 3	UDP 2	TCP 3	UDP 3	TCP 3	UDP 4	TCP 3	UDP 5	TCP 3
9.96	25.5 25.4 33.9 84.6	8.3 8.33 16.1	23.9 23.8 34.3 77.9	6.13 6.16 6.19 18.4	26.0 24.3 25.8 76.0	7.23 7.31 7.25 7.34 29.1	27.7 19.8 20.2 65.6	7.03 6.87 6.91 6.85 6.95 34.5	22.3 20.8 17.3 60.3
9.80	28.6 24.6 31.6 84.6	8.23 8.26 16.4	26.0 23.1 29.1 78	6.23 6.27 6.11 18.5	24.3 25.1 26.6 76.0	7.09 6.97 7.08 7.05 28.1	23.4 20.9 22.6 66.6	6.97 6.91 6.87 6.76 6.92 34.4	20.2 18.1 22.1 60.4
9.94	26.9 28.7 29.3 84.7	8.54 8.45 16.9	31.7 23.4 22.4 77.6	6.22 6.08 6.17 18.4	24.9 26.5 24.8 76.1	7.21 7.19 7.16 7.18 28.7	18.4 20.2 27.6 66.0	6.8 6.86 6.86 6.9 6.9 34.2	19.4 20.1 21.0 60.5

SUBJECT:
NO.:
DATE: / /



UDP		TCP 4	UDP 2	TCP 4	UDP 3	TCP 4	UDP 4	TCP 4	UDP 5	TCP 4
9.56		18.8 16.8 25.6 25.7 86.8	6.85 7.00 13.8	19.8 23.6 14.5 17.9 80.7	6.68 6.57 6.6 14.8	16.1 20.0 18.1 20.8 74.9	6.57 6.59 6.54 6.53 26.1	14.2 16.3 15.2 22.9 68.5	6.48 6.52 6.5 6.38 6.51 32.9	13.4 20.3 12.6 15.7 62.6
9.24		19.2 18.9 23.6 25.6 87	6.53 6.41 13.8	16.7 22.3 20.4 21.4 80.6	6.74 6.69 6.59 19.9	21.9 22.0 19.4 19.8 74.9	6.43 6.32 6.40 6.23 25.3	16.4 16.4 17.5 14.3 64.3	6.41 6.9 6.92 6.37 6.38 31.7	13.6 16.2 15.4 17.6 63.1
9.34		18.3 24.2 18.4 26.2 87	6.87 6.58 13.7	22.1 20.1 18.6 20.0 80.7	6.77 6.92 6.62 20.0	15.8 14.9 22.9 21.0 74.5	6.59 6.54 6.44 6.51 26.0	14.2 18.8 14.3 16.5 63.6	6.99 6.35 6.96 6.42 6.38 31.7	13.4 13.7 20.4 15.2 63.0

SUBJECT: | NO.: | DATE: / /

UDP	TCP 5	UDP 2	TCP 5	UDP 3	TCP 5	UDP 4	TCP 5	UDP 5	TCP 5
6.63	15.5	6.25	12.0	6.27	13.5	6.14	12.6	6.13	10.1
	13.4	6.38	14.6	6.23	19.8	6.08	14.8	5.97	14.4
	21.0		21.5	6.26	11.4	6.09	16.5	6.13	12.2
	19.3		15.0		16.0	6.18	11.9	5.98	10.4
	19.0		18.9		15.4		14.9	6.1	17.6
	87.7	12.6	81.8	18.7	75.8	24.4	70.2	30.2	64.5
6.69	17.1	6.35	14.7	6.09	12.8	6.0	18.7	6.08	10.8
	15.0	6.36	12.5	6.12	17.5	6.07	14.4	5.97	10.7
	15.6		17.3	6.11	15.5	6.03	11.3	5.99	16.3
	21.5		16.2		17.6	6.1	13.9	5.98	13.5
	18.9		19.2		13.8		12.6	6.16	13.6
	87.7	12.7	81.7	18.3	76.2	24.1	70.5	30.1	64.7
6.66	14.1	6.44	21.7	6.26	13.2	6.26	17.9	6.22	11.7
	14.1	6.44	14.1	6.12	13.4	6.09	14.9	6.24	9.76
	17.6		15.4	6.06	19.8	6.21	13.0	6.09	16.7
	20.5		17.3		13.6	6.19	13.2	6.14	16.2
	20.7		13.5		16.3		11.3	6.04	10
	87.6	12.8	81.0	18.4	76.2	24.6	70	30.6	64.2

