

Simple Transport Protocol Report

1. STP Description

The three-way handshake (stage 1)

The three way handshake has successfully been implemented in stage 1 of the main loop in the sender program. The sender initiates the handshake by sending a SYN segment. Once this is received by the receiver, a SYNACK is returned and a final ACK is sent by the sender. After this point, the handshake has been complete and stage 2 of the main loop is commenced.

Data Transfer (stage 2)

During the data transfer stage, the following features have been implemented:

- Buffer,
- Maximum segment size (MSS)
- Maximum window size (MWS)
- Timeout
- Fast retransmit
- Cumulative acknowledgment
- PLD module

Below is a brief discussion on each of these features.

Buffer

At the sender side, each new segment that is sent is added to the buffer. These segments are only taken out of the buffer when they or a later segment have been acknowledged. On the receiver side, only segments that arrive out of order are added to the buffer. The segments are then removed from the buffer once the previously missing segment/s has been retransmitted.

Maximum segment size (MSS)

The maximum segment size has been implemented at the beginning of the program before the main loop by the 'divide_file' function which takes the contents of a file and returns a contents list containing MSS size elements.

Maximum window size (MWS)

The maximum window size is maintained by taking into account the sequence number of the oldest unacknowledged byte and the next byte to be sent. If the difference of these two values plus the MSS is less than or equal to the MWS then another segment can be sent.

Timeout

To implement the timeout feature, a list of send times ('send_times') for all segments in the buffer is kept. The oldest time 'send_times[0]' in this list (which corresponds to the oldest unacknowledged segment) is then compared with the current time periodically (within a while loop). If the current time is greater than send_times[0] + timeout then a timeout event has occurred and the segment is retransmitted. Note that the socket object timeout value has been set to 0.01ms in this stage. This ensures that the program is constantly checking for timeout events and not simply waiting to receive segments.

Fast retransmit

The fast retransmit feature has been implemented by checking incoming ACK segments. If the incoming ACK segment contains an acknowledgment number below the oldest unacknowledged segment then the 'curr_dup' value is incremented by 1. The value of 'curr_dup' is checked periodically in the same way as timeout and triggers a retransmit once it hits a value of 3. The 'curr_dup' value is set to 0 after every retransmit or if a new ACK segment is received.

Cumulative Acknowledgment

As mentioned in the buffer section, the receiver program places all out of order segments in the buffer. Once the missing segment is received, the receiver program will check the buffer and find all packets that continue in order. The receiver will then send a single ACK segment that reflects the latest in order segment received. Once the sender receives this ACK segment it will check the buffer and remove any segments that have a sequence number below the acknowledgment number of the incoming ACK segment. It will also update its value of the oldest unacknowledged sequence number 'seq' which will move the window to allow more segments to be sent.

PLD module

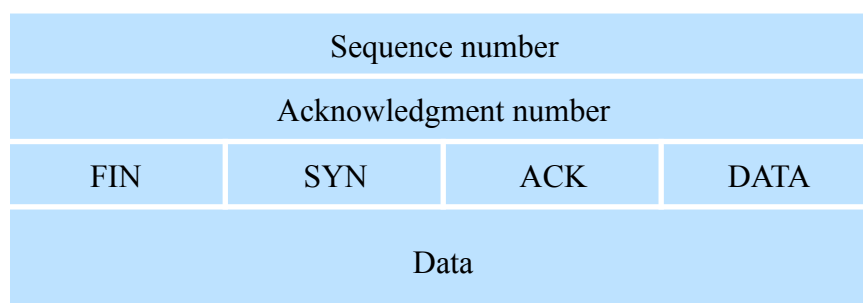
The PLD module determines whether to drop or send a segment. It does this by generating a random number and comparing it to pdrop. If the randomly generated number is greater than pdrop the segment is sent, otherwise it is dropped.

The four-segment connection termination (stage 3)

The four-segment connection termination has successfully been implemented in stage 3 of the main loop in the sender program. The sender initialises the handshake by sending a FIN segment. It then awaits an ACK segment followed by a FIN segment from the receiver. Finally it sends one last acknowledgment and terminates the connection.

2. STP Segment Structure

The STP segment structure consists of header fields and a data field. The header fields include sequence number, acknowledgment number and 4 flags (FIN, SYN, ACK, DATA). The diagram below (**Figure 1**) outlines the structure of the STP segment.

Figure 1:

An example of an STP segment is provided below:

'51|1|0001|return to Geneva; and I could not collect the cour'

As shown, the segment is sent as a string with each section separated by ' | ' so that it can be broken into a list and read later. The flag section contains 4 digits representing the 4 different flags. '0' implies that the flag is not set while '1' indicates that the flag is set. In this example the sequence number is 51, the acknowledgment number is 1, the DATA flag is set and there is 50 bytes of data in the data section.

