

1.0 Overview of Sender

The implementation for the data transfer logic of Sender is based on the *Simplified TCP Sender* available in the textbook under Figure 3.33. The Sender keeps a window which contains all the packets that have been sent and not yet acknowledge. After connection is established via the 3-way handshake, the sender sits in a loop waiting for 3 events: 1. when there's space in the window and data available to be sent ($\text{nextSeqNum} - \text{sendBase} < \text{mws}$), 2. when an ack has been received and 3. when a timeout event has occurred. When there is space in window, that amount of data is read from file, chunked into mss and placed in segments which are sent and then added to the send window. When an ack is received, all segments with sequence numbers less than the ackNum are removed from the send window. If the ackNum \leq the lowest seqNum of the unacked segments then it is considered a duplicate ack. 3 duplicate acks for the same packet result in fast retransmission of that packet. Lastly, when a timeout event occurs, the sender will immediately resend the first packet in the send window. (see section 1.3 for details on timer implementation)

1.1 Overview of Receiver

After the 3 way handshake, the receiver sits in a loop waiting for packets to arrive. There are 5 main cases/packets which the receiver must handle: a corrupt packet, a fin packet, a duplicate packet, an in-order packet and an out of order packet. The receiver will first check if it is a corrupt packet via the checksum. Corrupt packets are immediately discarded. No acknowledgement is sent for them, since none of the data contained can be trusted. Next it'll check if it is a fin packet in which case it'll break from the loop and begin the teardown process. It'll then check if the packet is a duplicate by checking if the sequence number $<$ receiver's ackNum. For duplicate packets, the receiver simply acks back the current ackNum. Receiver then checks if the packet has arrived out of order. An out of order packet is detected when its sequence number $>$ receiver's ackNum. Out of order packets are buffered in the receiver's buffer. An ack is sent to the sender with an unchanged ackNum. Finally, when an in-order packet arrives ($\text{seqNum} == \text{ackNum}$), then it is added to the buffer and all sequential packets are flushed and written to file. A cumulative ack is sent for all the packets that were written to file from buffer (increase ackNum by number of bytes written).

1.2 STP Segment / Header

32 bit sequence number	
32 bit acknowledgement number	
16 bit flags [FIN DATA ACK SYN]	16 bit checksum

STP Header Diagram

For the STP protocol, the sender and receiver communicate by sending STPSegments through UDP. The STPSegment includes a 12 byte header and up to MSS amount of data. The 12 byte header contains a sequence number, acknowledgement number, a flags field and a checksum. The **sequence number** is the index of the first byte in the data byte-stream being sent. The **acknowledge number** is the next byte that the receiver is expecting. The **checksum** is used to check that the data in the segment has not been corrupted. The sender calculates the checksum and places it the header of the STPSegment by summing the chunks of 16 bits of the segment and taking its one's compliment. The **flags field** describes the type of the segment. Although it is 16 bit field, only the first four bits are used. These bits correspond to the segment's type syn, ack, data and/or fin.

1.3 List of Implemented Features

Sequence Numbers, Cumulative Acks, Checksum, Three way handshake, Four Segment Teardown

Sender window / pipelining

The sender can send up to Maximum Window Size (MWS) bytes of unacknowledged data to the receiver. The sender does this by keeping a window of segments that have been sent such that the sum of the segment data length < MWS. Whenever an acknowledgement is received, segments with a sequence numbers less than the acknowledgement number are removed from the window. This makes room for new segments to be sent and added to the window.

Timer / timeout

The timeout interval is how long the Sender will wait for an ack before it considers a packet lost and retransmits it. When timeout occurs, the sender will retransmit the first packet in its window. For the sample RTT, the sender will initially time the first segment in it's send window. Sender will start the timer when that segment is first sent and stop it when it is acknowledge. If that packet is selected for RXT either due to timeout or dupAcks, then that sample is discarded. The next sample is taken for the next segment that is added to the window.

Fast retransmission

When the Sender receives 3 duplicates acknowledgements for a packet.

Receive buffer

The receiver buffers segments that arrive out of order to ensure that bandwidth capacity isn't wasted. Specifically, the receiver places these segments in a priority queue (ordered by sequence number) and will flush / write the first segment if its sequence number equals the current

acknowledgement number. After each flush, receiver will send back a cumulative acknowledgement for all in order data segments that were written the file.

1.4 Design Tradeoffs

File Chunking

In my implementation the reading and chunking of the data file into individual segments is done on demand. Whenever the last-byte-acked - last-byte-sent < mws, the sender will read in bytes of data into segments until this is no longer true. Another option would have been to pre-read and chunk the entire file and place them all into a send queue. This would've been perhaps easier to implement but is bad for large files since it would use up a lot of memory space.

Multi-threading

My implementation uses a single-thread for sending and receiving data. The sender will send any unsent packets within the window size and await for acks. Better utilisation can be achieved by using a multi-threaded implementation where the Sender is both sending and receiving packets at the same time. In a single-threaded implementation, when sending out a window of packets, an ack can only be received after the entire window is sent. In many cases, it should be received in between packets sent being sent out in the window. This actually effects the occurrence of fast retransmit since loss isn't detected until the entire window has been sent out. This is worse for large window sizes. In a multi-threaded implementation, you can detect packet loss via fast retransmission ideally within having sent out 3 successful in-order packets. In a single threaded, you have to wait for at least the entire window to be sent.