1 TCP & 1-5 UDP

	First	second	Third	AVG
1UDP	9.94	9.94	9.94	9.94
1TCP	84.4	84.4	84.4	84.4
2UDP	19.9	19.9	19.9	19.9
1TCP	74.7	74.6	74.6	74.65
3UDP	29.7	29.7	29.8	29.75
1TCP	65	64.9	64.9	64.95
4UDP	39.6	39.6	39.5	39.55
1TCP	55.2	55.2	55.3	55.25
5UDP	49.4	49.4	49.4	49.4
1TCP	45.7	45.7	45.7	45.7

2 TCP & 1-5 UDP

	First	second	Third	AVG
1UDP	9.88	9.89	9.88	9.883333
2TCP	84.5	84.5	84.5	84.5
2UDP	19.7	19.7	19.7	19.7
2TCP	74.8	74.8	74.8	74.8
3UDP	29.1	29.3	29.1	29.16667
2TCP	65.6	65.5	65.6	65.56667
4UDP	34.4	34.3	34.5	34.4
2TCP	60.4	60.4	60.3	60.36667
5UDP	39.9	40	39.7	39.86667
2TCP	55	54.9	55.1	55

3 TCP & 1-5 UDP

	First	second	Third	AVG
1UDP	9.76	9.8	9.74	9.766667
3TCP	84.6	84.6	84.7	84.63333
2UDP	16.1	16.4	16.9	16.46667
3TCP	77.9	78	77.6	77.83333
3UDP	18.4	18.5	18.4	18.43333
3TCP	76	76	76.1	76.03333
4UDP	29.1	28.1	28.7	28.63333
3TCP	65.6	66.6	66	66.06667
5UDP	34.5	34.4	34.2	34.36667
3TCP	60.3	60.4	60.5	60.4

4 TCP & 1-5 UDP

	First	second	Third	AVG
1UDP	7.56	7.24	7.34	7.38
4TCP	86.6	87	87	86.86667
2UDP	13.8	13.8	13.7	13.76667
4TCP	80.7	80.6	80.7	80.66667
3UDP	19.8	19.9	20	19.9
4TCP	74.7	74.7	74.5	74.63333
4UDP	26.1	25.3	26	25.8
4TCP	68.5	69.3	68.6	68.8
5UDP	32.3	31.7	31.7	31.9
4TCP	62.6	63.1	63	62.9

5TCP & 1-5 UDP

	First	second	Third	AVG
1UDP	6.63	6.69	6.66	6.66
5TCP	87.7	87.7	87.6	87.66667
2UDP	12.6	12.7	12.8	12.7
5TCP	81.8	81.7	81	81.5
3UDP	18.7	18.3	18.4	18.46667
5TCP	75.8	76.2	76.2	76.06667
4UDP	24.4	24.1	24.6	24.36667
5TCP	70.2	70.5	70	70.23333
5UDP	30.2	30.1	20.6	26.96667
5TCP	64.5	64.7	64.2	64.46667

TCP & UDP Session: (Experiment 2)