3. Experiments

a)

To find a suitable timeout value, a series of tests have been run on a file (22288 bytes in size). After each test, the receiver's log file is checked for the number of duplicate segments received. If the timeout value is too small, there are additional duplicates of segments that were sent prematurely. **Table 1** below shows the results of the tests, due to fluctuation each timeout value was run 5 times.

Table 1

Timeout value (ms)	Number of duplicate segments arriving at receiver	
	5 Tests	Average
1000	(31, 30, 31, 31, 29)	30
500	(31, 30, 29, 29, 30)	30
200	(29, 29, 30, 29, 29)	29
100	(29, 31, 29, 29, 29)	29
75	(29, 30, 29, 29, 33)	30
60	(29, 29, 29, 29, 29)	29
55	(29, 29, 31, 29, 29)	29
50	(29, 30, 39, 44, 37)	36
45	(29, 29, 32, 51, 39)	36
40	(30, 32, 30, 29, 47)	34
35	(69, 63, 34, 31, 43)	48
30	(72, 77, 68 59, 79)	71

As the table shows, once the timeout value is less than 55ms the amount of unnecessary duplicate segments sent by the sender begins to increase. Note that approximately 29 - 30 of these duplicate segments are sent because of fast retransmission.

Chosen timeout value:

55ms

Table 2 below shows the results of running experiments 1 and 2 on the text file 'test1.txt'.

Table 2:

Experiment 1 (pdrop = 0.1)			Experiment 2 (pdrop = 0.3)		
1	601	1351	1	651	1251
51	651	1401	51	701	801
drop 101	701	drop 1451	drop 101	751	drop 801
151	751	1501	151	drop 801	1301
201	801	1051	201	351	1351
251	851	1051	251	851	1401
301	901	1551	301	901	951
351	951	1451	drop 351	drop 951	1451
401	1001		401	501	drop 1001
451	drop 1051		451	drop 1001	drop 1001
501	1101		drop 501	551	1001
551	1151		drop 551	1051	1501
drop 101	1201		drop 101	1101	1551
101	1251		101	1151	
101	1301		601	1201	

Experiment 1 appears to have dropped a packet 4 times (2 times for packet 101). There are also two duplicate segments received by the receiver (101 and 1051), these have been retransmitted twice due to the fast retransmit mechanism.

In experiment 2, packets have been dropped 11 times. In contrast to experiment 1 there are no duplicate segments sent. the reason for this is that the drop rate is higher and therefore there is no instance where fast retransmit is triggered twice for the same packet.

b)

Table 3 below shows the results of running experiments 3, 4 and 5 on the text file 'test2.txt'.

Table 3:

Experiment	Timeout (ms)	Packets transmitted	Transfer time (ms)
Experiment 3	55	43	152.25
Experiment 4	220	43	169.85
Experiment 5	14	48	155.13

Experiments 3 and 4 appear to yield similar results, this is expected since the timeout value was selected to minimise retransmitting any segments unnecessarily. In experiment 5 it is clear that the timeout value is causing unnecessary packets to be retransmitted.

In terms of the transfer time, these were seen to fluctuate for each experiment and in general are relatively similar. The reason for this is that because the window size is large and the drop rate is low, all packets are retransmitted by the fast retransmit mechanism. This reduces the influence of the timeout value on the transfer time of each experiment.

Appendix

Experiment 1 (pdrop = 0.1, file = test1.txt, timeout = 55ms)

