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Report of The Term Project

First, we are going to talk about the code and what kind of logic, data structures we used and what kind of difficulties we encountered and how we solved them.

Some Common Functions Between Client and Server

Functions For Making Particular Packets

```
28
29 def makeHandshakePacket(filename):
30     filenameAsByteArr=bytearray(filename,"utf-8")
31     packet=bytearray([0,len(filenameAsByteArr)])
32     packet+=filenameAsByteArr
33     return bytes(packet)
34
35 def makeACKPacket(sequenceNumber):
36     return bytes(bytearray([1,sequenceNumber]))
37
38
39 def makeDATAPacket(dataAsByteArr:bytearray,sequenceNumber:int):
40     #dataAsByteArr=bytearray(data.to_bytes( (data.bit_length+7)//8,byteorder='big')
41     return bytes(bytearray([2,len(dataAsByteArr),sequenceNumber])+dataAsByteArr)
42
43 def makeFINPacket(sequenceNumber):
44     return bytes(bytearray([3,sequenceNumber]))
```

This part of the code is common between client and server side code, they both use these functions. According to the description in the homework pdf, those functions create the packets as bytes objects, ready to be sent.

receiveWithTimeout

```

def receiveWithTimeout(sock):
    readable, _, _ = select.select([sock], [], [], 0.0001)
    for sock in readable:
        data, address = sock.recvfrom(1024)
        return bytearray(data)
    return None

```

Like packet functions above, this is a fundamental function too for the overall program. It waits for 100 microseconds to timeout while listening to the UDP socket.

Client.py

main()

Let's begin with the client side. After it takes some inputs from the user, it summons the function to fetch a file from the server, then it prints the fetched file's content and reports how many milliseconds took to fetch the file from the server with which parameters, and save the file as txt file.

handshakeClient

This function sends a handshake packet 5 times before giving up, after all the client might try to get a file with a different file than one on the server. Getting a segment0 means a successful handshake between client and server.

getTheFile

Let me explain some of the important details here. To not get confused between the already received old packets and new packets with the same sequence number, size of the sequence number space should at least be twice of window size. In the client code, the buffer's size equals the size of the sequence number space.

Because `recv_base` and `segment0[2]`'s sequence number is the same, we can take whatever data `segment0` contains in the `file` variable and increment `recv_base` accordingly. Pay attention to how I update `recv_base`:

```

#client'taki olusmakta olan file'a data'yi ekle
buffer[segment0[2]]=segment0
filePiece=segment0[3:]
file+=filePiece.decode("utf-8")
buffer[recv_base]=None
recv_base+=1
recv_base=recv_base%bufferSize

```

This is a circular buffer and we must be careful when updating the index of the buffer because of that.

Now we came to the main loop of this function. If we successfully get a packet from the receiveWithTimeout function, first we check it is a data packet or FIN packet. If it is a FIN packet, that means the server finished sending the server file and started the ending sequence on its side thus the client should start its own ending sequence accordingly.

If the packet is a data packet, according to the packet's sequence number we try to understand where this packet belongs to in the circular buffer: If it was already received, according to the region where this packet's sequence number corresponds to, we might need to send its ACK packet again. If it corresponds to an empty and available region in the buffer, we accept the packet to the buffer. While I am calculating those said regions, I took into account the circular nature of the sequence number and the buffer.

If the packet's place in the buffer corresponds to the `recv_base`, from `recv_base` we can take the packets with continuous sequence numbers in the buffer to the `file` variable and unload those packets from the buffer.

endingSequenceClient

Sends some packets and waits for some packets according to the description in the homework PDF, simple like the handshake sequence. Server version is not much different.

