COMP3331 Assignment 1 Report
Student Id: z5117018

Q1.

To implement the STP protocol, I used the skeleton code in the textbook for the sender as a starting point. The receiver's structure was quite simple so no assistance was required.

I then modularised the key features/roles I believed were required at the time: StpMsg (for the Stp packets), StpTimer (for the Stp RTO timer), PacketLossDelay (for pld utilities) and utils (for misc utilities).

- The StpMsg is made up of a header and payload whereby the header contains a sequence number, acknowledgment number, payload length, checksum, timestamp, syn, ack and fin.
- Methods are in place such as to_bits and from_bits to serialise and deserialise these packets from/to the socket byte streams.

In order to implement the maximum segment size feature and only extract mss bytes from the app-layer, the split_data() function was implemented. Thus, a list of split payloads was maintained by the sender class.

When the sender class is initialised, the handshake() method is called. This is where the 3-way-handshake is performed and the sender's state transitions from Closed → Syn Sent → Established and the receiver's state transitions from Closed → Syn Received → Established. These states are implemented in utils as enums.

Sender implementation:

A separate thread for sending payloads and receiving acknowledgments were implemented: send_payloads() and threaded_recv().

- To ensure consistency between the two threads, a global lock was implemented that had to be acquired and released appropriately.
- Send_payloads() key variables:
    - Send_base = index of oldest unacked segment in MWS window, send_base_Seq_num = sequence number of oldests unacked segment in MWS window
    - Last_sent = index of most recently sent segment in MWS window, seq_num = sequence number of most recently sent segment in MWS window
- Send_payloads() implementation:
    - Heavily relies on stp_send() function which takes in a payload and header, creates an STP message and passes it through to pld module's stp_send() function where pdrop, pdup etc are calculated. Sequence numbers are also incremented here.
    - Send as many packets as possible within the MWS window - after sending 1 packet, release the lock in case the threaded_recv() has already received an ack.

- **Threaded_recv() implementation:**
    - As soon as an ack is received, try and acquire the global lock
    - Increment send_base and send_base_seq_num if correct acks are received i.e. ack > send_base_seq_num.
    - Closes if the acknowledgment received equals the expected final sequence number.
    - Fast retransmission also implemented when 3 duplicate acks are received.
    - Lock is released once all received acks have been addressed.

- **PLD implementation:**
    - pDrop: packet not sent through UDP_Send
    - pDup: Two identical packets sent through UDP_Send
    - pCorr: A bit in the packet is flipped and sent through UDP_Send
    - pDely: Once again, the thread module's timer is used to asynchronously send this packet through UDP_Send after a time within the uniform distribution of 0 and maxDelay.
    - pReord: the packet is held by the pld for max_order meanwhile, regular transmission of packets and receiving of acknowledgments continues. Once max_order is fulfilled then this packet is sent through UDP_Send.

- **RTO calculation implementation:**
    - StpTimer class calculates RTO, given a sample rtt.
    - Calculating sample rtt:
        - Include a sender timestamp in each segment sent to the receiver.
        - Receiver creates an acknowledgment message and includes the sender's timestamp in the header.
        - If a packet is sent due to retransmission, the timestamp is set to None.
        - When the sender receives a correct acknowledgment and the timestamp is not none, it calculates a new sample rtt by subtracting the timestamp with the current time.
        - **Important note**: the timestamp allows for calculation of rtts for segments that have had copies retransmitted (not the original). This is because the timestamps remove the ambiguities between segments with the identical sequence numbers as retransmissions/copies have timestamps of "None". **RFC 6298 (ch 3)**

- Once stp_close is called in the threaded_recv(), the sender's state transitions from Established → Fin_wait_1 → Fin_wait_2 → Closed whereas the receiver's state transitions from Established → Close_wait → Last_ack → Closed.

- Logging is handled by the SenderLogHandler and ReceiverLogHandler for the sender and receiver respectively.