Sender_log.txt	Receiver_log.txt
<pre> snd 0.09 S 0 0 0 rcv 18.09 SA 0 0 1 snd 18.38 A 1 0 1 snd 19.31 D 1 50 1 snd 20.40 D 51 50 1 drop 22.01 D 101 50 1 snd 23.33 D 151 50 1 snd 24.67 D 201 50 1 snd 26.31 D 251 50 1 snd 27.20 D 301 50 1 snd 28.45 D 351 50 1 snd 29.58 D 401 50 1 snd 30.73 D 451 50 1 rcv 38.51 A 1 0 51 snd 38.83 D 501 50 1 rcv 39.71 A 1 0 101 snd 40.91 D 551 50 1 rcv 42.24 A 1 0 101 rcv 43.38 A 1 0 101 rcv 44.51 A 1 0 101 drop 45.72 D 101 50 1 rcv 46.89 A 1 0 101 rcv 48.47 A 1 0 101 rcv 49.19 A 1 0 101 snd 50.28 D 101 50 1 rcv 51.69 A 1 0 101 rcv 52.70 A 1 0 101 rcv 53.56 A 1 0 101 snd 55.36 D 101 50 1 rcv 61.25 A 1 0 601 snd 61.49 D 601 50 1 snd 63.12 D 651 50 1 snd 64.46 D 701 50 1 snd 66.00 D 751 50 1 snd 67.35 D 801 50 1 snd 69.47 D 851 50 1 snd 69.73 D 901 50 1 snd 70.80 D 951 50 1 snd 71.21 D 1001 50 1 drop 72.78 D 1051 50 1 rcv 74.05 A 1 0 651 snd 75.88 D 1101 50 1 rcv 76.95 A 1 0 701 snd 77.42 D 1151 50 1 rcv 79.22 A 1 0 751 snd 80.11 D 1201 50 1 rcv 81.85 A 1 0 801 snd 83.39 D 1251 50 1 rcv 84.98 A 1 0 851 snd 86.12 D 1301 50 1 rcv 87.72 A 1 0 901 snd 89.07 D 1351 50 1 rcv 90.32 A 1 0 951 snd 92.47 D 1401 50 1 rcv 93.72 A 1 0 1001 drop 94.08 D 1451 50 1 rcv 96.42 A 1 0 1051 snd 99.88 D 1501 50 1 rcv 100.89 A 1 0 1051 rcv 102.43 A 1 0 1051 rcv 103.07 A 1 0 1051 snd 104.23 D 1051 50 1 rcv 105.72 A 1 0 1051 rcv 106.58 A 1 0 1051 rcv 107.81 A 1 0 1051 snd 109.17 D 1051 50 1 rcv 111.86 A 1 0 1051 rcv 112.93 A 1 0 1051 rcv 119.62 A 1 0 1451 snd 119.86 D 1551 41 1 rcv 122.09 A 1 0 1451 snd 149.45 D 1451 50 1 rcv 152.73 A 1 0 1592 snd 152.96 F 1592 0 1 rcv 154.42 A 1 0 1593 rcv 155.48 F 1 0 1593 snd 156.59 A 1593 0 2 </pre> <p> Amount of Data Transferred: 1591 Number of Data Segments Sent: 34 Number of Packets Dropped: 4 Number of Retransmitted Segments: 5 Number of Duplicate Acknowledgements received: 18 </p>	<pre> rcv 0.01 S 0 0 0 snd 17.36 SA 0 0 1 rcv 18.37 A 1 0 1 rcv 20.22 D 1 50 1 snd 20.85 A 1 0 51 rcv 22.19 D 51 50 1 snd 23.82 A 1 0 101 rcv 25.01 D 151 50 1 snd 26.49 A 1 0 101 rcv 27.68 D 201 50 1 snd 28.81 A 1 0 101 rcv 29.84 D 251 50 1 snd 31.07 A 1 0 101 rcv 32.38 D 301 50 1 snd 38.85 A 1 0 101 rcv 40.08 D 351 50 1 snd 41.37 A 1 0 101 rcv 42.57 D 401 50 1 snd 43.88 A 1 0 101 rcv 45.01 D 451 50 1 snd 46.11 A 1 0 101 rcv 47.25 D 501 50 1 snd 48.43 A 1 0 101 rcv 49.53 D 551 50 1 snd 50.94 A 1 0 101 rcv 51.96 D 101 50 1 snd 60.97 A 1 0 601 rcv 61.16 D 101 50 1 rcv 62.94 D 601 50 1 snd 63.72 A 1 0 651 rcv 64.86 D 651 50 1 snd 66.55 A 1 0 701 rcv 67.78 D 701 50 1 snd 70.68 A 1 0 751 rcv 71.49 D 751 50 1 snd 73.26 A 1 0 801 rcv 74.62 D 801 50 1 snd 76.61 A 1 0 851 rcv 77.99 D 851 50 1 snd 79.87 A 1 0 901 rcv 80.50 D 901 50 1 snd 82.41 A 1 0 951 rcv 83.53 D 951 50 1 snd 85.23 A 1 0 1001 rcv 86.37 D 1001 50 1 snd 87.99 A 1 0 1051 rcv 89.23 D 1101 50 1 snd 90.70 A 1 0 1051 rcv 92.76 D 1151 50 1 snd 94.14 A 1 0 1051 rcv 94.46 D 1201 50 1 snd 95.93 A 1 0 1051 rcv 99.15 D 1251 50 1 snd 100.01 A 1 0 1051 rcv 101.22 D 1301 50 1 snd 102.42 A 1 0 1051 rcv 103.53 D 1351 50 1 snd 104.69 A 1 0 1051 rcv 106.02 D 1401 50 1 snd 107.08 A 1 0 1051 rcv 108.25 D 1501 50 1 snd 110.38 A 1 0 1051 rcv 112.19 D 1051 50 1 snd 119.34 A 1 0 1451 rcv 119.53 D 1051 50 1 rcv 121.42 D 1551 41 1 snd 121.82 A 1 0 1451 rcv 150.31 D 1451 50 1 snd 152.32 A 1 0 1592 rcv 152.82 F 1592 0 1 snd 153.70 A 1 0 1593 snd 154.77 F 1 0 1593 rcv 156.46 A 1593 0 2 </pre> <p> Amount of Data received: 1591 Number of Data segments Received: 34 Number of duplicate segments received: 2 </p>