TPC (Mb/s)				
UDP Size(Mb)	1st Throughput	2nd Throughput	3rd Throughput	Average
1	93.2	93.2	93.2	93.2
2	92.2	92.2	92.2	92.2
3	91.2	91.2	91.2	91.2
4	90.2	90.2	90.2	90.2
5	89.2	89.3	89.3	89.2666667
6	88.3	88.3	88.3	88.3
7	87.3	87.3	87.3	87.3
8	86.3	86.3	86.4	86.3333333
9	85.4	85.4	85.4	85.4
10	84.4	84.3	84.4	84.3666667
11	83.4	83.4	83.4	83.4
12	82.4	82.4	82.5	82.4333333
13	81.5	81.5	81.5	81.5
14	80.5	80.5	80.5	80.5
15	79.5	79.5	79.5	79.5
16	78.6	78.5	78.5	78.5333333
17	77.6	77.6	77.6	77.6
18	76.6	76.6	76.6	76.6
19	75.6	75.6	75.6	75.6
20	74.7	74.6	74.7	74.6666667
21	73.7	73.7	73.7	73.7
22	72.7	72.7	72.7	72.7
23	71.7	71.7	71.7	71.7
24	70.8	70.8	70.8	70.8
25	69.8	69.8	69.8	69.8
26	68.8	68.9	68.8	68.8333333
27	67.8	67.8	67.8	67.8
28	66.9	66.9	66.9	66.9
29	65.9	65.9	65.8	65.8666667
30	64.9	64.9	64.9	64.9
31	63.9	64	63.9	63.9333333
32	63	63	63	63
33	62	61.9	62	61.9666667
34	61	61.1	61	61.0333333
35	60.1	60.1	61	60.4
36	59.1	59.1	59	59.0666667
37	58.1	58	58.1	58.0666667
38	57.1	57.1	57.1	57.1
39	56.2	56.2	56.2	56.2
40	55.3	55.2	55.3	55.2666667
41	54.3	54.2	54.2	54.2333333
42	53.5	53.6	53.6	53.5666667
43	53.4	53.6	53.7	53.5666667

44	53.4	53.6	53.7	53.5666667
45	53.2	53.2	53.1	53.1666667
46	52.9	53.1	52.5	52.8333333
47	52.9	52.9	52.8	52.8666667
48	52.7	52.6	52.7	52.6666667
49	52.4	52.6	52.6	52.5333333
50	52	52.3	52.2	52.1666667
51	51.8	51.8	51.7	51.7666667
52	51.4	51.6	51.5	51.5
53	51.3	51.3	51.3	51.3
54	51.2	51.2	51	51.1333333
55	51	50.9	51.1	51
56	50.8	50.4	50.7	50.6333333
57	50.6	50.1	50.6	50.4333333
58	50.3	49.8	50.3	50.1333333
59	50.2	50.1	50	50.1
60	49.8	49.8	49.5	49.7
61	49.5	49.5	49.7	49.5666667
62	49.5	49.4	49.2	49.3666667
63	49.1	49.5	49.6	49.4
64	48.9	49	48.6	48.8333333
65	48.3	48.2	48.1	48.2
66	48.3	48.8	48.5	48.5333333
67	48.2	49.1	48.1	48.4666667
68	48.4	48.6	47.6	48.2
69	47.4	47.3	46.9	47.2
70	47.3	47.2	47.2	47.2333333
71	46.3	46.6	46.9	46.6
72	46.4	46.9	46.4	46.5666667
73	46.3	46.6	46.8	46.5666667
74	46.2	47	45.9	46.3666667
75	46.6	47	45.9	46.5
76	45.3	46.5	45.5	45.7666667
77	44.8	45.4	45	45.0666667
78	44.6	44.5	44.5	44.5333333
79	44.9	44.3	44.1	44.4333333
80	44.8	43.8	43.8	44.1333333
81	43.7	43.3	43.5	43.5
82	43.1	43.4	43.1	43.2
83	42.9	42.8	42.7	42.8
84	42.4	43	43.5	42.9666667
85	41.9	41.8	41.4	41.7
86	41.2	41.7	41.2	41.3666667
87	41.1	42.6	41.4	41.7
88	40.8	40.5	40.3	40.5333333
89	40.3	42.2	41.1	41.2
90	39.6	41.2	41.5	40.7666667
91	39.4	39.7	39.7	39.6

