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CS 145 Project 1 Documentation: Parameter-Adaptive Reliable UDP-based Protocol

In Partial Fulfillment of the Requirements for the Course
CS 145: Computer Networks

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1 Introduction

The project is an implementation of the sender program for a reliable UDP-based protocol given certain hidden parameters. The assigned ___ levels further explained in the following sections of this document were successfully accomplished. The project can be found in the following `GitHub repository` and the corresponding video documentation can found in this link.

2 Declaration of Accomplished Levels

For this project, the first two (2) levels given in the project specifications were accomplished. The following section contains a line-by-line explanation of the sender code utilized to complete this project.

- **Level 1**: Able to send Intent Message (to the receiver or test server) and receive the Accept Message (from the receiver or test server).
- **Level 2:** Can do everything that Level 1 does, plus, able to send at least 50% of the payload to the receiver or test server

3 Sender implementation

To understand how the implementation of the sender works, we explain the code line by line. Note that the `sender.py` file also has corresponding comments that can help in understanding how the code works.

3.1 Importing modules (Lines 17-21)

Several libraries were used in the project shown in Figure 1:

- Line 17 imports the socket module which allows for the communication of the server and client by using socket endpoints
- Line 18 imports the sys module, which is mainly used to get the needed parameters from the command line
- Line 19 imports hashlib as instructed by the given compute_checksum function in the project specifications
- Line 20 imports time which is used to keep track of socket timeouts and how long transaction time is
- Finally, Line 21 imports the ceil function from the math module used in estimating and dividing payload size

```
17    import socket
18    import sys
19    import hashlib
20    import time
21    from math import ceil
```

Figure 1: `sender.py` *17:21*

3.2 Getting parameters (Lines 29-45)

The program is run on the terminal and certain parameters are given in the command line. These parameters are:

- Filename prefixed by the -f flag which denotes the filename of the payload
- The IP address of the server prefixed by the -a flag.
- The Port used by the server prefixed by the -s flag.
- The assigned port to be used by the student (given as a project credential) prefixed by the -c flag.
- Lastly, the unique ID assigned as a project credential as well, prefixed by the -i flag.

Figure 2 shows the code snippet of parameter getting and initialization of the program.

```
29  #Initialize parameters from terminal command
30  #-f path/to/file.txt -a SERVER IP ADDR -s SERVER PORT -c STUDENT PORT -i STUDENT ID
31  comms = sys.argv[1:]
32  for comm in range(len(comms)):
33      if comms[comm] == '-f': #filename
34          fn = comms[comm+1]
35      elif comms[comm] == '-a': #IP address of server
36          UDP_IP_ADDRESS = comms[comm+1]
37      elif comms[comm] == '-s': #Server port
38          UDP_PORT_NO = int(comms[comm+1])
39      elif comms[comm] == '-c': #Client port
40          CLIENT_PORT = int(comms[comm+1])
41      elif comms[comm] == '-i': #Student ID
42          ID = comms[comm+1]
43
44  #Set server IP addr and port to a tuple
45  UDP_IP_PORT = (UDP_IP_ADDRESS, UDP_PORT_NO)
46
```

Figure 2: sender.py; 29:45

Line 30 shows an example of the command line instruction used to run the program. Line 31 gets the list of command line arguments by making use of the sys.argv function. The output of this is an array with the arguments as elements. We slice the list starting from its first element, because element 0 will always be the name of the .py file (in this case casender.py).

Line 32 iterates over the array of command line arguments. Since order is not ensured when executing the command, we first check for the prefix and get the value next to it once we have encountered a match. The prefix flags for each parameter were as discussed above and in the lab specifications.

Variable	Prefix	Parameter
Fn	-f	Filename of payload data to be sent
UDP_IP_ADDRESS	-a	Server IP address
UDP_PORT_NO	-s	Server Port Number
CLIENT_PORT	-c	Student assigned port number
ID	-i	Student assigned ID

Line 45 just creates a tuple out of the receiver's IP address and Port. When sanding packets, these two values are zipped in a tuple in the `socket.sendto()` function. For brevity, we create a tuple variable of these two values in this line already.

These lines constitute getting and initializing the parameters to be used in the implementation of sender program.

3.3 Initializing a socket for the client (Lines 47-50)

The main idea of using sockets for communication over a network is by using sockets to form connections between two nodes – a server and a client. For this program, we initialize a UDP socket instance for the client to be able to receive ACK packets from the client.

```
47    #Create socket for receiving packets from server
48    clientSock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
49    clientSock.bind(('', 6745)) #bind at port 6745 (designated port for student)
50    clientSock.settimeout(10) #set timeout to default 10 seconds
51
```

Figure 3: sender.py; 47:50

The code snippet shows the creation of the socket instance and the assignment of a port to the created socket.

Line 48 assigns the created socket instance to the variable clientSock.

- The socket() function of the socket module creates a socket object or instance. It takes in two arguments which specifies the address family and the protocol that will be used to transport the messages.
- For this program, arguments passed to the socket() function are:
    - socket.AF_INET is the address family for IPv4 messages. This specifies that the created socket instance can only communicate with IPv4 addresses.
    - socket.SOCK_DGRAM specifies that the protocol that will be used to transport messages over this socket is through a datagram-based protocol or UDP.

Line 49 binds the socket instance to the unique designated port for the student. In my case, my assigned port number is 6745. Since an IPv4 address family was used, the bind() function expects a tuple containing the IP address and port number. However, since the IP address cannot always be sure for every runtime, this is left as an empty string to be identified on the server side. This socket instance will be used to listen to ACK messages from the server once we start sending packets.

- clientSock is binded to a two-tuple (host,port) = ('', 6745) where the empty string denotes the IP address of the client (to be identified by server) and 6745 is the unique designated port number for the student.

Line 50 sets a timeout value for messages sent from the client. Note that the project entails sending packets to a server with hidden parameters, hence, some packets may not get acknowledged. Without the timeout value set, the socket will continue to listen for an ACK message from the server (which may or may not come). Hence, we must set a specified time value to instruct the socket to give up waiting and retry sending a packet again once this value has been reached. Setting a timeout value too large gives us the risk of waiting for an ACK message for too long which will compromise the payload being sent. Setting a value too small will bypass the server's processing time and will just retry sending packets to the server, even if the server will send an ACK message back. Hence, we settle for 10 as the timeout value which is 8.33% of 120s – the specified time limit for Level 2 and 3. Note that this value was taken from trial-and-error executions.

We started with an initial value of 30 which is 25% of 120s. This value is too big. In the whole 120s transmission time, we would only be able to retry sending packets 4 times. We tried again using 15 which is 12.5% of 120s, again, payload could not be sent efficiently. Hence, we decrease the timeout value again and settle for 10 which is 6.33% of 120s.

3.4 Level 1 Implementation: Sending intent message and getting transaction ID (Lines 60-65)

Level 1 entails for being able to send an intent message to the server to establish a connection and get a transaction ID for consequent packet transmission. Figure 4 shows a code snippet of this in the sender.py file.

```
52  """
53  LEVEL 1 IMPLEMENTATION:
54  - append "ID" to student ID
55  - encode intent message and send to server using server IP and port
56  - server sends transaction ID back
57  - decode and store in trans_id variable
58  """
59
60  intent = "ID"+ID
61  clientSock.sendto(intent.encode(), UDP_IP_PORT)
62
63  trans_id, addr = clientSock.recvfrom(1024)
64  trans_id = trans_id.decode()
65  print(f"Trans ID: {trans_id}")
66
```

Figure 4: sender.py; 52:65

Line 60 prepares the intent message according to the specified format in the project specifications, where the first two characters are the letters "ID" followed by the 8-alphanumeric string specifying the unique student ID given as a project credential. In my case, this ID is 44919a94.

I	D	W	W	W	W	W	W	W	W
0	1	2	3	4	5	6	7	8	9

Table 1: Intent message format

Hence, line 61 concatenates the prefix "ID" to my assigned student ID. The intent message generated by my socket would look like this:

I	D	4	4	9	1	9	a	9	4
0	1	2	3	4	5	6	7	8	9

Table 2: Student intent message

Line 61 uses the sendto() function to send the intent message over UDP to the server. The function takes in two arguments, the first being the data to be sent, and the second being the two-tuple destination of the data (server IP address and port number). Note that we first encode the intent message to a byte string, by using the str.encode() method since the sendto() function does not accept strings.

- clientSock.sendto(intent.encode(), UDP_IP_PORT) is used to send intent message to server, where intent is the message containing student unique student ID to request to establish connection, we use intent.encode() to convert the string into bytestring format, and UDP_IP_PORT is a two-tuple variable containing the server's IP address and port number.

Lines 63 and 65 is responsible for listening to and retrieving the accept message to be sent by the server. The socket module's recvfrom() method takes in one required parameter which denotes the number of bytes to be read from the socket. This method returns a two-tuple value, the first one being the byte object read from the UDP socket, and the second element being the address of the sender (in this case, the server).

- clientSock.recvfrom(1024) receives 1024 bytes of data from the server
- trans_id, addr = clientSock.recvfrom(1024) assigns the two-tuple value from recvfrom() to the variables trans_id and address. Note that trans_id refers to the 7-digit integer denoting the transaction ID.

We are interested in the trans_id variable since this will be used in the generation of our packets and subsequent packet transmissions. Note that this is received in byte string format, hence we use the str.decode() method in line 64 to convert this into a string format which we can use. Finally, line 65 prints the transaction ID for identification and testing later on.

These lines constitute the Level 1 implementation of the project.

3.5 Opening and reading payload file (Lines 71-74)

Since the payload to be sent would be coming from a specified file, we must be able to open and read this file to get its contents. Note that the payload file is downloaded using the wget command.

```
71    #Open payload file and parse contents
72    f = open(fn,"rb")
73    dp = f.read()
74    dp = dp.decode()
75
```

Figure 5: sender.py; lines 71:74

- Line 72 uses Python's open() function to open the file specified from its filename, with rb as its permissions. This opens the payload file in binary mode for reading.
- Line 73 uses Python's read() function to read all contents of the file into a string.
- Line 74 decodes the binary form of the data into a string version to be used in our program.

These lines constitute the opening and parsing of the payload data to be sent to the server.

3.6 Initialization of flags for packet transmission (Lines 76-98)

After receiving the transaction ID from the server, we can now begin to transmit packets. However, we must first initialize flags that will help us in our packet transmission. According to the project specifications, the format of the data packet is as follows:

I	D	W	W	W	W	W	W	W	W
0	1	2	3	4	5	6	7	8	9
S	N	X	X	X	X	X	X	X	T
10	11	12	13	14	15	16	17	18	19
X	N	Y	Y	Y	Y	Y	Y	Y	L
20	21	22	23	24	25	26	27	28	29
A	S	T	Z	PAYLOAD					
30	31	32	33						

Table 3: Data packet format

Where:

- IDWWWWWWWW denotes the unique student ID assigned prefixed by "ID"
- SNXXXXXXX denotes the sequence number of packet prefixed by "SN"
- TXNYYYYYYY denotes the transaction id received from server prefixed by "TXN"
- Z denotes the last packet in transmission
- Lastly, the payload will be at the end of the data packet.

For these reasons, we must initial values for the variables Z, sequence number, as well as other variables that will help us in our packet transmission.

```
76  """
77  Set appropriate flags
78  Z variable is the Z flag which denotes last packet in transmission, initially 0
79  seq variable keeps track of the sequence number of packet, initially 0
80  charsent denotes how many characters of the payload has been sent thus far, initially 0
81
82  `accepted` flag if server accepts transmission of a packet, initially 0
83  (server has not accepted any packet yet)
84
85  `increment` flag to check if client can continue incrementing payload size being sent, initially 0
86  `maxed` flag to check if no more incrementation can be done - payload size has been exceeded, initially 0
87
88  empty string `sent` to keep track of all sent data from payload
89  (will be useful to check if correct packets are sent)
90  """
91  Z = seq = charsent = 0
92  accepted = increment = maxed = 0
93  dp_size = len(dp) #get length of payload for reference
94  sent = ''
95
```

Figure 6: sender.py; 76:94

Line 91 initializes variables Z, seq, and charsent to 0. The Z variable denotes the last packet of the transmission as per Table 3. The seq variable denotes the sequence number of the packet, and charsent denotes how many characters of the payload has been sent so far.

Other flags were also utilized in the program implementation which can be seen in line 92.

- The accepted variable is a flag which tells us if the initial packet we sent was accepted. This is initialized to 0.
- The increment flag tells us if we can continue incrementing the payload size or not. This is initialized to 0.
- The maxed flag tells us if we have maxed out the payload size of the transmission (i.e. we cannot increment the payload size of the packets anymore). This is initialized to 0.

We get the size of the payload to be sent in line 93 and put it in the variable dp_size which we will use as reference for our payload divisions. Lastly, we initialize an empty string variable sent which will hold all the character we have sent so far in our transmission. This is useful for error checking if the client is sending the correct part of the payload. After initializing these variables, we can move on to sending packets.

3.7 Packet transmission implementation (Lines 102-234)

For packet transmission, we devised a pseudocode as shown below:

Pseudocode for packet transmission

```
initialize best guess packet size for initial packet
packt_size = best guess
while charsent < dp_size:
    if packet is last to transmit:
        check remaining data to be sent
        Z = 1
        payload = dp[charsent:remaining]
    else:
        payload = dp[charsent:charsent+packt_size]
    compute for checksum
    send payload to server
    if socket has not timed out:
       get ACK response from server
       accepted = 1 #server has accepted initial payload size
       compute for checksum of ACK message from server
       bf checksums not equal:
            Break #there is an error
       charsent += packet_size
       seq += 1
       if can increment pckt_size:
            increment pckt_size
       if accepted = 1 and cant increment:
            maxed = 1 #maxed out payload size

    else: #socket has timed out, no ACK from server
```

```
        if maxed: #skip iteration, we just need to resend packet
             continue
        if accepted = 0: #initial pckt_size not accepted
             decrement pckt_size
        else: #packet has been accepted but timed out because we incremented too big
             increment = 0 #can no longer increment
             decrement pckt_size
     if transmission time > 120:
        break
```

The next subsections will go over the parts of the packet transmission program and explain them in detail.