Appendix (Continued)

Experiment 2 (pdrop = 0.3, file = test1.txt, timeout = 55ms)

Sender_log.txt	Receiver_log.txt
<pre> snd 0.09 S 0 0 0 rcv 1.22 SA 0 0 1 snd 147.56 A 1 0 1 snd 149.14 D 1 50 1 snd 149.98 D 51 50 1 drop 151.31 D 101 50 1 snd 152.78 D 151 50 1 snd 153.86 D 201 50 1 snd 155.31 D 251 50 1 snd 157.08 D 301 50 1 drop 158.02 D 351 50 1 snd 159.03 D 401 50 1 snd 160.14 D 451 50 1 rcv 161.43 A 1 0 51 drop 162.48 D 501 50 1 rcv 163.57 A 1 0 101 drop 164.74 D 551 50 1 rcv 165.87 A 1 0 101 rcv 167.20 A 1 0 101 rcv 168.90 A 1 0 101 drop 169.72 D 101 50 1 rcv 170.77 A 1 0 101 rcv 171.28 A 1 0 101 rcv 171.87 A 1 0 101 snd 172.40 D 101 50 1 rcv 177.50 A 1 0 351 snd 177.73 D 601 50 1 snd 179.77 D 651 50 1 snd 180.50 D 701 50 1 snd 181.44 D 751 50 1 drop 182.64 D 801 50 1 rcv 183.54 A 1 0 351 rcv 184.84 A 1 0 351 rcv 185.74 A 1 0 351 snd 187.28 D 351 50 1 rcv 188.61 A 1 0 351 rcv 196.25 A 1 0 501 snd 196.60 D 851 50 1 snd 197.08 D 901 50 1 drop 198.42 D 951 50 1 rcv 198.72 A 1 0 501 rcv 200.82 A 1 0 501 snd 217.59 D 501 50 1 rcv 218.58 A 1 0 551 drop 218.77 D 1001 50 1 snd 220.34 D 551 50 1 rcv 229.64 A 1 0 801 snd 229.99 D 1051 50 1 snd 231.10 D 1101 50 1 snd 231.64 D 1151 50 1 snd 234.71 D 1201 50 1 snd 235.37 D 1251 50 1 rcv 236.72 A 1 0 801 rcv 237.49 A 1 0 801 snd 238.80 D 801 50 1 rcv 239.71 A 1 0 801 rcv 240.80 A 1 0 801 rcv 242.06 A 1 0 801 drop 243.32 D 801 50 1 rcv 247.20 A 1 0 951 snd 247.41 D 1301 50 1 snd 248.75 D 1351 50 1 snd 250.05 D 1401 50 1 rcv 250.93 A 1 0 951 rcv 251.73 A 1 0 951 rcv 253.64 A 1 0 951 snd 254.17 D 951 50 1 rcv 256.19 A 1 0 1001 snd 256.74 D 1451 50 1 rcv 260.09 A 1 0 1001 drop 275.00 D 1001 50 1 drop 330.55 D 1001 50 1 snd 386.10 D 1001 50 1 rcv 392.61 A 1 0 1501 snd 392.85 D 1501 50 1 snd 394.22 D 1551 41 1 rcv 394.91 A 1 0 1551 rcv 397.27 A 1 0 1592 snd 397.48 F 1592 0 1 rcv 400.03 A 1 0 1593 rcv 401.01 F 1 0 1593 snd 401.64 A 1593 0 2 </pre> <p>Amount of Data Transferred: 1591 Number of Data Segments Sent: 32 Number of Packets Dropped: 11 Number of Retransmitted Segments: 7 Number of Duplicate Acknowledgements received: 21</p>	<pre> rcv 0.01 S 0 0 0 snd 0.35 SA 0 0 1 rcv 147.56 A 1 0 1 rcv 149.75 D 1 50 1 snd 150.36 A 1 0 51 rcv 151.53 D 51 50 1 snd 153.16 A 1 0 101 rcv 154.03 D 151 50 1 snd 155.98 A 1 0 101 rcv 157.30 D 201 50 1 snd 158.20 A 1 0 101 rcv 159.29 D 251 50 1 snd 160.34 A 1 0 101 rcv 161.82 D 301 50 1 snd 162.77 A 1 0 101 rcv 163.91 D 401 50 1 snd 165.00 A 1 0 101 rcv 166.13 D 451 50 1 snd 167.35 A 1 0 101 rcv 172.85 D 101 50 1 snd 177.11 A 1 0 351 rcv 179.54 D 601 50 1 snd 179.97 A 1 0 351 rcv 180.60 D 651 50 1 snd 181.70 A 1 0 351 rcv 182.82 D 701 50 1 snd 186.55 A 1 0 351 rcv 187.01 D 751 50 1 snd 188.07 A 1 0 351 rcv 188.99 D 351 50 1 snd 192.69 A 1 0 501 rcv 197.08 D 851 50 1 snd 198.25 A 1 0 501 rcv 199.39 D 901 50 1 snd 200.42 A 1 0 501 rcv 217.83 D 501 50 1 snd 218.23 A 1 0 551 rcv 221.73 D 551 50 1 snd 228.96 A 1 0 801 rcv 231.01 D 1051 50 1 snd 231.22 A 1 0 801 rcv 232.03 D 1101 50 1 snd 234.50 A 1 0 801 rcv 235.60 D 1151 50 1 snd 237.07 A 1 0 801 rcv 237.70 D 1201 50 1 snd 238.98 A 1 0 801 rcv 239.92 D 1251 50 1 snd 241.24 A 1 0 801 rcv 242.45 D 801 50 1 snd 246.89 A 1 0 951 rcv 248.50 D 1301 50 1 snd 248.70 A 1 0 951 rcv 250.00 D 1351 50 1 snd 250.87 A 1 0 951 rcv 252.08 D 1401 50 1 snd 253.30 A 1 0 951 rcv 254.87 D 951 50 1 snd 255.85 A 1 0 1001 rcv 258.39 D 1451 50 1 snd 259.26 A 1 0 1001 rcv 386.40 D 1001 50 1 snd 392.25 A 1 0 1501 rcv 394.01 D 1501 50 1 snd 394.49 A 1 0 1551 rcv 395.38 D 1551 41 1 snd 396.85 A 1 0 1592 rcv 398.71 F 1592 0 1 snd 399.67 A 1 0 1593 snd 400.68 F 1 0 1593 rcv 401.96 A 1593 0 2 </pre> <p>Amount of Data received: 1591 Number of Data segments Received: 32 Number of duplicate segments received: 0</p>

