ספר פרויקט - רשתות תקשורת

מגישים:

אליאן אילוק 214787483

אריאל לבוביץ 326535242

רואי סיבוני 214662439

תכלת שבח 212671358

הבהרות והערות לקוד ולקובץ:

1. בנוגע לתוצאות של ההרצות עם אחוז איבוד שונה בין כל הרצה, נשמים לב כי הזמן והמהירות של קצב שליחת הפקטות נשאר קבוע.
אנחנו מאמינים שזה נובע מהאלגוריתם שליחה מחדש של פקטות שהוגדרו כאבודות, שבעצם לא מחכה כמות זמן מסויימת וישר שולח וכך אין הבדל מהותי בין כל הרצה
2. בתיעוד הקוד תוכלו לשים לב לפונקציות שתוכננו להיבנות לתקשורת מרובת משתמשים, בפועל בפרוייקט זה לא השתמשנו בהם כי התבקשנו לבצע תקשורת עם קליינט יחיד.

Table of contents:

חלק יבש

1- חמש חסרונות של TCP:

א- כחלק מפרוטוקול TCP כאשר פקטה כלשהיא הולכת לאיבוד, יש צורך בלשחזר אותה ולשלוח אותה פעם נוספת, בזמן הביניים בין שמגלים שפקטה אכן אבדה ועד שמשחזרים אותה ושולחים אותה פעם נוספת, כל הפקטות שנמצאות כבר בתוך הרשת, יוצאות מהרשת "והולכות לאיבוד" גם כן.

ב- כאשר פקטה מסוימת הולכת לאיבוד, פרוטוקול TCP יעצור וימנע מפקטות אחרות להמשיך לעבור ברשת עד שנשחזר את הפקטה האבודה ונשלח אותה פעם נוספת ונקבל עליה אישור שהיא הגיעה בהצלחה.

ג- ישנו דיליי כאשר יוצרים את קשר הTCP מכיוון שצריך לבצע לחיצת ידיים משולשת. במידה ואחד הצדדים מעוניין לאבטח את הקשר צריך לבצע לחיצת ידיים פעם נוספת. ניתן להבין כי כל לחיצת ידיים לוקחת זמן ומעכבת את יצירת הקשר והתחלת העברת המידע.

ד- בheader של פרוטוקול TCP ישנם מספר שדות כאשר כל אחד מוגבל לכמות ביטים מסוימת. בנוסף לשדות הרגילים, יש גם שדה(בגודל 40 בתים) שהוא עבור שדה אופציונלי. כל אחד מהשדות הוא קטן מאוד(4-2 בתים לכל אחד) ולכן הגודל הקטן של השדות האלה מגביל את הביצועים של פרוטוקול TCP כאשר עובדים במהירות גבוהה מאוד.

ה- פרוטוקול TCP משתמש ובנוי על מספרי פורטים וIP ואלו דברים שבמהלך החיים יכולים להשתנות, ולכן במידה שאכן אחד מהם משתנה זה יגרום לקשר הקיים להתפרק ולכל המידע שעבר עד כה להיאבד. על מנת להתגבר על זה יש צורך בלחיצת ידיים משולשת נוספת.

2- חמש תפקידים שכל פרוטוקול תעבורה צריך למלא הם

א- הגדרת מזהה חיבור ומזהה נתונים

ב- העברת מידע אמינה עם בקרת זרימה מבוססת חלון-זמן, עושים זאת כך שלכל פקטה שעוברת שמים מזהה כלשהוא(בדרך כלל מספר סידורי) וכך ניתן לעקוב אחר כל הפקטות ולראות אם כולם הגיעו בשלמותם כמו שצריך או שפקטה מסוימת אבדה וצריך להתמודד עם זה.

ג- Congestion control על מנת להגביל את מספר הפקטות שנמצאות בתוך הרשת

ד- ניהול חיבורי תעבורה- חיבור ייחודי בין 2 צדדים, יצירה ופירוק של קשר, שליטה על העברת המידע בין 2 הצדדים, שינוי כתובת הIP בהתאם לשינויים מסוימים.

ה- אבטחת המידע שעובר בין 2 הצדדים

3- לחיצת הידיים של QUIC

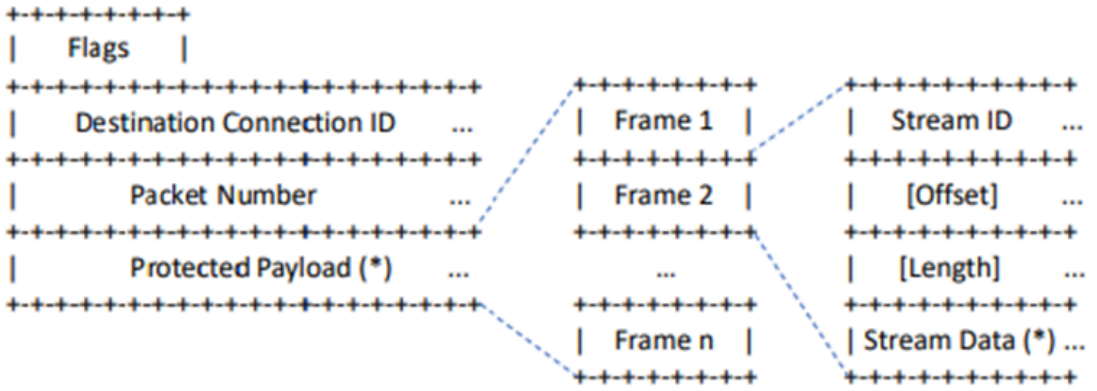
בלחיצת הידיים של פרוטוקול QUIC אנחנו משלבים בין לחיצת ידיים תעבורתית ולחיצת ידיים קריפטוגרפית ביחד, כך אנו יכולים לקבל את כל המידע הדרוש לנו בזמן של RTT אחד בלבד וזה מביא למינימום זמן את זמן פתיחת הקשר המאובטח בין הצדדים. על מנת לקבל את הID של כל אחד מהצדדים, הפרוטוקול שולח פקטה ראשונית כאשר כל צד יאכלס את השדה שלו בפקטה עם הID שהוא מעוניין בו לשליחה וקבלה של פקטות נוספות בעתיד. לאחר קבלת הפקטה הראשונית, השרת יכול(אם הוא רוצה בכך) לבחור לשלוח פקטה נוספת שתכיל טוקן מסוים שהלקוח יצטרך להשתמש בו שוב על מנת להמשיך בתהליך לחיצת הידיים. בנוסף לכך, הודעות לחיצת ידיים של הTLS גם כן נמצאות בתוך הפקטות הראשוניות האלה על מנת להבטיח שהקשר ושליחת הפקטות העתידיות יהיה מאובטח בRTT אחד בלבד.

תהליך לחיצת ידיים זאת משפר את החסרונות שיש לTCP בכך שלעומת TCP שלא יכול להתאושש משינוי פורט או כתובת IP מסוים, QUIC יכול לשרוד את השינויים האלה בעזרת השימוש בID של כל צד, לאחר השינוי הצד שהשתנה יכול לשלוח פקטה עם הכתובת החדשה להמשך הקשר, ועל מנת לאשר את השינוי הצד השני יבצע בדיקה שניתן להמשיך את שליחת הפקטות והמשך הקשר(שולחים מידע רנדומלי לכתובת החדשה ומחכים לתגובה שתכלול את אותו המידע הרנדומלי שנשלח בדיוק). בנוסף לכך, המידע שעבר לא ילך לאיבוד כמו מה שקורה בTCP אלה ממשיכים מאותו מקום בדיוק והמידע נשמר.

4- מבנה החבילה של פרוטוקול QUIC

לפרוטוקול זה יש 2 סוגים של headers, בהתחלה משתמשים בפקטות ארוכות לחיבור הקשר בין הצדדים והן צריכות להכיל כמה שדות שיכילו מידע שקשור ללחיצת הידיים. לאחר שהחיבור עבד, ישנם מספר שדות שאין בה יותר שימוש ולכן ניצור header אחר שיכיל רק את השדות הרלוונטים מפה והלאה(וזאת על מנת לייעל את העברת הנתונים ולחסוך בזיכרון).כל פקטה תכיל מספר ייחודי שתסמל את המספר הסידורי של הפקטה שיסביר את סדר הפקטות שמועברות ויעזור לנו לשים לב במידה ופקטות הולכות לאיבוד ולא מגיעות ליעד, וזה גם יכול להגיד לנו בכל רגע נתון כמה פקטות יש בתוך הרשת. בנוסף, לעומת השדה האופציונלי של הTCP שיכול להכיל עד 40 בתים ולכן להכיל רק עד 3 ACKS, QUIC יכול לתמוך בעד 256 סוגים שונים של ACKS וכך מבנה החבילה של QUIC משפר את TCP.

מבנה החבילה המקוצר של QUIC:



5- כאשר חבילות מגיעות באיחור או לא מגיעות בכלל, פקטה נחשבת בתור פקטה שנאבדה במקרה וack עבור פקטה "מאוחרת" יותר התקבלה בזמן שack עבור הפקטה הזו עדיין לא התקבלה וכאשר threshold מסוים התקבל. על מנת לאתר איבודי פקטות, פרוטוקול QUIC משתמש ב2 שיטות:

א- על ידי מספור של הפקטות(sequence number)- כאשר המספר הסידורי של הפקטה שהתקבלה קטן מהack האחרון שהתקבל, כל הפקטות שמספרם הסידורי הם בין המספר הסידורי של הפקטה האחרונה שהתקבלה לבין הack האחרון שהתקבל נחשבים "אבודים" וצריך לשלוח אותם מחדש.

ב- על ידי זמן השליחה של הפקטות- כאשר פקטה מסוימת מקבלת ack אזי מודדים את הזמן הגעה שלה, הthreshold שלנו הוא הזמן שאנחנו נותנים לפקטה להגיע לפני שאנחנו מכריזים עליה כעל פקטה "אבודה". במידה ומאז שקיבלנו את הפקטה האחרונה, הזמן שעבר הוא גדול יותר מהthreshold שהגדנו אזי אנחנו מכריזים על הפקטה הבאה כעל פקטה "אבודה" ואנו צריכים לשלוח אותה מחדש.

כאשר גילינו שפקטות מסוימות הלכו לאיבוד, המידע מוכנס לפקטות חדשות עם מספר סידורי חדש(ללא קשר לאיבוד פקטות) והן נשלחות מחדש.

6- **בקרת העומס(congestion control) של פרוטוקול QUIC עובדת כך-**
כמו TCP גם בפרוטוקול QUIC יש חלון מסוים שמהווה גבול מסוים של מספר הביטים שהלקוח יכול לשלוח לשרת כל פעם ובכך העברת המידע לא "מציפה" את הרשת ומעבירה את המידע במידתיות ובכך ניתן לאפשר העברת מידע בצורה אופטימלית בין הלקוח לשרת ולווסת את מספר הביטים שנמצאים בתוך הרשת בכל פעם כך שהקשר יפעל בצורה אופטימלית.