Server

main()

```
def main():
    global windowSize
    global errorRate
    global serverfilename
    global serverfile

    udp_socket = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
    udp_socket.bind(("127.0.0.1",server_port))

    with open("sorrowful_be_the_heart_penitent_one", "r") as file:
        serverfile = file.read()

    print(f"Server file name is {serverfilename}.")
    windowSize=int(input("Enter the window size(It should be same in the client and server)"))
    errorRate=int(input("Enter the error rate in the channel:"))

    address=listenForHandshake(udp_socket)
    address=handshakeServer(udp_socket,address)
    packets=packetizeFile(serverfile,windowSize)
    sendTheFile(udp_socket,address,windowSize,packets)
```

listenForHandshake

Server listens to the socket for the handshake from a client indefinitely, when it gets the handshake packet it returns the address as tuple (ip_address, port_number), if it does not get a valid packet, it continues to listen.

handshakeServer

It just sends an ACK packet and waits for its return as an answer.

packetSizeFile

From the read file, it creates DATA packets and returns them as a list. According to their index in the list, sequence numbers are assigned to the DATA packets. Specifically, list elements are 3 element list themselves, first element is DATA packet itself, second value represents time passed since packet's last transmission, third value represents did DATA packet ACK'ed or not.

sendTimeoutPackets

When this function is called, first it updates time passed since packets' last transmission and checks if their passed time exceeds the timeout value or not. If it exceeds, the function transmits them again and reset their time elapsed value.

sendTheFile

Here is the main while loop that transfers the file to the client. All file data is stored in the array as packetized elements and packets' sequence number is determined by their index value in this array. According to ACK'ed packets, the server's window slides from beginning of this array to its end.

In the loop, first it starts the timer to measure the elapsed time in the one loop run. In the end of the while loop, it will call the sendTimeoutPackets and update packets' elapsed time to notice timeout packets.

After getting a packet, it makes sure it is an ACK packet and after that, according to sequence number of ACK packet, it determines the index of the DATA packet which it came for, in the array. If its sequence number is less than the last transmitted packet in the array it belongs to the same sequence number run with the last packet, it is bigger it corresponds to the sequence number run just before the current one. According to this index of the DATA packet of the ACK packet is found.

Each loop run, it transmits one packet according to nextindex variable which is like nextseqnum in the book.

When it gets for the ACK packet for the last packet in the array, ending sequence is started.

Performance Of Project

First, we fixed the parameter of error rate to 20, and iterated respectively windows sizes of 1, 10, 50 and 100. We did the same for error rate, we fixed the window size to 10, and changed the error rate 1, 5, 10 and 20.

According to the results, naturally, if we increase error rate, more performance suffers. Best window size seems to be 10. Best window size from best to worst is 10, 100, 50 and lastly, 1.

You can see all the runs of the program with the results in the screenshots below.

Here is the results:

Error rate is fixed to 20%.

Window size: 1

Error rate: 20%

Time client took to fetch the file from the server: 8.497 milliseconds

Window size:10

Error rate:20%

Time client took to fetch the file from the server: 4.105 milliseconds

Window size:50

Error rate:20%

Time client took to fetch the file from the server: 5.944 milliseconds

Window size:100

Error rate:20%

Time client took to fetch the file from the server: 5.413 milliseconds

Window size is fixed to 10.