Appendix (Continued)

Experiment 3 (pdrop = 0.1, file = test2.txt, timeout = 55ms)

Sender_log.txt	Receiver_log.txt
<pre> snd 0.10 S 0 0 0 rcv 14.20 SA 0 0 1 snd 14.49 A 1 0 1 snd 15.64 D 1 50 1 snd 16.73 D 51 50 1 drop 17.75 D 101 50 1 snd 19.34 D 151 50 1 snd 20.39 D 201 50 1 snd 22.20 D 251 50 1 snd 23.19 D 301 50 1 snd 24.37 D 351 50 1 snd 25.58 D 401 50 1 snd 26.72 D 451 50 1 rcv 34.59 A 1 0 51 snd 35.05 D 501 50 1 rcv 35.80 A 1 0 101 snd 36.99 D 551 50 1 rcv 38.30 A 1 0 101 rcv 39.49 A 1 0 101 rcv 40.71 A 1 0 101 drop 41.79 D 101 50 1 rcv 42.97 A 1 0 101 rcv 44.41 A 1 0 101 rcv 45.37 A 1 0 101 snd 46.44 D 101 50 1 rcv 47.68 A 1 0 101 rcv 48.77 A 1 0 101 rcv 50.36 A 1 0 101 snd 51.49 D 101 50 1 rcv 57.53 A 1 0 601 snd 57.75 D 601 50 1 snd 59.56 D 651 50 1 snd 60.73 D 701 50 1 snd 62.33 D 751 50 1 snd 63.21 D 801 50 1 snd 65.38 D 851 50 1 snd 66.26 D 901 50 1 snd 68.06 D 951 50 1 snd 69.30 D 1001 50 1 drop 71.03 D 1051 50 1 rcv 71.95 A 1 0 651 snd 73.72 D 1101 50 1 rcv 74.80 A 1 0 701 snd 76.43 D 1151 50 1 rcv 77.70 A 1 0 751 snd 79.55 D 1201 50 1 rcv 80.90 A 1 0 801 snd 82.21 D 1251 50 1 rcv 83.69 A 1 0 851 snd 84.99 D 1301 50 1 rcv 86.08 A 1 0 901 snd 87.15 D 1351 50 1 rcv 88.53 A 1 0 951 snd 89.56 D 1401 50 1 rcv 90.65 A 1 0 1001 drop 92.01 D 1451 50 1 rcv 94.20 A 1 0 1051 snd 96.86 D 1501 50 1 rcv 97.94 A 1 0 1051 rcv 99.08 A 1 0 1051 rcv 100.49 A 1 0 1051 snd 101.52 D 1051 50 1 rcv 102.73 A 1 0 1051 rcv 103.98 A 1 0 1051 rcv 105.08 A 1 0 1051 snd 106.44 D 1051 50 1 rcv 109.74 A 1 0 1051 rcv 111.03 A 1 0 1051 rcv 115.86 A 1 0 1451 snd 116.12 D 1551 50 1 snd 117.21 D 1601 50 1 snd 118.41 D 1651 50 1 snd 121.12 D 1701 50 1 snd 122.48 D 1751 50 1 snd 123.46 D 1801 50 1 snd 124.43 D 1851 50 1 snd 126.01 D 1901 50 1 rcv 127.22 A 1 0 1451 rcv 128.26 A 1 0 1451 rcv 129.34 A 1 0 1451 snd 131.31 D 1451 50 1 rcv 132.50 A 1 0 1451 rcv 133.50 A 1 0 1451 rcv 134.51 A 1 0 1451 snd 135.72 D 1451 50 1 rcv 136.91 A 1 0 1451 rcv 137.95 A 1 0 1451 rcv 145.40 A 1 0 1951 snd 145.62 D 1951 2 1 rcv 147.82 A 1 0 1953 snd 148.30 F 1953 0 1 rcv 150.57 A 1 0 1954 rcv 151.64 F 1 0 1954 snd 152.25 A 1954 0 2 </pre>	<pre> rcv 0.01 S 0 0 0 snd 13.42 SA 0 0 1 rcv 