TestQuicChat

מחלקה זו מיועדת לבדיקת התקשורת באמצעות QUIC וכוללת מספר בדיקות יחידה לאימות פונקציונליות שונות של שליחה וקבלת חבילות תקשורת.

פונקציות במחלקה:

setUp

הגדרות ראשוניות לפני כל בדיקה. מאתחלת כתובת לקוח לשימוש בבדיקות.

test_send_package

בדיקה זו מאמתת שחבילה אחת נשלחת בהצלחה מהלקוח לשרת. הבדיקה משתמשת במתודה send_package מהמודול QuicFunc. היא מוודאת שהפונקציה sendto של מופע הסוקט נקראה ושהכתובת שאליה נשלחה החבילה מתאימה לכתובת שהוגדרה בהגדרות המבחן.

test_send_packages_from_file

בדיקה זו בודקת את יכולת המערכת לשלוח רצף של חבילות נתונים מקובץ. הבדיקה מדמה קריאה מקובץ עם נתונים מסוימים ובודקת שהחבילות נשלחות כראוי דרך הפונקציה
send_packages_from_file. היא משתמשת במודול MagicMock לדמיית פעולת הקובץ.

test_receive_package

בדיקה זו בודקת את תהליך קבלת חבילה ועיבודה. היא משתמשת במודול patch לדמיית קבלת חבילה מהרשת ולאחר מכן בודקת שהתוכן של החבילה שנקלטה תואם למה שציפינו לקבל.

test_resend_lost_packages

בדיקה זו מאמתת שחבילות שאבדו במהלך השידור נשלחות מחדש. הבדיקה מגדירה חבילה כאילו היא אבדה ולאחר מכן בודקת שפונקציית השליחה מחדש resend_lost_packages פועלת כשורה.

test_incorrect_package_format

בדיקה זו נועדה לאתר ולהתמודד עם חבילות בפורמט שגוי. היא בודקת שהמערכת מעלה שגיאה במקרה של נתונים לא תקינים, מה שמדגים את יכולת המערכת לזהות ולנהל כשלים בפורמט של הנתונים.

test_connection_timeout

בדיקה זו בודקת כיצד המערכת מגיבה לטיימאאוט של החיבור. היא משתמשת ב-patch לדמיית טיים- אאוט על פעולת קבלת נתונים מהסוקט, ומוודאת שהמערכת מזהה ומטפלת בזמן המתנה החורג.

test_full_message_cycle

בדיקה זו מבצעת סימולציה של שליחה, קבלה ואישור של חבילה, בדוקה שהמעגל השלם של תקשורת עובד כשורה. היא משלבת שליחה, קבלה ואישור כדי לבדוק את יכולת המערכת לטפל בתהליכים רבים במקביל.

test_edge_case_package_handling

בדיקה זו מתמקדת במקרי קצה בהם נשלחות חבילות עם נתונים ריקים או חבילה גדולה במיוחד. היא בודקת את התנהגות המערכת במקרים אלו לוודא שהמערכת יכולה לטפל גם בנתונים לא סטנדרטיים.

test_high_volume_package_handling

בדיקה זו נועדה לבדוק את עמידות המערכת בפני נפח גבוה של תקשורת במהלך זמן קצר. היא דומה לבדיקת עומס, שבה המערכת צריכה להתמודד עם כמות גדולה של חבילות מהר מאוד.

שימוש במודולים

- `unittest`: מודול ליצירת מבחני יחידה.
- `MagicMock` ו-`patch` מהמודול `unittest.mock`: למיתוג ובדיקת קוד שמבוסס על פונקציות או מחלקות שמבצעות גישה למשאבים חיצוניים.
- `socket`: מודול לניהול תקשורת רשת.
- `QuicFunc` ו-`QuicPackage`: מודולים מותאמים אישית שמכילים את הפונקציונליות הספציפית להעברת וקליטת חבילות באמצעות QUIC, את המודלים האלה אנחנו בנינו.

Server.py

clarification:
program flow- to know and understand the flow of the functions through the output stream, at run time.

STAT
stats for the file transmission, string parsing and printing to the output stream

```python
def stat(start_time,end_time,filename):
    global total_time,total_send,total_speed
    elapsed_time = (end_time - start_time) * 1000  # Convert to milliseconds
    file_size = os.path.getsize(filename)
    speed = file_size / (elapsed_time / 1000)  # Convert elapsed time back to seconds for speed calculation
    total_time += elapsed_time
    total_send += 1
    total_speed += speed
    print("_____STATISTICS_____")
    print("_____FOR THE CURRENT FILE_____")
    print(f"Time taken to receive file: {elapsed_time:.2f} ms")
    print(f"Speed of file transfer: {speed:.2f} bytes/second")
    print("_____AVERAGE_____")
    print(f"average time :{total_time / total_send} ms")
    print(f"average speed :{total_speed / total_send} bytes/second")
```

The globals that are declared at the start are set as default as zero, used in stats to remember the past runs.

```python
total_time=0 #to see the avg after sending couple of files
total_send=0
total_speed=0
```

Handle_client

```
"""
    handles two options for the client,
    first option is to receiver a text message, usually a small one(about couple of kbs)
    Second option is to send a text file, bigger than the text, up to 10 mb's as required in the assigment;
    we parse the input to get the name of the file, and then we get the rest of the file in recv_file

"""
1 usage
def handle_client(client_address, name):  # Takes client data and address as argument.
    """Handles a single client connection."""
    try:
        while True:
            # print("while")    #for debugging
            data, _ = server_socket.recvfrom(BUFSIZ) #get the starting packet from the client
            new_package = QuicFunc.recreate_package(data) #parse the string to packet so it will be easier to work with.
            msg = new_package.payload
```

“ Text “ option

```
if msg[:4] == "TEXT": #if the pefix is TEXT then this is simple text
    print("enterd text")
    broadcast_text(new_package, name + ": ")
    print("sending done")
```

“ File “ option

```
elif msg[:4] == "FILE": #if the prefix is File then we are receving multiple packets.
    print("enterd file: " + msg[4:])
    receivedname = msg[4:]
    filename = str(Path.cwd()) + r'//(2)' + receivedname
    with open(filename,"w") as file:
        recv_file(file,filename) #recv all the packets and return acks.
        print("done file") #just to know what part we are in the code, if we done a file also helps with debug
```

Recv_file

```
"""
    Called by handle_client function
    this func uses QuicFunc.recv_pacakge_list_from file
    and then redirect the list to write to file, which recreated the file that had been sent from the user (client)
"""

1 usage
def recv_file(file_towrite, filename): # gets file_towrite and the name of the file
    start_time = time.time() #the start time
    package_list = QuicFunc.recv_package_list_from_file(server_socket)  # gets all the packets from the user and  \
    # return array of all the packets

    write_to_file(package_list, file_towrite) #creates a replica of what we got

    end_time = time.time() # end time
    stat(start_time, end_time, filename) #for vars used for stats
    print("exit file") #used for debug and to understand program flow
```

broadcast text

shares msgs, with the gui to all clients.

```
"""
    broadcast the text msgs to the client (using our gui)
"""
2 usages
def broadcast_text(text_package: QuicPackage, prefix=""):  # prefix is for name identificatio
    """Broadcasts a message to all the clients."""
    print(text_package.payload)
    text_package.payload = text_package.payload[:4] + prefix + text_package.payload[4:]
    for addr in client_addresses:
        print(client_address)
        QuicFunc.send_package(text_package, server_socket, addr)
    print("done broadcast")
```

broadcast_file
to all the users, throw a middle person (the server)

```
def broadcast_file(msg, prefix=""):
    path, s = os.path.split(msg)
    s = s[3:]
    for addr in client_addresses:
        server_socket.sendto(s, addr)
        file1 = open(msg, 'rb')
        slice = file1.read(128)
        while slice:
            server_socket.sendto(slice, addr)
            slice = file1.read(128)
```

new connection

```
"""
    handles a new connection a broadcasts his name,
    it's like a new user to the system the client assigns his name
    and after this, he can send texts and everyone will know it's him
"""
1 usage
def new_connection(data, client_address):
    print("thread")
    client_addresses.add(client_address)
    new_package = QuicFunc.recreate_package(data)
    name = new_package.payload[4:]
    welcome = f'&TEXTWelcome %s! If you ever want to quit, you can just stop typing. The Connection ID is {CONNECTION_ID}' % name
    welcome_package = QuicPackage( pos: 0, welcome, CONNECTION_ID)
    QuicFunc.send_package(welcome_package, server_socket, client_address)
    msg = "TEXT%s has joined the chat!" % name
    new_package = QuicPackage( pos: 0, msg, CONNECTION_ID)  # start the connection
    print(welcome)
    broadcast_text(new_package)
    client_thread = Thread(target=handle_client, args=(client_address, name))
    client_thread.start()
```

handshake

#being used by the wait_for_connection function

```
"""
    checks for conenction, and sends back the connection id in which they will use.
"""
1 usage
def handshake(new_pack,address):
    if new_pack.payload == "hello":
        CONNECTION_ID = new_pack.connection_id
        print("The connection ID is: " + CONNECTION_ID)
        QuicFunc.send_package(new_pack, server_socket, address)
        return True
    return False
```

wait for connection

```
"""
    waiting for the first connection and assure that we got the first packet
    using handshake function to verify we got a connection.
"""
1 usage
def wait_for_connection():
    global CONNECTION_ID
    start = time.time()
    timeout = 1  # Timeout for retransmission
    while True:
        try:
            server_socket.settimeout(timeout)
            pack, address = server_socket.recvfrom(BUFSIZ)
            new_pack = QuicFunc.recreate_package(pack)

            if handshake(new_pack, address): #if we found the user we can stop waiting for him
                break

        except socket.timeout:
            if time.time() - start > timeout:
                print("Didn't receive pack in time, waiting again...")
                start = time.time()  # Reset the start time for the next timeout

        except Exception as e:
            print(f"An error occurred: {e}")
```

definitions
for the connection to the server:

```
HOST = '127.0.0.1' #ip
PORT = 33002 #port
BUFSIZ = 1024 #buffsize for the socket
ADDR = (HOST, PORT)
CONNECTION_ID = 0 #the connection id for the server is always the same
```

the socket definition

```
#create a socket using the UDP protocol.
server_socket = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
server_socket.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR,  _value: 1)
server_socket.bind(ADDR)
```

main

```
if __name__ == "__main__":
    print("Waiting for connection...")
    flag_file = False
    # while True: #don't know if it's good or not
    time.sleep(5)
    wait_for_connection()
    server_socket.settimeout(None)
    data, client_address = server_socket.recvfrom(BUFSIZ)
    if client_address not in client_addresses:
        print("new connection, list: " + str(client_addresses))
        new_connection(data, client_address)
    else:
        if not flag_file:
            print("why?")
            print(threading.current_thread())
        else:
            print("main")
            print(file1)
```