Window size:10

Error rate:1%

Time client took to fetch the file from the server: 1.796 milliseconds

Window size:10

Error rate:5%

Time client took to fetch the file from the server: 7.975 milliseconds

Window size:10

Error rate:10%

Time client took to fetch the file from the server: 3.597 milliseconds

Window size:10

Error rate:20%

Time client took to fetch the file from the server: 4.105 milliseconds

Screenshots

```
Activities Terminal 25 Oct 16:50 ahmet@ahmet:~/Desktop/okul/BLG433E/term_project
[1] + 1000 pts 0:10 python3 server.py
Got the ACK for packet with sequence number 1
Sent the packet with sequence number 0
Timeout for the packet with sequence number 0, it is sent again.
Got the ACK for packet with sequence number 1
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 1
Got the ACK for packet with sequence number 1
Sent the packet with sequence number 0
Timeout for the packet with sequence number 0, it is sent again.
Timeout for the packet with sequence number 0, it is sent again.
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 1
Timeout for the packet with sequence number 1, it is sent again.
Got the ACK for packet with sequence number 1
Got the ACK for the last remaining packet of the file, let the end begin.
Sent the FIN of the server.
Sent the FIN of the server.
Sent the ACK for FIN of the client.
ahmet@ahmet:~/Desktop/okul/BLG433E/term_project$ python3 server.py
Server file name is sorrowful_be_the_hearth_pitiful_one.
Enter the window size(should be same in the client and the server):10
Enter the error rate in the channel:20
Got the handshake packet from a client.
Sent ACK for handshake packet of the client.
Got the ACK for handshake from the client.
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 0
Timeout for the packet with sequence number 0, it is sent again.
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 1
Timeout for the packet with sequence number 1, it is sent again.
Got the ACK for packet with sequence number 1
Sent the packet with sequence number 2
Timeout for the packet with sequence number 2, it is sent again.
Got the ACK for packet with sequence number 2
Sent the packet with sequence number 3
Got the ACK for packet with sequence number 3
Sent the packet with sequence number 4
Got the ACK for packet with sequence number 4
Sent the packet with sequence number 5
Got the ACK for packet with sequence number 5
Sent the packet with sequence number 6
Got the ACK for packet with sequence number 6
Sent the packet with sequence number 7
Timeout for the packet with sequence number 7, it is sent again.
```

```
Activities Terminal 25 Oca 16:50 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
Timeout for the packet with sequence number 22, it is sent again.
Timeout for the packet with sequence number 24, it is sent again.
Timeout for the packet with sequence number 26, it is sent again.
Got the ACK for packet with sequence number 22
Got the ACK for packet with sequence number 26
Got the ACK for the last remaining packet of the file, let the end begin.
Sent the FIN of the server.
ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project$ python3 server.py
Server file name is sorrowful_be_the_heart_penitent_one.
Enter the window size(It should be same in the client and the server):100
Enter the error rate in the channel:20
Got the handshake packet from a client.
Sent ACK for handshake packet of the client.
Got the ACK for handshake from the client.
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 0
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 1
Got the ACK for packet with sequence number 1
Sent the packet with sequence number 2
Got the ACK for packet with sequence number 2
Sent the packet with sequence number 3
Got the ACK for packet with sequence number 3
Sent the packet with sequence number 4
Got the ACK for packet with sequence number 4
Sent the packet with sequence number 5
Got the ACK for packet with sequence number 5
Sent the packet with sequence number 6
Got the ACK for packet with sequence number 6
Sent the packet with sequence number 7
Got the ACK for packet with sequence number 7
Sent the packet with sequence number 8
Got the ACK for packet with sequence number 8
Sent the packet with sequence number 9
Got the ACK for packet with sequence number 9
Sent the packet with sequence number 10
Got the ACK for packet with sequence number 10
Sent the packet with sequence number 11
Got the ACK for packet with sequence number 11
Sent the packet with sequence number 12
Got the ACK for packet with sequence number 12
Sent the packet with sequence number 13
Got the ACK for packet with sequence number 13
Sent the packet with sequence number 14
Got the ACK for packet with sequence number 14
Sent the packet with sequence number 15
Got the ACK for packet with sequence number 15
Sent the packet with sequence number 16
Got the ACK for packet with sequence number 16
Sent the packet with sequence number 17
Got the ACK for packet with sequence number 17
Sent the packet with sequence number 18
Got the ACK for packet with sequence number 18
```

```
Activities Terminal 25 Oca 16:50 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