2.0 Program Test Questions

A. See figures 1-4 in appendix

Drop 0.3 took 37.46s compared to 0.1's 0.05s. The main reason drop 0.3 took so long is that none of the drops resulted in fast retransmits. This is because the window size is too small and drop rate too high. The maximum number of sequential packets is 5 in the beginning. But because the first window has multiple drops, every drop in the window results in a timeout. At this point the timeout interval is 1.62s (we initialise estimatedRTT = 500 and devRTT = 250 as per the spec). If you refer to the overall sender_log.txt for pDrop = 0.3 it can be seen that the Sender never receives more than 2 duplicate acks for a packets + the initial ack for that number. Besides the initial send, the sender never sends more than 2 successful INORDER packets. On the other hand, pDrop=0.1 is significantly faster because it doesn't have any timeouts because the drop rate is so small. A drop is always followed by 3 successful in order packets leading to a fast retransmit.

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Test 1 (pDrop = 0.1)	Test 2 (pDrop = 0.3)
0	0
1	1
1	1
<drop 101>	<drop 101>
201	201
301	<drop 301>
401	<drop 401>
501	<drop 501>
101	101
601	<drop 601>
701	701
801	<drop 301 RXT>
901	301
1001	801
1101	<drop 401 RXT>
1201	401
1301	<drop 901>
1401	501
1501	1001
1601	601
1701	<drop 1101>
1801	1201
<1901 dropped>	901
.	.
.	.
.	.
3030	3030

B. See figures 5-10 in appendix

Gamma	STP Packets Transferred	Overall Transfer Time (sec)	Overall Transfer Time (mins)
2	12181	6654.56	110.9
4	12181	10134.58	168.9
6	12181	14025.87	233.8

Overall each of the gamma values results in the same amount of packets transferred, since they have the same probability for corrupt, drop, reorder of packets. However, the time taken between the tests varies a substantially. The algorithm for calculating timeout is: **TimeoutInterval = EstimatedRTT + gamma * DevRTT**. This means a larger gamma makes the timeout interval much larger than estimatedRTT. Therefore retransmissions due to packet loss or corruption would take much longer to occur, dramatically increasing the overall transfer time. On the other hand, a

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smaller gamma makes the timeout interval much closer to the estimatedRTT. The time between the loss of a packet and its timeout retransmission is much smaller. This decreases the overall time.

C. See figures 11 & 12 in appendix

The file test2.pdf was successfully transferred. Overall it took **85.25 seconds**. The time is mostly effected by the occurrence of timer timeouts which is mostly effected by the occurrence of pCorrupt and pDrop. I have concluded this based on the following reasons:

- pDuplicate has little effect on the overall time because there is no need for Sender to resend anything in that case. The receiver simply has to drop the duplicate packet and no timeout occurs.
- pOrder has more of an effect on the overall time than pDuplicate because reordering of packets at the end of a window causes timeouts. Since the maxOrder is 4 and the window size is equivalent to 10 packets ($500 \text{ mws} / 50 = 10 \text{ packets}$), timeout happens only for the last 3 packets. All other reorders would result in a fast retransmit if the subsequence 3 packets are reliably sent. A reorder is also better than a drop and corrupt packet (even when window is smaller than maxOrder) because it will at worst still generate a duplicate ack from the Receiver which increases the chance of fast retransmission occurring (instead of a timeout). For example packet 1551 below generates a duplicate ack allowing for retransmit of 1301. If 1551 was instead dropped or corrupted then there would've been a timeout instead increasing the overall transfer time.

snd/RXT	8.17	D	1051	50	1
rcv	8.17	A	1	0	1301
snd	8.18	D	1601	50	1
snd	8.18	D	1651	50	1
drop	8.18	D	1701	50	1
drop	8.18	D	1751	50	1
rcv/DA	8.18	A	1	0	1301
rcv/DA	8.18	A	1	0	1301
snd/rord	9.80	D	1551	50	1
rcv/DA	9.80	A	1	0	1301
snd/RXT	9.80	D	1301	50	1

- A drop is more critical than a reorder because it will almost always result in a timeout unless three succeeding packets in the sending window make it for fast retransmission. The impact of drops is exacerbated when it occurs multiple times in a window because they don't result in an ack of any sort. This decreases the chance of fast retransmit occurring. For example in a window of 10 packets if the first 4 are dropped and the next 6 are sent - only the first two packets will be fast retransmitted. The next two will cause timeouts.
- pCorrupt has a significant effect on the overall time for the same reasons to pDrop. In addition to this pCorrupt is slightly worse than pDrop because a corrupted packet wastes bandwidth and time on the receiver end being processed, deserialised, checking checksum etc.