Sender: App-layer file → cut out MSS bytes → create segment → parse through PLD → send over UDP → wait for ACK

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Receiver implementation:

- Listens for packets
- Receives a packet and determines if it has the correct sequence number
    - If corrupted: discard packet and send dup ACK
    - If incorrect sequence number but not yet seen: append to msg_buffer and return dup ACK
        - Msg_buffer holds packets that have been received but not yet appended to the file because the correct base sequence number has not been received.
    - If incorrect sequence number and already seen: do not append to msg_buffer and return dup ACK
    - If correct sequence number: go through the msg_buffer and append payloads of packets that are in correct chronological order.
- All acknowledgments returned contains the same timestamp that the received packet held in its header. This assists in the RTO calculation in the sender.
- Close after last ack in response to receiver's fin is received.

Receiver: Listen for packet → receive packet → determine if correct sequence number → send ack → extract payload → append to file

Implemented	Not Implemented
Both: Three way handshake (SYN SYNACK ACK)	
Both: Four way connection termination (FIN ACK FIN ACK)	
Sender: Single timer for timeout operation	
Sender: Setting and managing retransmission timeout interval	
Receiver: Immediate acknowledgments/ACKs	
Both: Sequence numbers and acknowledgment numbers	
Sender: Maximum Segment Size (MSS)	
Sender: Maximum Window Size (MWS)	
Sender: Packet Loss Delay module (PLD)	
Sender: Constant Timeout	
Sender: Fast Retransmit	

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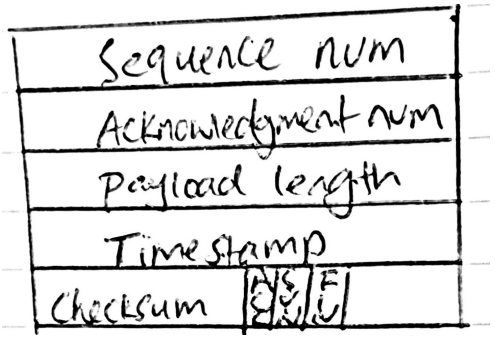
Q2. A detailed diagram of your STP header and a quick explanation of all fields (similar to the diagrams that we have used in the lectures to understand TCP/UDP headers).



- The sequence number keeps track of the file-byte-offset for a payload that is being sent.
- The acknowledgment number keeps track of which file-byte-offset is expected from the next received sequence number.
- The payload length keeps track of the payload length of a packet so it does not have to be calculated at the sender side and at the receiver side.
- The checksum is used for error detection purposes whereby the 16 bit sum of the packet is calculated and then negated. At the receiver's side, the bit sum of the packet is calculated and then summed with the calculated checksum, if this does not equal 0xffff then the packet has been corrupted.
- The timestamp keeps track of when the packet was sent from the sender to the receiver. This is used to calculate the rtt when a correct acknowledgment is received.
- The ACK, SYN and FIN are single booleans: acknowledgment (acknowledges received data), synchronize (initiate a connection) and final (terminates a connection).

Q3. Discuss any design trade-offs considered and made. Describe possible improvements and extensions to your program and indicate how you could realise them.

- One trade off that was made was converting the program from being synchronous and simple to asynchronous and more complex. This required quite a bit of refactoring, however, showcased the correct implementation.
- Improvements: Further modularise behaviours. There are some commonalities between receiver and sender that could be abstracted to a separate module.
- As an extension, bi-directional transfer of data could be implemented between the sender and the receiver. In order to implement this, the sender and receiver class may need to be refactored and partially combined into a single module. For example the receiver's acknowledgment logic needs to be refactored into the sender's threaded recv function or the msg_buffer needs to be a new property in the sender for receiving data from the receiver.
- Delayed Acks could also be implemented: this simply requires a timer for 500 msec and if the next in-order segment does not arrive by then, send the original ack.