3.7.1 Setting initial packet size and starting transmission timer (Lines 102-106)

```
102    packet_size = int(ceil(0.03125 * dp_size))
103
104    print(f"Length: {dp_size}")
105    #start timer for timeout (to check if packets were not ACKed)
106    startTime = time.time()
107
```

Figure 7: sender.py; 102-106

- Line 102 initializes the best guess packet size to be ~3% of the total data size. This value arose from trial-and-error executions.
    - Too big of a value, say 25%, would give too much of an overhead in terms of decrementing the packet size if it was too big.
    - Too small of a value, say 1%, would not let us deliver packets. We settle for ~3% of the data size instead.
- Line 106 starts the time for the transmission time. This is needed to make sure that the client stops trying to send packets even after the 120s allotted transmission time.

3.7.2 Data packet creation

According to the data packet format shown in Table 3 and as discussed in the project specifications document, there are certain parts of the data packet that we must make sure to follow, or the server will not acknowledge our packet. Standard creation of data packets in the implementation are given by:

```
payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:charsent+packet_size]}")
```

Figure 8: Packet creation

The payload variable holds the data packet to be sent. We use an f-string in Python to format the packet according to the specifications shown in Table 3.

- First part of the data packet is the intent message, which was formatted already (i.e. prefix “ID” added) when the transaction ID was requested from the server.
- Next, we have the sequence number prefixed with “SN” and followed by the value of the seq variable. Since the sequence number in the specifications called for a 7-digit integer, we pad our sequence number in the packet using the .zfill() function of Python.
- Next, we have the transaction ID, received from the server from the Level 1 implementation. This is prefixed with “TXN”.
- Next, we have the last packet flag Z, which is prefixed by “LAST”.
- Lastly, we have the payload to be sent, where we get the data in the data packet from the last character sent by the previous packet, up to the specified packet size.

3.7.3 Main Loop: Check for last packet (Lines 109-139)

To continuously transmit packets from the client to server, we use a while loop which keeps executing until the length of the data packet has been reached. Figure 11 shows the first part of the while loop, which constitutes the creation of the payload to be sent. Line 109 shows the while loop and its condition for execution which is if the current characters sent are less than the size of the total data packet to be sent. If there is still data to be sent to the server, we keep sending packets.

We first have a conditional statement to check if the packet to be sent is the last packet in the transmission or not. To determine if a packet is the last packet, we check the remaining data in the data packet by subtracting the number of sent characters from the total data packet size in line 114.

From here, there are two possible scenarios:

- The remaining data to be sent is exactly 0 (shown in line 116)
    - If the remaining data is exactly 0, then we set the last packet (Z) flag to 1 and get payload from the last character sent up to the last character in the data packet.

```
payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:dp_size]}")
```

Figure 9: Packet creation for last packet (rem = 0)

- The remaining data to be sent is not zero, but Is less than the packet size (shown in line 131)
    - We still set the last packet (Z) flag to 1. This time, we get payload from the last character sent up to the remaining data in the data packet.

```
payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:charsent+rem]}")
```

Figure 10: Packet creation for last packet (rem < packet size)

```python
#start sending
while charsent < dp_size:
    #last packet rules
    #if packetsize and current size of data sent exceeds remaining payload size
    if (charsent + packet_size >= dp_size):
        #to get remaining data left, subtract payload size from sent characters so far
        rem = dp_size - charsent
        #if 0 is the answer, then there are no more data left to send
        if rem == 0:
            #Tell server this is the last packet, set Z to 1
            Z = 1

            """
            Create payload using specifications:
            ID = 44919a94 (given as project credential)
            SN = sequence number padded with zeroes using .zfill
            TXN = transaction id taken from server
            PAYLOAD = take data from payload starting from the last sent character
            to the length of the data packet size
            """
            payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:dp_size]}")

        #remaining data may not be equal to 0 but is still less than packet size
        elif rem > 0 and rem < packet_size:
            #this is still the last packet to be sent, set Z to 1
            Z = 1
            #take payload to be from the last character sent up to the remaining data
            payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:charsent+rem]}")
    #if packet isn't last, packet is for transmission
    #take payload to be from last character sent up to the size of packet
    else:
        payload = (f"{intent}SN{str(seq).zfill(7)}TXN{trans_id}LAST{Z}{dp[charsent:charsent+packet_size]}")
```

Figure 11: sender.py; 109:139

If the packet to be sent is not the last packet in the transmission, then we just follow the standard creation of packets discussed in Section 3.7.2.

3.7.4 Main Loop: Packet sending (Lines 145-149)

After creating the packet to be sent, we can now send them to the server. Figure 12 shows the code snippet responsible for this.

```python
141        #print payload for checking/debugging
142        #print("Current payload", payload)
143
144        #use provided checksum function to generate checksum (client side)
145        checksum = compute_checksum(payload)
146
147        #send payload to server
148        clientSock.sendto(payload.encode(), UDP_IP_PORT)
149        print("Packet sending...")
```

Figure 12: Sending packet to server (sender.py; 141:149)

Line 145 computes for the checksum of the packet to be sent for error checking purposes. The helped function used for this is the compute_checksum function provided in the project specifications.

Afterwards, we send the packet to the server using the sendto() method shown in line 148. Again, this method takes in two arguments – the data to be sent, and where to send it to. In this case, the data to be sent is the packet (variable payload). But first, we must encode it into byte string format. The address and port of the server are again initialized in the UDP_IP_PORT variable.

3.7.5 ACK message

The server acknowledges the packet if it was sent successfully and will send an ACK packet back to the client in the following format:

A	C	K	X	X	X	X	X	X	X
0	1	2	3	4	5	6	7	8	9
T	X	N	Y	Y	Y	Y	Y	Y	Y
10	11	12	13	14	15	16	17	18	19
M	D	5	CHECKSUM						
20	21	22							

Table 4: ACK packet format

Where:

- ACKXXXXXXX denotes the sequence number of the packet acknowledged prefixed by "ACK"
- TXNYYYYYYY denotes the transaction ID prefixed by "TXN"
- MD5CHECKSUM denotes the checksum of the packet from the receiver/server side.

This is the expected ACK message that will be received from the server.

3.7.6 Getting the ACK

Since we know what the ACK message from the server, there are two possible scenarios. First, if the server was able to send an ACK message, and if the server did not send an ACK message. We use a try-except block for this, since the socket will time out (i.e. the settimeout() value initialized) if it hasn't received a response form the server. If the socket times out, it will throw an error. Thus, we use a try-except block to catch the timeout error to be thrown.

- If the server was able to ACK the packet that we sent, then we can either:
  - Continue sending packets AND increment packet size; OR
  - Continue sending packets ONLY (this means that packet size has been maxed)
- If the server was NOT able to send an ACK, then we can either:
  - Decrement packet size AND retry sending packet; OR
  - Retry sending packet ONLY.

The implementation of the first scenario is shown in Figure 13. For the try block of the code, this means that if the socket has not reached the specified timeout value yet, then we can get a response from the server. This is done line 158 using the recvfrom() method, taking in 1024 bytes of data from the server. The response of the server is then initialized into the response variable. Once a response has been received, then we know that the server has accepted our initial payload size. And so, we set the accepted flag to 1 in line 160. After this, we update the sent variable to hold the sent data so far in line 162. We decode the server's response in line 168, and then get the checksum part (refer to Table 4) of the response in line 169.

We then check if the checksums of the client-sent packet and server-packet matches. If they do, then we know that the right packet has been sent and received. If they don't match, we break out of the loop since this means that there has been an error in packet transmission. These are shown in lines 172 to 176.

In line 179, we increment the charsent variable with the packet size. If the packet has been accepted, then the last character sent will also change depending on how big the packet was sent. We also increment the sequence number of the packet in line 181.

Lines 185 to 194 constitute the incrementation of the packet size. Remember that the increment flag ells us if the packet can be incremented or not. If this flag is 0, then this means that pervious packets that has been sent were not rejected by the server, and next packet can be incremented. The formula follows that of the initial packet sizing in Section 3.7.1 but with a smaller percentage.

```
packet_size += int(ceil(0.02*(dp_size-packet_size)))
```

We increment our packet size only by a fraction of the data size when subtracted by the size of the current packet. We use the ceil function of Python's math module to round this value up and convert it into an integer. Again, this value was taken from a series of trial-and-error executions. Percentages ranging from 2 – 10% of the remaining data size were compare and the percentage that to led to successful runs and manageable fluctuations of packet sizes was determined to be 2%. Hence, this value was used in our implementation.

If the server has already accepted packets, but the increment flag is set to 1, then we know that the payload size has been maxed out. And so, we set the maxed flag to 1 in line 201.

For the second scenario where the socket times out and the server fails to send an ACK reply to the packet sent, then we know that our packet has an incorrect payload size, and we need to decrement the current payload size that we have. Figure 14 shows the except block which handles this scenario.

Lines 214-215 checks if the maxed flag is set to 1. If it is, then we skip the iteration (i.e. just send the packet to the server). Line 219-220 checks if the accepted flag is set to 0. If it is, then we know that the initial packet has not been accepted by the server, and so we decrement the initial packet size by 2% of the data packet size subtracted from the packet size. Again, note that this value was taken from trial-and-error executions, testing different percentages, and choosing 2% as the most viable increment.

Lines 228-231 checks if the packet has been accepted. If the accepted flag is set to 1, then we know that previous packets has been accepted by the server already. However, the server may have not sent an ACK reply because the incrementation of the packet size was too big. So, we revert back to the previous packet size.

Finally, lines 234-235 checks if the transmission time has exceeded 120 seconds, if it has, packet transmission must be terminated and while loop must stop executing.

Lines 237-238 check if the payload that was sent matches the original payload for debugging and error checking purposes.

```
try:
    #try getting ACK response from server
    response, addr = clientSock.recvfrom(1024)
    #if response was received, server was able to receive packet, set `accepted` flag to 1
    accepted = 1
    #increment `sent` variable to hold current sent data (for checking)
    sent += dp[charsent:charsent+packet_size]

    print("ACK received...")

    #decode response from server to get checksum; checksum at index 23 onwards of ACK packet
    #according to project specs
    rescheck = response.decode()
    rescheck = rescheck[23:]

    #if checksums are not equal, break transmission
    if rescheck != checksum:
        print(f"Server checksum: {rescheck}")
        print(f"Client checksum: {checksum}")
        print("Checksum error")
        break

    #increment the last sent character to be packet size
    charsent += packet_size
    #increment sequence number of packet by 1
    seq += 1

    #increment flag used to check if payload can still be increased
    #if this flag is 0, incrementation can still be done
    if increment == 0:
        """
        increment packet size by subracting current packet size from total
        data packet size

        get only 2 percent of size to add
        this value was gotten from trial and error. implementation first tested by
        getting 50% -> 25% -> 10% -> 5% -> 2%
        """
        packet_size += int(ceil(0.02*(dp_size-charsent)))

    #accepted flags and increments flags will be set to 1 if packet was:
    # 1) accepted by server
    # 2) but can no longer be incrremented
    #this means that payload size has been maxed out and we set `maxed` flag to 1
    if accepted == 1 and increment == 1:
        maxed = 1

    print(f"Current packet size {packet_size}, remaining {dp_size-charsent}")
```

Figure 13: Server sends an ACK message (sender.py; 158:203)

```
210     except socket.timeout:
211         print("Server NACKed")
212         print(f"Packet not accepted because of payload size: {packet_size}")
213 
214         if maxed == 1:
215             continue
216 
217         #if accepted flag has not been set to 1, inital packet sent was not accepted, adjust payload size
218         #values same as used during incrementation of initial packet
219         if accepted == 0:
220             packet_size -= int(ceil(0.02*(dp_size-packet_size)))
221 
222         #if accepted flag has been set to 1, transmission has already been accepted by server
223         #but socket has timed out either because of:
224         #1) payload size
225         #2) being in the queue
226         #in this case, we want to decrease payload size still and send again
227         #in general, increment bigger, decrement smaller
228         elif accepted == 1:
229             #set increment flag to 1 to signify that we can't increment payload size anymore
230             increment = 1
231             packet_size -= int(ceil(0.003*(dp_size-packet_size)))
232 
233     #checker if 120 second time allotment has passes
234     if time.time() - startTime > 120:
235         break
236 
237 print("Packet transmission finished.")
238 print(f"Sent data equal to payload? {sent == dp}")
```

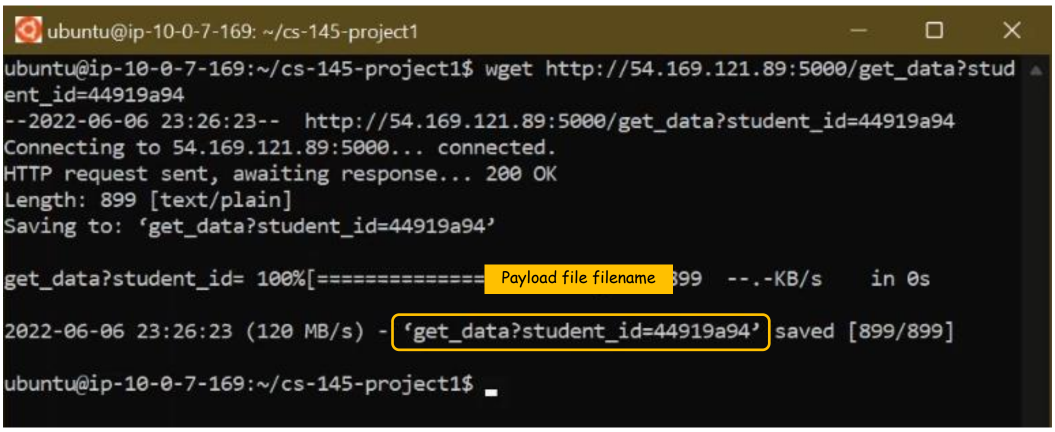
Figure 14: Server does not an ACK message (sender.py; 210:238)

4 Testing

To test the implementation of the sender program, five transactions were initiated.

