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# README

## Command execution format

There are two program executable files that get generated after you run make. Following are the formats of running the same:-

1. **webserver\_udp <PORT> <WINDOW\_SIZE> [<ENABLE\_PACKET\_LOSS (1/0) Default: 0>] [DROP\_PERCENTAGE]**

* PORT – Port on which the server would run.
* WINDOW\_SIZE – Initial window size to start with. Theoretically it should be 1.
* ENABLE\_PACKET\_LOSS – Flag to enable packet loss simulation ( 1-> Enable/ 0-> Disable). This defaults to 0
* DROP\_PERCENTAGE – This parameter is required if ENABLE\_PACKET\_LOSS is provided. It is a numerical percentage value for the number of packets to be dropped.

1. **webclient\_udp <HOST> <PORT> <FILENAME> <WINDOW\_SIZE> [<DELAYS\_ENABLED (1/0) Default: 0>]**

* HOST – Hostname of the server from which you would request a file.
* PORT – Port that is being used by the server.
* FILENAME – Name of the file to request.
* WINDOW\_SIZE – Initial window size to expect from the server. Typically this is same as the ‘WINDOW\_SIZE’ parameter for ‘webserver\_udp’.
* DELAYS\_ENABLED – Flag to enable delays, simulating high latency communication (1-> Enable/ 0-> Disable). This defaults to 0.

## Steps to execute the UDP programs for various scenarios described

In assignment\_dir run make:-

[mawagle@silo assignment\_dir]$ make

gcc -o client/webclient\_udp client/webclient\_udp.c

gcc -o server/webserver\_udp server/webserver\_udp.c

I would then typically open two duplicate terminals, one for server and another for client, with assignment\_dir as current directory.

To run server in server terminal:-

From assignment\_dir, change to server directory and execute the compiled executable webserver\_udp.

[mawagle@silo assignment\_dir]$ **cd server**

[mawagle@silo server]$ **./webserver\_udp <ARGS…>**

To run client in client terminal:-

From assignment\_dir, change to client directory and execute the compiled executable webserver\_udp.

[mawagle@silo assignment\_dir]$ **cd client**

[mawagle@silo server]$ **./webclient\_udp <ARGS…>**

Following examples are created using the sample file ‘**hello.txt**’ included in the submitted assignment archive in the server directory.

Files requested to be transferred by the client should be present in the same directory as the compiled server executable.

### Simple run without packet drop or delay

**On the Server Side:-**

[mawagle@silo server]$ **./webserver\_udp 2222 1**

Server started. Waiting for datagram requests...

Waiting for handshake from client for next 60 seconds...