Client.py

definitions

```python
#global vairables being used for the resend algorithm
packages_list = {}
no_acks = []
ack_list = []
seq_threshold = 3
time_threshold = 0.002
```

valid mode#hellper for resending algo

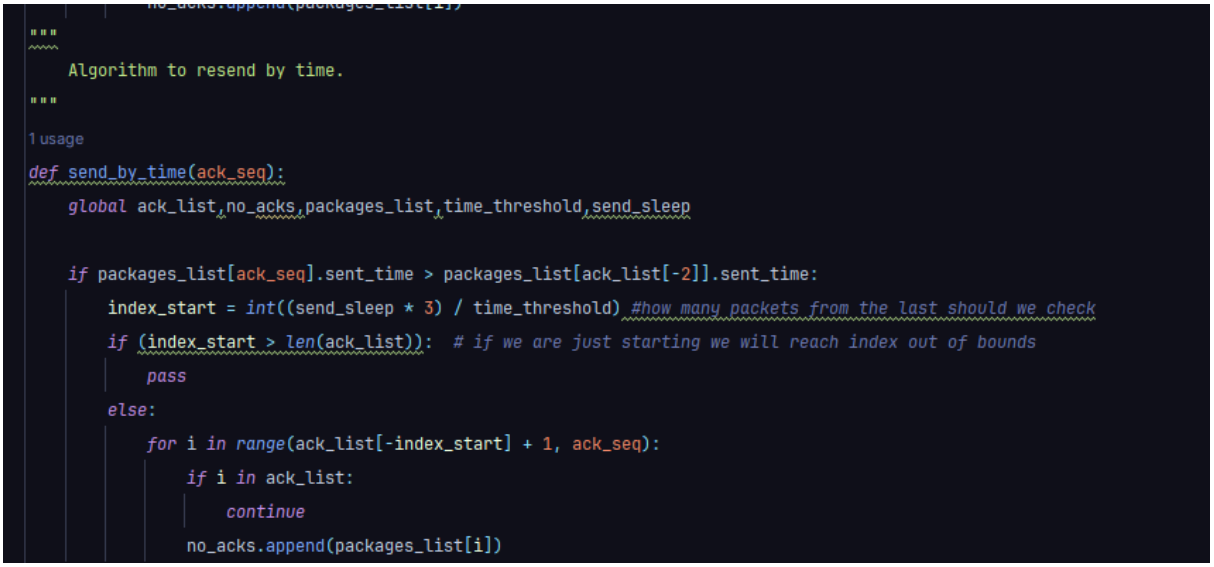
```python
    determines if we in need to resend, considering the mode.
"""


1 usage
def valid_mode(mode):
    global no_acks
    global time_threshold

    match mode:
        case 1:  # time
            return time.time() - no_acks[0].sent_time > time_threshold

        case 2:  #seq
            return list(packages_list.values())[-1].seq - no_acks[0].seq > seq_threshold

        case 3:  #both
            return list(packages_list.values())[-1].seq - no_acks[0].seq > seq_threshold and time.time() - no_acks[0].sent_time > time_threshold
```

send by seq algo #helper

```python
"""
    Algorithm to send by seq number.
"""
1 usage
def send_by_seq(ack_seq):
```

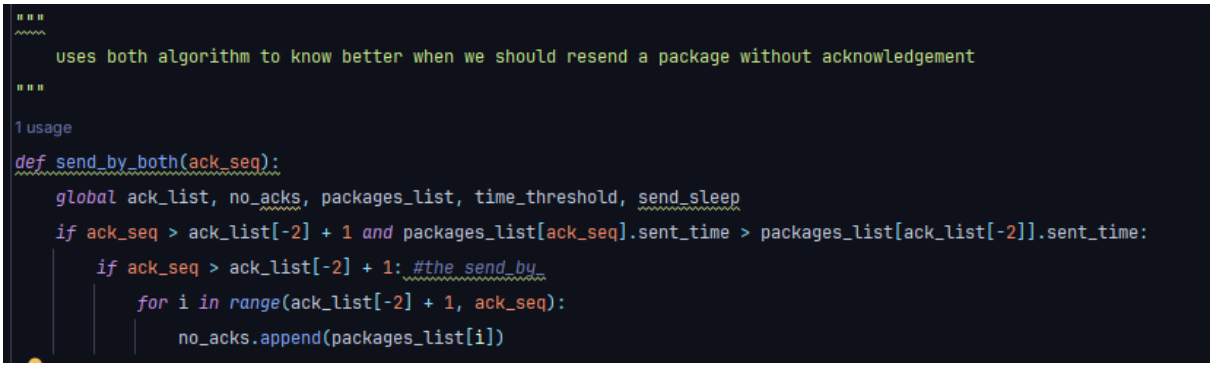
send by time

send by time, uses the threshold and send_sleep to give a rough estimate when a packet should have come already if it didn't we need to resend it.



```
"""
    Algorithm to resend by time.
"""
1 usage
def send_by_time(ack_seq):
    global ack_list,no_acks,packages_list,time_threshold,send_sleep

    if packages_list[ack_seq].sent_time > packages_list[ack_list[-2]].sent_time:
        index_start = int((send_sleep * 3) / time_threshold) #how many packets from the last should we check
        if (index_start > len(ack_list)):  # if we are just starting we will reach index out of bounds
            pass
        else:
            for i in range(ack_list[-index_start] + 1, ack_seq):
                if i in ack_list:
                    continue
                no_acks.append(packages_list[i])
```

send by both, applying both algorithms to be more accurate.



```
"""
    uses both algorithm to know better when we should resend a package without acknowledgement
"""
1 usage
def send_by_both(ack_seq):
    global ack_list, no_acks, packages_list, time_threshold, send_sleep
    if ack_seq > ack_list[-2] + 1 and packages_list[ack_seq].sent_time > packages_list[ack_list[-2]].sent_time:
        if ack_seq > ack_list[-2] + 1: #the send_by_
            for i in range(ack_list[-2] + 1, ack_seq):
                no_acks.append(packages_list[i])
```

Append noack

inserting a no acked packets that are potentially lost, if we later on got acknowledge tha they have reached the destination we will remove them. but for now we see them as lost. (uses send_by_time, send_by_seq, send_by_both functions)

```
"""
    3 modes to choose the mode in which we are going to use
    The mode is given by the user
    the mode we have will have a different algorithm to determine a packet as lost or not.
"""
1 usage
def append_noack(mode, ack_seq):
    global no_acks
    global time_threshold
    global send_sleep

    match mode:
        case 1:  # time
            send_by_time(ack_seq)
        case 2:  #seq
            send_by_seq(ack_seq)
        case 3:  #both
            send_by_both(ack_seq)
```

resending_algo

if the no_ack list is not empty then we want to empty it using the right mode
we are using func valid mode to determine it.
removes the packet it just rescinded from the current no_ack list

```
"""
    resending using the mode we got from the user
    also uses resend_lost_packages (which is in QuicFunc.py)
"""


1 usage
def resending_algo(package_list, no_acks, client_sockt, ADDR, mode):
    if len(packages_list) > 0 and len(no_acks) > 0:
        if valid_mode(mode):
            print("resend")
            resend_lost_packages(packages_list, no_acks, client_socket, SERVER_ADDR)
            no_acks.remove(no_acks[0])
```

acked

```
"""
    check if the packet is an ACK
"""
1 usage
def acked(data):
    return data[:3] == "ACK".encode('utf-8')
```

almost_exec

```
1 usage
def almost_exec(ack_seq):  #almost someone who got acked sent again
    for index, packet in enumerate(no_acks):  # we check if it's in the acks and remove it
        if not compare(packages_list[ack_seq], packet):
            no_acks.remove(packet)
```

receive function

using helper functions-
acked, almost_exec, resending_algo,append_noAck,valid_mode

```
"""
    Functions that manages the sent packets and resends if needed
    using functions:
        acked - checks if the packet that we got is a ACK packet
        almost_exec - checks if the packet is in the no_ack list if so removes it
        resending_algo - depending on the mode it chooses the algo to use
        append_noAck - depending on the mode, main reason to colerate with the resending_algo
        valid_mode - depending on the mode does it's check
"""
1 usage
def receive():
    """Handles receiving of messages."""
    global Running  #needed for hand of connection curretly doesn't work #tchelet
    global packages_list  #dictionary contains all the packets we sent so far
    global no_acks  # is list for the packets we need to resend sometimes we removre elements from it if we got a ack for them :)
    global flag_send  #don't know #tchelet
    global ack_list  #list of all seq's we got so far
```

mid part

we are checking if the ack that we got are in the no_ack list if so it removes it from the list, so we won't resend the acked packet.
then we check if we need to append into no ack

```
while Running:  #when we need to keep running the thread we switch this off

    try:

        resending_algo(packages_list, no_acks, client_socket, SERVER_ADDR, mode)  #checks there's packets to resend and resends
        data, n = client_socket.recvfrom(BUFSIZ)

        if acked(data):  #if we got ack we check if we lost in the way someone else
            print(data.decode("utf-8"))
            ack_seq = int(data[5:])

            try:
                packages_list[ack_seq].recvack()
                ack_list.append(ack_seq)
                almost_exec(ack_seq)
                append_noack(mode, ack_seq)

            except(KeyError):
                print("KeyError: " + str(data[5:]))
                ack_list.append(int(data[5:]))
```

to show the msg on the gui.

```
            else:
                recv_package = recreate_package(data)
                msg = recv_package.payload[4:]
                msg_list.insert(END, *elements: msg)  # Insert the received message into the message list
        except OSError as e:  # Possibly server has left the chat.
            pass
```

send

```
"""
    send basic msg between the client to the server.
"""
3 usages
def send(event=None):
    """Handles sending of messages."""
    msg = "TEXT" + my_msg.get()
    my_msg.set("")  # Clears input field.
    new_package = QuicPackage( pos: 0, str(msg), CONNECTION_ID)
    QuicFunc.send_package(new_package, client_socket, SERVER_ADDR)

    #client_socket.sendto(bytes("TEXT" + msg, "utf-8"), SERVER_ADDR)
    print(SERVER_ADDR)
    if msg == "{quit}":
        client_socket.close()
        root.quit()
```

send_attach #for files
we get the path to the file from the filedialog, by the user

```
"""
    send attachment, it lets you select in the gui the file in the father directory as a default
    after it, it usess the func send_packages_from_file
    which create small packages and sends to the server
"""
1 usage
def sendattach():
    """Handles sending of files (attachments)."""
    global ack_list
    global no_acks

    filename = filedialog.askopenfilename(initialdir="../", title="Select A File", # ../ the father of this directory
                                          filetypes=(("jpeg files", "*.txt"), #the file type we want to transmit
                                                     ("all files", "*.*")))
    if (filename == ""):  #if we got nothing then we can't send natting
        client_socket.close()
        root.quit()
        return
```