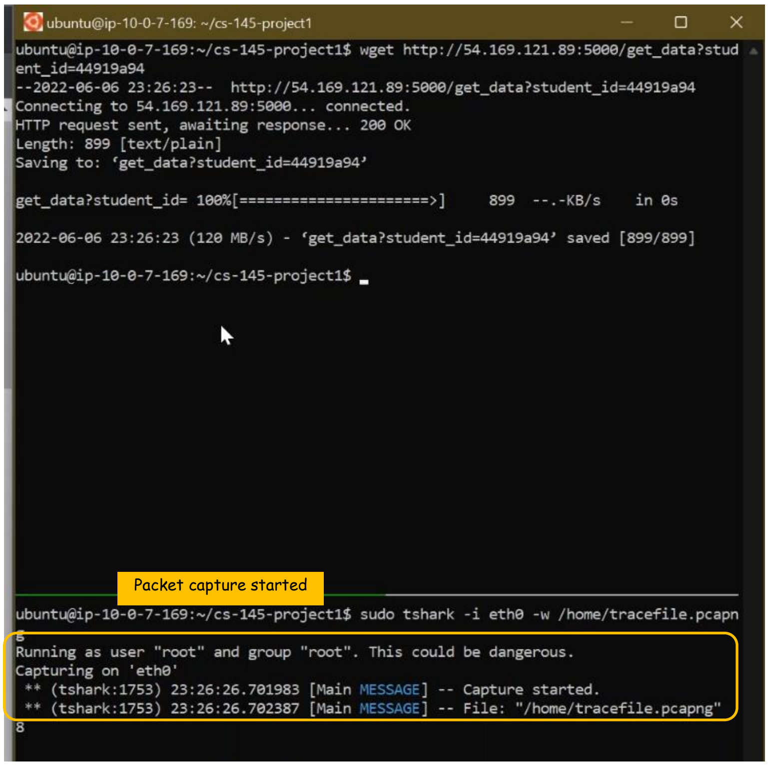
4.1 Transaction 1

For the first transaction, we first download the following payload file:

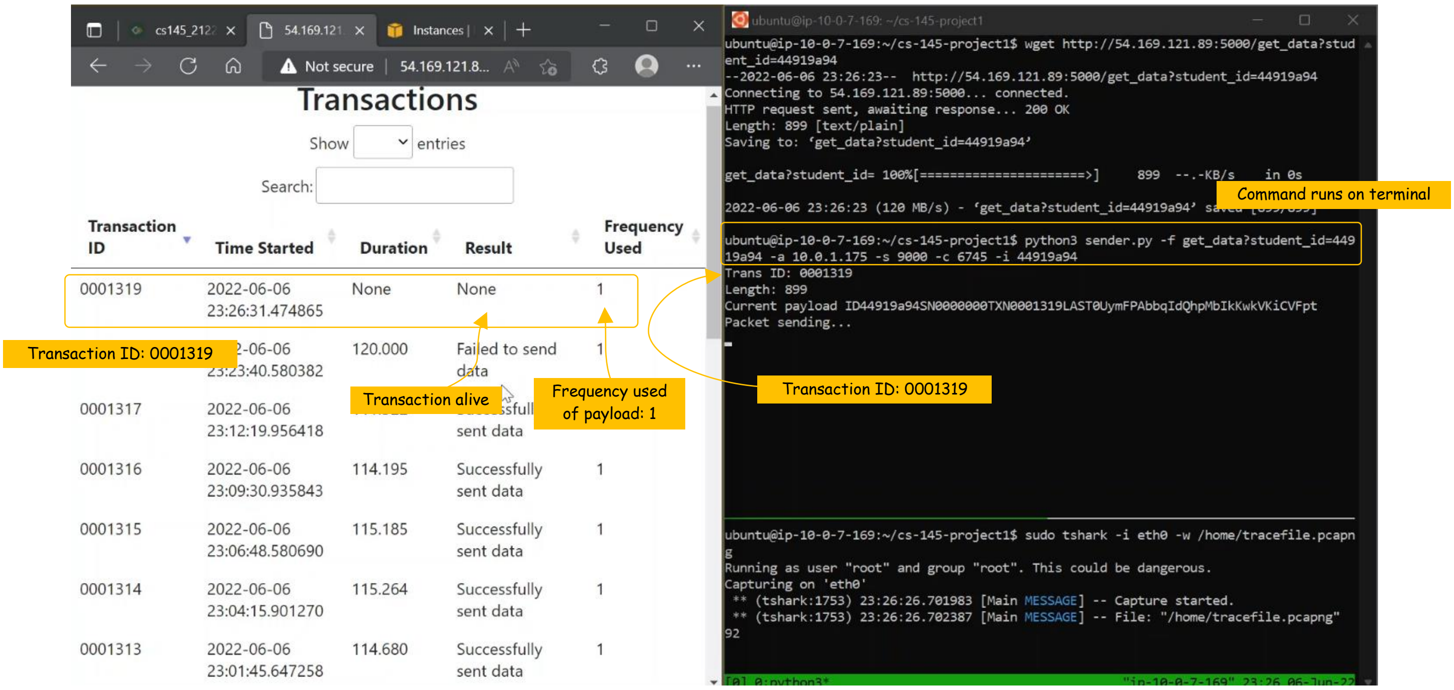


```
ubuntu@ip-10-0-7-169: ~/cs-145-project1
ubuntu@ip-10-0-7-169:~/cs-145-project1$ wget http://54.169.121.89:5000/get_data?stud
ent_id=44919a94
--2022-06-06 23:26:23--  http://54.169.121.89:5000/get_data?student_id=44919a94
Connecting to 54.169.121.89:5000... connected.
HTTP request sent, awaiting response... 200 OK
Length: 899 [text/plain]
Saving to: 'get_data?student_id=44919a94'

get_data?student_id= 100%[==============   899  --.-KB/s    in 0s

2022-06-06 23:26:23 (120 MB/s) - 'get_data?student_id=44919a94' saved [899/899]

ubuntu@ip-10-0-7-169:~/cs-145-project1$
```

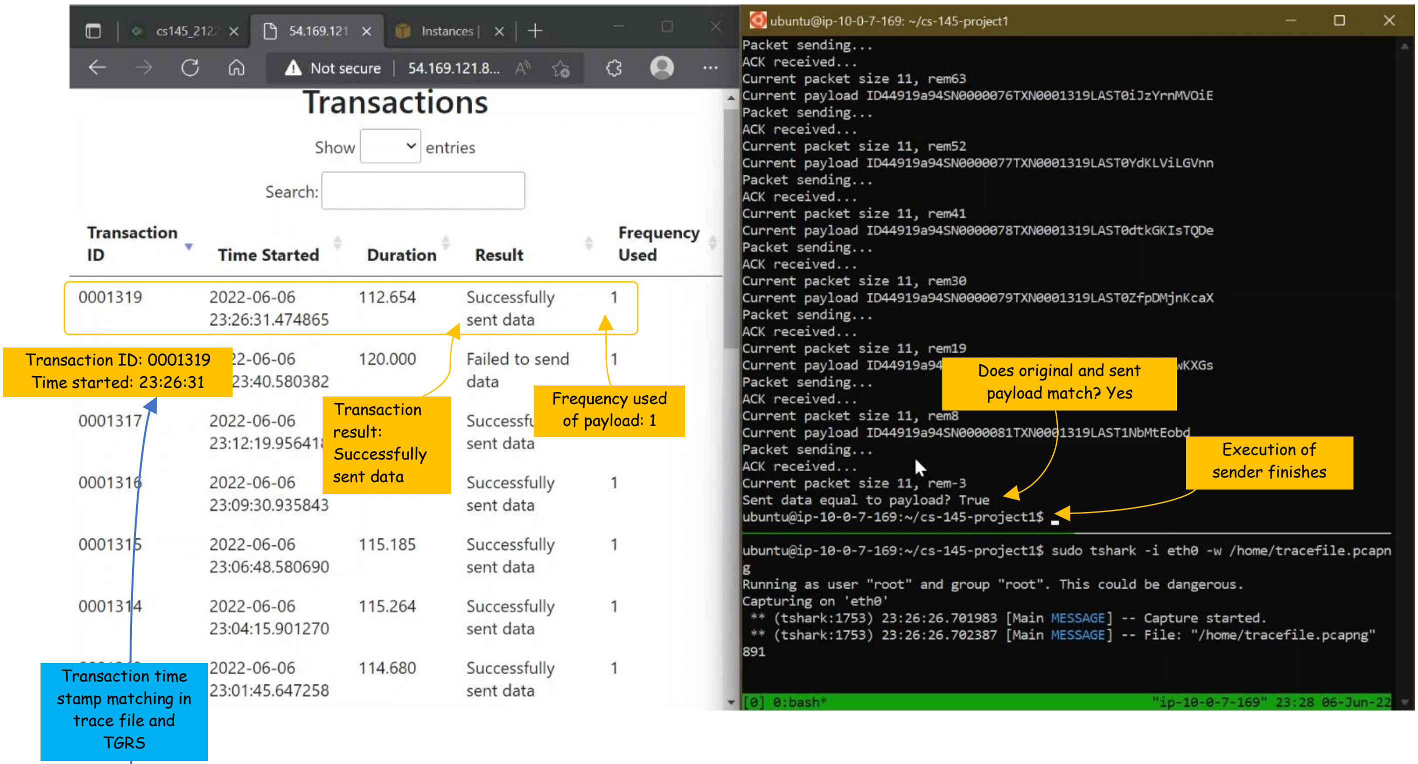

Then, we start tshark before initiating a transaction with the server.



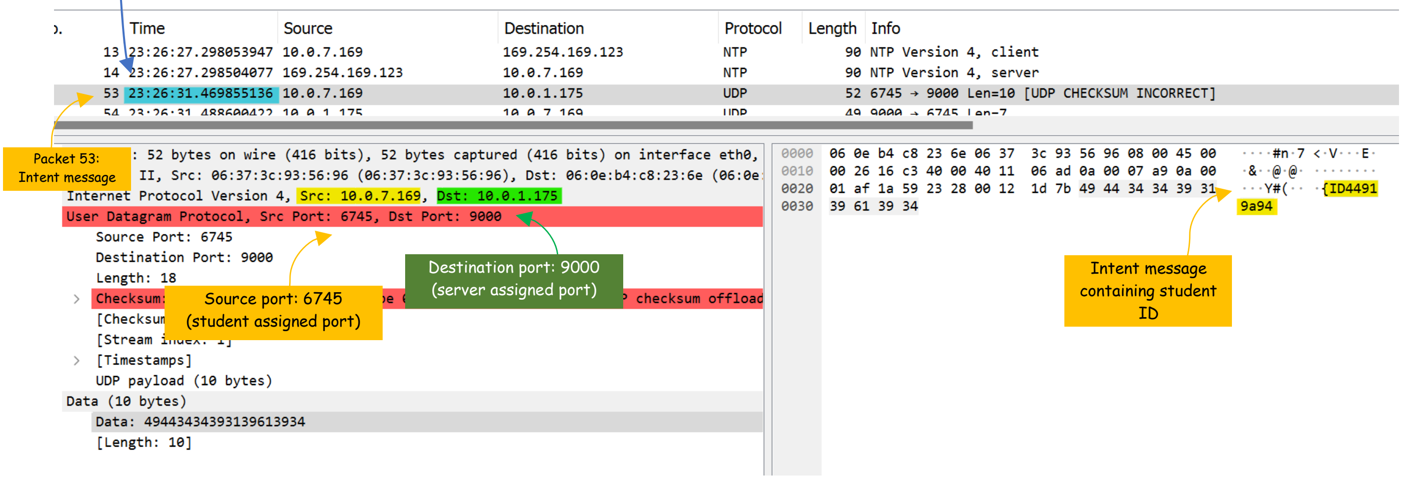
Once tshark has started capturing packets, we can now run our sender program via the command `"python3 sender.py -f get_data?student_id=44919a94 -a 10.0.1.175 -s 9000 -c 6745 -i 44919a94."`

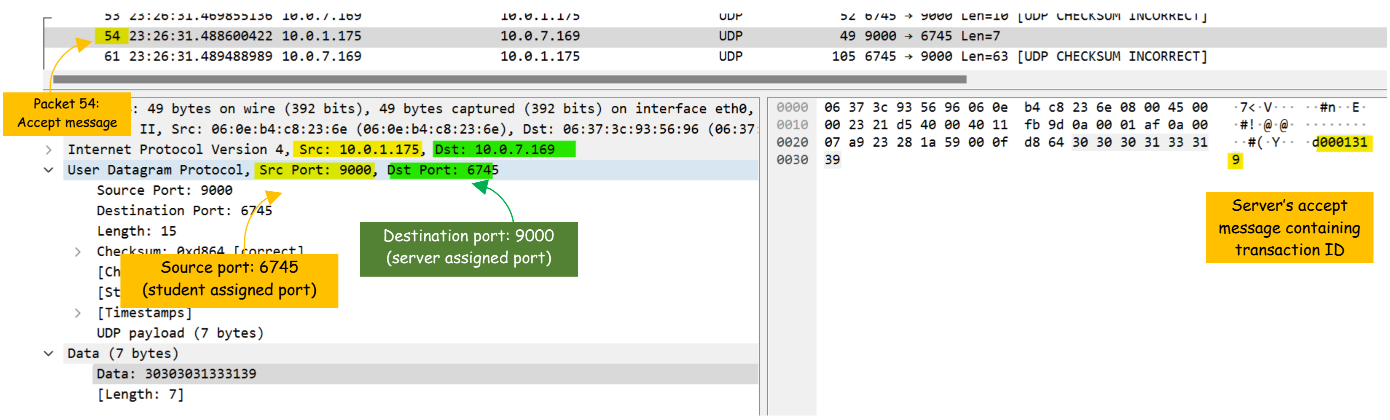


Note that this transaction has a transaction ID of 0001319. After successfully sending the packets, the sender program finishes executing and the result in the TGRS is updated and is shown to have **successfully sent data**.

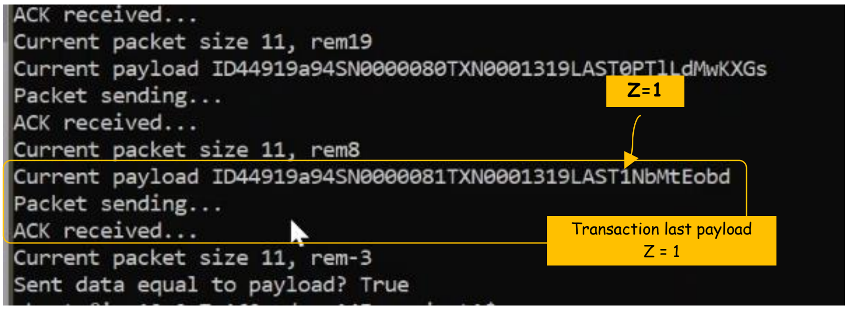


By checking the transaction in the tracefile generated, we can verify that the intent message was indeed sent as packet 53 in the tracefile by filtering out the UDP packets and checking their payload. The server's accept message can also be verified as packet 54 which contains the transaction ID.

