Question 1

I first wrote a **skeleton class for both Sender and Receiver** and also an **STPPacket class** which would act as the base segment structure for all my segments.

- I added in the necessary variables for both Sender and Receiver as defined by the assignment
- I also added in extra variables for tracking state, seq numbers, ack numbers and more.

I then wrote methods for **creating packets, receiving segments, sending packets over UDP** and **closing the connection** for both the sender / receiver

- I tested by "receiving" a file from the app-layer, creating a segment with all the file bytes, sending the whole payload over UDP to the receiver.
- I made sure UDP was functioning properly by checking the difference between test1.txt and the final file receiver.txt. I repeated the same experiment with test2.txt with receiver.txt

Then I added in a method **split_data() to test Max Segment Size feature**, extracting only the max size number of bytes from the app-layer file then appending it to the segment payload before sending it over UDP.

- I tested this by choosing various values of MSS and running the two programs to make sure each packet was being split properly by the MSS value, payload added to the segment then sent over UDP.
- I double checked that all the split packets arrived correct at the receiver side, by again checking diff between test.txt with receiver.txt

Then I added in methods for **creating SYN SYNACK ACK FIN segments** and logic to **increment Sequence / Acknowledgement numbers** for both the Sender and Receiver. On top of this, I created a method for **updating sender_log.txt / receiver_log.txt files** so that I can keep track of what is going on in the program.

- I tested this many times, so that the seq / ack numbers were correct on both sides.
- I made sure that the **3-way-handshake worked correctly**
- I made sure that the **FIN – ACK FIN – ACK worked correctly**

I created a **Packet Loss Drop Class** for the PLD feature and also a **method to take in packets as an argument and generate a pseudorandom number to drop or transmit the packet**

- I tested this by choosing various **Packet Loss Drop values** and checked in my log output that packets were being dropped.

I created a **Timer feature**, by calling the **time.clock()** function to keep track of current time and assist with **timeout and retransmissions**

- I tested this against dropped packages, where all dropped packages would have a given constant timeout value before retransmitting.

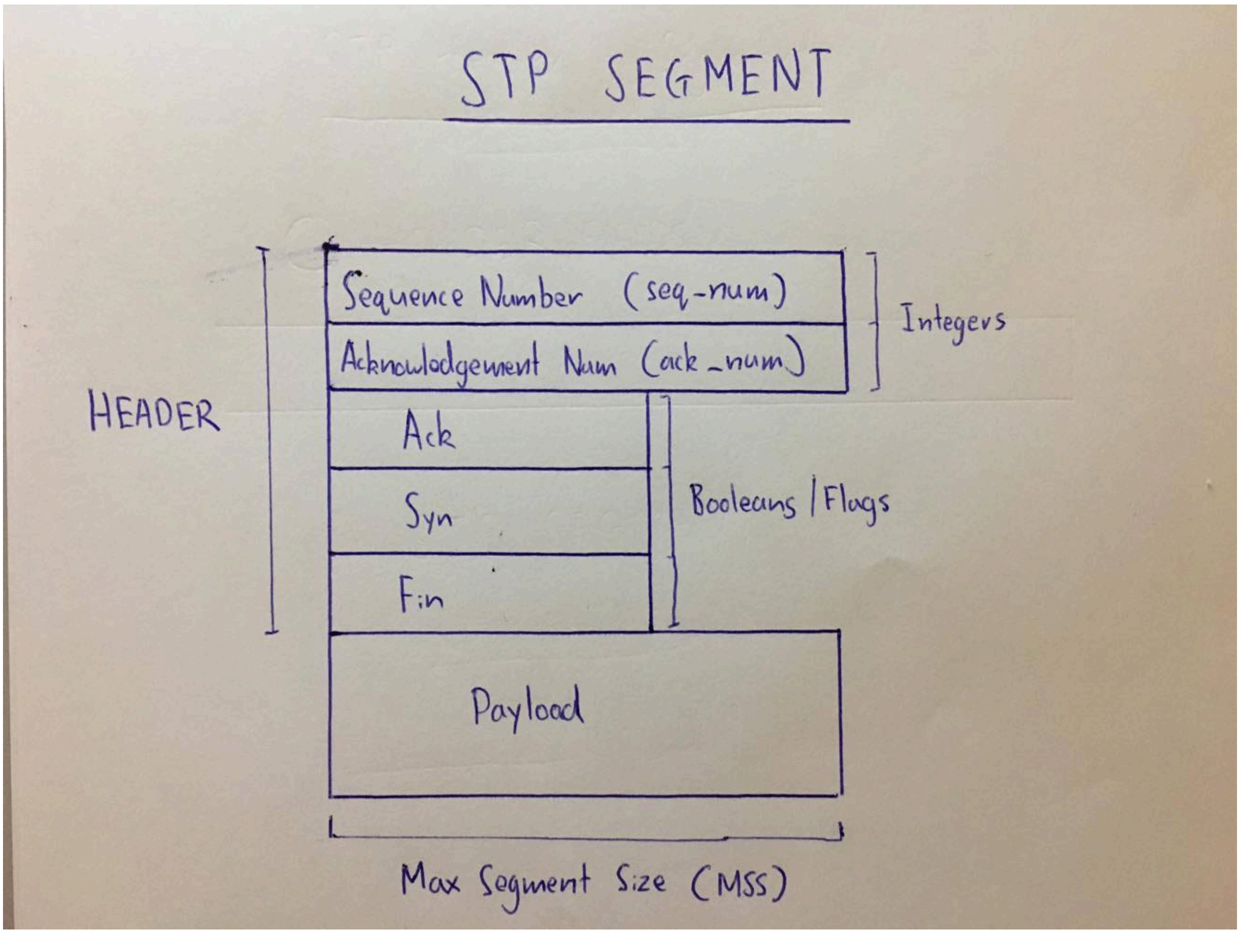
Everything was held together by **main methods on both the Sender / Receiver side**, where there are **several events / states** which keep track of what and when to send / receive packets and when to close the connection.