**Here is where the handshake occurs and receiver sends the file name to the sender to be transmitted**

HANDSHAKE SYN Received

HANDSHAKE SYNACK Sent

HANDSHAKE ACK Received

-------- Handshake Successful --------

Packet Buffer Length = 12

-------- Data Packets transfer begins --------

Packet sent: Seq. No: 1 | Sent time- 1444587992: 239783 **🡨 Packet sent**

Received ACK: 2 **🡨 Acknowledgement received from the receiver**

---------- Calculating Estimated RTT and Timeout ----------

Packet 1 | Send time: 1444587992:239783 | Ack Time: 1444587992:239820

Sampled RTT: 37

**On receipt of every acknowledgement, the sender calculates the Estimated RTT and new timeout value.**

Estimated RTT: 494.212494

RTT Deviation: 228.500000

Updated Timeout: 1408

Window Size = 2 **🡨 Window size increases by 1 for every ACK received.**

Packet sent: Seq. No: 2 | Sent time- 1444587992: 239853

Packet sent: Seq. No: 3 | Sent time- 1444587992: 239860

Received ACK: 4

---------- Calculating Estimated RTT and Timeout ----------

Packet 3 | Send time: 1444587992:239860 | Ack Time: 1444587992:239893

Sampled RTT: 33

Estimated RTT: 488.447357

RTT Deviation: 341.750000

Updated Timeout: 1855

Window Size = 3

Packet sent: Seq. No: 4 | Sent time- 1444587992: 239925

Packet sent: Seq. No: 5 | Sent time- 1444587992: 239938

Packet sent: Seq. No: 6 | Sent time- 1444587992: 239944

Received ACK: 7

---------- Calculating Estimated RTT and Timeout ----------

Packet 6 | Send time: 1444587992:239944 | Ack Time: 1444587992:240031

Sampled RTT: 87

Estimated RTT: 483.429260

RTT Deviation: 368.875000

Updated Timeout: 1958

Window Size = 4

Packet sent: Seq. No: 7 | Sent time- 1444587992: 240067

Packet sent: Seq. No: 8 | Sent time- 1444587992: 240075

Packet sent: Seq. No: 9 | Sent time- 1444587992: 240081

Packet sent: Seq. No: 10 | Sent time- 1444587992: 240089

Received ACK: 11

---------- Calculating Estimated RTT and Timeout ----------

Packet 10 | Send time: 1444587992:240089 | Ack Time: 1444587992:240177

Sampled RTT: 88

Estimated RTT: 478.486420

RTT Deviation: 379.437500

Updated Timeout: 1996

Window Size = 5

Packet sent: Seq. No: 11 | Sent time- 1444587992: 240209

Packet sent: Seq. No: 12 | Sent time- 1444587992: 240219

Received ACK: 13

---------- Calculating Estimated RTT and Timeout ----------

Packet 12 | Send time: 1444587992:240219 | Ack Time: 1444587992:240318

Sampled RTT: 99

Estimated RTT: 473.742828

RTT Deviation: 376.718750

Updated Timeout: 1980

Window Size = 6

**Transmission did not enter the Congestion Avoidance phase and 100% of the packets were sent in slow start.**

-------- Data Packets transfer ends --------

Number of packets transmitted in slow start: 12

Number of packets transmitted in Congestion Control phase: 0

Percentage of packets transmitted in slow start: 100.000000 percent

Percentage of packets transmitted in Congestion Control phase: 0.000000 percent

**On the client side:-**

[mawagle@silo client]$ **./webclient\_udp localhost 2222 hello.txt 1**

**Handshake initiated by Client (Receiver) to request a file from the Server (Sender).**

HANDSHAKE SYN Sent

HANDSHAKE SYNACK received

HANDSHAKE ACK Sent

-------- Handshake Successful --------

-------- Data Packets transfer begins --------

Received Packet: Seq. Num: 1

ACK: 2 Sent

Received Packet: Seq. Num: 2 **🡨 Packets being received from sender.**

Received Packet: Seq. Num: 3

ACK: 4 Sent **🡨 ACKs being sent to the Sender.**

Received Packet: Seq. Num: 4

Received Packet: Seq. Num: 5

Received Packet: Seq. Num: 6

ACK: 7 Sent

Received Packet: Seq. Num: 7

Received Packet: Seq. Num: 8

Received Packet: Seq. Num: 9

Received Packet: Seq. Num: 10

ACK: 11 Sent **🡨 Notice that the receiver client is sending cumulative ACKs**

Received Packet: Seq. Num: 11

Received Packet: Seq. Num: 12

All packets received and placed in order, Transfer finished **🡨 NOTE**

ACK: 13 Sent

-------- Data Packets transfer ends --------

Received packet count: 12

### Flow control with Congestion Avoidance in action with packet drops and high latency simulations

**On server side:-**

[mawagle@silo server]$ ./webserver\_udp 2222 1 1 30 **🡨 Drop enabled with 30%**

Server started. Waiting for datagram requests...

Waiting for handshake from client for next 60 seconds...

HANDSHAKE SYN Received

HANDSHAKE SYNACK Sent

HANDSHAKE ACK Received

-------- Handshake Successful --------

Packet Buffer Length = 12

3 packets will not be transmitted for simulating packet drop...