we parse the input and then starting, to send the file using helper functions.

```
    #parsing the input
    s = filename.split("/")

    with open(filename, "rb") as file1: #opening the file and transmiting to the server
        entry = "FILE" + str(s[-1])
        entry_package = QuicPackage( pos: 0, entry, CONNECTION_ID)
        ack_list.append(entry_package.seq)
        QuicFunc.send_package(entry_package, client_socket, SERVER_ADDR)
        QuicFunc.send_packages_from_file(file1, client_socket, SERVER_ADDR, packages_list, no_acks, CONNECTION_ID)
```

gui related functions:

```
def on_entry_click(event):
    """function that gets called whenever entry1 is clicked"""
    global firstclick
    if firstclick:  # if this is the first time they clicked it
        firstclick = False
        entry_field.delete( first: 0,  last: "end")  # delete all the text in the entry
```

when we close the connetion and the gui

```
2 usages
def on_closing(event=None):
    """This function is to be called when the window is closed."""
    my_msg.set("{quit}")
    send()
```

```
def sendquit():
    global Running
    on_closing()
    root.destroy()
    Running = False
```

```
2 usages
def send_first_ack():
    print("Send first")
    pack = QuicPackage( pos: 0,  payload: "hello", CONNECTION_ID)
    QuicFunc.send_package(pack, client_socket, SERVER_ADDR)
    wait_for_ack()
```

```
1 usage
def wait_for_ack():
    print("Enter ack")
    start = time.time()
    timeout = 1  # Timeout for retransmission
    while True:
        try:
            client_socket.settimeout(timeout)
            data, n = client_socket.recvfrom(BUFSIZ)
            new_pack = QuicFunc.recreate_package(data)

            if new_pack.payload == "hello":
                print("Connection is good")
                return

        except socket.timeout:
            if time.time() - start > timeout:
                print("Didn't receive ack in time, resending...")
                send_first_ack()
                return

        except Exception as e:
            print(f"An error occurred: {e}")
```

The gui is created in this code, we created here the chat window and the buttons. there is also the creation of the socket and the input for connection ID and mode of packet loss recovery algorithm(time, sequence number or both).

```
root = Tk()
root.title("ChatIO")
root.geometry('500x500')

messages_frame = Frame(root)
my_msg = StringVar()  # For the messages to be sent.
my_msg.set("Type your messages here.")
yscrollbar = Scrollbar(messages_frame)  # To navigate through past messages.
xscrollbar = Scrollbar(messages_frame, orient=HORIZONTAL)  # To navigate through long messages.
# Following will contain the messages.
msg_list = Listbox(messages_frame, height=20, width=50, xscrollcommand=xscrollbar.set, yscrollcommand=yscrollbar.set)
yscrollbar.pack(side=RIGHT, fill=Y)
xscrollbar.pack(side=BOTTOM, fill=X)
msg_list.pack(side=LEFT, fill=BOTH)
messages_frame.pack()
yscrollbar.config(command=msg_list.yview)
xscrollbar.config(command=msg_list.xview)

entry_field = Entry(root, width=42, textvariable=my_msg)
entry_field.bind('<FocusIn>', on_entry_click)
entry_field.bind("<Return>", send)
entry_field.place(x=15, y=344)
send_button = Button(root, text="Send", command=send)
send_button.place(x=280, y=340)
send_attach = Button(root, text="Send Attachment", command=sendattach)
send_attach.place(x=50, y=375)
send_button = Button(root, text="Quit Chat", command=sendquit)
send_button.place(x=175, y=375)
root.protocol( name: "WM_DELETE_WINDOW", on_closing)

#----Socket code----
HOST = "127.0.0.1"
PORT = 33002
BUFSIZ = 1024
SERVER_ADDR = (HOST, PORT)
CONNECTION_ID=int(input("Enter the connection id"))
mode = int(input("Enter the mode of packet loss between 1-3\n"))
while mode not in [1,2,3]:
    mode=int(input("bro be trolling 1-3"))


client_socket = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
send_first_ack()

receive_thread = Thread(target=receive)
receive_thread.start()
root.mainloop()
```

During the project, we thought it would be cool to add a GUI that opens once the connection is established. Through this GUI, we can send necessary information, such as an opening message to set the user's name. The interface would also include buttons for sending messages and attachments. Every time an action is performed in the GUI, it triggers a corresponding function in the communication protocol.

QuicPackage.py*

recreate && send packets

```python
# function for recreating packets, we get encoded packet and we decode it, each variable acording to its kind
11 usages
def recreate_package(str_package: bytes):
    list_package = str_package.decode("utf-8").split( sep: "&",  maxsplit: 4)  # the packet encoded using & between each field
    new_package = QuicPackage(int(list_package[1]), list_package[3], list_package[4])  # create the new packet
    new_package.recreate_from_str(float(list_package[2]),
                                  list_package[0])  # setting the time anf sequence number fot the packet
    return new_package  # return the new packet


# function for sending the packet using the "sendto" function from the socket library
14 usages
def send_package(package: QuicPackage, sock: socket, ADDR):  # event is passed by binders.
    """Handles sending of messages."""
    sock.sendto(package.encode_package(), ADDR)
```

send packaged from file

function to get information from file, store it in packets and send the packets

```python
# function to read information from the file, store it in packet objects and sending the packets
1 usage
def send_packages_from_file(file1, sock: socket, ADDR, package_list, no_ack, connect):
    """Handles sending of files (attachments)."""
    global send_sleep
    pos = 0
    print("Sending file...")

    while True:  # while we can still read from the file
        slice = file1.read(268)  # read 268 bytes from the file
        # print("hello\n",slice)
        if not slice:  # if we are done reading from the file
            time.sleep(0.5)  # wait for 0.5 seconds
            # new_package = QuicPackage(pos, "DONE",connect)
            # send_package(new_package, sock, ADDR)
            send_last_ack(connect, sock, ADDR)  # send the last packet and wait for ack
            return package_list  # return all the packets we sent from the file

        time.sleep(send_sleep)  # wait
        new_package = QuicPackage(pos, slice, connect)  # create the new packet
        package_list[new_package.seq] = new_package  # add the new packet to the list
        send_package(new_package, sock, ADDR)  # send the packet
        pos += 1  # increase the position of the packets by one
```

send last ack

intended to send the last packet and wait for acknoledgment
to verify that we ended the file sending stream

```python
# function to send the last packet and wait for response from the server that we it was received successfully
2 usages
def send_last_ack(con, client_socket, SERVER_ADDR):
    print("Send last")
    pack = QuicPackage( pos: 0,  payload: "DONE", con)  # create the last packet
    send_package(pack, client_socket, SERVER_ADDR)  # send the last packet
    wait_for_ack(con, client_socket, SERVER_ADDR)  # wait for the server to receive it, send again if it didn't


# function to wait for the server to receive the last packet, and send again if it didn't
2 usages
def wait_for_ack(con, client_socket, SERVER_ADDR):
    print("Enter ack")
    start = time.time()
    timeout = 1  # Timeout for retransmission
    while True:  # while the server don't get the packet
        try:
            client_socket.settimeout(timeout)  # wait
            data, n = client_socket.recvfrom(1024)  # receive the acknowledged packet from the server
            new_pack = recreate_package(data)  # decoded the packet

            if new_pack.payload == "DONE":  # if the packet we received is the acknowledgment packet from the server
                print("sent last packet")
                return  # quit the function

        except socket.timeout:
            if time.time() - start > timeout:  # if we didn't receive the acknowledgment packet from the server in time
                print("Didn't receive last ack in time, resending...")
                send_last_ack(con, client_socket, SERVER_ADDR)  # send again the last packet
                return
```

wait for last ack

server function wo wait to receive the last packet and to send acknowledgement about receiving it

```python
# function for the server to receive the last ack and send an acknowledgment packet back to the client
1 usage
def wait_for_last_ack(server_socket, new_package):
    start = time.time()
    timeout = 1  # Timeout for retransmission
    while True:  # while we didn't get the last packet
        try:
            server_socket.settimeout(timeout)  # wait
            pack, address = server_socket.recvfrom(1024)  # receive the last packet
            new_pack = recreate_package(pack)  # decode the packet

            if new_pack.payload == "DONE":  # if the packet received is the last one, send acknowledgment packet
                # print("The connection ID is: " + CONNECTION_ID)
                send_package(new_pack, server_socket, address)  # send the acknowledgment packet
                return

        except socket.timeout:
            if time.time() - start > timeout:  # if we didn't receive the last packet from the server in time, wait
                print("Didn't receive last pack in time, waiting again...")
                start = time.time()  # reset the start time for the next timeout

        except Exception as e:
            print(f"An error occurred: {e}")


```

recv packaged list from file && compare (simple compare)

functions to receive packets from the file sending by the client and to compare packets by their position

```python
# function to receive the packets from the client
1 usage
def recv_package_list_from_file(sock: socket):
    package_list = []  # initialize a list of packets
    while True:  # while we get packets
        package, addr = sock.recvfrom(1024)  # receive the packets
        if not package:  # if the packet we received is None, there are no longer packets to receive
            print("done recv")
            return package_list  # return the list of packets
        new_package = recreate_package(package)  # decode the received packet
        if new_package.payload == "DONE":  # if its the last one
            # print("done recv")
            wait_for_last_ack(sock, new_package)  # wait to receive it and send ack
            return package_list
        # time.sleep(0.00002)
        print("ack for ", new_package.getpos())  # send ack for receiving packets
        new_package.send_ack(sock, addr)  # send ack
        package_list.append(new_package)  # add the new packet to the list


# function to compare packets by position
2 usages
def compare(x, y):
    return x.getpos() - y.getpos()# return True if the x packet is bigger that the y packet by its position

```

remove duplicates && write to file
functions to remove duplicated packets
so we won't write duplicated to the file

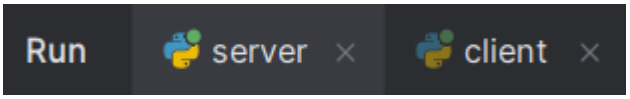
```python
# function to remove duplicates packets, we know its duplicate by position
1 usage
def remove_duplicates(list):
    seen_x = set()
    unique_packets = []

    for pac in list:
        if pac.getpos() not in seen_x:
            unique_packets.append(pac)
            seen_x.add(pac.getpos())

    return unique_packets


# function to write the packets received from the file sent by the client into a new file
1 usage
def write_to_file(package_list: [], file1):
    unique_sorted_package_list = remove_duplicates(package_list)# remove duplicated packets
    package_list = sorted(unique_sorted_package_list, key=cmp_to_key(compare))# sort the packets by position

    f = open("packetPos.txt", "w")# open the packetPos file to write their the packets position
    for payload in package_list:
        f.write(str(payload.getpos()) + "\n")  #print packet pos
        # f.write("\n")
        file1.write(payload.payload)  #print the packet itself
    f.close()