3.0 Appendix

Question A. Log Files

Figure 1. Sender_log.txt for transfer of test0.pdf with pDrop=0.1

snd	0.00	S	0	0	0
rcv	0.02	S/A	0	0	1
snd	0.02	A	1	0	1
snd	0.02	D	1	100	1
drop	0.02	D	101	100	1
snd	0.02	D	201	100	1
snd	0.02	D	301	100	1
snd	0.02	D	401	100	1
rcv	0.02	A	1	0	101
snd	0.02	D	501	100	1
rcv/DA	0.03	A	1	0	101
rcv/DA	0.03	A	1	0	101
rcv/DA	0.03	A	1	0	101
snd/RXT	0.03	D	101	100	1
rcv/DA	0.03	A	1	0	101
rcv	0.03	A	1	0	601
snd	0.03	D	601	100	1
snd	0.03	D	701	100	1
snd	0.03	D	801	100	1
snd	0.03	D	901	100	1
snd	0.03	D	1001	100	1
rcv	0.03	A	1	0	701
snd	0.03	D	1101	100	1
rcv	0.03	A	1	0	801
snd	0.03	D	1201	100	1
rcv	0.03	A	1	0	901
snd	0.03	D	1301	100	1
rcv	0.03	A	1	0	1001
snd	0.03	D	1401	100	1
rcv	0.03	A	1	0	1101
snd	0.03	D	1501	100	1
rcv	0.03	A	1	0	1201
snd	0.03	D	1601	100	1
rcv	0.03	A	1	0	1301
snd	0.03	D	1701	100	1
rcv	0.03	A	1	0	1401
snd	0.03	D	1801	100	1
rcv	0.03	A	1	0	1501
drop	0.04	D	1901	100	1
rcv	0.04	A	1	0	1601
snd	0.04	D	2001	100	1
rcv	0.04	A	1	0	1701
snd	0.04	D	2101	100	1
rcv	0.04	A	1	0	1801
snd	0.04	D	2201	100	1
rcv	0.04	A	1	0	1901
snd	0.04	D	2301	100	1
rcv/DA	0.04	A	1	0	1901
rcv/DA	0.04	A	1	0	1901
rcv/DA	0.04	A	1	0	1901
snd/RXT	0.04	D	1901	100	1
rcv/DA	0.04	A	1	0	1901
rcv	0.04	A	1	0	2401
snd	0.04	D	2401	100	1
snd	0.04	D	2501	100	1
snd	0.04	D	2601	100	1
snd	0.04	D	2701	100	1
snd	0.04	D	2801	100	1

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rcv          0.04          A      1      0      2501
snd          0.04          D    2901 100      1
rcv          0.04          A      1      0      2601
snd          0.04          D    3001 28       1
rcv          0.04          A      1      0      2701
rcv          0.04          A      1      0      2801
rcv          0.04          A      1      0      2901
rcv          0.04          A      1      0      3001
rcv          0.04          A      1      0      3029
snd          0.04          F    3029 0        1
rcv          0.05          A      1      0      3030
rcv          0.05          F      1      0      3030
snd          0.05          A    3030 0        2
=====

```

```

Size of the file(in Bytes)      3028
Segments transmitted (including drop & RXT) 37
Number of Segments handled by PLD 33
Number of Segments dropped      2
Number of Segments Corrupted    0
Number of Segments Re-ordered   0
Number of Segments Duplicated   0
Number of Segments Delayed      0
Number of Retransmissions due to TIMEOUT 0
Number of FAST RETRANSMISSION  2
Number of DUP ACKS received     8
=====

```

Figure 2. Receiver_log.txt for transfer of test0.pdf with pDrop=0.1

```

rcv          0.00          S      0      0      0
snd          0.02          S/A    0      0      1
rcv          0.02          A      1      0      1
rcv          0.02          D      1    100     1
snd          0.02          A      1      0    101
rcv          0.02          D    201    100     1
snd/DA       0.02          A      1      0    101
rcv          0.02          D    301    100     1
snd/DA       0.02          A      1      0    101
rcv          0.02          D    401    100     1
snd/DA       0.03          A      1      0    101
rcv          0.03          D    501    100     1
snd/DA       0.03          A      1      0    101
rcv          0.03          D    101    100     1
snd          0.03          A      1      0    601
rcv          0.03          D    601    100     1
snd          0.03          A      1      0    701
rcv          0.03          D    701    100     1
snd          0.03          A      1      0    801
rcv          0.03          D    801    100     1
snd          0.03          A      1      0    901
rcv          0.03          D    901    100     1
snd          0.03          A      1      0   1001
rcv          0.03          D   1001    100     1
snd          0.03          A      1      0   1101
rcv          0.03          D   1101    100     1
snd          0.03          A      1      0   1201
rcv          0.03          D   1201    100     1
snd          0.03          A      1      0   1301
rcv          0.03          D   1301    100     1
snd          0.03          A      1      0   1401
rcv          0.03          D   1401    100     1
snd          0.03          A      1      0   1501
rcv          0.03          D   1501    100     1
snd          0.04          A      1      0   1601
rcv          0.04          D   1601    100     1
snd          0.04          A      1      0   1701

```

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```

rcv          0.04          D    1701 100 1
snd          0.04          A     1   0 1801
rcv          0.04          D    1801 100 1
snd          0.04          A     1   0 1901
rcv          0.04          D    2001 100 1
snd/DA       0.04          A     1   0 1901
rcv          0.04          D    2101 100 1
snd/DA       0.04          A     1   0 1901
rcv          0.04          D    2201 100 1
snd/DA       0.04          A     1   0 1901
rcv          0.04          D    2301 100 1
snd/DA       0.04          A     1   0 1901
rcv          0.04          D    1901 100 1
snd          0.04          A     1   0 2401
rcv          0.04          D    2401 100 1
snd          0.04          A     1   0 2501
rcv          0.04          D    2501 100 1
snd          0.04          A     1   0 2601
rcv          0.04          D    2601 100 1
snd          0.04          A     1   0 2701
rcv          0.04          D    2701 100 1
snd          0.04          A     1   0 2801
rcv          0.04          D    2801 100 1
snd          0.04          A     1   0 2901
rcv          0.04          D    2901 100 1
snd          0.04          A     1   0 3001
rcv          0.04          D    3001 28 1
snd          0.04          A     1   0 3029
rcv          0.04          F    3029 0 1
snd          0.05          A     1   0 3030
snd          0.05          F     1   0 3030
rcv          0.05          A    3030 0 2
=====
Amount of data received (bytes) 3028
Total Segments Received      35
Data segments received      31
Data segments with Bit Errors 0
Duplicate data segments received 0
Duplicate ACKs sent          8
=====