14.46 A 1 0 1 rcv 16.57 D 1 50 1 snd 17.00 A 1 0 51 rcv 18.19 D 51 50 1 snd 19.85 A 1 0 101 rcv 20.76 D 151 50 1 snd 22.49 A 1 0 101 rcv 23.63 D 201 50 1 snd 24.83 A 1 0 101 rcv 25.94 D 251 50 1 snd 27.09 A 1 0 101 rcv 28.44 D 301 50 1 snd 34.82 A 1 0 101 rcv 36.19 D 351 50 1 snd 37.44 A 1 0 101 rcv 38.68 D 401 50 1 snd 39.92 A 1 0 101 rcv 41.08 D 451 50 1 snd 42.23 A 1 0 101 rcv 43.39 D 501 50 1 snd 44.83 A 1 0 101 rcv 45.69 D 551 50 1 snd 46.91 A 1 0 101 rcv 47.99 D 101 50 1 snd 57.26 A 1 0 601 rcv 57.46 D 101 50 1 rcv 59.43 D 601 50 1 snd 59.76 A 1 0 651 rcv 61.22 D 651 50 1 snd 62.50 A 1 0 701 rcv 64.02 D 701 50 1 snd 65.60 A 1 0 751 rcv 66.64 D 751 50 1 snd 68.51 A 1 0 801 rcv 69.75 D 801 50 1 snd 71.19 A 1 0 851 rcv 72.24 D 851 50 1 snd 74.44 A 1 0 901 rcv 75.63 D 901 50 1 snd 76.81 A 1 0 951 rcv 78.09 D 951 50 1 snd 80.11 A 1 0 1001 rcv 80.88 D 1001 50 1 snd 82.86 A 1 0 1051 rcv 83.99 D 1101 50 1 snd 85.68 A 1 0 1051 rcv 86.53 D 1151 50 1 snd 87.57 A 1 0 1051 rcv 88.86 D 1201 50 1 snd 89.92 A 1 0 1051 rcv 91.54 D 1251 50 1 snd 92.40 A 1 0 1051 rcv 96.13 D 1301 50 1 snd 97.40 A 1 0 1051 rcv 98.28 D 1351 50 1 snd 99.77 A 1 0 1051 rcv 100.82 D 1401 50 1 snd 101.97 A 1 0 1051 rcv 103.22 D 1501 50 1 snd 104.37 A 1 0 1051 rcv 105.41 D 1051 50 1 snd 115.30 A 1 0 1451 rcv 115.51 D 1051 50 1 rcv 117.15 D 1551 50 1 snd 117.60 A 1 0 1451 rcv 118.73 D 1601 50 1 snd 121.14 A 1 0 1451 rcv 122.69 D 1651 50 1 snd 124.05 A 1 0 1451 rcv 125.09 D 1701 50 1 snd 126.43 A 1 0 1451 rcv 127.60 D 1751 50 1 snd 128.69 A 1 0 1451 rcv 130.14 D 1801 50 1 snd 131.72 A 1 0 1451 rcv 132.77 D 1851 50 1 snd 133.84 A 1 0 1451 rcv 134.98 D 1901 50 1 snd 136.14 A 1 0 1451 rcv 137.23 D 1451 50 1 snd 145.09 A 1 0 1951 rcv 145.28 D 1451 50 1 rcv 147.20 D 1951 2 1 snd 147.56 A 1 0 1953 rcv 148.65 F 1953 0 1 snd 150.22 A 1 0 1954 snd 151.31 F 1 0 1954 rcv 152.42 A 1954 0 2 </pre>
<p>Amount of Data Transferred: 1952 Number of Data Segments Sent: 43 Number of Packets Dropped: 4 Number of Retransmitted Segments: 6 Number of Duplicate Acknowledgements received: 25</p>	<p>Amount of Data received: 1952 Number of Data segments Received: 43 Number of duplicate segments received: 3</p>