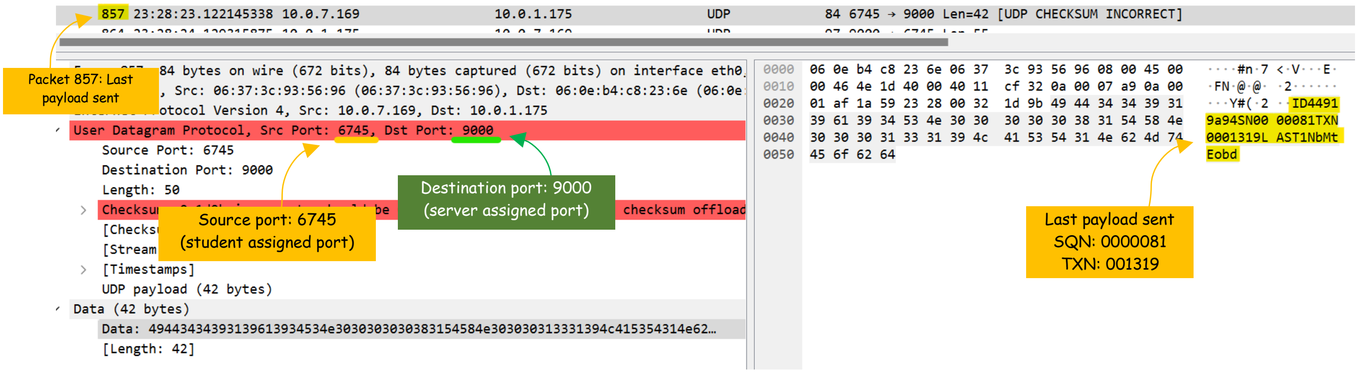




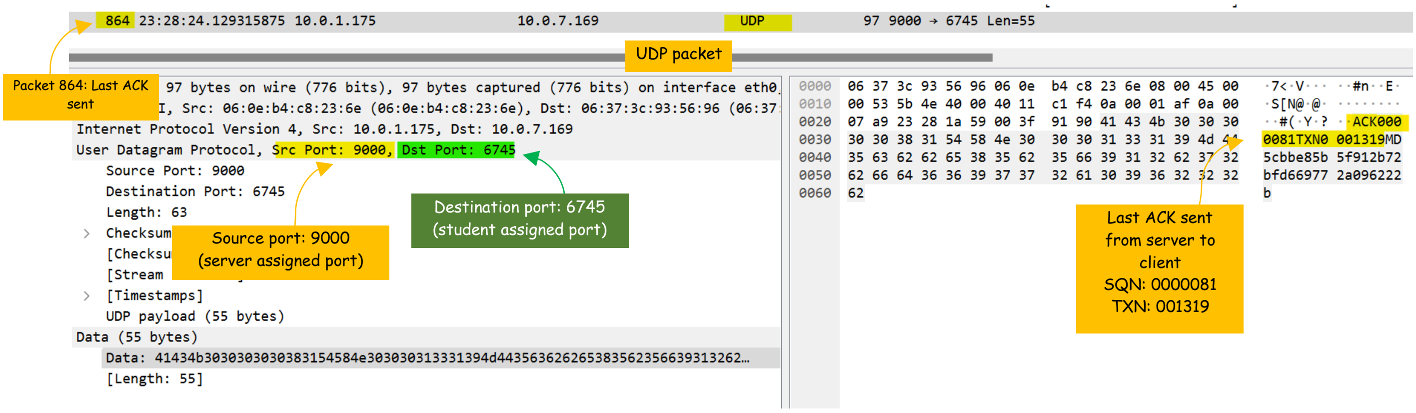
We can also verify that the last packet sent has the following payload:



If we analyze the tracefile, the last packet sent for this transaction from my machine to the server was packet number 857. We can verify the payload of the packet and check that it indeed corresponds to the payload printed by the sender program.



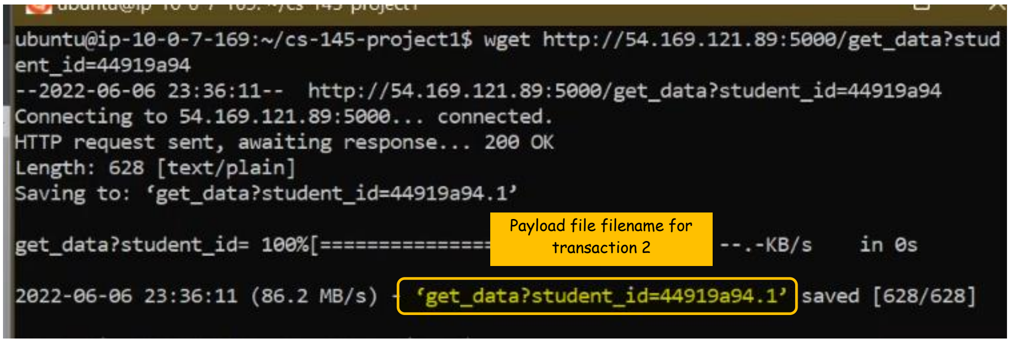
Correspondingly, the server has also sent the last ACK message for this payload in packet 864.



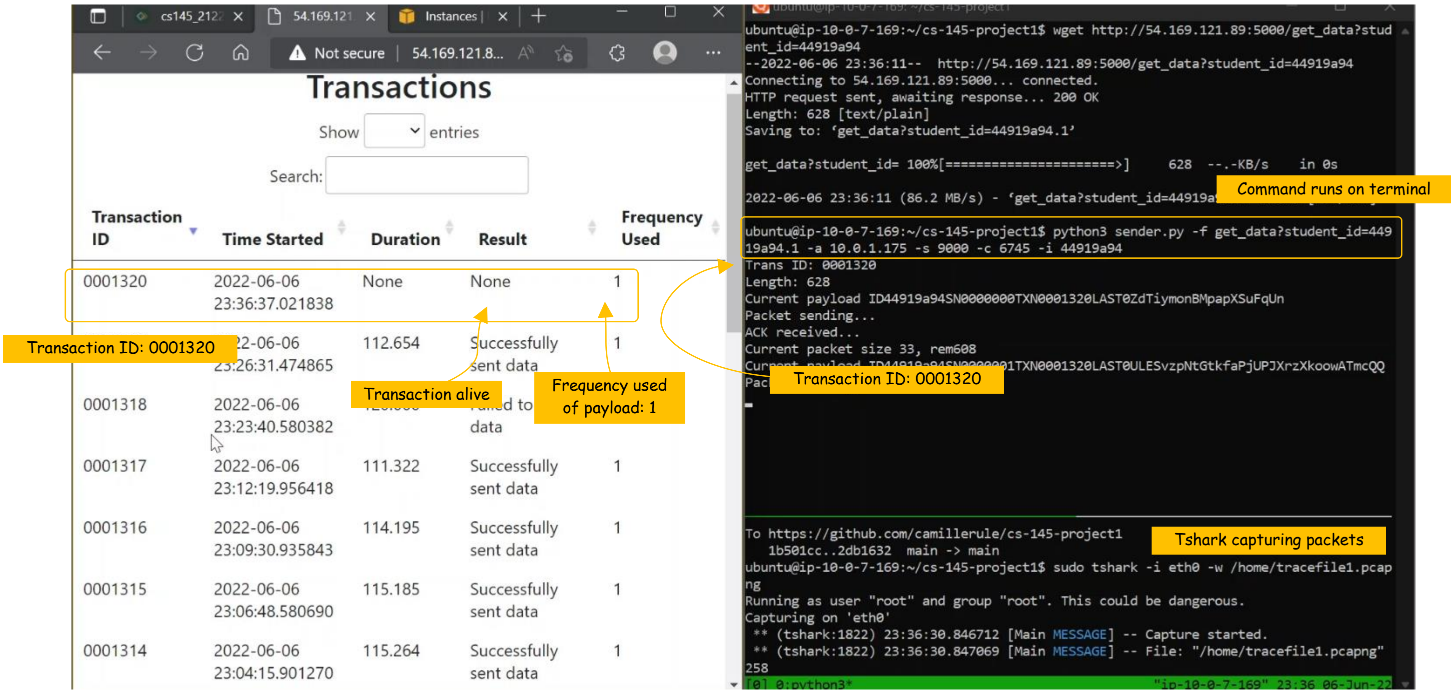
Thus, it can be shown that the sender implementation is indeed successful in sending data from the client to the server in this transaction.

4.2 Transaction 2

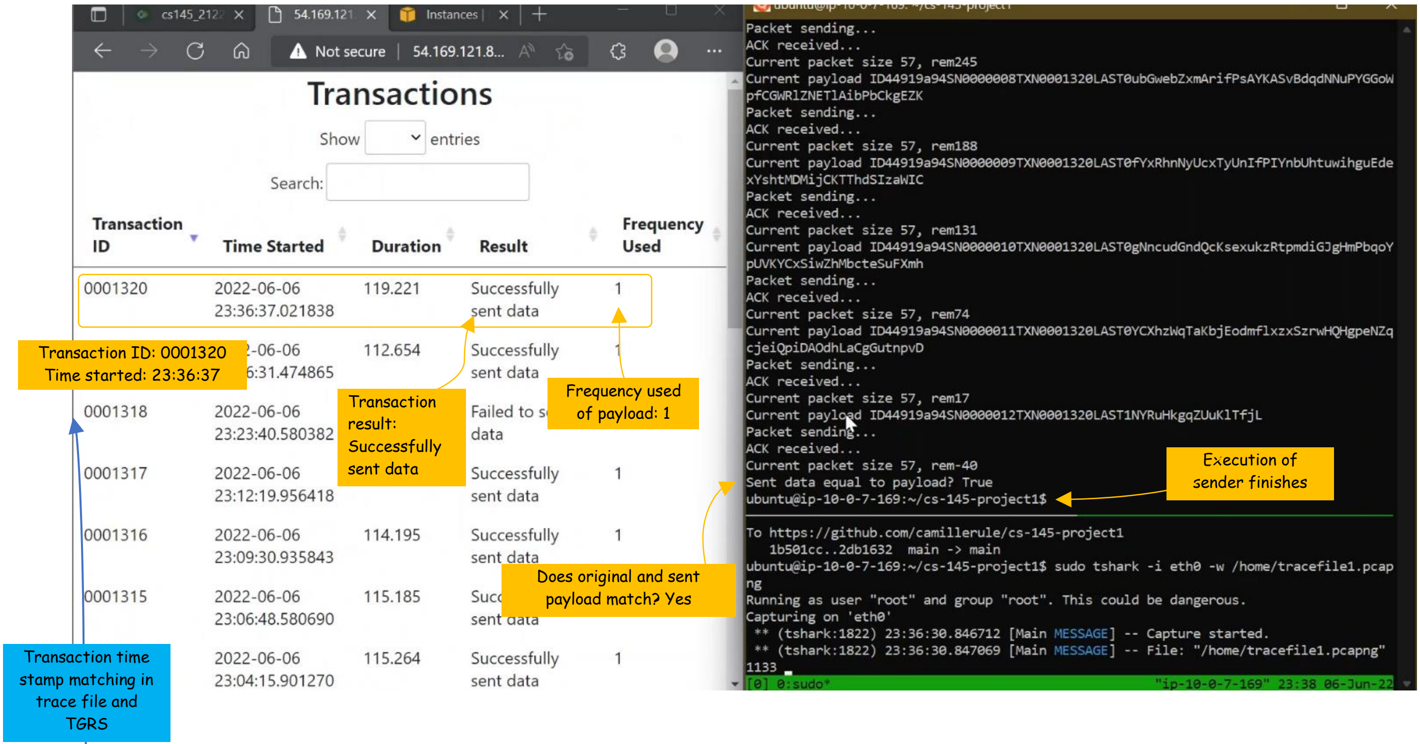
We do the same thing for another transaction and start by downloading a new payload file.



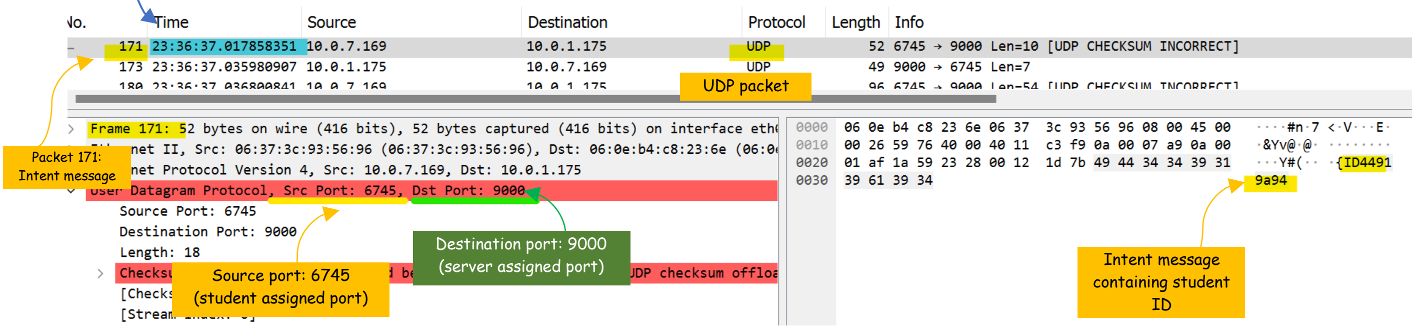
Start tshark and use the new payload filename to execute the sender program via command line. We use the command "`python3 sender.py -f get_data?student_id=44919a94.1 -a 10.0.1.175 -s 9000 -c 6745 -i 44919a94`"

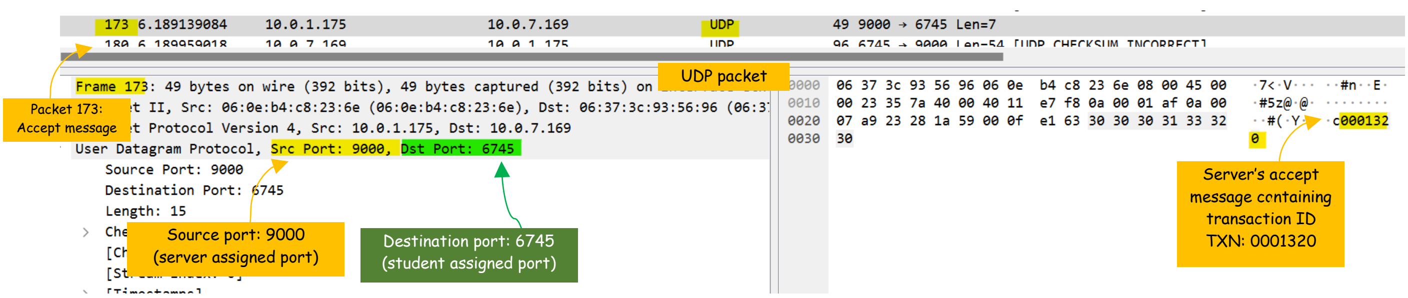


Note that this transaction has a transaction ID of 0001320. After successfully sending the packets, the sender program finishes executing and the result in the TGRS is updated and is shown to have **successfully sent data**.