92	39.4	39.5	38.7	39.2
93	38.5	43.2	42.7	41.4666667
94	38	38.9	41.6	39.5
95	38.4	38.4	38	38.2666667
96	37	38.3	42.6	39.3
97	38.1	37.9	37.8	37.9333333
98	37	40.2	36.9	38.0333333
99	37.7	37	40	38.2333333
100	37	36.9	37.1	37

UDP(Mb/s)				
UDP(Mb)	1st Throughput	2nd Throughput	3rd Throughput	Average
1	0.994	0.994	0.995	0.994333333
2	1.99	1.99	1.99	1.99
3	2.98	2.98	2.98	2.98
4	3.98	3.98	3.98	3.98
5	4.97	4.97	4.97	4.97
6	5.97	5.96	5.97	5.966666667
7	6.96	6.96	6.96	6.96
8	7.95	7.95	7.95	7.95
9	8.95	8.95	8.95	8.95
10	9.94	9.94	9.94	9.94
11	10.9	10.9	10.9	10.9
12	11.9	11.9	11.9	11.9
13	12.9	12.9	12.9	12.9
14	13.9	13.9	13.9	13.9
15	14.9	14.9	14.9	14.9
16	15.9	15.9	15.9	15.9
17	16.9	16.9	16.9	16.9
18	17.9	17.9	17.9	17.9
19	18.9	18.9	18.9	18.9
20	19.9	19.9	19.9	19.9
21	20.9	20.9	20.9	20.9
22	21.9	21.9	21.9	21.9
23	22.9	22.9	22.9	22.9
24	23.8	23.8	23.8	23.8
25	24.8	24.8	24.8	24.8
26	25.8	25.8	25.8	25.8
27	25.8	25.8	25.8	25.8
28	27.8	27.8	27.8	27.8
29	28.8	28.8	28.8	28.8
30	29.8	29.8	29.8	29.8
31	30.8	30.8	30.8	30.8
32	31.8	31.8	31.8	31.8
33	32.8	32.8	32.8	32.8
34	33.8	33.8	33.8	33.8

35	34.7	34.7	34.7	34.7
36	35.8	35.8	35.8	35.8
37	36.8	36.8	36.8	36.8
38	37.7	37.7	37.7	37.7
39	38.7	38.7	38.7	38.7
40	39.6	39.6	39.6	39.6
41	40.7	40.7	40.7	40.7
42	41.5	41.4	41.3	41.4
43	41.5	41.4	41.3	41.4
44	41.6	41.8	41.6	41.66666667
45	41.7	41.7	41.8	41.73333333
46	42	41.9	42.5	42.13333333
47	42.1	42.1	42.2	42.13333333
48	42.3	42.3	42.2	42.26666667
49	42.6	42.4	42.4	42.46666667
50	42.9	42.6	42.8	42.76666667
51	43.2	43.1	43.4	43.23333333
52	43.6	43.6	43.5	43.56666667
53	43.7	43.6	43.7	43.66666667
54	43.8	43.8	43.9	43.83333333
55	44	44	44	44
56	44.2	44.5	44.3	44.33333333
57	44.4	45	44.5	44.63333333
58	44.7	45.1	44.7	44.83333333
59	44.8	44.9	44.9	44.86666667
60	45.3	45.1	45.5	45.3
61	45.5	45.4	45.4	45.43333333
62	45.6	45.7	45.8	45.7
63	46	45.6	45.4	45.66666667
64	46.2	46.1	46.5	46.26666667
65	46.7	46.9	46.9	46.83333333
66	46.8	46.2	46.5	46.5
67	46.9	46	46.9	46.6
68	46.7	46.5	47.5	46.9
69	47.6	47.9	48.2	47.9
70	47.8	48	47.9	47.9
71	48.7	48.4	48.1	48.4
72	48.7	48.3	48.7	48.56666667
73	48.8	48.4	48.4	48.53333333
74	48.4	49.1	48.8	48.76666667
75	48.6	48	49.3	48.63333333
76	49.8	48.6	49.6	49.33333333
77	50.2	49.7	50.1	50
78	50.6	50.7	50.6	50.63333333
79	50.3	50.9	51	50.73333333
80	50.4	51.4	51.3	51.03333333
81	51.4	52	51.7	51.7
82	52.1	51.7	51.8	51.86666667