-------- Data Packets transfer begins --------

Packet sent: Seq. No: 1 | Sent time- 1444596194: 398209

ACK receiving timed out... **🡨 ACK timed out indicating high latency**

!!! Transmission entering Congestion Avoidance Mode !!! **🡨 NOTE**

Window Size = 2

Packet sent: Seq. No: 1 | Sent time- 1444596194: 399813

Packet sent: Seq. No: 2 | Sent time- 1444596194: 399820

Received ACK: 2

---------- Calculating Estimated RTT and Timeout ----------

Packet 1 | Send time: 1444596194:399813 | Ack Time: 1444596194:399844

Sampled RTT: 31

Estimated RTT: 494.137512

RTT Deviation: 231.500000

Updated Timeout: 1420

Window Size = 2

Packet sent: Seq. No: 2 | Sent time- 1444596194: 399877

Packet sent: Seq. No: 3 | Sent time- 1444596194: 399884

Received ACK: 3

---------- Calculating Estimated RTT and Timeout ----------

Packet 2 | Send time: 1444596194:399877 | Ack Time: 1444596194:399891

Sampled RTT: 14

Estimated RTT: 488.135773

RTT Deviation: 352.750000

Updated Timeout: 1899

Window Size = 2

Packet sent: Seq. No: 3 | Sent time- 1444596194: 399910

Packet sent: Seq. No: 4 | Sent time- 1444596194: 399916

Received ACK: 4

---------- Calculating Estimated RTT and Timeout ----------

Packet 3 | Send time: 1444596194:399910 | Ack Time: 1444596194:399955

Sampled RTT: 45

Estimated RTT: 482.596588

RTT Deviation: 394.875000

Updated Timeout: 2062

Window Size = 3 **🡨 Window size is being increased cautiously**

Packet sent: Seq. No: 4 | Sent time- 1444596194: 399975

Packet sent: Seq. No: 5 | Sent time- 1444596194: 399983

Packet sent: Seq. No: 6 | Sent time- 1444596194: 399989

Received ACK: 7

---------- Calculating Estimated RTT and Timeout ----------

Packet 6 | Send time: 1444596194:399989 | Ack Time: 1444596194:401605

Sampled RTT: 1616

Estimated RTT: 496.764160

RTT Deviation: 756.937500

Updated Timeout: 3524

Window Size = 3

Packet with Seq. No. 7 Dropped! **🡨 Packet 7 Dropped**

Packet sent: Seq. No: 8 | Sent time- 1444596194: 401642

Packet sent: Seq. No: 9 | Sent time- 1444596194: 401649

Received ACK: 7 **🡨 Received ACK for the missed packet**

---------- Calculating Estimated RTT and Timeout ----------

Packet 6 | Send time: 1444596194:399989 | Ack Time: 1444596194:401605

Sampled RTT: 1616

Estimated RTT: 510.754639

RTT Deviation: 930.968750

Updated Timeout: 4234

Window Size = 3

Packet sent: Seq. No: 7 | Sent time- 1444596194: 402783

Packet sent: Seq. No: 8 | Sent time- 1444596194: 402793

Packet sent: Seq. No: 9 | Sent time- 1444596194: 402799

Received ACK: 10

---------- Calculating Estimated RTT and Timeout ----------

Packet 9 | Send time: 1444596194:402799 | Ack Time: 1444596194:402842

Sampled RTT: 43

Estimated RTT: 504.907715

RTT Deviation: 695.984375

Updated Timeout: 3288

Window Size = 4

Packet sent: Seq. No: 10 | Sent time- 1444596194: 402879

Packet with Seq. No. 11 Dropped!

Packet sent: Seq. No: 12 | Sent time- 1444596194: 402890

Received ACK: 11

---------- Calculating Estimated RTT and Timeout ----------

Packet 10 | Send time: 1444596194:402879 | Ack Time: 1444596194:405543

Sampled RTT: 2664

Estimated RTT: 531.896362

RTT Deviation: 1413.992188

Updated Timeout: 6187

Window Size = 4

Packet sent: Seq. No: 11 | Sent time- 1444596194: 405578

Packet sent: Seq. No: 12 | Sent time- 1444596194: 405586

Received ACK: 13

---------- Calculating Estimated RTT and Timeout ----------

Packet 12 | Send time: 1444596194:405586 | Ack Time: 1444596194:405625

Sampled RTT: 39

Estimated RTT: 525.735168

RTT Deviation: 949.996094

Updated Timeout: 4325

Window Size = 4

-------- Data Packets transfer ends --------

Number of packets transmitted in slow start: 0

Number of packets transmitted in Congestion Control phase: 12

Percentage of packets transmitted in slow start: 0.000000 percent

Percentage of packets transmitted in Congestion Control phase: 100.000000 percent

**On the client side:-**

[mawagle@silo client]$ ./webclient\_udp localhost 2222 hello.txt 1 1 **🡨 Delay enabled**

HANDSHAKE SYN Sent

HANDSHAKE SYNACK received

HANDSHAKE ACK Sent

-------- Handshake Successful --------

-------- Data Packets transfer begins --------

Received Packet: Seq. Num: 1

!!! Adding delay of 1500 micro seconds!!! **🡨 DELAY**

ACK: 2 Sent

Received Packet: Seq. Num: 1 **🡨 ACK 2 got delayed so server retransmits**

Received Packet: Seq. Num: 2

ACK: 3 Sent

Received Packet: Seq. Num: 2

Received Packet: Seq. Num: 3

Received Packet: Seq. Num: 3

ACK: 4 Sent

Received Packet: Seq. Num: 4

Received Packet: Seq. Num: 4

Received Packet: Seq. Num: 5

Received Packet: Seq. Num: 6

!!! Adding delay of 1500 micro seconds!!!

ACK: 7 Sent

Received Packet: Seq. Num: 8

Received Packet: Seq. Num: 9

Packet receiving timed out. Expected packet with Seq. Number: 7

ACK: 7 Sent **🡨 Sending acked for dropped packet 7**

Received Packet: Seq. Num: 7

Received Packet: Seq. Num: 8

Received Packet: Seq. Num: 9

ACK: 10 Sent

Received Packet: Seq. Num: 10

Received Packet: Seq. Num: 12

Packet receiving timed out. Expected packet with Seq. Number: 11

!!! Adding delay of 1500 micro seconds!!!