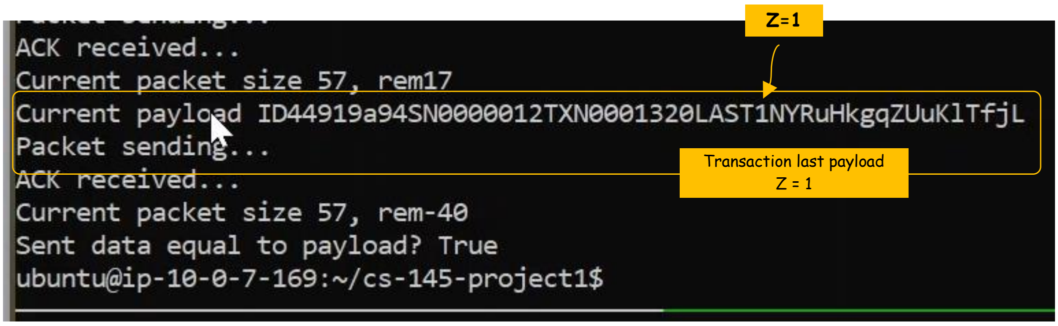


By checking the transaction in the tracefile generated, we can verify that the intent message was indeed sent as packet 171 in the tracefile by filtering out the UDP packets and checking their payload. The server's accept message can also be verified as packet 173 which contains the transaction ID.

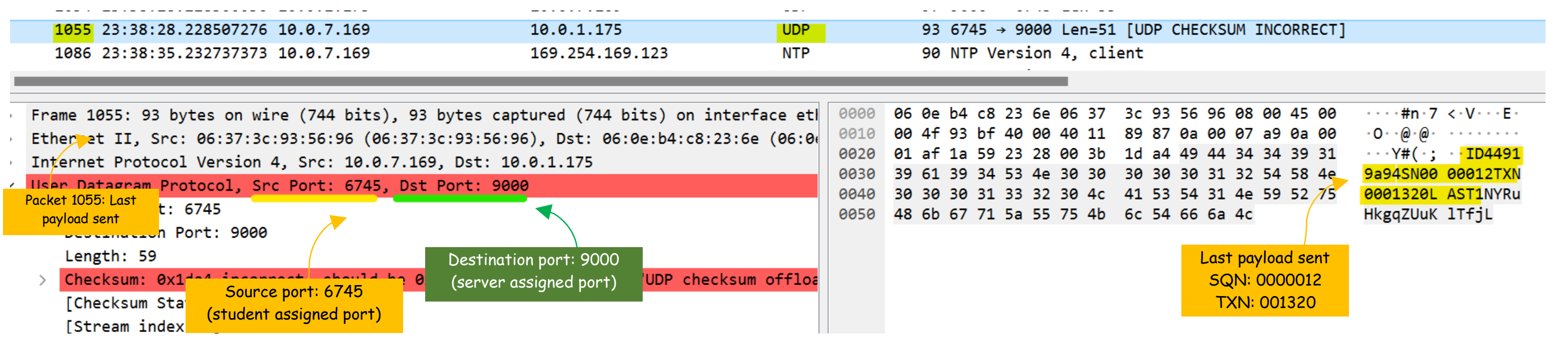


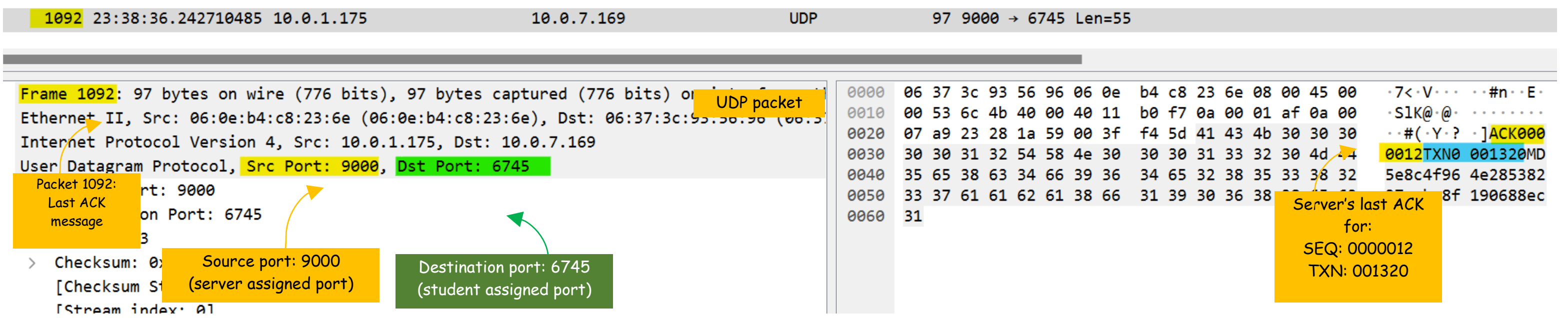


We can also verify that the last packet sent has the following payload:



If we analyze the tracefile, the last packet sent for this transaction from my machine to the server was packet number 1055. We can verify the payload of the packet and check that it indeed corresponds to the payload printed by the sender program.

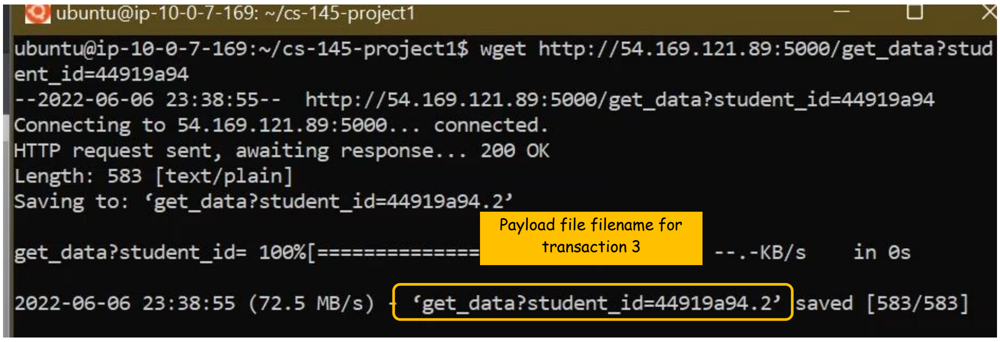




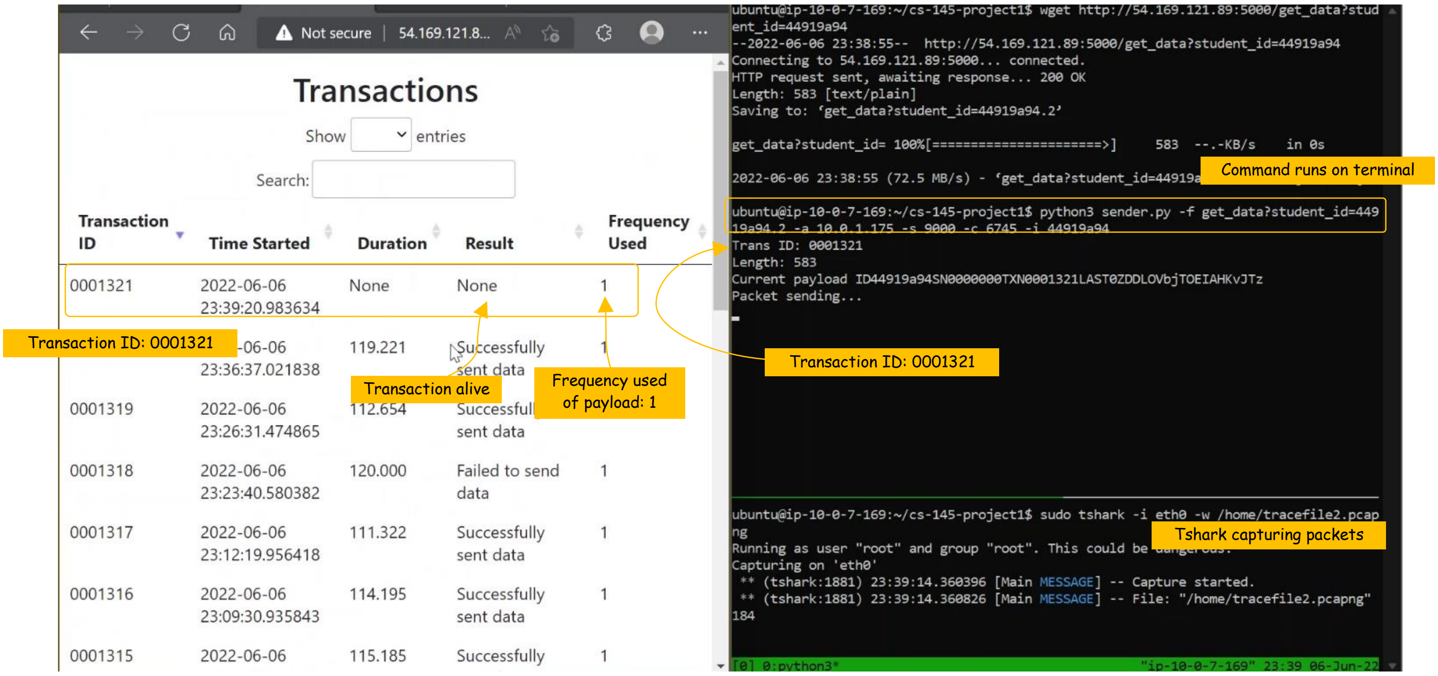
The server also sends its last ACK message for the corresponding packet shown as packet number 1092 in the trace file. Thus, it can be shown that the sender implementation is indeed successful in sending data from the client to the server in this transaction as well.

4.3 Transaction 3

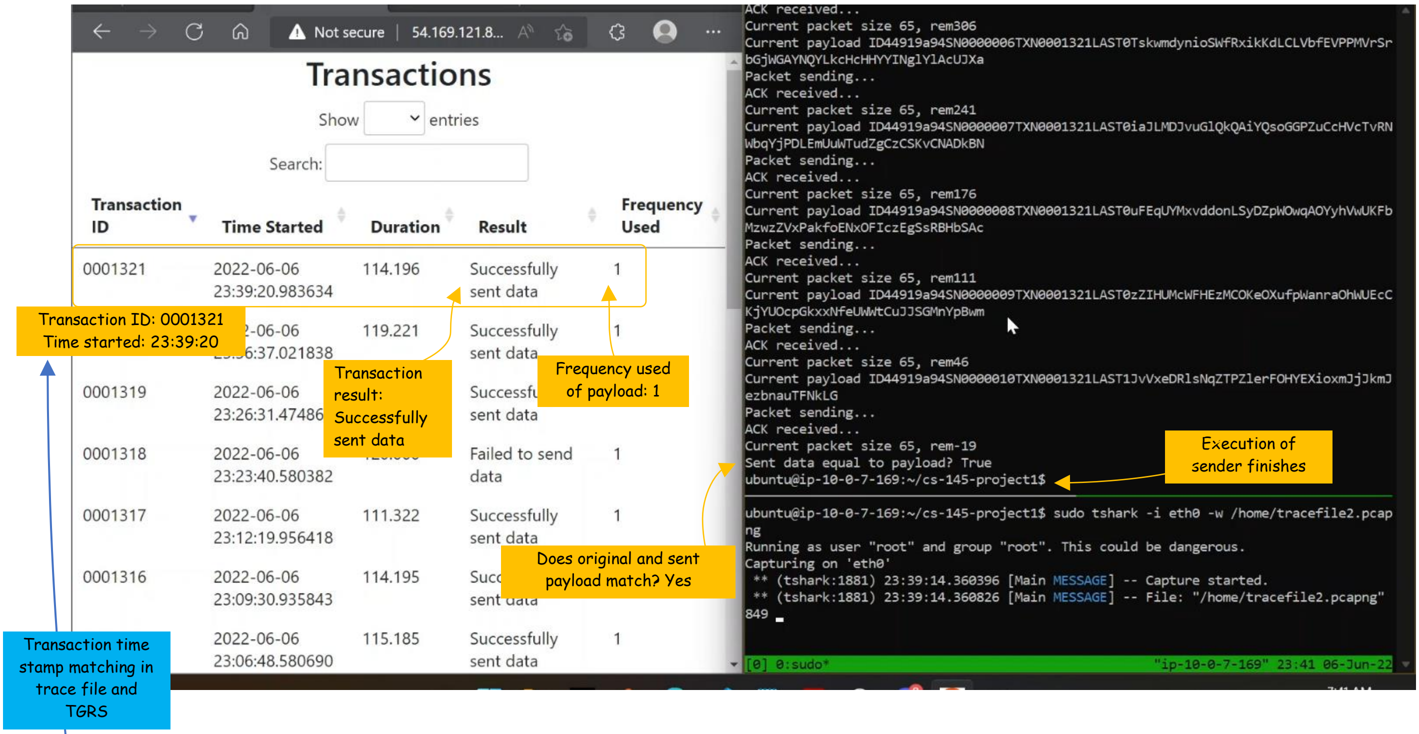
We do the same thing for another transaction and start by downloading a new payload file.