```

Figure 3. Sender_log.txt for transfer of test0.pdf with pDrop=0.3

```

snd          0.00          S     0   0 0
rcv          0.02          S/A    0   0 1
snd          0.02          A     1   0 1
snd          0.02          D     1  100 1
drop         0.03          D    101 100 1
snd          0.03          D    201 100 1
drop         0.03          D    301 100 1
drop         0.03          D    401 100 1
rcv          0.03          A     1   0 101
drop         0.03          D    501 100 1
rcv/DA       0.03          A     1   0 101
snd/RXT      1.65          D    101 100 1
rcv          1.65          A     1   0 301
drop         1.65          D    601 100 1
snd          1.65          D    701 100 1
rcv/DA       1.66          A     1   0 301
drop/RXT     3.28          D    301 100 1
snd/RXT      4.91          D    301 100 1
rcv          4.91          A     1   0 401
snd          4.91          D    801 100 1
rcv/DA       4.91          A     1   0 401
drop/RXT     6.54          D    401 100 1
snd/RXT      8.17          D    401 100 1

```


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rcv	8.17	A	1	0	501
drop	8.17	D	901	100	1
snd/RXT	9.79	D	501	100	1
rcv	9.79	A	1	0	601
snd	9.79	D	1001	100	1
rcv/DA	9.79	A	1	0	601
snd/RXT	11.42	D	601	100	1
rcv	11.42	A	1	0	901
drop	11.42	D	1101	100	1
snd	11.42	D	1201	100	1
drop	11.42	D	1301	100	1
rcv/DA	11.42	A	1	0	901
snd/RXT	13.05	D	901	100	1
rcv	13.05	A	1	0	1101
snd	13.05	D	1401	100	1
snd	13.05	D	1501	100	1
rcv/DA	13.05	A	1	0	1101
rcv/DA	13.05	A	1	0	1101
drop/RXT	14.68	D	1101	100	1
drop/RXT	16.30	D	1101	100	1
snd/RXT	17.93	D	1101	100	1
rcv	17.93	A	1	0	1301
snd	17.93	D	1601	100	1
drop	17.93	D	1701	100	1
rcv/DA	17.93	A	1	0	1301
drop/RXT	19.56	D	1301	100	1
snd/RXT	21.19	D	1301	100	1
rcv	21.19	A	1	0	1701
drop	21.19	D	1801	100	1
snd	21.19	D	1901	100	1
drop	21.19	D	2001	100	1
snd	21.19	D	2101	100	1
rcv/DA	21.19	A	1	0	1701
rcv/DA	21.19	A	1	0	1701
drop/RXT	22.82	D	1701	100	1
drop/RXT	24.44	D	1701	100	1
snd/RXT	26.07	D	1701	100	1
rcv	26.07	A	1	0	1801
drop	26.07	D	2201	100	1
snd/RXT	27.70	D	1801	100	1
rcv	27.70	A	1	0	2001
snd	27.70	D	2301	100	1
drop	27.70	D	2401	100	1
rcv/DA	27.70	A	1	0	2001
snd/RXT	29.32	D	2001	100	1
rcv	29.32	A	1	0	2201
snd	29.32	D	2501	100	1
snd	29.32	D	2601	100	1
rcv/DA	29.33	A	1	0	2201
rcv/DA	29.33	A	1	0	2201
snd/RXT	30.95	D	2201	100	1
rcv	30.95	A	1	0	2401
drop	30.95	D	2701	100	1
drop	30.95	D	2801	100	1
snd/RXT	32.58	D	2401	100	1
rcv	32.58	A	1	0	2701
snd	32.58	D	2901	100	1
drop	32.58	D	3001	28	1
rcv/DA	32.58	A	1	0	2701
snd/RXT	34.21	D	2701	100	1
rcv	34.21	A	1	0	2801
snd/RXT	35.83	D	2801	100	1
rcv	35.84	A	1	0	3001
snd/RXT	37.46	D	3001	28	1
rcv	37.46	A	1	0	3029
snd	37.46	F	3029	0	1
rcv	37.46	A	1	0	3030
rcv	37.46	F	1	0	3030
snd	37.46	A	3030	0	2

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```

=====
Size of the file(in Bytes)      3028
Segments transmitted (including drop & RXT) 58
Number of Segments handled by PLD 54
Number of Segments dropped      23
Number of Segments Corrupted    0
Number of Segments Re-ordered   0
Number of Segments Duplicated   0
Number of Segments Delayed      0
Number of Retransmissions due to TIMEOUT 23
Number of FAST RETRANSMISSION  0
Number of DUP ACKS received     14
=====

```

Figure 4. Receiver_log.txt for transfer of test0.pdf with pDrop=0.3