- Sender states: CLOSED, SYN_SENT, TIMEOUT, ESTABLISHED, END
  Receiver states: LISTEN, SYN_RECV, SYNACK_SENT, ETABLISHED, END
- On the both Sender / Receiver sides, they will go through the **3-way-handshake** before moving to an **ESTABLISHED CONNECTION** state.
- During the established connection state, the Sender will grab data from the app-layer file, create new packets based on MSS, parse it through the PLD system, transmit to the Receiver for processing.
- Likewise, the Receiver will be **listening for any Data segments** and as soon as it receives them, it will **generate a corresponding ACK**

SENDER: App-layer file → cut out MSS bytes → create segment → parse segment through PLD → send over UDP → wait for ACK
RECEIVER: Listen for packet → receive packet → determine if correct seq_num → send ACK → extract payload → append to file

Implemented Features	Not Implemented
Both: Three-way-handshake (SYN SYNACK ACK)	**Sender:** Fast retransmit
Both: Four-segment cnnt termination (FIN ACK FIN ACK)	**Sender:** Maximum Window Size (MWS)
Sender: Single-timer for timeout operation	
Sender: Simple timeout retransmit	
Receiver: Immediate acknowledgement / ACKs	
Both: Sequence Numbers, Acknowledgement Numbers	
Sender: Maximum Segment Size (MSS)	
Sender: Packet Loss and Delay (PLD)	
Sender: Constant timeout	

Question 2



Question 3

(a)

A suitable timeout value is 2 * the average Round-Trip Time, which is calculated based off running average RTT.

Test1.txt with timeout = 100ms

```
### FINAL RECEIVER LOG ###
rcv  52.608  S   0    0    0
snd  53.391  SA  0    0    1
rcv  53.929  A   1    0    1
snd  54.624  A   1    0    51
rcv  54.908  D   1    50   1
snd  55.498  A   51   0    101
rcv  55.732  D   51   50   1
snd  56.287  A   101  0    151
rcv  56.542  D   101  50   1
snd  57.108  A   151  0    201
rcv  57.354  D   151  50   1
snd  57.916  A   201  0    251
rcv  58.155  D   201  50   1
snd  58.742  A   251  0    301
rcv  58.981  D   251  50   1
snd  59.706  A   301  0    351
rcv  60.271  D   301  50   1
snd  61.075  A   351  0    401
rcv  61.352  D   351  50   1
snd  61.946  A   401  0    451
rcv  62.204  D   401  50   1
snd  62.787  A   451  0    501
rcv  63.042  D   451  50   1
snd  63.607  A   501  0    551
rcv  63.842  D   501  50   1
snd  64.405  A   551  0    601
rcv  64.648  D   551  50   1
snd  65.207  A   601  0    651
rcv  65.438  D   601  50   1
snd  65.932  A   651  0    701
rcv  66.162  D   651  50   1
snd  66.7    A   701  0    751
rcv  66.954  D   701  50   1
snd  67.5    A   751  0    801
```

```
rcv  67.73   D   751  50   1
snd  68.282  A   801  0    851
rcv  68.508  D   801  50   1
snd  69.057  A   851  0    901
rcv  69.299  D   851  50   1
snd  69.855  A   901  0    951
rcv  70.096  D   901  50   1
snd  70.699  A   951  0    1001
rcv  70.929  D   951  50   1
snd  71.494  A   1001 0    1051
rcv  71.737  D   1001 50   1
snd  72.281  A   1051 0    1101
rcv  72.516  D   1051 50   1
snd  72.993  A   1101 0    1151
rcv  73.193  D   1101 50   1
snd  73.697  A   1151 0    1201
rcv  73.912  D   1151 50   1
snd  74.601  A   1201 0    1251
rcv  74.943  D   1201 50   1
snd  75.577  A   1251 0    1301
rcv  75.812  D   1251 50   1
snd  76.418  A   1301 0    1351
rcv  76.66   D   1301 50   1
snd  77.203  A   1351 0    1401
rcv  77.443  D   1351 50   1
snd  78.012  A   1401 0    1451
rcv  78.24   D   1401 50   1
snd  78.794  A   1451 0    1501
rcv  79.017  D   1451 50   1
snd  79.54   A   1501 0    1551
rcv  79.779  D   1501 50   1
snd  80.397  A   1551 0    1594
rcv  80.693  D   1551 43   1
rcv  81.228  F   1594 0    1
snd  82.173  FA  1594 0    1595
rcv  82.876  A   1594 0    2
```