Timeout for the packet with sequence number 19, it is sent again.
Timeout for the packet with sequence number 22, it is sent again.
Timeout for the packet with sequence number 25, it is sent again.
Got the ACK for packet with sequence number 20
Got the ACK for packet with sequence number 21
Timeout for the packet with sequence number 23, it is sent again.
Timeout for the packet with sequence number 24, it is sent again.
Timeout for the packet with sequence number 26, it is sent again.
Got the ACK for packet with sequence number 24
Got the ACK for packet with sequence number 22
Timeout for the packet with sequence number 19, it is sent again.
Timeout for the packet with sequence number 25, it is sent again.
Got the ACK for packet with sequence number 25
Got the ACK for packet with sequence number 12
Timeout for the packet with sequence number 23, it is sent again.
Timeout for the packet with sequence number 26, it is sent again.
Got the ACK for packet with sequence number 20
Got the ACK for packet with sequence number 23
Timeout for the packet with sequence number 19, it is sent again.
Got the ACK for packet with sequence number 21
Got the ACK for packet with sequence number 24
Timeout for the packet with sequence number 26, it is sent again.
Got the ACK for packet with sequence number 26
Got the ACK for the last remaining packet of the file, let the end begin.
Sent the FIN of the server.
ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project$ python3 server.py
Server file name is sorrowful_be_the_heart_penitent_one.
Enter the window size(It should be same in the client and the server):10
Enter the error rate in the channel:1
Got the handshake packet from a client.
Sent ACK for handshake packet of the client.
Got the ACK for handshake from the client.
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 0
Got the ACK for packet with sequence number 0
Sent the packet with sequence number 1
Got the ACK for packet with sequence number 1
Sent the packet with sequence number 2
Got the ACK for packet with sequence number 2
Sent the packet with sequence number 3
Got the ACK for packet with sequence number 3
Got the ACK for packet with sequence number 3
```

```

Activities Terminal 25 Oca 16:51 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
Client already sent ACK for packet with sequence number 3, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 6, nevertheless it is sent again now.
Got the FIN packet, the beginning of the end..
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Here is the file client wanted:
? Dunyanin
sonunda,
bosluktan
asagi
dustum,
Gunese
bakmakan
kor
oldum,
ona
yakin
ucmakan
kanatlari
yandi...
I
dug
too
deep.
insan
oldugumu
unuttum,
taniyl
oldurneye
kalktim.
Yardim
et
bana.
With 10% error rate and 10 window size, client took 3.597 milliseconds to fetch the file from server.
ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project$ 
```

```

Activities Terminal 25 Oca 16:51 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
bana.

With 5% error rate and 10 window size, client took 7.975 milliseconds to fetch the file from server.
ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project$ python3 client.py
Enter the file name to fetch from server:sorrowful_be_the_heart_penitent_one
Enter the window size(It should be same in the client and the server):10
Enter the error rate in the channel:10
Handshake packet was sent.
Handshake packet was sent.
Handshake packet was sent.
ACK from server for handshake came.
Same ACK packet was sent to the server, by the client
Client got the packet with sequence number 0
Got the packet with sequence number 1
Sent ACK For the packet with sequence number 1
Got the packet with sequence number 2
Sent ACK For the packet with sequence number 2
Got the packet with sequence number 3
Sent ACK For the packet with sequence number 3
Got the packet with sequence number 4
Sent ACK For the packet with sequence number 4
Got the packet with sequence number 5
Sent ACK For the packet with sequence number 5
Client already sent ACK for packet with sequence number 4, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 5, nevertheless it is sent again now.
Got the packet with sequence number 7
Sent ACK For the packet with sequence number 7
Client already sent ACK for packet with sequence number 4, nevertheless it is sent again now.
Got the packet with sequence number 6
Sent ACK For the packet with sequence number 6
Client already sent ACK for packet with sequence number 7, nevertheless it is sent again now.
Got the packet with sequence number 9
Sent ACK For the packet with sequence number 9
Got the packet with sequence number 11
Sent ACK For the packet with sequence number 11
Got the packet with sequence number 8
Sent ACK For the packet with sequence number 8
Client already sent ACK for packet with sequence number 9, nevertheless it is sent again now.
Got the packet with sequence number 12
Sent ACK For the packet with sequence number 12
Got the packet with sequence number 13
Sent ACK For the packet with sequence number 13
Got the packet with sequence number 10
Sent ACK For the packet with sequence number 10
Got the packet with sequence number 14