```

rcv          0.00          S    0    0    0
snd          0.02          S/A  0    0    1
rcv          0.02          A    1    0    1
rcv          0.02          D    1   100  1
snd          0.02          A    1    0   101
rcv          0.03          D   201  100  1
snd/DA       0.03          A    1    0   101
rcv          1.65          D   101  100  1
snd          1.65          A    1    0   301
rcv          1.65          D   701  100  1
snd/DA       1.65          A    1    0   301
rcv          4.91          D   301  100  1
snd          4.91          A    1    0   401
rcv          4.91          D   801  100  1
snd/DA       4.91          A    1    0   401
rcv          8.17          D   401  100  1
snd          8.17          A    1    0   501
rcv          9.79          D   501  100  1
snd          9.79          A    1    0   601
rcv          9.79          D  1001  100  1
snd/DA       9.79          A    1    0   601
rcv          11.42         D   601  100  1
snd          11.42         A    1    0   901
rcv          11.42         D  1201  100  1
snd/DA       11.42         A    1    0   901
rcv          13.05         D   901  100  1
snd          13.05         A    1    0  1101
rcv          13.05         D  1401  100  1
snd/DA       13.05         A    1    0  1101
rcv          13.05         D  1501  100  1
snd/DA       13.05         A    1    0  1101
rcv          17.93         D  1101  100  1
snd          17.93         A    1    0  1301
rcv          17.93         D  1601  100  1
snd/DA       17.93         A    1    0  1301
rcv          21.19         D  1301  100  1
snd          21.19         A    1    0  1701
rcv          21.19         D  1901  100  1
snd/DA       21.19         A    1    0  1701
rcv          21.19         D  2101  100  1
snd/DA       21.19         A    1    0  1701
rcv          26.07         D  1701  100  1
snd          26.07         A    1    0  1801
rcv          27.70         D  1801  100  1
snd          27.70         A    1    0  2001
rcv          27.70         D  2301  100  1
snd/DA       27.70         A    1    0  2001
rcv          29.32         D  2001  100  1
snd          29.32         A    1    0  2201
rcv          29.32         D  2501  100  1
snd/DA       29.32         A    1    0  2201

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rcv	29.32	D	2601	100	1
snd/DA	29.32	A	1	0	2201
rcv	30.95	D	2201	100	1
snd	30.95	A	1	0	2401
rcv	32.58	D	2401	100	1
snd	32.58	A	1	0	2701
rcv	32.58	D	2901	100	1
snd/DA	32.58	A	1	0	2701
rcv	34.21	D	2701	100	1
snd	34.21	A	1	0	2801
rcv	35.83	D	2801	100	1
snd	35.83	A	1	0	3001
rcv	37.46	D	3001	28	1
snd	37.46	A	1	0	3029
rcv	37.46	F	3029	0	1
snd	37.46	A	1	0	3030
snd	37.46	F	1	0	3030
rcv	37.46	A	3030	0	2

```

=====
Amount of data received (bytes) 3028
Total Segments Received      35
Data segments received       31
Data segments with Bit Errors 0
Duplicate data segments received 0
Duplicate ACKs sent          14
=====

```

Question B. Log Files

Figure 5. Sender_log.txt for test1.pdf with gamma = 2 (only first and last 20 logs)

```

snd          0.00          S      0      0      0
rcv          0.02        S/A      0      0      1
snd          0.02          A      1      0      1
snd          0.03          D      1     50      1
drop         0.03          D     51     50      1
snd          0.03          D    101     50      1
drop         0.03          D    151     50      1
snd          0.03          D    201     50      1
snd          0.03          D    251     50      1
snd          0.03          D    301     50      1
drop         0.03          D    351     50      1
snd          0.03          D    401     50      1
snd          0.03          D    451     50      1
rcv          0.03          A      1      0     51
rcv/DA       0.03          A      1      0     51
rcv/DA       0.03          A      1      0     51
rcv/DA       0.03          A      1      0     51
snd/RXT      0.03          D     51     50      1
rcv/DA       0.03          A      1      0     51
rcv/DA       0.03          A      1      0     51
.
.
.
drop/RXT     6646.75        D   307651  50      1
drop/RXT     6647.86        D   307651  50      1
snd/RXT      6648.98        D   307651  50      1
rcv          6648.98        A      1      0   307801
drop         6648.98        D   308151  50      1
snd          6648.98        D   308201  3       1
rcv/DA       6648.98        A      1      0   307801
snd/RXT      6650.09        D   307801  50      1
rcv          6650.09        A      1      0   308001
snd/RXT      6651.21        D   308001  50      1
rcv          6651.21        A      1      0   308051
drop/RXT     6652.32        D   308051  50      1
snd/RXT      6653.44        D   308051  50      1
rcv          6653.44        A      1      0   308151
snd/RXT      6654.56        D   308151  50      1
rcv          6654.56        A      1      0   308204
snd          6654.56        F   308204  0       1
rcv          6654.56        A      1      0   308205
rcv          6654.56        F      1      0   308205
snd          6654.56        A   308205  0       2
=====
Size of the file(in Bytes)      308203
Segments transmitted (including drop & RXT) 12181
Number of Segments handled by PLD 12177
Number of Segments dropped      6010
Number of Segments Corrupted    0
Number of Segments Re-ordered    0
Number of Segments Duplicated    0
Number of Segments Delayed      1171
Number of Retransmissions due to TIMEOUT 5771
Number of FAST RETRANSMISSION    241
Number of DUP ACKS received      3100
=====