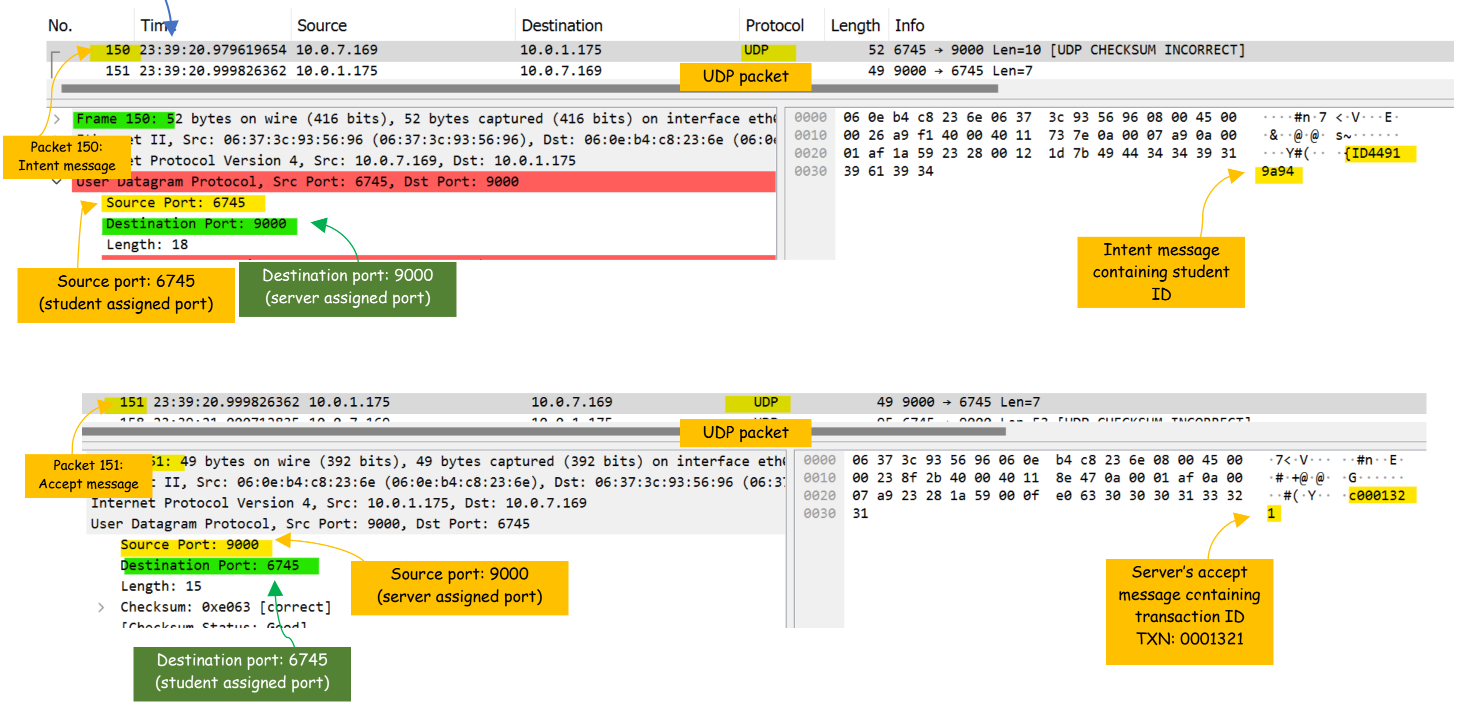
Start tshark and use the new payload filename to execute the sender program via command line. We use the command "`python3 sender.py -f get_data?student_id=44919a94.2 -a 10.0.1.175 -s 9000 -c 6745 -i 44919a94`"



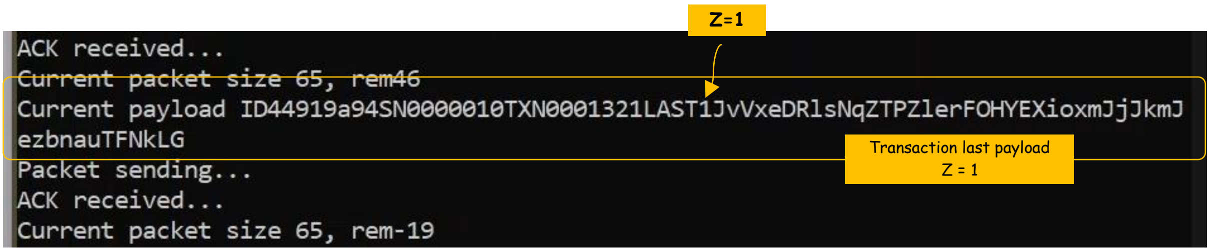
Note that this transaction has a transaction ID of 0001321. After successfully sending the packets, the sender program finishes executing and the result in the TGRS is updated and is shown to have **successfully sent data**.



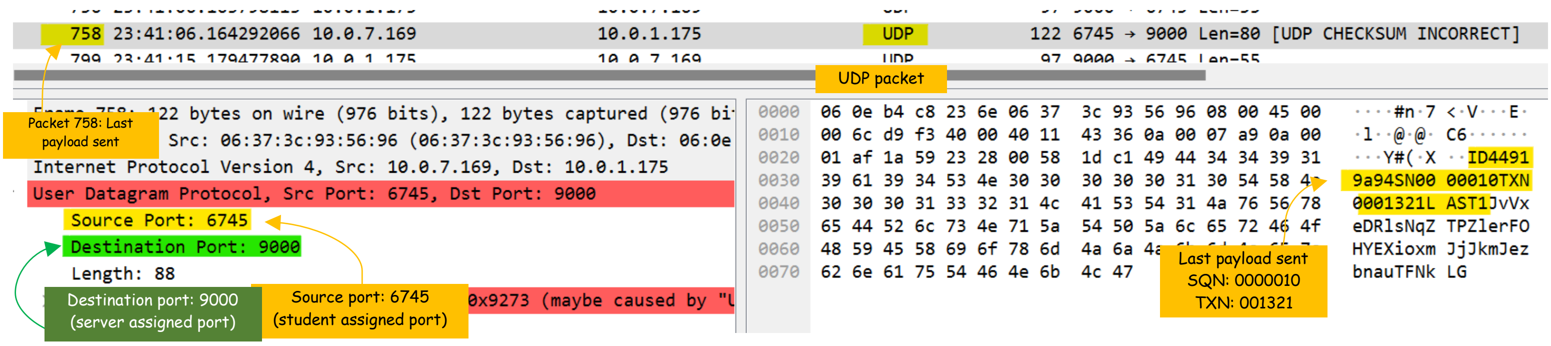
By checking the transaction in the tracefile generated, we can verify that the intent message was indeed sent as packet 150 in the tracefile by filtering out the UDP packets and checking their payload. The server's accept message can also be verified as packet 151 which contains the transaction ID.

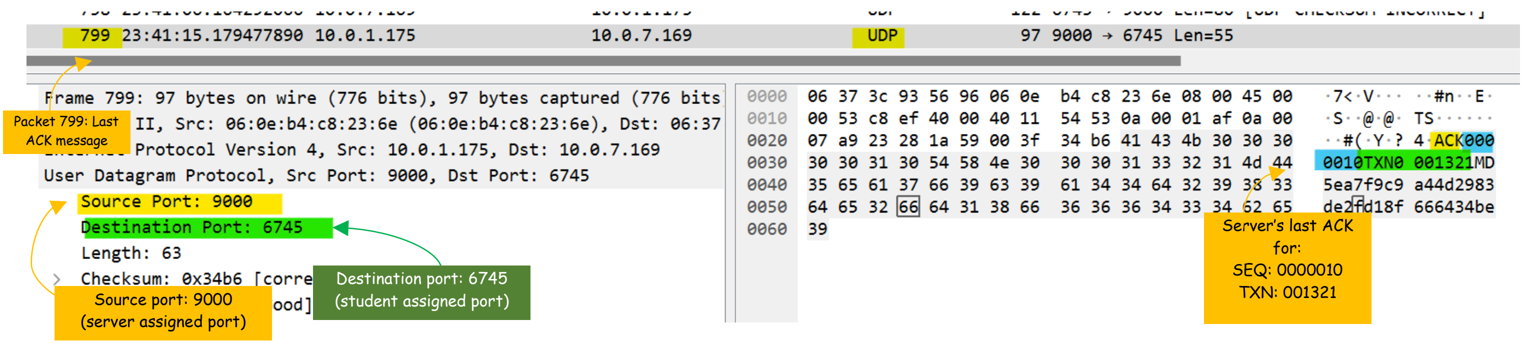


We can also verify that the last packet sent has the following payload:



If we analyze the tracefile, the last packet sent for this transaction from my machine to the server was packet number 758. We can verify the payload of the packet and check that it indeed corresponds to the payload printed by the sender program.

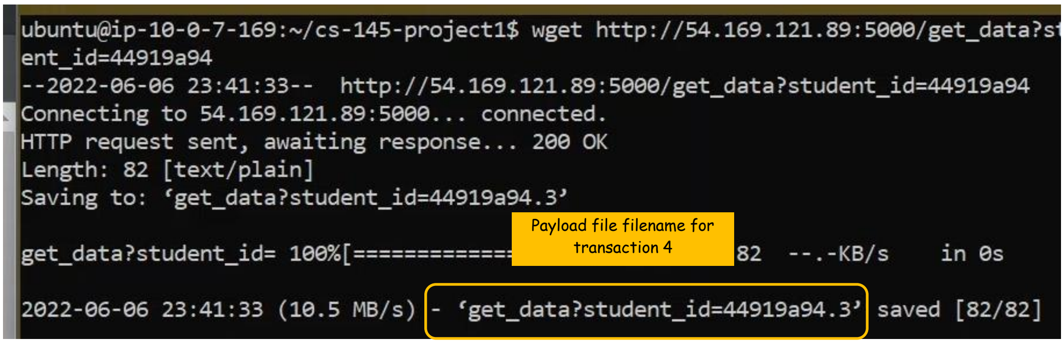




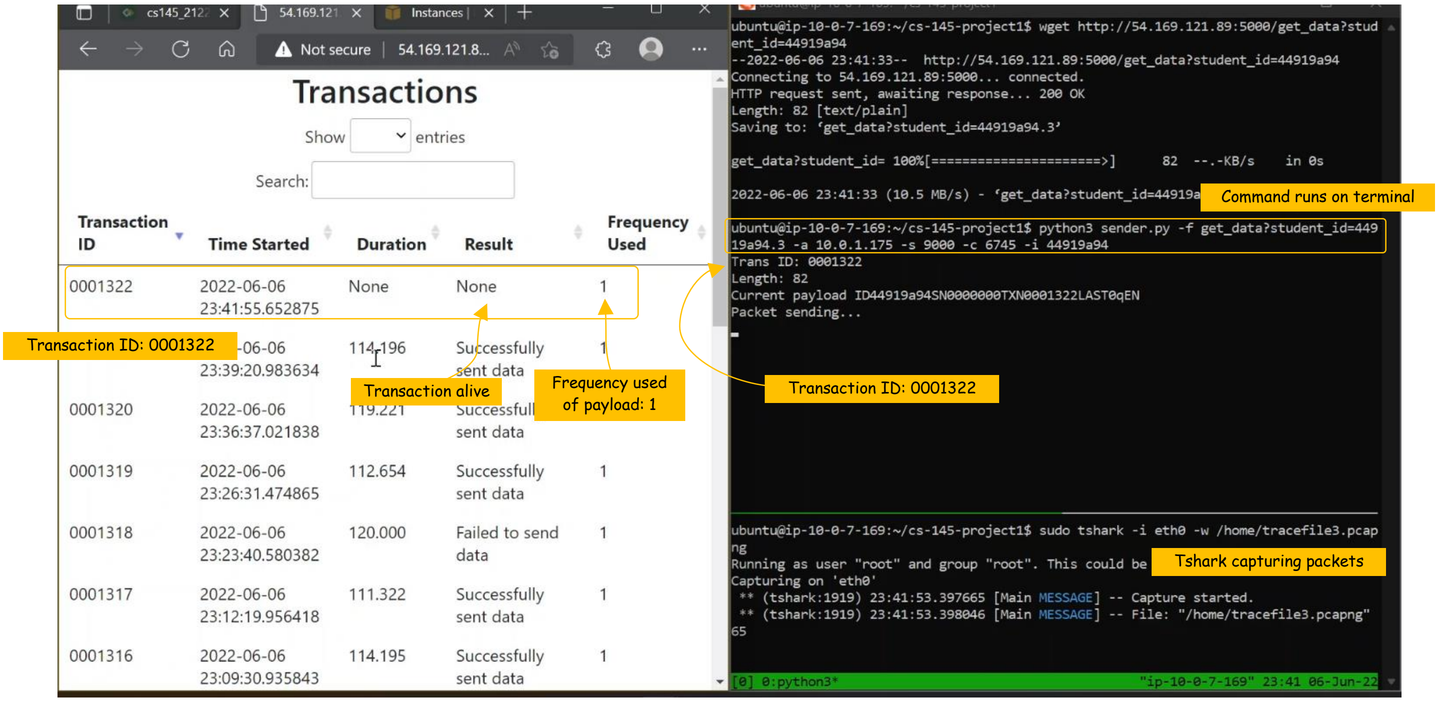
The server also sends its last ACK message for the corresponding packet shown as packet number 799 in the trace file. Thus, it can be shown that the sender implementation is indeed successful in sending data from the client to the server in this transaction as well.