83	52.3	52.5	52.4	52.4
84	52.8	52.3	51.6	52.23333333
85	53.2	53.4	53.7	53.43333333
86	53.9	53.5	54.1	53.83333333
87	54	52.6	53.8	53.46666667
88	54.4	54.7	54.9	54.66666667
89	55	53	54.1	54.03333333
90	55.6	53.9	53.7	54.4
91	55.7	55.6	55.8	55.7
92	55.9	55.6	56.4	55.96666667
93	56.7	52.1	52.6	53.8
94	57.2	56.3	53.6	55.7
95	56.9	56.7	57.2	56.93333333
96	58.3	57	52.6	55.96666667
97	57.2	57.3	57.4	57.3
98	58.3	55	58.2	57.16666667
99	57.6	58.3	55.2	57.03333333
100	58	58.4	58.3	58.23333333

SUM (Mb/s)			
Size of UDP (Mb)	Average TCP	Average UDP	SUM
1	93.2	0.994333333	94.1943333
2	92.2	1.99	94.19
3	91.2	2.98	94.18
4	90.2	3.98	94.18
5	89.26666667	4.97	94.2366667
6	88.3	5.966666667	94.2666667
7	87.3	6.96	94.26
8	86.33333333	7.95	94.2833333
9	85.4	8.95	94.35
10	84.36666667	9.94	94.3066667
11	83.4	10.9	94.3
12	82.43333333	11.9	94.3333333
13	81.5	12.9	94.4
14	80.5	13.9	94.4
15	79.5	14.9	94.4
16	78.53333333	15.9	94.4333333
17	77.6	16.9	94.5
18	76.6	17.9	94.5
19	75.6	18.9	94.5
20	74.66666667	19.9	94.5666667
21	73.7	20.9	94.6
22	72.7	21.9	94.6
23	71.7	22.9	94.6
24	70.8	23.8	94.6

25	69.8	24.8	94.6
26	68.83333333	25.8	94.6333333
27	67.8	25.8	93.6
28	66.9	27.8	94.7
29	65.86666667	28.8	94.6666667
30	64.9	29.8	94.7
31	63.93333333	30.8	94.7333333
32	63	31.8	94.8
33	61.96666667	32.8	94.7666667
34	61.03333333	33.8	94.8333333
35	60.4	34.7	95.1
36	59.06666667	35.8	94.8666667
37	58.06666667	36.8	94.8666667
38	57.1	37.7	94.8
39	56.2	38.7	94.9
40	55.26666667	39.6	94.8666667
41	54.23333333	40.7	94.9333333
42	53.56666667	41.4	94.9666667
43	53.56666667	41.4	94.9666667
44	53.56666667	41.66666667	95.2333333
45	53.16666667	41.73333333	94.9
46	52.83333333	42.13333333	94.9666667
47	52.86666667	42.13333333	95
48	52.66666667	42.26666667	94.9333333
49	52.53333333	42.46666667	95
50	52.16666667	42.76666667	94.9333333
51	51.76666667	43.23333333	95
52	51.5	43.56666667	95.0666667
53	51.3	43.66666667	94.9666667
54	51.13333333	43.83333333	94.9666667
55	51	44	95
56	50.63333333	44.33333333	94.9666667
57	50.43333333	44.63333333	95.0666667
58	50.13333333	44.83333333	94.9666667
59	50.1	44.86666667	94.9666667
60	49.7	45.3	95
61	49.56666667	45.43333333	95
62	49.36666667	45.7	95.0666667
63	49.4	45.66666667	95.0666667
64	48.83333333	46.26666667	95.1
65	48.2	46.83333333	95.0333333
66	48.53333333	46.5	95.0333333
67	48.46666667	46.6	95.0666667
68	48.2	46.9	95.1
69	47.2	47.9	95.1
70	47.23333333	47.9	95.1333333
71	46.6	48.4	95
72	46.56666667	48.56666667	95.1333333