```

Assignment for Session 2, 2018 Report

Figure 6. Receiver_log.txt for test1.pdf with gamma = 2 (only first and last 20 logs)

```

rcv      0.00      S      0      0      0
snd      0.02      S/A    0      0      1
rcv      0.02      A      1      0      1
rcv      0.03      D      1      50     1
snd      0.03      A      1      0     51
rcv      0.03      D     101     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D     201     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D     251     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D     301     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D     401     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D     451     50     1
snd/DA    0.03      A      1      0     51
rcv      0.03      D      51     50     1
snd      0.03      A      1      0    151
rcv      0.09      D     501     50     1
.
.
.
snd      6643.22    A      1      0    307501
rcv      6643.22    D    307951  50      1
snd/DA    6643.22    A      1      0    307501
rcv      6644.34    D    307501  50      1
snd      6644.34    A      1      0    307551
rcv      6645.46    D    307551  50      1
snd      6645.46    A      1      0    307651
rcv      6645.63    D    308101  50      1
snd/DA    6645.63    A      1      0    307651
rcv      6648.98    D    307651  50      1
snd      6648.98    A      1      0    307801
rcv      6648.98    D    308201  3       1
snd/DA    6648.98    A      1      0    307801
rcv      6650.09    D    307801  50      1
snd      6650.09    A      1      0    308001
rcv      6651.20    D    308001  50      1
snd      6651.21    A      1      0    308051
rcv      6653.44    D    308051  50      1
snd      6653.44    A      1      0    308151
rcv      6654.56    D    308151  50      1
snd      6654.56    A      1      0    308204
rcv      6654.56    F    308204  0       1
snd      6654.56    A      1      0    308205
snd      6654.56    F      1      0    308205
rcv      6654.56    A    308205  0       2
=====
Amount of data received (bytes) 308303
Total Segments Received      6171
Data segments received      6167
Data segments with Bit Errors 0
Duplicate data segments received 2
Duplicate ACKs sent        3100
=====

```

Assignment for Session 2, 2018 Report

Figure 7. Sender_log.txt for test1.pdf with gamma = 4 (only first and last 20 logs)

```

snd          0.00          S    0    0    0
rcv          0.02          S/A  0    0    1
snd          0.02          A    1    0    1
snd          0.02          D    1   50    1
drop         0.02          D   51   50    1
snd          0.02          D   101  50    1
drop         0.02          D   151  50    1
snd          0.02          D   201  50    1
snd          0.02          D   251  50    1
snd          0.02          D   301  50    1
drop         0.02          D   351  50    1
snd          0.03          D   401  50    1
snd          0.03          D   451  50    1
rcv          0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
snd/RXT      0.03          D   51   50    1
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
.
.
.
drop/RXT     10122.39       D  307651 50    1
drop/RXT     10124.13       D  307651 50    1
snd/RXT      10125.87       D  307651 50    1
rcv          10125.87       A    1    0  307801
drop         10125.87       D  308151 50    1
snd          10125.87       D  308201 3     1
rcv/DA       10125.87       A    1    0  307801
snd/RXT      10127.61       D  307801 50    1
rcv          10127.61       A    1    0  308001
snd/RXT      10129.35       D  308001 50    1
rcv          10129.36       A    1    0  308051
drop/RXT     10131.10       D  308051 50    1
snd/RXT      10132.84       D  308051 50    1
rcv          10132.84       A    1    0  308151
snd/RXT      10134.58       D  308151 50    1
rcv          10134.58       A    1    0  308204
snd          10134.58       F  308204 0     1
rcv          10134.58       A    1    0  308205
rcv          10134.58       F    1    0  308205
snd          10134.58       A  308205 0     2
=====
Size of the file(in Bytes)      308203
Segments transmitted (including drop & RXT) 12181
Number of Segments handled by PLD 12177
Number of Segments dropped      6010
Number of Segments Corrupted    0
Number of Segments Re-ordered    0
Number of Segments Duplicated    0
Number of Segments Delayed      1171
Number of Retransmissions due to TIMEOUT 5771
Number of FAST RETRANSMISSION  241
Number of DUP ACKS received     3100
=====