4.4 Transaction 4

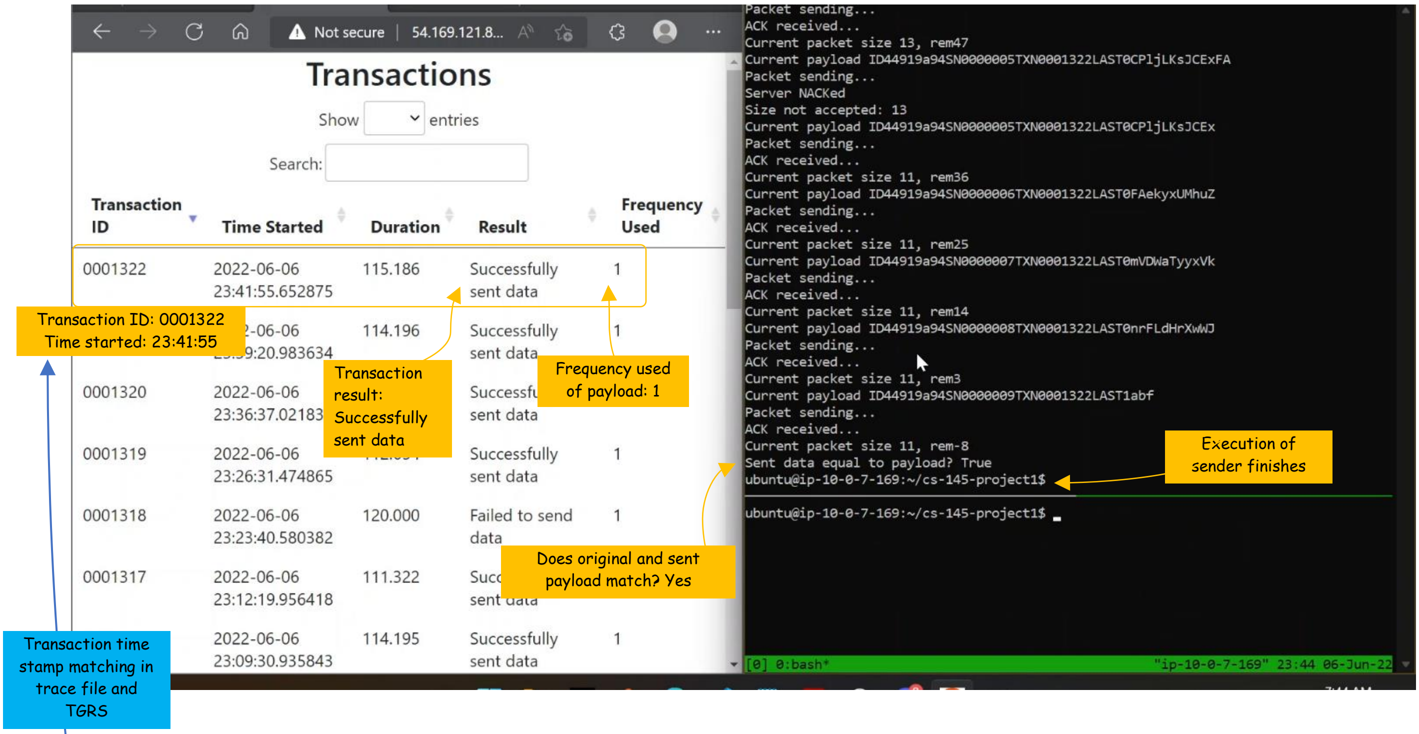
We do the same thing for another transaction and start by downloading a new payload file.



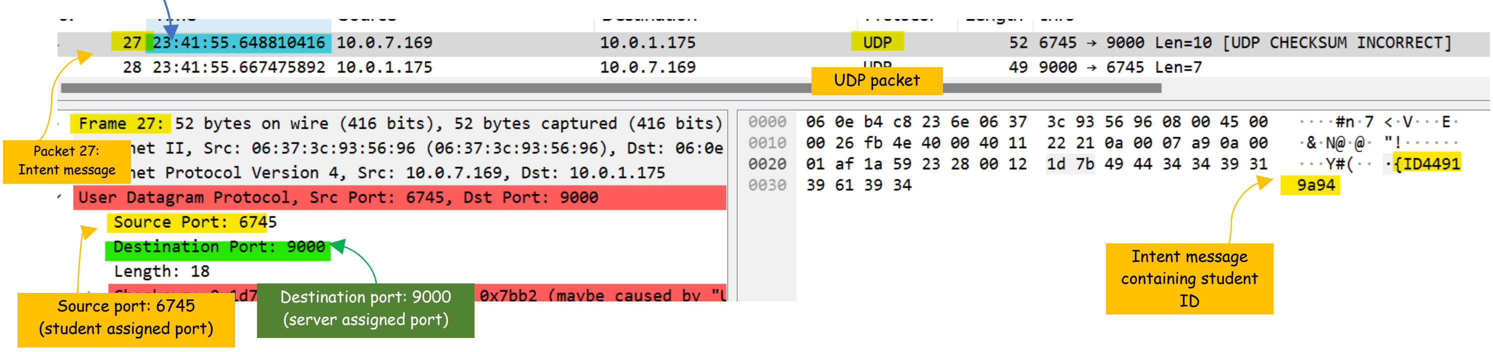
Start tshark and use the new payload filename to execute the sender program via command line. We use the command "`python3 sender.py -f get_data?student_id=44919a94.3 -a 10.0.1.175 -s 9000 -c 6745 -i 44919a94`"

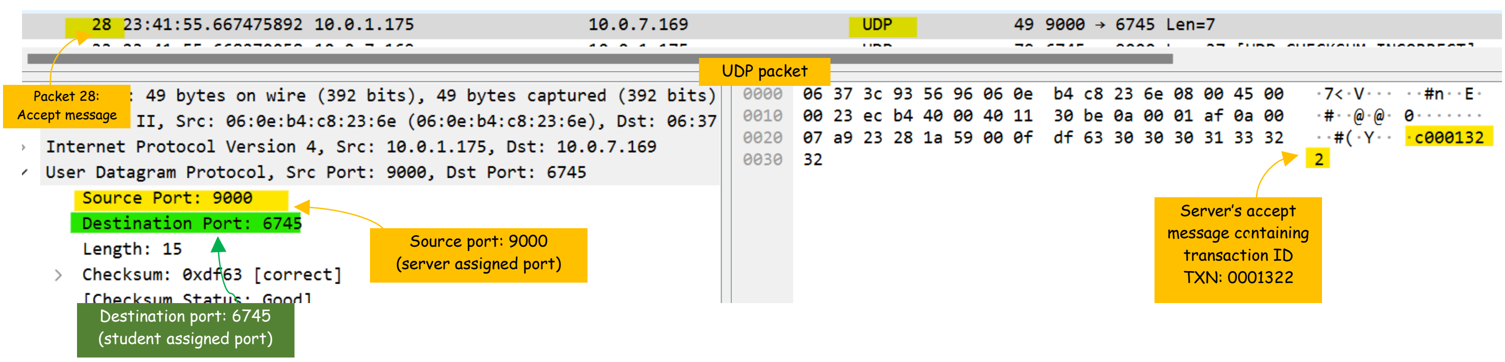


Note that this transaction has a transaction ID of 0001322. After successfully sending the packets, the sender program finishes executing and the result in the TGRS is updated and is shown to have **successfully sent data**.

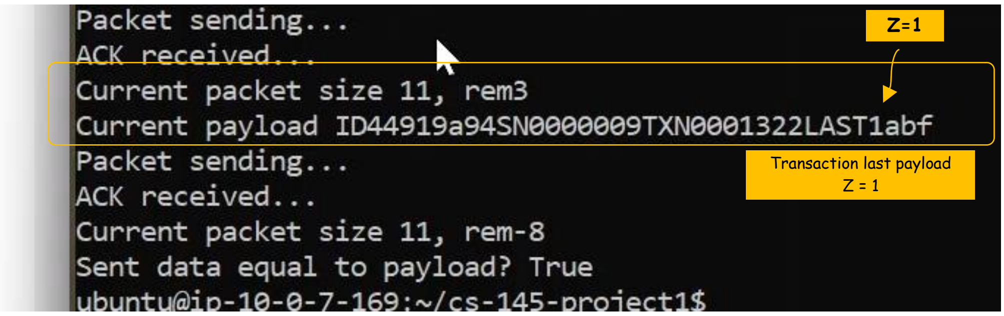


By checking the transaction in the tracefile generated, we can verify that the intent message was indeed sent as packet 27 in the tracefile by filtering out the UDP packets and checking their payload. The server's accept message can also be verified as packet 28 which contains the transaction ID.

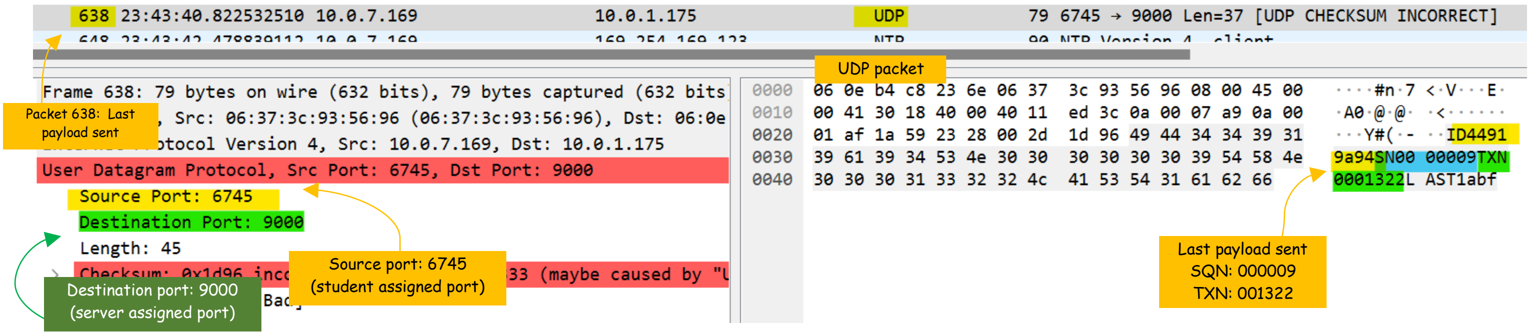


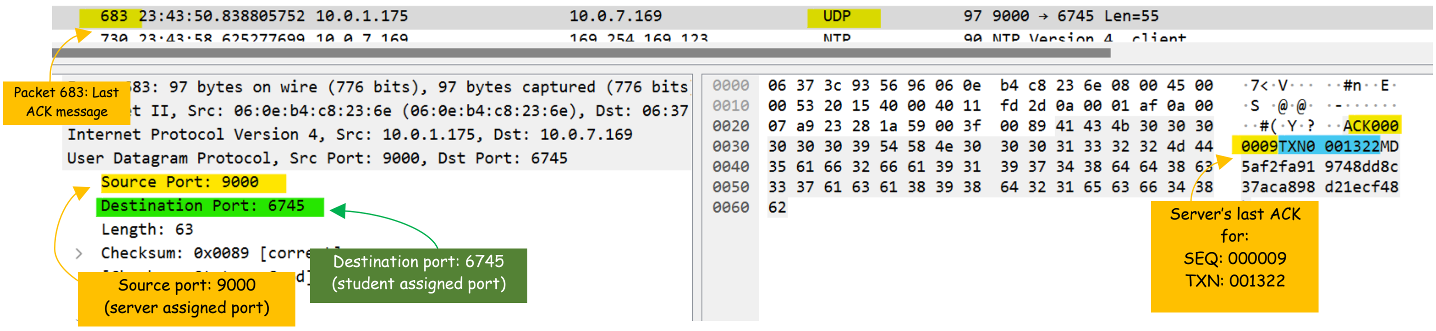


We can also verify that the last packet sent has the following payload:



If we analyze the tracefile, the last packet sent for this transaction from my machine to the server was packet number 638. We can verify the payload of the packet and check that it indeed corresponds to the payload printed by the sender program.

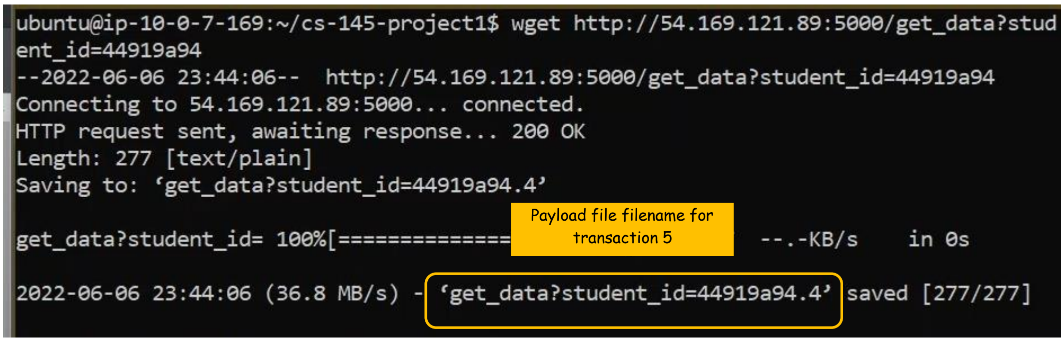




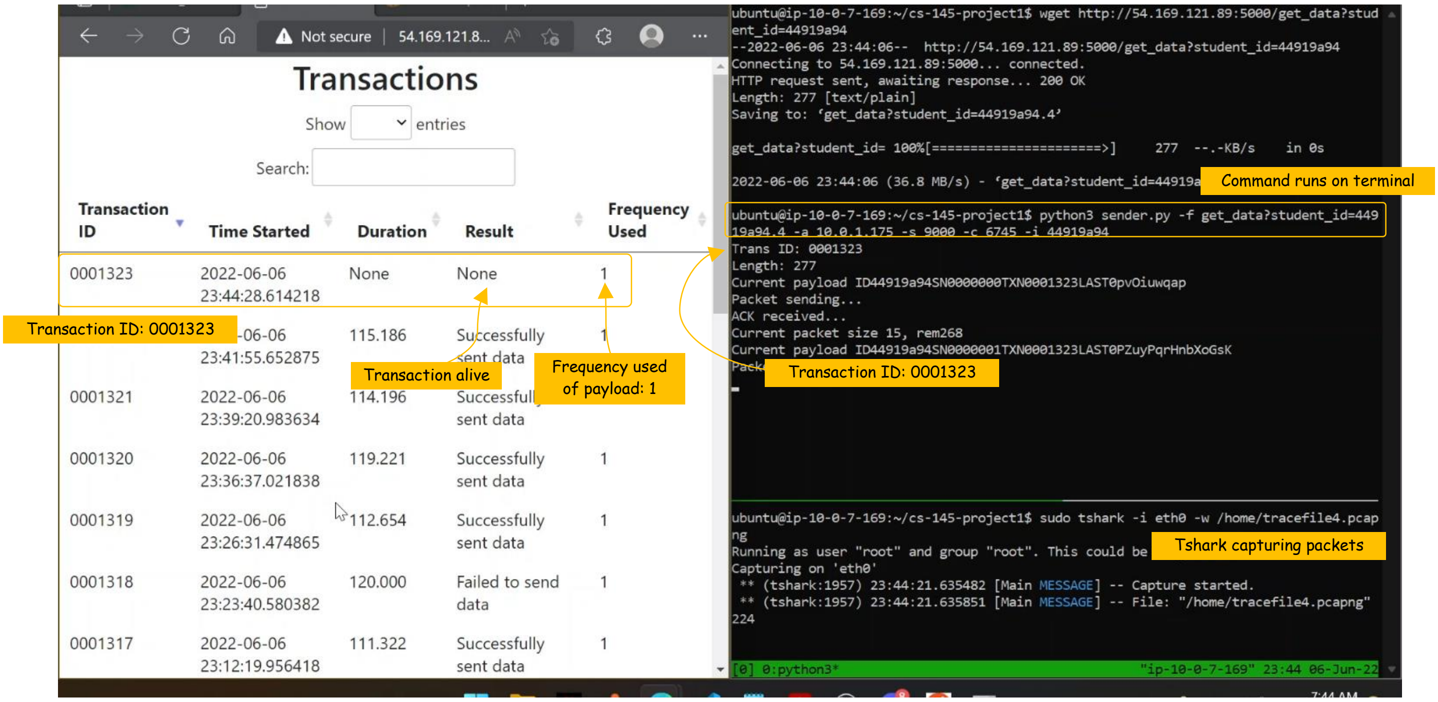
The server also sends its last ACK message for the corresponding packet shown as packet number 683 in the trace file. Thus, it can be shown that the sender implementation is indeed successful in sending data from the client to the server in this transaction as well.