ACK: 11 Sent **🡨 Sending ACK for missed order packet 11**

Received Packet: Seq. Num: 11

All packets received and placed in order, Transfer finished

ACK: 13 Sent

-------- Data Packets transfer ends --------

Received packet count: 12

## Known issues:

* Server and Client go out of sync for files with size more than around 15KB and end up terminating with segmentation fault.
* There is a memory inconsistency issue while writing last two packets to the received file on the client side, after the transfer is complete, and gives the following error, though the file gets created successfully with most of the content added:-

\*\*\* Error in `./webclient\_udp': free(): invalid next size (normal): 0x0000000034324e30 \*\*\*

======= Backtrace: =========

/lib64/libc.so.6(+0x7d1fd)[0x7f5249bf41fd]

/lib64/libc.so.6(fclose+0x155)[0x7f5249be2ae5]

./webclient\_udp[0x401426]

./webclient\_udp[0x401f4e]

./webclient\_udp[0x40201c]

/lib64/libc.so.6(\_\_libc\_start\_main+0xf5)[0x7f5249b98af5]

./webclient\_udp[0x400d29]

======= Memory map: ========

00400000-00403000 r-xp 00000000 00:27 78775093 /nfs/nfs4/home/mawagle/Assignment2/webclient\_udp

00602000-00603000 r--p 00002000 00:27 78775093 /nfs/nfs4/home/mawagle/Assignment2/webclient\_udp

00603000-00604000 rw-p 00003000 00:27 78775093 /nfs/nfs4/home/mawagle/Assignment2/webclient\_udp

00604000-32604000 rw-p 00000000 00:00 0

34313000-34334000 rw-p 00000000 00:00 0 [heap]

7f524715f000-7f5247174000 r-xp 00000000 08:02 1074502824 /usr/lib64/libgcc\_s-4.8.3-20140911.so.1

7f5247174000-7f5247373000 ---p 00015000 08:02 1074502824 /usr/lib64/libgcc\_s-4.8.3-20140911.so.1

7f5247373000-7f5247374000 r--p 00014000 08:02 1074502824 /usr/lib64/libgcc\_s-4.8.3-20140911.so.1

7f5247374000-7f5247375000 rw-p 00015000 08:02 1074502824 /usr/lib64/libgcc\_s-4.8.3-20140911.so.1

7f5247375000-7f5249b77000 rw-p 00000000 00:00 0

7f5249b77000-7f5249d2d000 r-xp 00000000 08:02 1074504867 /usr/lib64/libc-2.17.so

7f5249d2d000-7f5249f2d000 ---p 001b6000 08:02 1074504867 /usr/lib64/libc-2.17.so

7f5249f2d000-7f5249f31000 r--p 001b6000 08:02 1074504867 /usr/lib64/libc-2.17.so

7f5249f31000-7f5249f33000 rw-p 001ba000 08:02 1074504867 /usr/lib64/libc-2.17.so

7f5249f33000-7f5249f38000 rw-p 00000000 00:00 0

7f5249f38000-7f5249f59000 r-xp 00000000 08:02 1074504860 /usr/lib64/ld-2.17.so

7f524a100000-7f524a103000 rw-p 00000000 00:00 0

7f524a113000-7f524a115000 rw-p 00000000 00:00 0

7f524a115000-7f524a158000 r--s 00000000 00:12 61680 /run/nscd/dbLKLoxW (deleted)

7f524a158000-7f524a159000 rw-p 00000000 00:00 0

7f524a159000-7f524a15a000 r--p 00021000 08:02 1074504860 /usr/lib64/ld-2.17.so

7f524a15a000-7f524a15b000 rw-p 00022000 08:02 1074504860 /usr/lib64/ld-2.17.so

7f524a15b000-7f524a15c000 rw-p 00000000 00:00 0

7ffc7ec7e000-7ffc7ec9f000 rw-p 00000000 00:00 0 [stack]

7ffc7ed08000-7ffc7ed0a000 r-xp 00000000 00:00 0 [vdso]

ffffffffff600000-ffffffffff601000 r-xp 00000000 00:00 0 [vsyscall]

Aborted

***P.S.*** *I assume the grading is only for the flow control, congestion control scenario implementations and does not take into account the size of file supported or writing file on the client side (nothing has been mentioned in the problem statement about it). Hence I concentrated more on getting to work and improving the flow and congestion aspects than debugging these above issues.*