```

Assignment for Session 2, 2018 Report

Figure 8. Receiver_log.txt for test1.pdf with gamma = 4 (only first and last 20 logs)

```

rcv          0.00          S    0    0    0
snd          0.02          S/A  0    0    1
rcv          0.02          A    1    0    1
rcv          0.02          D    1   50    1
snd          0.02          A    1    0   51
rcv          0.02          D   101  50    1
snd/DA       0.02          A    1    0   51
rcv          0.02          D   201  50    1
snd/DA       0.02          A    1    0   51
rcv          0.02          D   251  50    1
snd/DA       0.02          A    1    0   51
rcv          0.03          D   301  50    1
snd/DA       0.03          A    1    0   51
rcv          0.03          D   401  50    1
snd/DA       0.03          A    1    0   51
rcv          0.03          D   451  50    1
snd/DA       0.03          A    1    0   51
rcv          0.03          D    51  50    1
snd          0.03          A    1    0  151
rcv          0.32          D   501  50    1
.
.
.
snd          10116.62       A    1    0  307501
rcv          10116.62       D  307951 50    1
snd/DA       10116.62       A    1    0  307501
rcv          10118.36       D  307501 50    1
snd          10118.36       A    1    0  307551
rcv          10120.10       D  307551 50    1
snd          10120.10       A    1    0  307651
rcv          10120.64       D  308101 50    1
snd/DA       10120.64       A    1    0  307651
rcv          10125.87       D  307651 50    1
snd          10125.87       A    1    0  307801
rcv          10125.87       D  308201 3    1
snd/DA       10125.87       A    1    0  307801
rcv          10127.61       D  307801 50    1
snd          10127.61       A    1    0  308001
rcv          10129.35       D  308001 50    1
snd          10129.35       A    1    0  308051
rcv          10132.84       D  308051 50    1
snd          10132.84       A    1    0  308151
rcv          10134.58       D  308151 50    1
snd          10134.58       A    1    0  308204
rcv          10134.58       F  308204 0    1
snd          10134.58       A    1    0  308205
snd          10134.58       F    1    0  308205
rcv          10134.58       A  308205 0    2
=====
Amount of data received (bytes) 308303
Total Segments Received      6171
Data segments received       6167
Data segments with Bit Errors 0
Duplicate data segments received 2
Duplicate ACKs sent          3100
=====

```

Assignment for Session 2, 2018 Report

Figure 9. Sender_log.txt for test1.pdf with gamma = 6 (only first and last 20 logs)

```

snd          0.00          S    0    0    0
rcv          0.02          S/A  0    0    1
snd          0.02          A    1    0    1
snd          0.02          D    1   50    1
drop         0.02          D   51   50    1
snd          0.02          D   101  50    1
drop         0.02          D   151  50    1
snd          0.02          D   201  50    1
snd          0.02          D   251  50    1
snd          0.02          D   301  50    1
drop         0.02          D   351  50    1
snd          0.02          D   401  50    1
snd          0.02          D   451  50    1
rcv          0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
snd/RXT      0.03          D   51   50    1
rcv/DA       0.03          A    1    0   51
rcv/DA       0.03          A    1    0   51
.
.
.
drop/RXT     14012.52       D  307651 50    1
drop/RXT     14014.42       D  307651 50    1
snd/RXT      14016.33       D  307651 50    1
rcv          14016.33       A    1    0  307801
drop         14016.33       D  308151 50    1
snd          14016.33       D  308201 3     1
rcv/DA       14016.33       A    1    0  307801
snd/RXT      14018.23       D  307801 50    1
rcv          14018.23       A    1    0  308001
snd/RXT      14020.14       D  308001 50    1
rcv          14020.14       A    1    0  308051
drop/RXT     14022.05       D  308051 50    1
snd/RXT      14023.95       D  308051 50    1
rcv          14023.95       A    1    0  308151
snd/RXT      14025.86       D  308151 50    1
rcv          14025.86       A    1    0  308204
snd          14025.87       F  308204 0     1
rcv          14025.87       A    1    0  308205
rcv          14025.87       F    1    0  308205
snd          14025.87       A  308205 0     2
=====
Size of the file(in Bytes)      308203
Segments transmitted (including drop & RXT) 12181
Number of Segments handled by PLD 12177
Number of Segments dropped      6010
Number of Segments Corrupted    0
Number of Segments Re-ordered    0
Number of Segments Duplicated    0
Number of Segments Delayed      1171
Number of Retransmissions due to TIMEOUT 5765
Number of FAST RETRANSMISSION  247
Number of DUP ACKS received     3102
=====

```


Assignment for Session 2, 2018 Report

Figure 10. Receiver_log.txt for test1.pdf with gamma = 6 (only first and last 20 logs)

```

rcv          0.00          S      0      0      0
snd          0.02          S/A    0      0      1
rcv          0.02          A      1      0      1
rcv          0.02          D      1     50      1
snd          0.02          A      1      0     51
rcv          0.02          D     101    50      1
snd/DA       0.02          A      1      0     51
rcv          0.02          D     201    50      1
snd/DA       0.02          A      1      0     51
rcv          0.02          D     251    50      1
snd/DA       0.02          A      1      0     51
rcv          0.03          D     301    50      1
snd/DA       0.03          A      1      0     51
rcv          0.03          D     401    50      1
snd/DA       0.03          A      1      0     51
rcv          0.03          D     451    50      1
snd/DA       0.03          A      1      0     51
rcv          0.03          D      51    50      1
snd          0.03          A      1      0    151
rcv          0.18          D     601    50      1
.
.
.
snd          14006.26       A      1      0    307501
rcv          14006.26       D    307951  50      1
snd/DA       14006.26       A      1      0    307501
rcv          14008.19       D    307501  50      1
snd          14008.19       A      1      0    307551
rcv          14010.10       D    307551  50      1
snd          14010.10       A      1      0    307651
rcv          14010.61       D    308101  50      1
snd/DA       14010.61       A      1      0    307651
rcv          14016.33       D    307651  50      1
snd          14016.33       A      1      0    307801
rcv          14016.33       D    308201  3      1
snd/DA       14016.33       A      1      0    307801
rcv          14018.23       D    307801  50      1
snd          14018.23       A      1      0    308001
rcv          14020.14       D    308001  50      1
snd          14020.14       A      1      0    308051
rcv          14023.95       D    308051  50      1
snd          14023.95       A      1      0    308151
rcv          14025.86       D    308151  50      1
snd          14025.86       A      1      0    308204
rcv          14025.87       F    308204  0      1
snd          14025.87       A      1      0    308205
snd          14025.87       F      1      0    308205
rcv          14025.87       A    308205  0      2
=====
Amount of data received (bytes) 308303
Total Segments Received      6171
Data segments received       6167
Data segments with Bit Errors 0
Duplicate data segments received 2
Duplicate ACKs sent          3102
=====