```

resend lost packages
function to resend lost packets
called by the client

```python
# function to resend lost packets
1 usage
def resend_lost_packages(package_list, no_ack, sock, ADDR):
    print("resend lost package")
    pack = no_ack[0]# send the first packet in the no_acks list, its the first packet that need to resend
    print("I lost this :", pack.seq, "and this is the pos somehow", pack.getpos())
    pack.update_for_resend()# update the packet for resend
    send_package(pack, sock, ADDR)# send the packet again
    package_list[pack.seq] = pack# add the packet to the list of sending packets

```

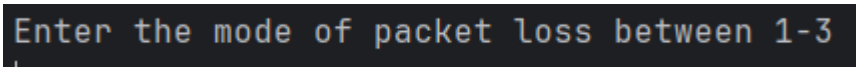
User Manual for GUI

As you can see, in our project we also created a GUI for texting and sending files from client to the server. The client side can send any text file in any size(we chose the second option for the implementation of the QUIC protocol, so the client can send also big files that can get to 10MB and even more).
In this page we will show you how to use the GUI properly and how to send texts and files from the client to the server:
First step: run the server and the client

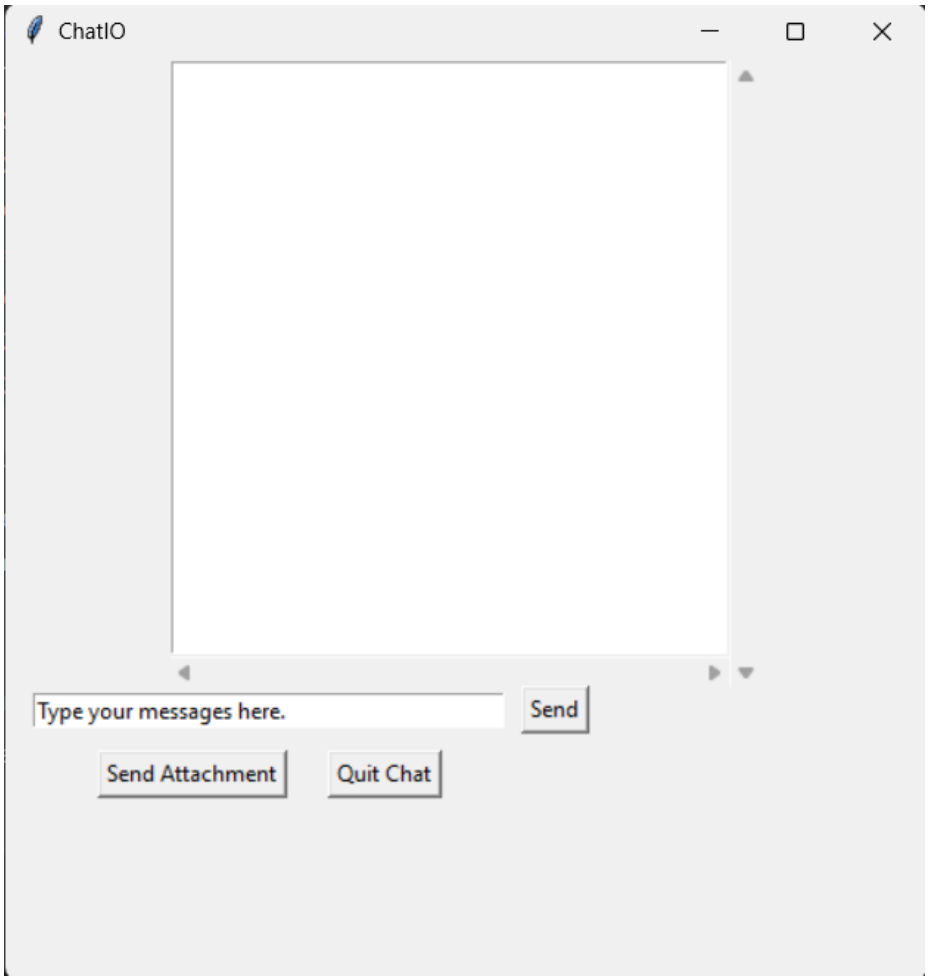


Second step: in the client side, type the connection ID for the connection between the server and the client. The connection ID is is a unique identifier used to distinguish different connections between a client and a server. if the connection fail at some point, with the connection ID the client can connect again and continue the sending to the server from the exact same point where the connection failed without the worry that the files or messages sent earlier will be deleted of thrown away.

Third step: in the client side, type the scenario of packet loss handling you want the code to use: 1 for time, 2 for sequence number, 3 for both(time and sequence number)

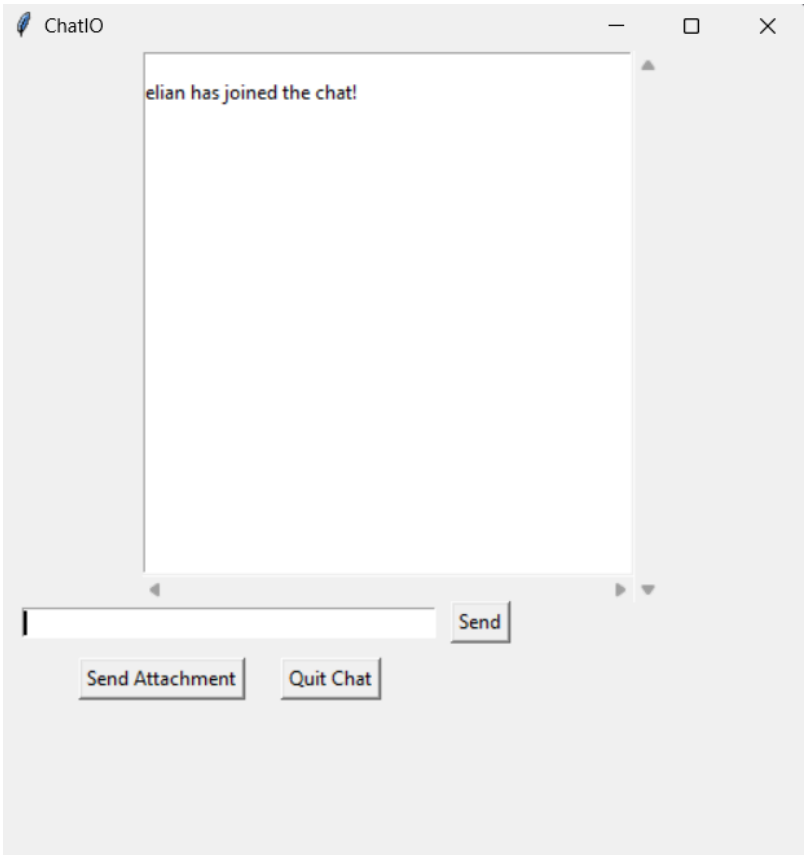


Fourth step: the GUI will open straight to the screen, this is how the GUI looks:

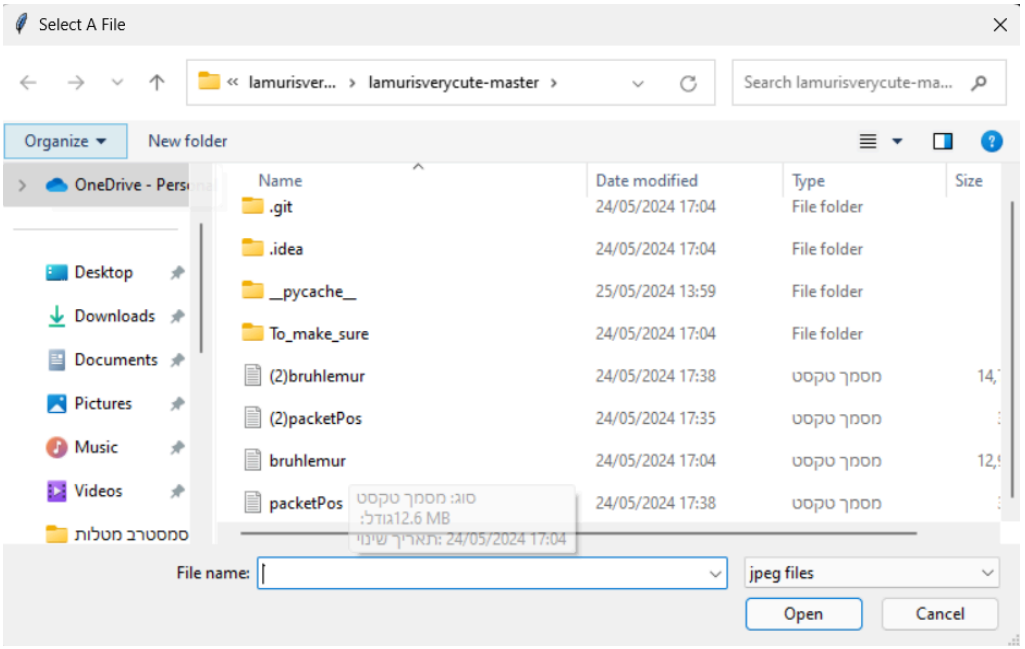


Fifth step: type your name in the filling box and press send:

the result will be- your name will be printed to the GUI screen as follows:

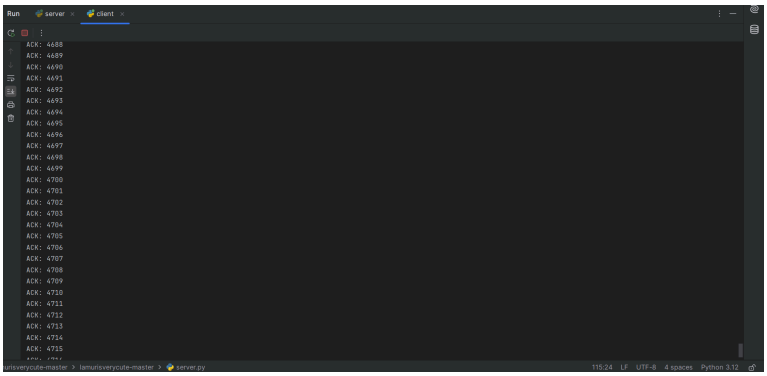


Sixth step: send the file you would like to send to the server by pressing the “Send Attachment” button, it will open the “File Explorer” and all you need to monitor to the file you would like to send and double click on it(or click once and select “open”) :