Appendix (Continued)

Experiment 4 (pdrop = 0.1, file = test2.txt, timeout = 220ms)

Sender_log.txt	Receiver_log.txt
<pre> snd 0.09 S 0 0 0 rcv 1.16 SA 0 0 1 snd 37.33 A 1 0 1 snd 39.09 D 1 50 1 snd 39.90 D 51 50 1 drop 40.46 D 101 50 1 snd 43.04 D 151 50 1 snd 43.73 D 201 50 1 snd 45.42 D 251 50 1 snd 46.52 D 301 50 1 snd 47.72 D 351 50 1 snd 48.81 D 401 50 1 snd 50.43 D 451 50 1 rcv 53.01 A 1 0 51 snd 53.86 D 501 50 1 rcv 55.06 A 1 0 101 snd 56.06 D 551 50 1 rcv 57.26 A 1 0 101 rcv 58.31 A 1 0 101 rcv 59.38 A 1 0 101 drop 60.55 D 101 50 1 rcv 63.12 A 1 0 101 rcv 64.05 A 1 0 101 rcv 65.48 A 1 0 101 snd 66.44 D 101 50 1 rcv 67.57 A 1 0 101 rcv 68.82 A 1 0 101 rcv 70.00 A 1 0 101 snd 71.28 D 101 50 1 rcv 79.40 A 1 0 601 snd 79.79 D 601 50 1 snd 80.88 D 651 50 1 snd 82.12 D 701 50 1 snd 85.30 D 751 50 1 snd 86.56 D 801 50 1 snd 88.38 D 851 50 1 snd 89.57 D 901 50 1 snd 91.21 D 951 50 1 snd 92.38 D 1001 50 1 drop 94.92 D 1051 50 1 rcv 96.19 A 1 0 651 snd 97.51 D 1101 50 1 rcv 98.86 A 1 0 701 snd 100.21 D 1151 50 1 rcv 101.69 A 1 0 751 snd 102.61 D 1201 50 1 rcv 104.52 A 1 0 801 snd 105.91 D 1251 50 1 rcv 107.21 A 1 0 851 snd 108.91 D 1301 50 1 rcv 109.73 A 1 0 901 snd 110.75 D 1351 50 1 rcv 112.01 A 1 0 951 snd 112.97 D 1401 50 1 rcv 114.20 A 1 0 1001 drop 115.42 D 1451 50 1 rcv 116.60 A 1 0 1051 snd 117.76 D 1501 50 1 rcv 118.79 A 1 0 1051 rcv 119.88 A 1 0 1051 rcv 120.98 A 1 0 1051 snd 122.14 D 1051 50 1 rcv 123.30 A 1 0 1051 rcv 124.51 A 1 0 1051 rcv 125.60 A 1 0 1051 snd 126.77 D 1051 50 1 rcv 128.04 A 1 0 1051 rcv 129.98 A 1 0 1051 rcv 134.40 A 1 0 1451 snd 134.61 D 1551 50 1 snd 136.21 D 1601 50 1 snd 137.27 D 1651 50 1 snd 138.41 D 1701 50 1 snd 139.45 D 1751 50 1 snd 141.82 D 1801 50 1 snd 142.67 D 1851 50 1 snd 143.78 D 1901 50 1 rcv 145.06 A 1 0 1451 rcv 146.09 A 1 0 1451 rcv 147.25 A 1 0 1451 snd 148.39 D 1451 50 1 rcv 149.93 A 1 0 1451 rcv 151.29 A 1 0 1451 rcv 152.53 A 1 0 1451 snd 153.43 D 1451 50 1 rcv 154.81 A 1 0 1451 rcv 155.82 A 1 0 1451 rcv 163.28 A 1 0 1951 snd 163.49 D 1951 2 1 rcv 165.55 A 1 0 1953 snd 166.26 F 1953 0 1 rcv 168.40 A 1 0 1954 rcv 169.45 F 1 0 1954 snd 169.85 A 1954 0 2 </pre>	<pre> rcv 0.01 S 0 0 0 snd 0.39 SA 0 0 1 rcv 37.22 A 1 0 1 rcv 39.72 D 1 50 1 snd 40.06 A 1 0 51 rcv 40.69 D 51 50 1 snd 43.27 A 1 0 101 rcv 44.36 D 151 50 1 snd 45.63 A 1 0 101 rcv 46.97 D 201 50 1 snd 47.99 A 1 0 101 rcv 49.16 D 251 50 1 snd 50.66 A 1 0 101 rcv 53.12 D 301 50 1 