```

Activities Terminal 25 Oca 16:51 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project 98%

```
Got the packet with sequence number 2
Sent ACK for the packet with sequence number 2
Got the packet with sequence number 3
Sent ACK for the packet with sequence number 3
Got the packet with sequence number 4
Sent ACK for the packet with sequence number 4
Got the packet with sequence number 5
Sent ACK for the packet with sequence number 5
Got the packet with sequence number 6
Sent ACK for the packet with sequence number 6
Got the FIN packet, the beginning of the end...
Sent ACK for FIN of the server.
Sent FIN of the client.
Got the ACK for FIN of the client.

Here is the file client wanted:
Dunyanin
sonunda,
bosluktan
asagi
dustum,
Gunese
bakmactan
kor
oldum,
ona
yakin
ucmakan
kanatlariim
yandi...
I
dug
too
deep.
insan
oldugumu
unuttum,
taniyil
oldurmeye
kalktim.
Yardim
et
bana.

With 1% error rate and 10 window size, client took 1.796 milliseconds to fetch the file from server.
```

Activities Terminal 25 Oca 16:51 ahmet@ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project 98%

```
Client already sent ACK for packet with sequence number 23, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 26, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 26, nevertheless it is sent again now.
Got the FIN packet, the beginning of the end...
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.

Here is the file client wanted:
Dunyanin
sonunda,
bosluktan
asagi
dustum,
Gunese
bakmactan
kor
oldum,
ona
yakin
ucmakan
kanatlariim
yandi...
I
dug
too
deep.
insan
oldugumu
unuttum,
taniyil
oldurmeye
kalktim.
Yardim
et
bana.

With 20% error rate and 100 window size, client took 5.413 milliseconds to fetch the file from server.
```

Activities Terminal 25 Oca 16:52 ahmet@ahmet-ThinkPad-E14-Gen-4:~/Desktop/okul/BLG433E/term_project 98 %

```
Client already sent ACK for packet with sequence number 26, nevertheless it is sent again now.  
Client already sent ACK for packet with sequence number 22, nevertheless it is sent again now.  
Client already sent ACK for packet with sequence number 24, nevertheless it is sent again now.  
Got the FIN packet, the beginning of the end..  
Sent ACK for FIN of the server.  
Sent FIN of the client.  
Sent ACK for FIN of the server.  
Sent FIN of the client.  
Sent ACK for FIN of the server.  
Sent FIN of the client.  
Sent ACK for FIN of the server.  
Sent FIN of the client.  
Here is the file client wanted:  
Dunyanin  
sonunda,  
bosluktan  
asagi  
dustum.  
Gunese  
bakmaktan  
kor  
oldum,  
ona  
yakin  
ucmaktan  
kanatlarim  
yandi...  
I  
dug  
too  
deep.  
insan  
oldugumu  
unuttum,  
tariyl  
oldurmeye  
kalktim.  
Yardim  
et  
bana.  
With 20% error rate and 50 window size, client took 5.944 milliseconds to fetch the file from server.
```

```
Activities Terminal 25 Oca 16:52 ahmet@Ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
Client already sent ACK for packet with sequence number 3, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 6, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 5, nevertheless it is sent again now.
Client already sent ACK for packet with sequence number 6, nevertheless it is sent again now.
Got the FIN packet, the beginning of the end...
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Got the ACK for FIN of the client.

Here is the file client wanted:
Dünyanın
sonunda,
bosluktan
asağı
dustum.
Günese
bakmaktadır
kor
oldum,
ona
yakın
ucmaktan
kanatlarım
yandı...
I
dug
too
deep.
İnsan
oldugumu
unuttum,
tanıyl
oldurmeye
kalktım.
Yardım
et
bana.

With 20% error rate and 10 window size, client took 4.105 milliseconds to fetch the file from server.
ahmet@Ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project $ python3 client.py
```

```
Activities Terminal 25 Oca 16:52 ahmet@Ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project
Client already sent ACK for packet with sequence number 0, nevertheless it is sent again now.
Got the packet with sequence number 1
Sent ACK for the packet with sequence number 1
Client already sent ACK for packet with sequence number 1, nevertheless it is sent again now.
Got the FIN packet, the beginning of the end...
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.
Sent ACK for FIN of the server.
Sent FIN of the client.

Here is the file client wanted:
Dünyanın
sonunda,
bosluktan
asağı
dustum.
Günese
bakmaktadır
kor
oldum,
ona
yakın
ucmaktan
kanatlarım
yandı...
I
dug
too
deep.
İnsan
oldugumu
unuttum,
tanıyl
oldurmeye
kalktım.
Yardım
et

With 20% error rate and 1 window size, client took 8.497 milliseconds to fetch the file from server.
ahmet@Ahmet-ThinkPad-E14-Gen-4: ~/Desktop/okul/BLG433E/term_project $
```