73	46.56666667	48.53333333	95.1
74	46.36666667	48.76666667	95.1333333
75	46.5	48.63333333	95.1333333
76	45.76666667	49.33333333	95.1
77	45.06666667	50	95.0666667
78	44.53333333	50.63333333	95.1666667
79	44.43333333	50.73333333	95.1666667
80	44.13333333	51.03333333	95.1666667
81	43.5	51.7	95.2
82	43.2	51.86666667	95.0666667
83	42.8	52.4	95.2
84	42.96666667	52.23333333	95.2
85	41.7	53.43333333	95.1333333
86	41.36666667	53.83333333	95.2
87	41.7	53.46666667	95.1666667
88	40.53333333	54.66666667	95.2
89	41.2	54.03333333	95.2333333
90	40.76666667	54.4	95.1666667
91	39.6	55.7	95.3
92	39.2	55.96666667	95.1666667
93	41.46666667	53.8	95.2666667
94	39.5	55.7	95.2
95	38.26666667	56.93333333	95.2
96	39.3	55.96666667	95.2666667
97	37.93333333	57.3	95.2333333
98	38.03333333	57.16666667	95.2
99	38.23333333	57.03333333	95.2666667
100	37	58.23333333	95.2333333

TCP sessions over varying duration.

1st duration	2nd duration	Throughput		
		1st	2nd	SUM
0 - 10	-	94.8		
0 - 30	-	94.4		
First TCP time interval [0,60] and second TCP time interval [0,10].				
0 - 60	0 - 10	86.3	47.5	133.8
0 - 60	10 - 20	86.6	45.3	131.9
0 - 60	20 - 30	87.5	40.4	127.9
0 - 60	30 - 40	87.4	40.7	128.1
0 - 60	40 - 50	87.7	39.0	126.7
0 - 60	50 - 60	87.6	40.4	128
First TCP time interval [0,60] and second TCP time interval [0,20].				
0 - 60	0 - 20	78.5	47.0	125.5
0 - 60	10 - 30	79.6	43.7	123.3
0 - 60	20 - 40	79.9	43.0	122.9
0 - 60	30 - 50	79.6	43.8	123.4
0 - 60	40 - 60	79.7	43.9	123.6
0 - 60	50 - 70	87.6	67.1	154.7
First TCP time interval [0,60] and second TCP time interval [0,30].				
0 - 60	0 - 30	70.4	47.8	118.2
0 - 60	10 - 40	71.8	44.9	116.7
0 - 60	20 - 50	71.8	44.9	116.7
0 - 60	30 - 60	71.9	45.0	116.9
0 - 60	40 - 70	79.7	60.0	139.7
0 - 60	50 - 80	87.6	76.3	163.9
First TCP time interval [0,60] and second TCP time interval [0,40].				
0 - 60	0 - 40	62.8	47.1	109.9
0 - 60	10 - 50	63.1	46.8	109.9
0 - 60	20 - 60	63.7	45.9	109.6
0 - 60	30 - 70	71.9	57.2	129.1
0 - 60	40 - 80	79.4	69.4	148.8
0 - 60	50 - 90	87.3	81.1	168.4
First TCP time interval [0,60] and second TCP time interval [0,50].				
0 - 60	0 - 50	55.0	47.1	102.1
0 - 60	10 - 60	56.4	45.6	102
0 - 60	20 - 70	64.5	54.6	119.1
0 - 60	30 - 80	72.1	64.3	136.4
0 - 60	40 - 90	79.9	73.7	153.6
0 - 60	50 - 100	87.7	83.1	170.8
First TCP time interval [0,60] and second TCP time interval [0,60].				
0 - 60	0 - 60	47.1	47.2	94.3
0 - 60	10 - 70	56.7	53.3	110
0 - 60	20 - 80	64.0	61.7	125.7
0 - 60	30 - 90	71.9	69.5	141.4
0 - 60	40 - 100	79.4	77.6	157
0 - 60	50 - 110	87.8	84.9	172.7