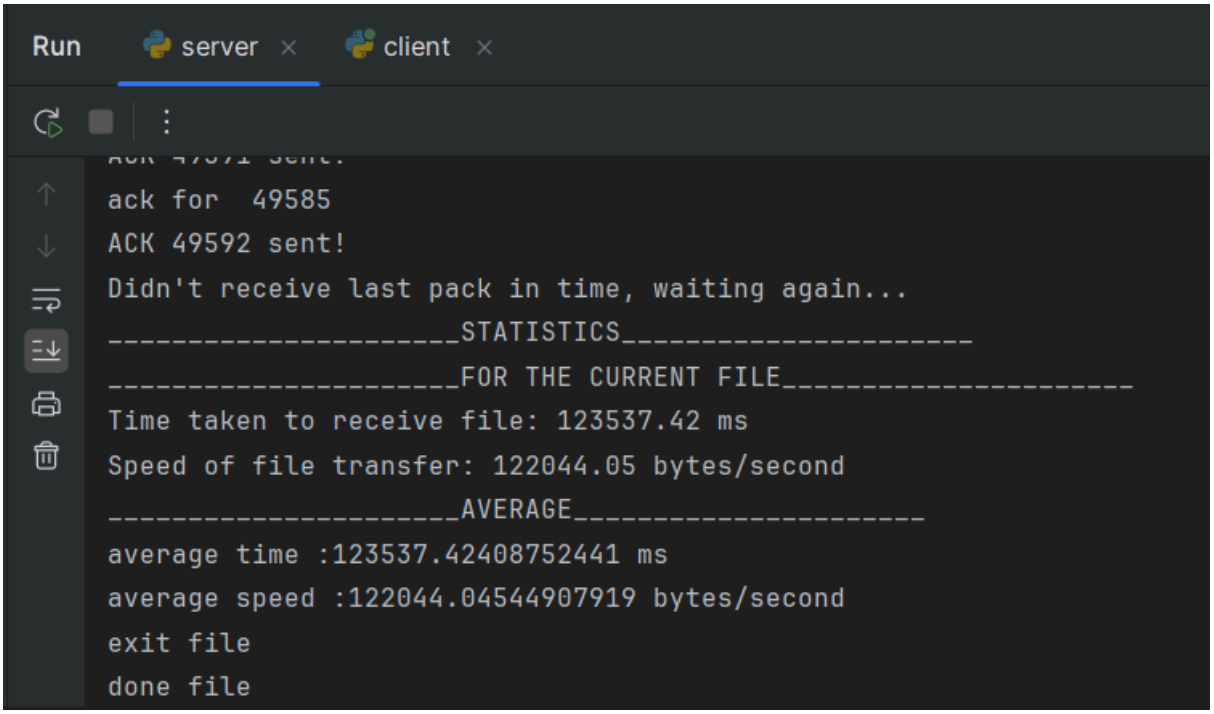


Seventh step: the file will be sending and you can monitor the progress of the sending in the terminal of the server and the client to see the packets getting sent to

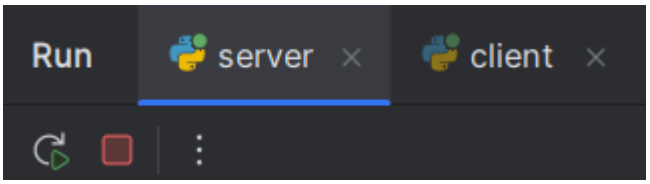
the other side by seeing the acks(each received packets will print ack to the terminal):



Eight step: after the file will be sent completely, it will print statistics to the screen- the time it was taken to send the file and the speed that the file was sent on. it will print it for every file you will send(the 2 lined after the “FOR THE CURRENT FILE”) and will print the average speed and time for all the files sent until now.



Ninth step: in this final step you can choose to send again the file(or different file) and return to the sixth step of you can close the connection by click on the “Quit Chat” or to terminate the python files by clicking on the red box:



Results for resend by seq:

with 0%

```
ACK 37654 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84636.26 ms
Speed of file transfer: 119123.42 bytes/second
```

with 1%

```
ACK 38411 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84977.13 ms
Speed of file transfer: 118645.57 bytes/second
```

with 2%

```
ACK 39204 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 86634.62 ms
Speed of file transfer: 116375.65 bytes/second
```

with 3%

```
ACK 40042 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84976.83 ms
Speed of file transfer: 118645.99 bytes/second
```

with 4%

```
ACK 40875 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84604.98 ms
Speed of file transfer: 119167.46 bytes/second
```

with 5%

```
ACK 41769 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84698.00 ms
Speed of file transfer: 119036.57 bytes/second
```

with 6%

```
ACK 42609 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83732.31 ms
Speed of file transfer: 120409.43 bytes/second
                    AVERAGE
```

with 7%

```
ACK 43555 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83631.97 ms
Speed of file transfer: 120553.90 bytes/second
```

with 8%

```
ACK 44458 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 84507.03 ms
Speed of file transfer: 119305.57 bytes/second
_____AVERAGE_____
```

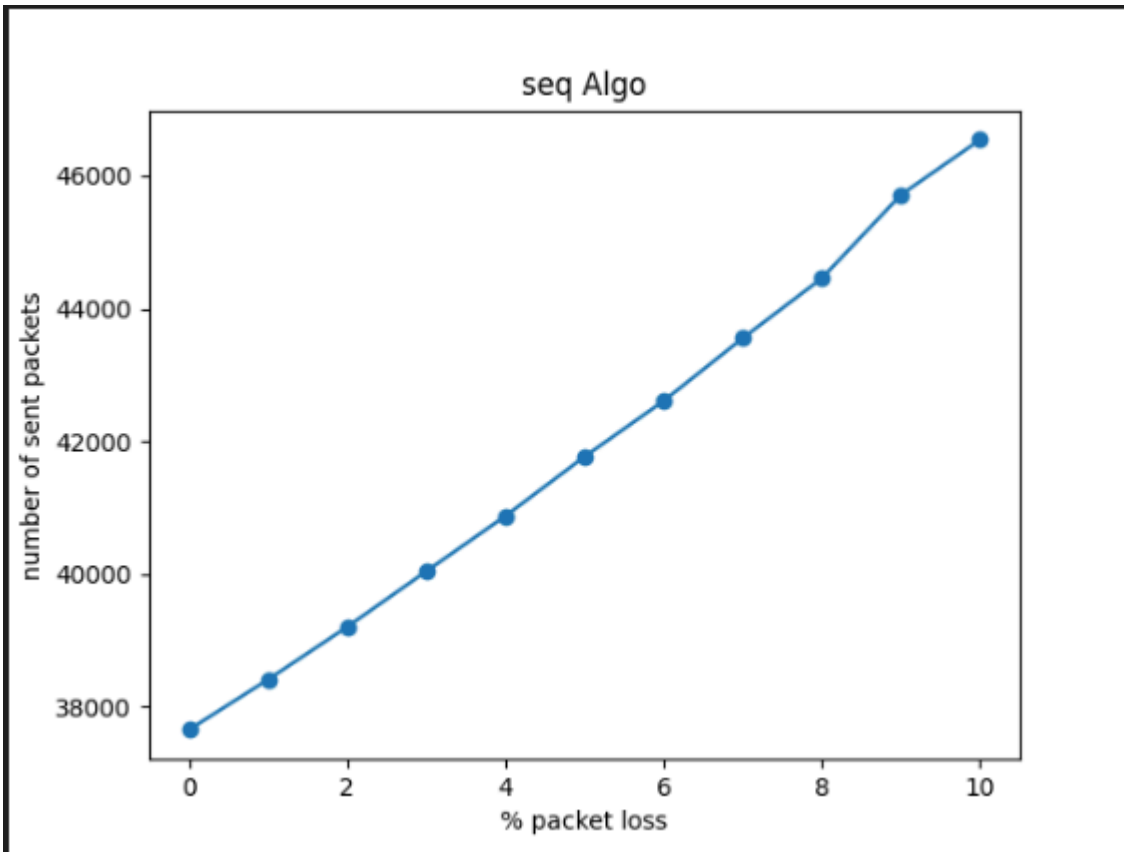
with 9%

```
ACK 45715 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 85164.55 ms
Speed of file transfer: 118384.47 bytes/second
                    AVERAGE
```

with 10%

```
ACK 46545 sent!
done recv
----------------------STATISTICS----------------------
----------------------FOR THE CURRENT FILE----------------------
Time taken to receive file: 83893.39 ms
Speed of file transfer: 120178.25 bytes/second
```

Graph that represent the chane of the among of packets send as a result of packet loss percentage



data size is 10.4 mb

result/ packet loss	0	1	2	3	4	5	6	7	8	9	10
Time(s)	84.5	85	86.6	85	84.6	84.5	83.7	83.6	84.5	85	83.9
last packet sequence	37654	38411	39204	40042	40875	41769	42609	43555	44458	45715	46545

results running by time

Statistics- for each packet loss scenario we ran the program and recorded it with Wireshark and calculate its statistics(time it was taken to send the file from the client to the server, speed for the sending in bytes per second and the number of packets we sent in total from the client to the server including the packet loss and the recovery):
with 0% packet loss:

```
ack for  37645
ACK 37652 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 107622.42 ms
Speed of file transfer: 93680.85 bytes/second
_____________________AVERAGE_____________________
average time :107622.41888046265 ms
average speed :93680.85297542291 bytes/second
exit file
done file
```

with 1% packet loss:

```
ACK 39059 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 106929.92 ms
Speed of file transfer: 94287.55 bytes/second
_____________________AVERAGE_____________________
average time :106929.92091178894 ms
average speed :94287.54752673206 bytes/second
exit file
done file
```

with 2% packet loss:

```
ACK 40594 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 108066.93 ms
Speed of file transfer: 93295.51 bytes/second
_____________________AVERAGE_____________________
average time :108066.93172454834 ms
average speed :93295.51453999271 bytes/second
exit file
done file
```

with 3% packet loss:

```
ACK 41977 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 105052.54 ms
Speed of file transfer: 95972.55 bytes/second
_____________________AVERAGE_____________________
average time :105052.53911018372 ms
average speed :95972.5494062108 bytes/second
exit file
done file
```

with 4% packet loss:

```
ACK 43506 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 106463.57 ms
Speed of file transfer: 94700.57 bytes/second
_____________________AVERAGE_____________________
average time :106463.56749534607 ms
average speed :94700.56505894123 bytes/second
exit file
done file
```

s:

with 5% packet loss:

```
ACK 45098 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 108242.21 ms
Speed of file transfer: 93144.44 bytes/second
_____________________AVERAGE_____________________
average time :108242.20585823059 ms
average speed :93144.44324245417 bytes/second
exit file
done file
```

with 6% packet loss:

```
ACK 46582 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 109752.11 ms
Speed of file transfer: 91863.02 bytes/second
_____________________AVERAGE_____________________
average time :109752.11215019226 ms
average speed :91863.01568577456 bytes/second
exit file
done file
```

with 7% packet loss:

```
ACK 48109 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 108149.82 ms
Speed of file transfer: 93224.01 bytes/second
_____________________AVERAGE_____________________
average time :108149.81722831726 ms
average speed :93224.01330291062 bytes/second
exit file
done file
```

with 8% packet loss:

```
ACK 49651 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 103317.55 ms
Speed of file transfer: 97584.19 bytes/second
_____AVERAGE_____
average time :103317.55352020264 ms
average speed :97584.19219661974 bytes/second
exit file
done file
```

with 9% packet loss:

```
ACK 50887 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 108429.17 ms
Speed of file transfer: 92983.84 bytes/second
_____AVERAGE_____
average time :108429.16655540466 ms
average speed :92983.83747004328 bytes/second
exit file
done file
```

with 10% packet loss:

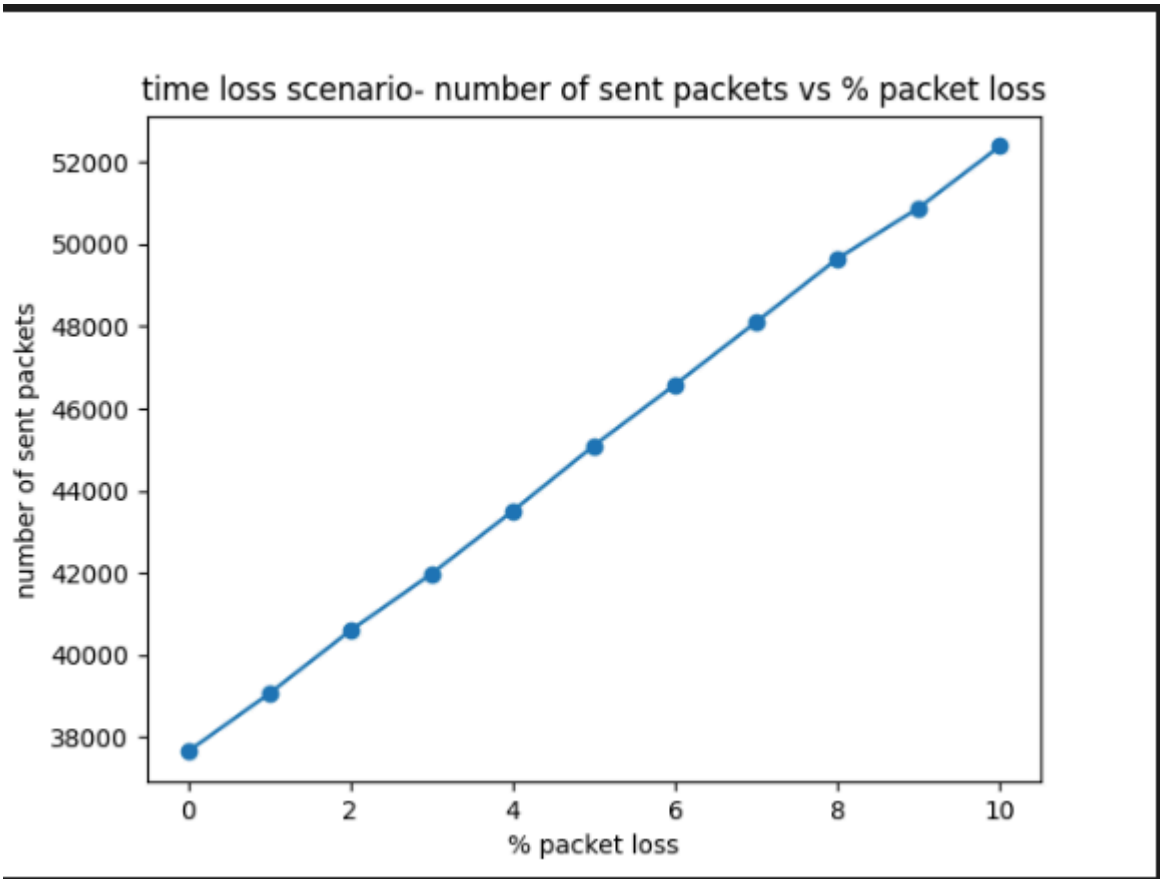
```
ACK 52389 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 107747.25 ms
Speed of file transfer: 93572.32 bytes/second
_____AVERAGE_____
average time :107747.25389480591 ms
average speed :93572.31516863767 bytes/second
exit file
done file
```

Table of statistics:

result/%	6%	7%	8%	9%	10%
Time(ms)	109752.11	108149.82	103317.55	108429.17	107747.25
speed(b/s)	91863.02	93224.01	97584.19	92983.84	93572.32
last packet sequence	46582	48109	49651	50887	52386

result/%	0%	1%	2%	3%	4%	5%
Time(ms)	107622.42	106929.92	108066.93	105052.54	106463.57	108242.21
speed(b/s)	93680.85	94287.55	93295.51	95972.55	94700.57	93144.44
last packet sequence	37652	39059	40594	41977	43506	45098

The graph that show the relationship between the percentage of lost packets to the number of sent packets, as we can see we sent more packets when the percentage of lost packets is bigger and this is because when we lost a packet we need to send it again and when there is more % of packet loss there are more packets that get lost and we need to send again.



the code to create the Graph:

```python
import matplotlib.pyplot as plt

# The Graph for the Time packet loss scenerio
x = [0, 1, 2, 3, 4, 5,6,7,8,9,10] #packey loss percentage in %
# y = [108044,107919,109085,107416,105896,109106,110829,105578,109945,111132,111933]#time
# z=[93314,93423,92424,93860,95207,92406,90969,95494,91701,90722,90072]#speed
a=[37652,39059,40594,41977,43506,45098,46582,48109,49651,50887,52386]
# Create a plot
plt.plot( *args: x, a, marker='o')

# Add titles and labels
plt.title('time loss scenario- number of sent packets vs % packet loss')
plt.xlabel('% packet loss')
plt.ylabel('number of sent packets')

# Show the plot
plt.show()
```

Running by time + sequence number:

Statistic- for each packet loss scenario we ran the program and recorded it with Wirshark and calculate its statistics(time it was taken to send the file from the client to the server, and speed for the sending in bytes per econd):

with 0% packet loss:

```
ACK 37652 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83425.06 ms
Speed of file transfer: 120852.89 bytes/second
_____AVERAGE_____
average time :83425.06051063538 ms
average speed :120852.89406190702 bytes/second
exit file
done file
```

with 1% packet loss:

```
ACK 38410 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83302.99 ms
Speed of file transfer: 121029.99 bytes/second
_____AVERAGE_____
average time :83302.99258232117 ms
average speed :121029.98568792916 bytes/second
exit file
done file
```

with 2% packet loss:

```
ACK 39222 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83094.77 ms
Speed of file transfer: 121333.27 bytes/second
_____AVERAGE_____
average time :83094.7654247284 ms
average speed :121333.27470709271 bytes/second
exit file
done file
```

with 3% packet loss:

```
ACK 40055 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 82911.76 ms
Speed of file transfer: 121601.08 bytes/second
_____AVERAGE_____
average time :82911.76223754883 ms
average speed :121601.0820167325 bytes/second
exit file
done file
```

with 4% packet loss:

```
ACK 40902 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83111.26 ms
Speed of file transfer: 121309.20 bytes/second
_____AVERAGE_____
average time :83111.25564575195 ms
average speed :121309.20080155626 bytes/second
exit file
done file
```

with 5% packet loss:

```
ACK 41735 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83067.68 ms
Speed of file transfer: 121372.83 bytes/second
_____AVERAGE_____
average time :83067.68250465393 ms
average speed :121372.83352566311 bytes/second
exit file
done file
```

with 6% packet loss:

```
ACK 42518 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 82382.25 ms
Speed of file transfer: 122382.67 bytes/second
_____AVERAGE_____
average time :82382.25269317627 ms
average speed :122382.66945127014 bytes/second
exit file
done file
```

with 7% packet loss:

```
ACK 43498 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83130.06 ms
Speed of file transfer: 121281.75 bytes/second
_____AVERAGE_____
average time :83130.06448745728 ms
average speed :121281.75362502219 bytes/second
exit file
done file
```

with 8% packet loss:

```
ACK 44480 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83109.43 ms
Speed of file transfer: 121311.87 bytes/second
_____AVERAGE_____
average time :83109.42912101746 ms
average speed :121311.8668559153 bytes/second
exit file
done file
```

with 9% packet loss

```
ACK 45412 sent!
done recv
_____STATISTICS_____
_____FOR THE CURRENT FILE_____
Time taken to receive file: 83142.70 ms
Speed of file transfer: 121263.32 bytes/second
_____AVERAGE_____
average time :83142.70234107971 ms
average speed :121263.31856089477 bytes/second
exit file
done file
```

with 10% packet loss:

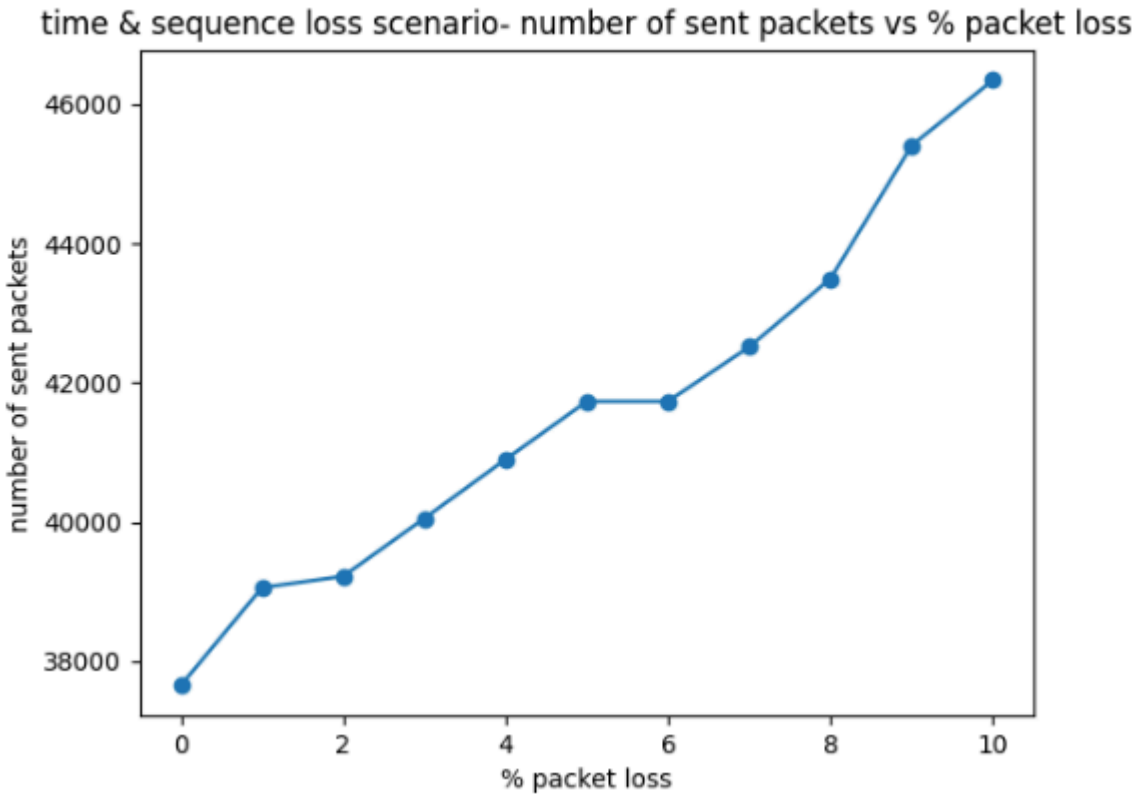
```
ACK 46348 sent!
done recv
_____________________STATISTICS_____________________
_____________________FOR THE CURRENT FILE_____________________
Time taken to receive file: 82925.47 ms
Speed of file transfer: 121580.98 bytes/second
_____________________AVERAGE_____________________
average time :82925.47273635864 ms
average speed :121580.97707870504 bytes/second
exit file
done file
```