```

Question C. Log Files

Figure 11. Sender_log.txt for test2.pdf (only first and last 20 logs)

```

snd          0.00          S      0      0      0
rcv          0.02        S/A      0      0      1
snd          0.02          A      1      0      1
snd          0.02          D      1     50      1
snd          0.02          D     51     50      1
snd          0.02          D    101     50      1
snd          0.02          D    151     50      1
snd          0.03          D    201     50      1
corr         0.03          D    251     50      1
corr         0.03          D    301     50      1
snd          0.03          D    351     50      1
snd          0.03          D    401     50      1
snd          0.03          D    451     50      1
snd/dup      0.03          D    451     50      1
rcv          0.03          A      1      0     51
snd          0.03          D    501     50      1
rcv          0.03          A      1      0    101
snd          0.03          D    551     50      1
rcv          0.03          A      1      0    151
snd          0.03          D    601     50      1
.
.
.
snd          85.25         D   1605301  50      1
snd          85.25         D   1605351  50      1
snd          85.25         D   1605401  50      1
snd          85.25         D   1605451  50      1
snd          85.25         D   1605501  50      1
snd/dup      85.25         D   1605501  50      1
snd          85.25         D   1605551  35      1
rcv          85.25         A      1      0   1605251
rcv          85.25         A      1      0   1605301
rcv          85.25         A      1      0   1605351
rcv          85.25         A      1      0   1605401
rcv          85.25         A      1      0   1605451
rcv          85.25         A      1      0   1605501
rcv          85.25         A      1      0   1605551
rcv/DA       85.25         A      1      0   1605551
rcv          85.25         A      1      0   1605586
snd          85.25         F   1605586  0        1
rcv          85.25         A      1      0   1605587
rcv          85.25         F      1      0   1605587
snd          85.25         A   1605587  0        2
=====
Size of the file(in Bytes)      1605585
Segments transmitted (including drop & RXT) 42240
Number of Segments handled by PLD 42236
Number of Segments dropped      4186
Number of Segments Corrupted    3325
Number of Segments Re-ordered   2438
Number of Segments Duplicated   3804
Number of Segments Delayed      0
Number of Retransmissions due to TIMEOUT 2905
Number of FAST RETRANSMISSION  7219
Number of DUP ACKS received     28738
=====

```

Assignment for Session 2, 2018 Report

Figure 12. Receiver_log.txt for test2.pdf (Only the first and last 50)

```

rcv          0.00          S    0    0    0
snd          0.02          S/A  0    0    1
rcv          0.02          A    1    0    1
rcv          0.02          D    1   50    1
snd          0.02          A    1    0   51
rcv          0.02          D   51   50    1
snd          0.02          A    1    0  101
rcv          0.02          D  101   50    1
snd          0.02          A    1    0  151
rcv          0.03          D  151   50    1
snd          0.03          A    1    0  201
rcv          0.03          D  201   50    1
snd          0.03          A    1    0  251
rcv/corr     0.03          D  251   50    1
rcv/corr     0.03          D  301   50    1
rcv          0.03          D  351   50    1
snd/DA       0.03          A    1    0  251
rcv          0.03          D  401   50    1
snd/DA       0.03          A    1    0  251
rcv          0.03          D  451   50    1
.
.
.
snd/DA       85.25         A    1    0  1604701
rcv          85.25         D  1604701 50    1
snd          85.25         A    1    0  1605201
rcv          85.25         D  1605201 50    1
snd          85.25         A    1    0  1605251
rcv          85.25         D  1605251 50    1
snd          85.25         A    1    0  1605301
rcv          85.25         D  1605301 50    1
snd          85.25         A    1    0  1605351
rcv          85.25         D  1605351 50    1
snd          85.25         A    1    0  1605401
rcv          85.25         D  1605401 50    1
snd          85.25         A    1    0  1605451
rcv          85.25         D  1605451 50    1
snd          85.25         A    1    0  1605501
rcv          85.25         D  1605501 50    1
snd          85.25         A    1    0  1605551
rcv          85.25         D  1605501 50    1
snd/DA       85.25         A    1    0  1605551
rcv          85.25         D  1605551 35    1
snd          85.25         A    1    0  1605586
rcv          85.25         F  1605586 0     1
snd          85.25         A    1    0  1605587
snd          85.25         F    1    0  1605587
rcv          85.25         A  1605587 0     2
=====
Amount of data received (bytes) 1926435
Total Segments Received      38533
Data segments received       38529
Data segments with Bit Errors 3325
Duplicate data segments received 6417
Duplicate ACKs sent          28738
=====

```