Test1.txt with timeout = 100ms with pdrop = 0.3

```
### FINAL RECEIVER LOG ###
rcv  80.197  S   0    0    0
snd  80.591  SA  0    0    1
rcv  80.989  A   1    0    1
snd  81.572  A   1    0    51
rcv  81.792  D   1    50   1
snd  82.181  A   51   0    101
rcv  82.405  D   51   50   1
snd  82.936  A   101  0    151
rcv  83.158  D   101  50   1
snd  83.689  A   151  0    201
rcv  83.893  D   151  50   1
snd  84.397  A   201  0    251
rcv  84.606  D   201  50   1
snd  85.134  A   251  0    301
rcv  85.384  D   251  50   1
snd  85.884  A   301  0    351
rcv  86.1    D   301  50   1
snd  86.605  A   351  0    401
rcv  86.841  D   351  50   1
snd  87.372  A   401  0    451
rcv  87.611  D   401  50   1
snd  88.103  A   451  0    501
rcv  88.316  D   451  50   1
snd  88.79   A   501  0    551
rcv  89.018  D   501  50   1
snd  89.521  A   551  0    601
rcv  89.754  D   551  50   1
snd  90.299  A   601  0    651
rcv  90.52   D   601  50   1
snd  91.122  A   651  0    701
rcv  91.45   D   651  50   1
snd  92.048  A   701  0    751
rcv  92.546  D   701  50   1
snd  93.274  A   751  0    801
rcv  93.513  D   751  50   1
snd  94.033  A   801  0    851
rcv  94.277  D   801  50   1
snd  94.812  A   851  0    901
rcv  95.051  D   851  50   1
snd  95.604  A   901  0    951
rcv  95.871  D   901  50   1
snd  96.441  A   951  0    1001
rcv  96.7    D   951  50   1
snd  97.217  A   1001 0    1051
rcv  97.44   D   1001 50   1
snd  98.143  A   1051 0    1101
```

```
rcv  98.547  D   1051 50   1
snd  99.176  A   1101 0    1151
rcv  99.531  D   1101 50   1
snd  100.241 A   1151 0    1201
rcv  100.508 D   1151 50   1
snd  101.136 A   1201 0    1251
rcv  101.454 D   1201 50   1
snd  102.074 A   1251 0    1301
rcv  102.31  D   1251 50   1
snd  102.847 A   1301 0    1351
rcv  103.073 D   1301 50   1
snd  103.657 A   1351 0    1401
rcv  103.955 D   1351 50   1
snd  104.609 A   1401 0    1451
rcv  104.971 D   1401 50   1
snd  105.729 A   1451 0    1501
rcv  106.001 D   1451 50   1
snd  106.668 A   1501 0    1551
rcv  106.939 D   1501 50   1
snd  107.679 A   1551 0    1594
rcv  108.224 D   1551 43   1
rcv  108.6   F   1594 0    1
snd  109.08  FA  1594 0    1595
rcv  109.553 A   1594 0    2
```

(b)

TCurrent	**36/40** transmitted, 120.41 – 84.474 = **35ms**
4 * TCurrent	**35/40** transmitted, 119.783 – 85.928 = **33.85ms**
Tcurrent / 4	**38/40** transmitted, 82.323 – 50.282 = **32.041ms**