Table of statistics:

result/%	6%	7%	8%	9%	10%
Time(ms)	83067.68	82382.25	83130.06	83142.70	82925.47
speed(b/s)	121372.83	122382.67	121281.75	121263.32	121580.98
last seq	41735	42518	43498	45412	46348

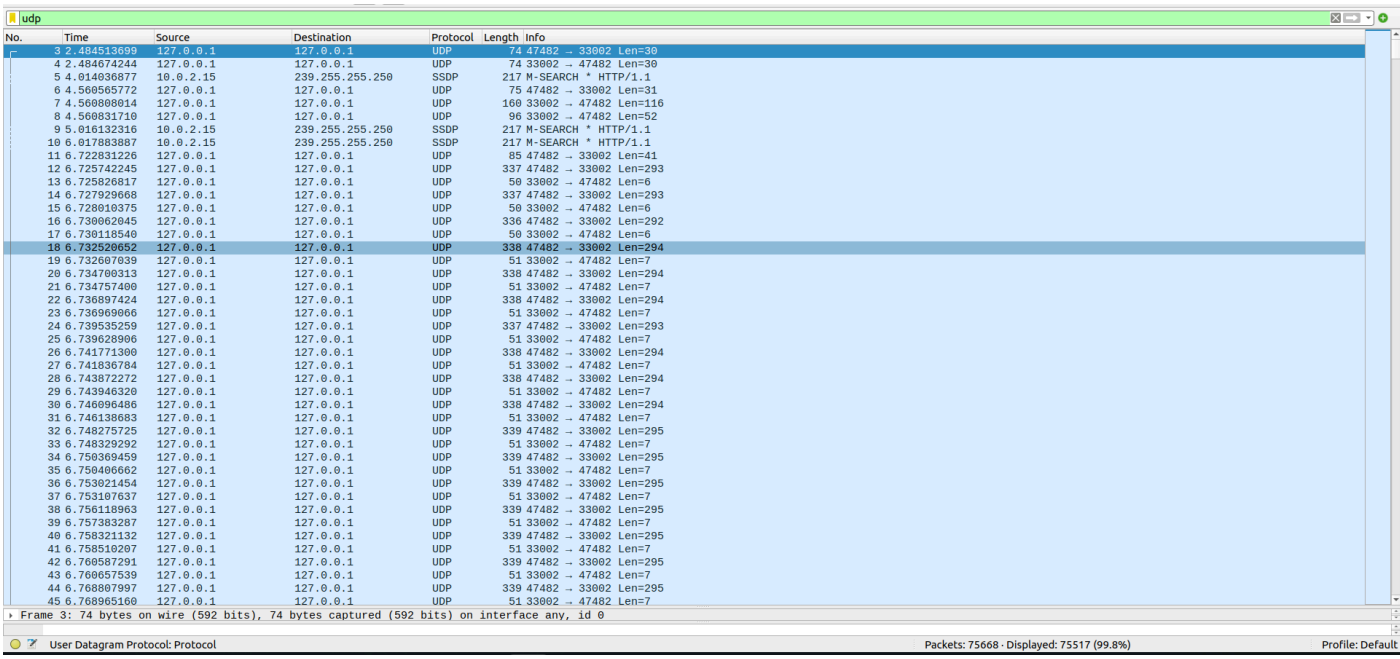
result/%	0%	1%	2%	3%	4%	5%
Time(ms)	108044.68	107919.01	109085.24	107416.47	105896.39	109106.22
speed(b/s)	93314.72	93423.39	92424.61	93860.47	95207.78	92406.83
last seq	37652	39059	39222	40055	40902	41735

Graph:



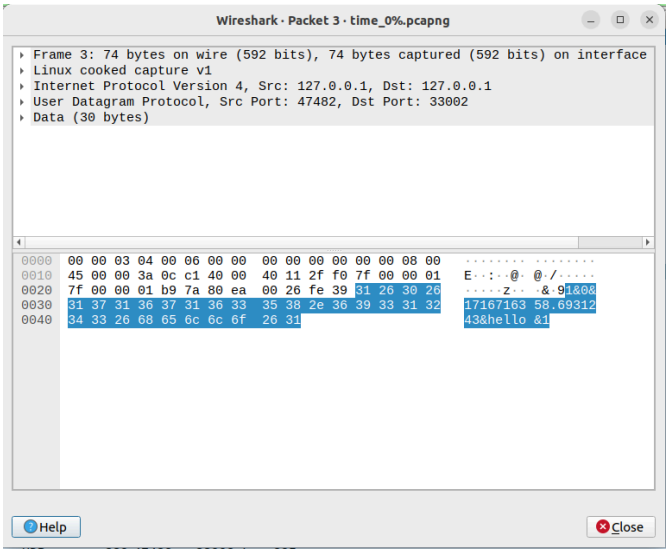
as we can see, when there is bigger packet loss percentage we send more packets in total also if we handle the packet loss with both time and sequence number scenario together. As before, its because when a packet get lost we need to send it again so the more packet loss percentage means the more packets that are getting lost and the more packets we need to send again.

Wireshark recording- explanation

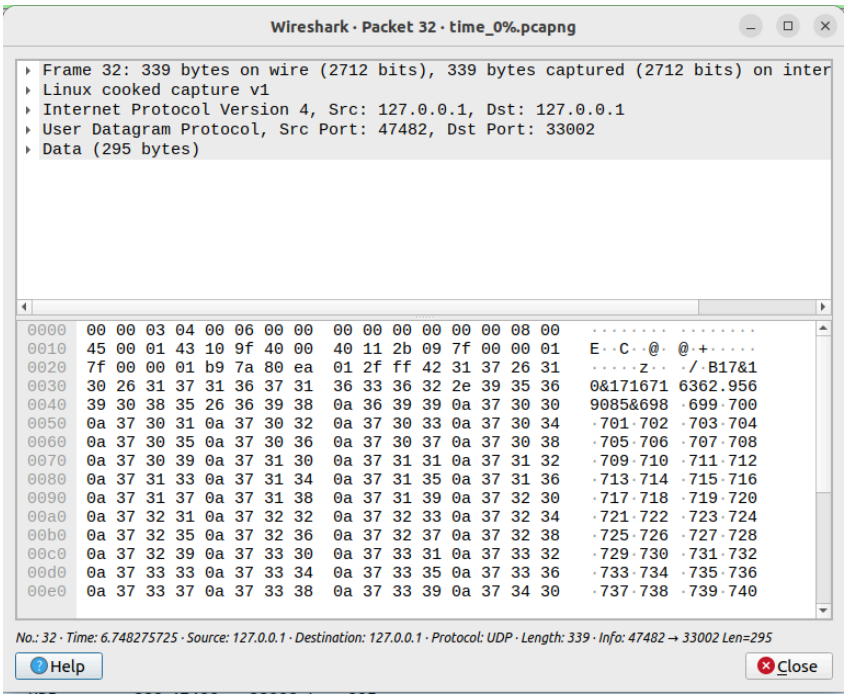


This is how a Wireshark recording looks like for our code, we can see the packets that were sent from the client to the server and the opposite. The client sent to the server packets, each in size of 295 bytes that include the file which the client sends to the server and more information that each packet contains such as sequence number, the time of the packet creation(which is the time the packet getting sent) and more. In return, the server sent ack that the packet received which is in length of 7 bytes.

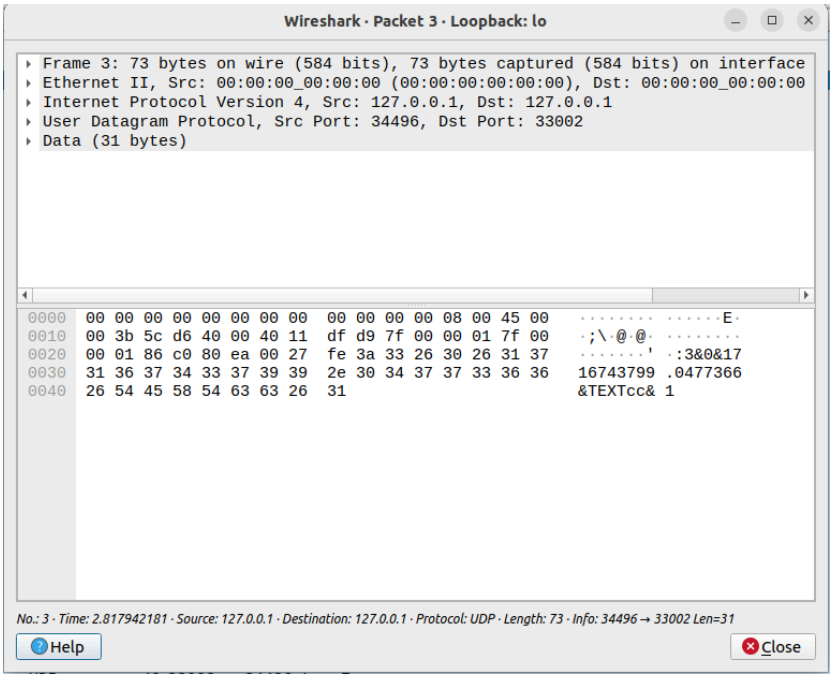
This picture shows the packet for the handshake, the client send a packet with the payload “hello” and the connection ID(which in this example is 1) that the client would like to use.
We can see the protocol we are using(UDP), the source port(47482) and the destination port(33002).



This picture shows the structure of an information packet. This built the same as the handshake packet, the only difference is that the payload is different and its the text from the file the client sent.



This is the packet the client send to the server with his name so he can start to send the files he would like. We can see the payload is “cc” is the name of the client and the frame is 3, so its the third packet that was sent between the client and the server, the first one is the “hello” packet from before(the first packet) its the same one which the client send the connection ID for the connection. The second packet is the packet the server send to let the client know the he received the opening packet and the connection is good and they can start messaging and sending files.



This is the last packet of the file that was sent from the client to the server, we can know that by seeing the payload which is “DONE”, this is the signal of the last packet that was sent about the file.