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Q4.
The only segment borrowed was the logic of the sender from the course textbook (appendix).
Q5.
(a)
With pdrop = 0.1, dropping occurs at sequence numbers: 201, 2001, 2701, 2801
With pdrop = 0.3, dropping occurs at sequence numbers: 1, 401, 601, 701, 901, 1301, 1401, 1501, 1901, 2401, 2501, 2601, 2901
(b)

Gamma	Number of STP packets	Time taken (seconds)
2	12552	7453.74
4	12449	9814.43
6	12457	9839.42

The long duration of these file transfers can be explained by the 50% probability of dropout leading to many timeout retransmissions as well as cancellations of timeout interval calculations.
The increase in time taken as gamma increases can be explained by the formula: timeout interval = estimated_rtt + gamma * dev_rtt. Increasing the value of gamma increased the timeout intervals for retransmission and hence the sender was left in a longer idle state of waiting for an acknowledgment before a packet was retransmitted.
The increase in the number of STP packets transmitted as gamma decreased can be explained by shorter timeout intervals. This can lead to a retransmission before a correct acknowledgment could have been potentially received. An increase in gamma, increased the timeout intervals and therefore left a longer period of time for correct acknowledgments to be received, reducing the number of unnecessary retransmissions, evidencing the lower total STP packets. In terms of standard deviations, +1σ will cover about 84.1%, +2σ will cover about 97.7%, +3σ will cover about 99.8%, and +4σ will cover about 99.9%. Hence there is no real difference in STP packets when setting gamma as 4 or 6, the latter will only take longer due to the increased retransmission times.
(c)
Yes the file has been successfully transferred. It took 149.33 seconds.
The factor that is most critical in determining overall transfer time is pDrop. This was determined by swapping the ordering of the conditional statements for the four factors in the PLD module so they received equal probability evaluations from the seeded random function. Then I gradually increased the input probabilities one at a time for each factor and ran the tests, keeping all other conditions constant. It was clear that pDrop and pCorrupt had the greatest influences. Increasing the probability of corrupting packets led to more fast retransmissions as the receiver was replying with duplicate acks whereas, increasing the probability of dropping packets led to more retransmissions from timeout. Hence pDrop was the greatest contributor to overall transfer time.

Q4.

Source: Computer Networking A Top-Down Approach, 6th Edition.

```
/* Assume sender is not constrained by TCP flow or congestion control, that data from above is less
than MSS in size, and that data transfer is in one direction only. */

NextSeqNum=InitialSeqNumber
SendBase=InitialSeqNumber

loop (forever) {
    switch(event)

        event: data received from application above
            create TCP segment with sequence number NextSeqNum
            if (timer currently not running)
                start timer
            pass segment to IP
            NextSeqNum=NextSeqNum+length(data)
            break;

        event: timer timeout
            retransmit not-yet-acknowledged segment with
                smallest sequence number
            start timer
            break;

        event: ACK received, with ACK field value of y
            if (y > SendBase) {
                SendBase=y
                if (there are currently any not-yet-acknowledged segments)
                    start timer
                }
            break;

    } /* end of loop forever */
```

Q5 (a) Dropout 0.1

Sender log:

1	snd	0.00	S	0	0	0
2	rcv	0.00	AS	0	0	1
3	snd	0.00	A	1	0	1
4	snd	0.00	D	1	100	1
5	rcv	0.00	A	1	0	101
6	snd	0.00	D	101	100	1
7	drop	0.00	D	201	100	1
8	snd	0.00	D	301	100	1
9	rcv	0.00	A	1	0	201
10	rcv/DA	0.00	A	1	0	201
11	snd	0.01	D	401	100	1
12	snd	0.01	D	501	100	1
13	rcv/DA	0.01	A	1	0	201
14	rcv/DA	0.01	A	1	0	201
15	snd/RXT	0.01	D	201	100	1
16	rcv	0.01	A	1	0	601
17	snd	0.01	D	601	100	1
18	snd	0.01	D	701	100	1
19	rcv	0.01	A	1	0	701
20	rcv	0.01	A	1	0	801
21	snd	0.01	D	801	100	1
22	rcv	0.01	A	1	0	901
23	snd	0.01	D	901	100	1
24	rcv	0.01	A	1	0	1001
25	snd	0.01	D	1001	100	1
26	rcv	0.02	A	1	0	1101
27	snd	0.02	D	1101	100	1
28	rcv	0.02	A	1	0	1201
29	snd	0.02	D	1201	100	1
30	rcv	0.03	A	1	0	1301
31	snd	0.03	D	1301	100	1
32	rcv	0.03	A	1	0	1401
33	snd	0.03	D	1401	100	1
34	rcv	0.03	A	1	0	1501
35	snd	0.03	D	1501	100	1
36	rcv	0.04	A	1	0	1601
37	snd	0.04	D	1601	100	1
38	rcv	0.04	A	1	0	1701
39	snd	0.04	D	1701	100	1
40	snd	0.04	D	1801	100	1
41	rcv	0.04	A	1	0	1801
42	rcv	0.04	A	1	0	1901
43	snd	0.04	D	1901	100	1
44	rcv	0.04	A	1	0	2001
45	drop	0.04	D	2001	100	1
46	snd	0.04	D	2101	100	1
47	snd	0.04	D	2201	100	1
48	rcv/DA	0.04	A	1	0	2001
49	rcv/DA	0.04	A	1	0	2001
50	snd	0.05	D	2301	100	1
51	rcv/DA	0.05	A	1	0	2001
52	snd/RXT	0.05	D	2001	100	1
53	rcv	0.05	A	1	0	2401
54	snd	0.05	D	2401	100	1
55	rcv	0.06	A	1	0	2501
56	snd	0.06	D	2501	100	1
57	snd	0.06	D	2601	100	1
58	rcv	0.06	A	1	0	2601
59	rcv	0.06	A	1	0	2701
60	drop	0.06	D	2701	100	1
61	drop	0.06	D	2801	100	1
62	snd	0.06	D	2901	100	1
63	snd	0.06	D	3001	28	1
64	rcv/DA	0.07	A	1	0	2701
65	rcv/DA	0.07	A	1	0	2701
66	snd/RXT	0.39	D	2701	100	1
67	rcv	0.40	A	1	0	2801
68	snd/RXT	0.72	D	2801	100	1
69	rcv	0.72	A	1	0	3029
70	snd	0.72	F	3029	0	1
71	rcv	0.72	A	1	0	3030
72	rcv	0.72	F	1	0	3030
73	snd	0.72	A	3030	0	2

```
74  Size of file: 3028
75                Segments transmitted: 39
76                Number of Segments handled by PLD: 35
77                Number of Segments Dropped: 4
78                Number of Segments Corrupted: 0
79                Number of Segments Re-ordered: 0
80                Number of segments Duplicated: 0
81                Number of Segments Delayed: 0
82                Number of Retransmissions due to timeout: 2
83                Number of Fast Retransmissions: 2
84                Number of Duplicate Acknowledgements received: 8
85
```

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Receiver log:

1	rcv	0.0	S	0	0	0
2	snd	0.0	AS	0	0	1
3	rcv	0.001	A	1	0	1
4	rcv	0.001	D	1	100	1
5	snd	0.001	AD	1	0	101
6	rcv	0.002	D	101	100	1
7	snd	0.002	AD	1	0	201
8	rcv	0.002	D	301	100	1
9	snd/DA	0.002	AD	1	0	201
10	rcv	0.004	D	401	100	1
11	snd/DA	0.005	AD	1	0	201
12	rcv	0.005	D	501	100	1
13	snd/DA	0.005	AD	1	0	201
14	rcv	0.006	D	201	100	1
15	snd	0.006	AD	1	0	601
16	rcv	0.008	D	601	100	1
17	snd	0.008	AD	1	0	701
18	rcv	0.009	D	701	100	1
19	snd	0.009	AD	1	0	801
20	rcv	0.011	D	801	100	1
21	snd	0.011	AD	1	0	901
22	rcv	0.012	D	901	100	1
23	snd	0.012	AD	1	0	1001
24	rcv	0.014	D	1001	100	1
25	snd	0.014	AD	1	0	1101
26	rcv	0.015	D	1101	100	1
27	snd	0.015	AD	1	0	1201
28	rcv	0.025	D	1201	100	1
29	snd	0.025	AD	1	0	1301
30	rcv	0.028	D	1301	100	1
31	snd	0.028	AD	1	0	1401
32	rcv	0.031	D	1401	100	1
33	snd	0.031	AD	1	0	1501
34	rcv	0.033	D	1501	100	1
35	snd	0.034	AD	1	0	1601
36	rcv	0.035	D	1601	100	1
37	snd	0.035	AD	1	0	1701
38	rcv	0.037	D	1701	100	1
39	snd	0.037	AD	1	0	1801
40	rcv	0.038	D	1801	100	1
41	snd	0.038	AD	1	0	1901
42	rcv	0.04	D	1901	100	1
43	snd	0.04	AD	1	0	2001
44	rcv	0.044	D	2101	100	1
45	snd/DA	0.044	AD	1	0	2001
46	rcv	0.044	D	2201	100	1
47	snd/DA	0.044	AD	1	0	2001
48	rcv	0.046	D	2301	100	1
49	snd/DA	0.046	AD	1	0	2001
50	rcv	0.047	D	2001	100	1
51	snd	0.047	AD	1	0	2401
52	rcv	0.05	D	2401	100	1
53	snd	0.05	AD	1	0	2501
54	rcv	0.059	D	2501	100	1
55	snd	0.059	AD	1	0	2601
56	rcv	0.06	D	2601	100	1
57	snd	0.06	AD	1	0	2701
58	rcv	0.063	D	2901	100	1
59	snd/DA	0.064	AD	1	0	2701
60	rcv	0.064	D	3001	28	1
61	snd/DA	0.064	AD	1	0	2701
62	rcv	0.385	D	2701	100	1
63	snd	0.385	AD	1	0	2801
64	rcv	0.722	D	2801	100	1
65	snd	0.723	AD	1	0	3029
66	rcv	0.723	F	3029	0	1
67	snd	0.724	A	1	0	3030
68	snd	0.724	F	1	0	3030
69	rcv	0.724	A	3030	0	2

```
Amount of Data Receiver: 3028
                Total Segments Received: 35
                Data segments received: 31
                Data Segments with bit errors: 0
                Duplicate data segments received: 0
                Duplicate Acks sent: 8
```

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Dropout: 0.3
Sender log:

1	snd	0.00	S	0	0	0
2	rcv	0.00	AS	0	0	1
3	snd	0.00	A	1	0	1
4	drop	0.00	D	1	100	1
5	snd	0.00	D	101	100	1
6	snd	0.00	D	201	100	1
7	snd	0.00	D	301	100	1
8	drop	0.00	D	401	100	1
9	rcv/DA	0.01	A	1	0	1
10	rcv/DA	0.03	A	1	0	1
11	rcv/DA	0.05	A	1	0	1
12	drop	0.05	D	1	100	1
13	drop	1.01	D	1	100	1
14	snd/RXT	2.02	D	1	100	1
15	rcv	2.03	A	1	0	401
16	snd	2.04	D	501	100	1
17	drop	2.04	D	601	100	1
18	drop	2.04	D	701	100	1
19	snd	2.04	D	801	100	1
20	rcv/DA	2.05	A	1	0	401
21	rcv/DA	2.05	A	1	0	401
22	snd/RXT	3.05	D	401	100	1
23	rcv	3.05	A	1	0	601
24	drop	3.06	D	901	100	1
25	snd	3.06	D	1001	100	1
26	rcv/DA	3.06	A	1	0	601
27	snd/RXT	4.06	D	601	100	1
28	rcv	4.07	A	1	0	701
29	snd	4.07	D	1101	100	1
30	rcv/DA	4.08	A	1	0	701
31	snd/RXT	5.09	D	701	100	1
32	rcv	5.09	A	1	0	901
33	snd	5.09	D	1201	100	1
34	drop	5.09	D	1301	100	1
35	rcv/DA	5.11	A	1	0	901
36	snd/RXT	6.11	D	901	100	1
37	rcv	6.11	A	1	0	1301
38	drop	6.12	D	1401	100	1
39	drop	6.12	D	1501	100	1
40	snd	6.12	D	1601	100	1
41	snd	6.12	D	1701	100	1
42	rcv/DA	6.13	A	1	0	1301
43	rcv/DA	6.13	A	1	0	1301
44	drop	7.13	D	1301	100	1
45	snd/RXT	8.14	D	1301	100	1
46	rcv	8.14	A	1	0	1401
47	snd	8.14	D	1801	100	1
48	rcv/DA	8.16	A	1	0	1401
49	snd/RXT	9.17	D	1401	100	1
50	rcv	9.18	A	1	0	1501
51	drop	9.18	D	1901	100	1
52	drop	10.19	D	1501	100	1
53	drop	11.20	D	1501	100	1
54	drop	12.21	D	1501	100	1
55	drop	13.22	D	1501	100	1
56	snd/RXT	14.23	D	1501	100	1
57	rcv	14.24	A	1	0	1901
58	snd	14.24	D	2001	100	1
59	snd	14.24	D	2101	100	1
60	snd	14.24	D	2201	100	1
61	snd	14.24	D	2301	100	1
62	rcv/DA	14.26	A	1	0	1901
63	rcv/DA	14.26	A	1	0	1901
64	rcv/DA	14.27	A	1	0	1901
65	drop	14.27	D	1901	100	1
66	rcv/DA	14.27	A	1	0	1901
67	snd/RXT	15.25	D	1901	100	1
68	rcv	15.26	A	1	0	2401
69	drop	15.26	D	2401	100	1
70	drop	15.26	D	2501	100	1
71	drop	15.26	D	2601	100	1
72	snd	15.26	D	2701	100	1
73	snd	15.26	D	2801	100	1
74	rcv/DA	15.28	A	1	0	2401

```
74              rcv/DA      15.28               A            1            0         2401
75              rcv/DA      15.29               A            1            0         2401
76                drop      16.27               D         2401          100            1
77             snd/RXT      17.27               D         2401          100            1
78                 rcv      17.28               A            1            0         2501
79                drop      17.28               D         2901          100            1
80             snd/RXT      18.30               D         2501          100            1
81                 rcv      18.31               A            1            0         2601
82                 snd      18.31               D         3001           28            1
83              rcv/DA      18.33               A            1            0         2601
84                drop      19.32               D         2601          100            1
85             snd/RXT      20.32               D         2601          100            1
86                 rcv      20.34               A            1            0         2901
87                drop      21.35               D         2901          100            1
88             snd/RXT      22.37               D         2901          100            1
89                 rcv      22.38               A            1            0         3029
90                 snd      22.38               F         3029            0            1
91                 rcv      22.38               A            1            0         3030
92                 rcv      22.38               F            1            0         3030
93                 snd      22.38               A         3030            0            2
94    Size of file: 3028
95                 Segments transmitted: 59
96                 Number of Segments handled by PLD: 55
97                 Number of Segments Dropped: 24
98                 Number of Segments Corrupted: 0
99                 Number of Segments Re-ordered: 0
100                Number of segments Duplicated: 0
101                Number of Segments Delayed: 0
102                Number of Retransmissions due to timeout: 22
103                Number of Fast Retransmissions: 2
104                Number of Duplicate Acknowledgements received: 18
```

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Receiver log:

1	rcv	0.0	S	0	0	0
2	snd	0.0	AS	0	0	1
3	rcv	0.0	A	1	0	1
4	rcv	0.001	D	101	100	1
5	snd/DA	0.001	AD	1	0	1
6	rcv	0.001	D	201	100	1
7	snd/DA	0.002	AD	1	0	1
8	rcv	0.002	D	301	100	1
9	snd/DA	0.002	AD	1	0	1
10	rcv	2.019	D	1	100	1
11	snd	2.02	AD	1	0	401
12	rcv	2.035	D	501	100	1
13	snd/DA	2.035	AD	1	0	401
14	rcv	2.044	D	801	100	1
15	snd/DA	2.044	AD	1	0	401
16	rcv	3.046	D	401	100	1
17	snd	3.047	AD	1	0	601
18	rcv	3.055	D	1001	100	1
19	snd/DA	3.055	AD	1	0	601
20	rcv	4.057	D	601	100	1
21	snd	4.057	AD	1	0	701
22	rcv	4.071	D	1101	100	1
23	snd/DA	4.071	AD	1	0	701
24	rcv	5.085	D	701	100	1
25	snd	5.086	AD	1	0	901
26	rcv	5.093	D	1201	100	1
27	snd/DA	5.094	AD	1	0	901
28	rcv	6.106	D	901	100	1
29	snd	6.107	AD	1	0	1301
30	rcv	6.116	D	1601	100	1
31	snd/DA	6.116	AD	1	0	1301
32	rcv	6.116	D	1701	100	1
33	snd/DA	6.116	AD	1	0	1301
34	rcv	8.139	D	1301	100	1
35	snd	8.139	AD	1	0	1401
36	rcv	8.157	D	1801	100	1
37	snd/DA	8.157	AD	1	0	1401
38	rcv	9.169	D	1401	100	1
39	snd	9.169	AD	1	0	1501
40	rcv	14.232	D	1501	100	1
41	snd	14.232	AD	1	0	1901
42	rcv	14.24	D	2001	100	1
43	snd/DA	14.24	AD	1	0	1901
44	rcv	14.24	D	2101	100	1
45	snd/DA	14.24	AD	1	0	1901
46	rcv	14.24	D	2201	100	1
47	snd/DA	14.241	AD	1	0	1901
48	rcv	14.241	D	2301	100	1
49	snd/DA	14.241	AD	1	0	1901
50	rcv	15.251	D	1901	100	1
51	snd	15.251	AD	1	0	2401
52	rcv	15.26	D	2701	100	1
53	snd/DA	15.26	AD	1	0	2401
54	rcv	15.26	D	2801	100	1
55	snd/DA	15.26	AD	1	0	2401
56	rcv	17.269	D	2401	100	1
57	snd	17.269	AD	1	0	2501
58	rcv	18.295	D	2501	100	1
59	snd	18.295	AD	1	0	2601
60	rcv	18.309	D	3001	28	1
61	snd/DA	18.309	AD	1	0	2601
62	rcv	20.322	D	2601	100	1
63	snd	20.323	AD	1	0	2901
64	rcv	22.367	D	2901	100	1
65	snd	22.367	AD	1	0	3029
66	rcv	22.381	F	3029	0	1
67	snd	22.381	A	1	0	3030
68	snd	22.381	F	1	0	3030
69	rcv	22.381	A	3030	0	2

```
70  Amount of Data Receiver: 3028
71                  Total Segments Received: 35
72                  Data segments received: 31
73                  Data Segments with bit errors: 0
74                  Duplicate data segments received: 0
75                  Duplicate Acks sent: 18
76
```

Q5 (c)

Sender log:
First 20 logs:

1	snd	0.00	S	0	0	0
2	rcv	0.00	AS	0	0	1
3	snd	0.00	A	1	0	1
4	snd/corr	0.02	D	1	50	1
5	rcv/DA	0.02	A	1	0	1
6	snd	0.03	D	51	50	1
7	rcv/DA	0.03	A	1	0	1
8	snd	0.03	D	101	50	1
9	snd	0.03	D	151	50	1
10	snd	0.03	D	201	50	1
11	rcv/DA	0.03	A	1	0	1
12	snd	0.03	D	1	50	1
13	snd/dup	0.03	D	1	50	1
14	rcv/DA	0.03	A	1	0	1
15	rcv/DA	0.03	A	1	0	1
16	rcv	0.03	A	1	0	251
17	rcv/DA	0.03	A	1	0	251
18	snd	0.03	D	251	50	1
19	rcv	0.03	A	1	0	301
20	snd/corr	0.04	D	301	50	1

Last 20 logs:

89745	rcv/DA	149.30	A	1	0	1605101
89746	snd	149.30	D	1605351	50	1
89747	snd	149.30	D	1605401	50	1
89748	rcv/DA	149.30	A	1	0	1605101
89749	rcv/DA	149.30	A	1	0	1605101
89750	snd/RXT	149.30	D	1605101	50	1
89751	snd/rord	149.30	D	1605101	50	1
89752	rcv	149.30	A	1	0	1605451
89753	rcv/DA	149.30	A	1	0	1605451
89754	snd	149.30	D	1605451	50	1
89755	snd/dup	149.30	D	1605451	50	1
89756	rcv	149.31	A	1	0	1605501
89757	rcv/DA	149.31	A	1	0	1605501
89758	snd	149.31	D	1605501	50	1
89759	rcv	149.31	A	1	0	1605551
89760	snd	149.31	D	1605551	35	1
89761	rcv	149.33	A	1	0	1605586
89762	snd	149.33	F	1605586	0	1
89763	rcv	149.33	A	1	0	1605587
89764	rcv	149.33	F	1	0	1605587
89765	snd	149.33	A	1605587	0	2

COMP3331 Assignment 1 Report
Student Id: z5117018

Receiver log:

First 20 logs:

1	rcv	0.0	S	0	0	0
2	snd	0.0	AS	0	0	1
3	rcv	0.001	A	1	0	1
4	rcv/corr	0.022	D	1	50	1
5	snd/DA	0.022	AD	1	0	1
6	rcv	0.026	D	51	50	1
7	snd/DA	0.027	AD	1	0	1
8	rcv	0.029	D	101	50	1
9	snd/DA	0.029	AD	1	0	1
10	rcv	0.029	D	151	50	1
11	snd/DA	0.029	AD	1	0	1
12	rcv	0.029	D	201	50	1
13	snd/DA	0.03	AD	1	0	1
14	rcv	0.03	D	1	50	1
15	snd	0.03	AD	1	0	251
16	rcv	0.03	D	1	50	1
17	snd/DA	0.03	AD	1	0	251
18	rcv	0.032	D	251	50	1
19	snd	0.032	AD	1	0	301
20	rcv/corr	0.035	D	301	50	1

Last 20 logs:

85357	snd/DA	149.295	AD	1	0	1605101
85358	rcv	149.297	D	1605351	50	1
85359	snd/DA	149.297	AD	1	0	1605101
85360	rcv	149.298	D	1605401	50	1
85361	snd/DA	149.298	AD	1	0	1605101
85362	rcv	149.299	D	1605101	50	1
85363	snd	149.299	AD	1	0	1605451
85364	rcv	149.3	D	1605101	50	1
85365	snd/DA	149.3	AD	1	0	1605451
85366	rcv	149.303	D	1605451	50	1
85367	snd	149.303	AD	1	0	1605501
85368	rcv	149.304	D	1605451	50	1
85369	snd/DA	149.304	AD	1	0	1605501
85370	rcv	149.308	D	1605501	50	1
85371	snd	149.308	AD	1	0	1605551
85372	rcv	149.311	D	1605551	35	1
85373	snd	149.311	AD	1	0	1605586
85374	rcv	149.329	F	1605586	0	1
85375	snd	149.329	A	1	0	1605587
85376	snd	149.33	F	1	0	1605587
85377	rcv	149.33	A	1605587	0	2