4.5 Transaction 5

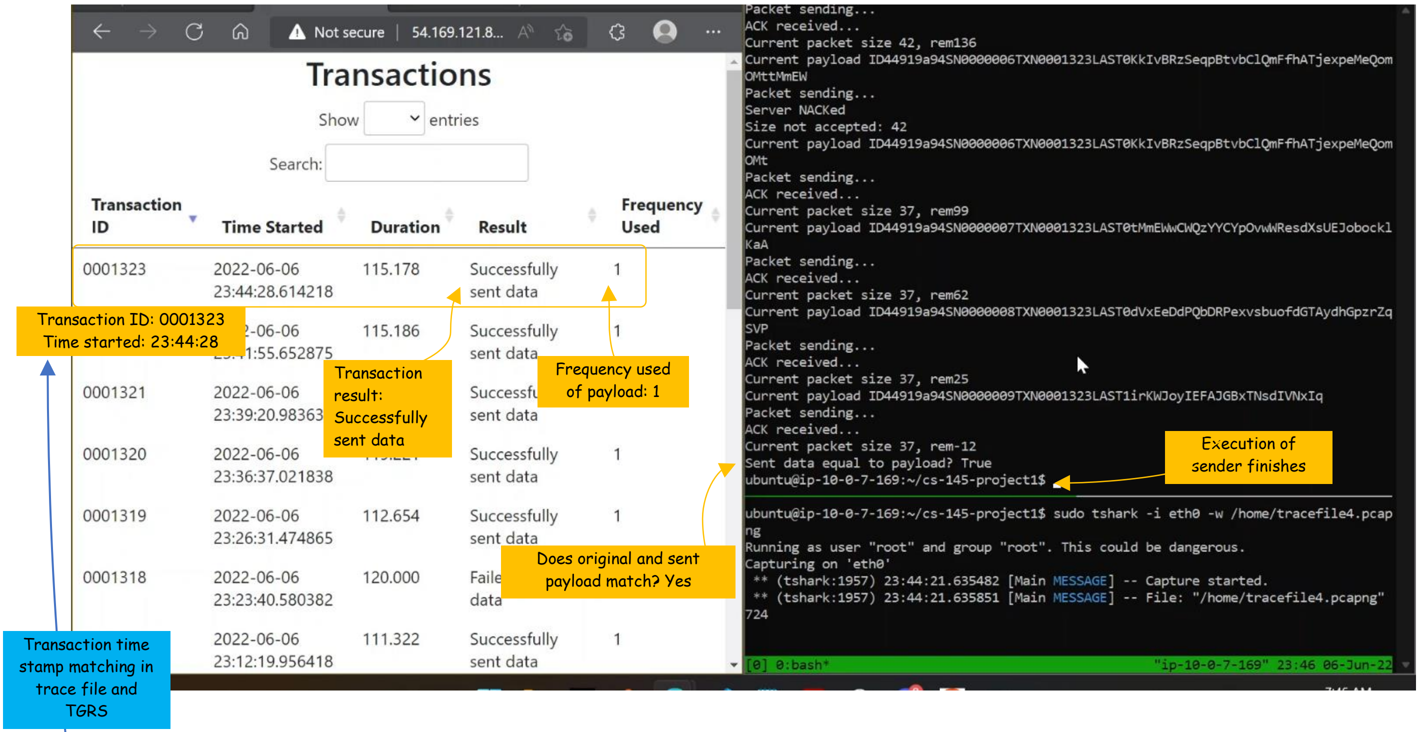
We do the same thing for another transaction and start by downloading a new payload file.



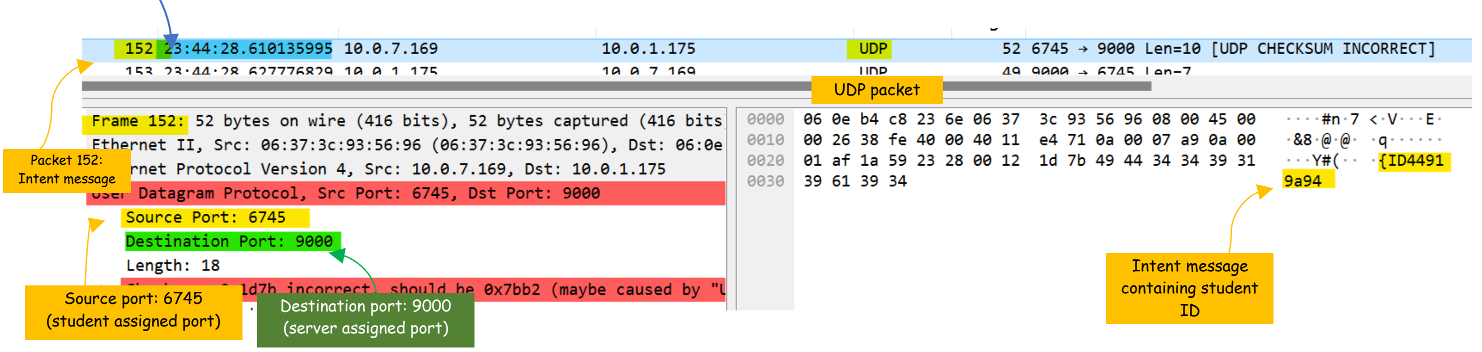
Start tshark and use the new payload filename to execute the sender program via command line. We use the command "`python3 sender.py -f get_data?student_id=44919a94.4 -a 10.0.1.175 -s 9000 -c 6745 -i 44919a94`"

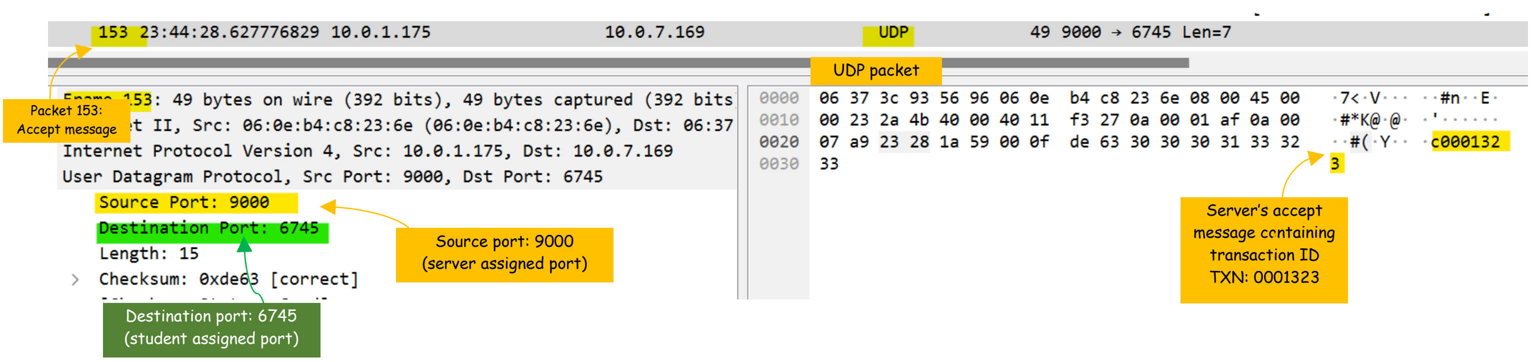


Note that this transaction has a transaction ID of 0001323. After successfully sending the packets, the sender program finishes executing and the result in the TGRS is updated and is shown to have **successfully sent data**.

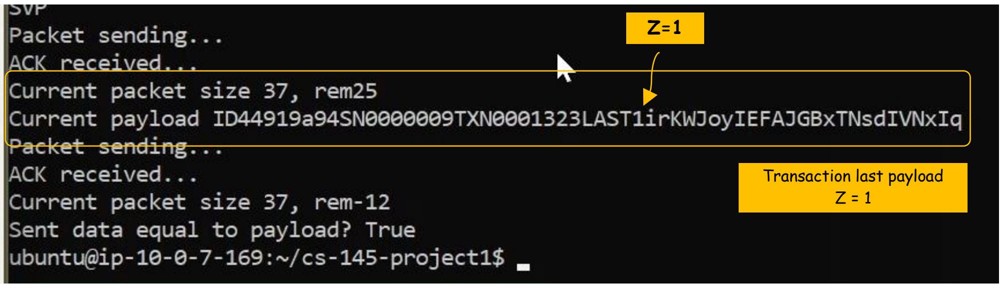


By checking the transaction in the tracefile generated, we can verify that the intent message was indeed sent as packet 152 in the tracefile by filtering out the UDP packets and checking their payload. The server's accept message can also be verified as packet 153 which contains the transaction ID.

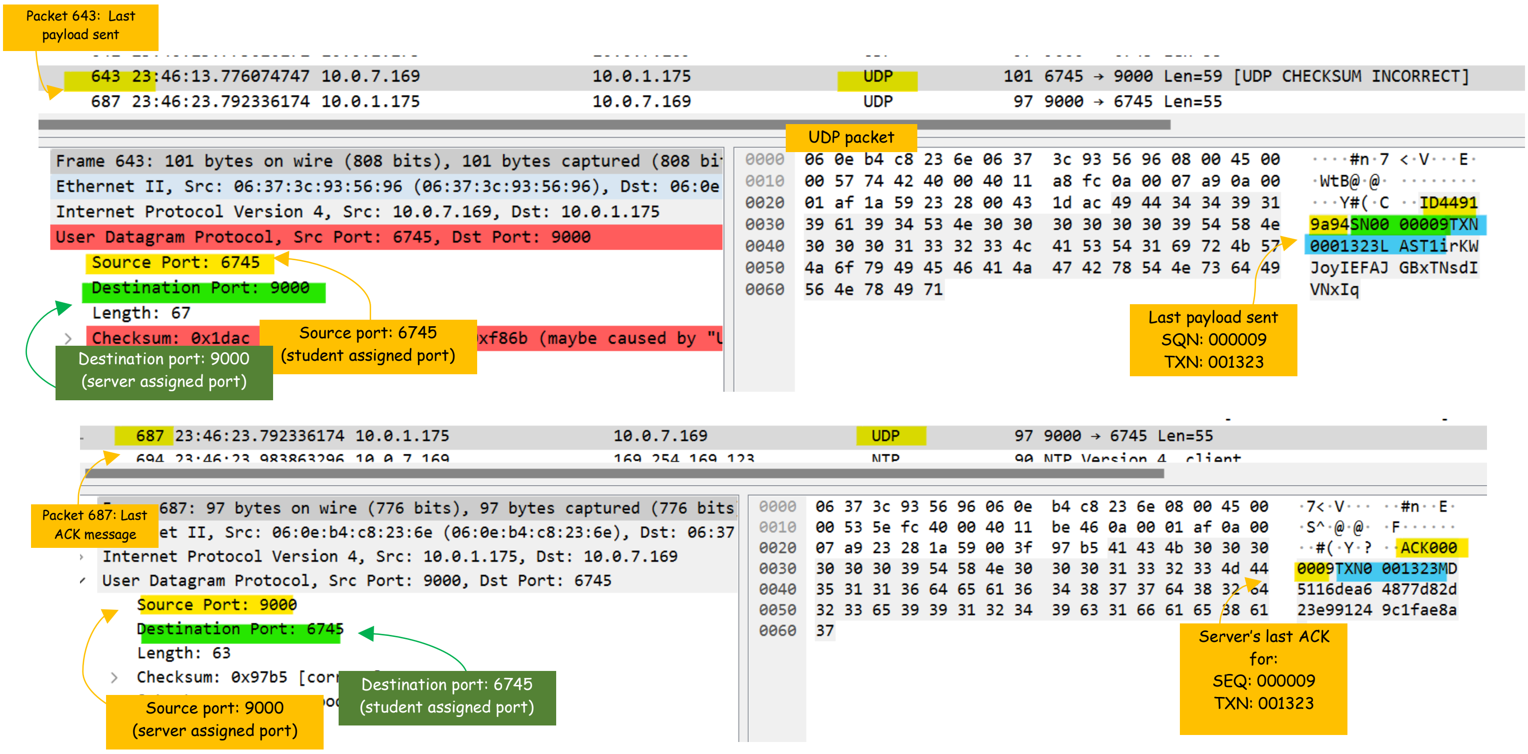




We can also verify that the last packet sent has the following payload:



If we analyze the tracefile, the last packet sent for this transaction from my machine to the server was packet number 643. We can verify the payload of the packet and check that it indeed corresponds to the payload printed by the sender program.



The server also sends its last ACK message for the corresponding packet shown as packet number 687 in the trace file. Thus, it can be shown that the sender implementation is indeed successful in sending data from the client to the server in this transaction as well.

5 Conclusion

Although all testing transactions were successful in sending data, the implementation proved to be inconsistent especially for larger sets of payload (i.e. 4k+). Hence, only level 2 was declared to be implemented.