snd 54.26 A 1 0 101 rcv 55.30 D 351 50 1 snd 56.44 A 1 0 101 rcv 57.50 D 401 50 1 snd 58.61 A 1 0 101 rcv 59.74 D 451 50 1 snd 61.21 A 1 0 101 rcv 63.31 D 501 50 1 snd 64.53 A 1 0 101 rcv 65.68 D 551 50 1 snd 66.77 A 1 0 101 rcv 68.04 D 101 50 1 snd 79.11 A 1 0 601 rcv 79.29 D 101 50 1 rcv 80.82 D 601 50 1 snd 81.46 A 1 0 651 rcv 82.13 D 651 50 1 snd 85.82 A 1 0 701 rcv 86.91 D 701 50 1 snd 88.47 A 1 0 751 rcv 90.08 D 751 50 1 snd 91.51 A 1 0 801 rcv 92.68 D 801 50 1 snd 95.13 A 1 0 851 rcv 96.23 D 851 50 1 snd 98.01 A 1 0 901 rcv 99.20 D 901 50 1 snd 101.24 A 1 0 951 rcv 101.91 D 951 50 1 snd 103.71 A 1 0 1001 rcv 104.73 D 1001 50 1 snd 106.44 A 1 0 1051 rcv 107.50 D 1101 50 1 snd 108.87 A 1 0 1051 rcv 110.20 D 1151 50 1 snd 111.27 A 1 0 1051 rcv 112.25 D 1201 50 1 snd 113.37 A 1 0 1051 rcv 114.67 D 1251 50 1 snd 115.90 A 1 0 1051 rcv 116.88 D 1301 50 1 snd 118.00 A 1 0 1051 rcv 119.10 D 1351 50 1 snd 120.32 A 1 0 1051 rcv 121.44 D 1401 50 1 snd 122.47 A 1 0 1051 rcv 123.75 D 1501 50 1 snd 124.83 A 1 0 1051 rcv 125.92 D 1051 50 1 snd 134.12 A 1 0 1451 rcv 134.29 D 1051 50 1 rcv 136.06 D 1551 50 1 snd 136.34 A 1 0 1451 rcv 137.61 D 1601 50 1 snd 138.68 A 1 0 1451 rcv 141.10 D 1651 50 1 snd 142.03 A 1 0 1451 rcv 142.98 D 1701 50 1 snd 144.27 A 1 0 1451 rcv 145.33 D 1751 50 1 snd 146.41 A 1 0 1451 rcv 147.63 D 1801 50 1 snd 148.81 A 1 0 1451 rcv 150.56 D 1851 50 1 snd 151.58 A 1 0 1451 rcv 152.69 D 1901 50 1 snd 153.79 A 1 0 1451 rcv 154.81 D 1451 50 1 snd 163.00 A 1 0 1951 rcv 163.18 D 1451 50 1 rcv 164.96 D 1951 2 1 snd 165.29 A 1 0 1953 rcv 166.69 F 1953 0 1 snd 168.13 A 1 0 1954 snd 169.19 F 1 0 1954 rcv 170.18 A 1954 0 2 </pre>
<p>Amount of Data Transferred: 1952 Number of Data Segments Sent: 43 Number of Packets Dropped: 4 Number of Retransmitted Segments: 6 Number of Duplicate Acknowledgements received: 25</p>	<p>Amount of Data received: 1952 Number of Data segments Received: 43 Number of duplicate segments received: 3</p>

Appendix (Continued)

Experiment 5 (pdrop = 0.1, file = test2.txt, timeout = 14ms)

Sender_log.txt	Receiver_log.txt
<pre> snd 0.10 S 0 0 0 rcv 20.24 SA 0 0 1 snd 20.59 A 1 0 1 snd 21.57 D 1 50 1 snd 22.74 D 51 50 1 drop 24.29 D 101 50 1 snd 25.68 D 151 50 1 snd 26.79 D 201 50 1 snd 28.21 D 251 50 1 snd 30.41 D 301 50 1 snd 32.14 D 351 50 1 snd 32.55 D 401 50 1 snd 33.20 D 451 50 1 rcv 36.33 A 1 0 51 snd 36.59 D 501 50 1 snd 37.79 D 51 50 1 rcv 39.15 A 1 0 101 drop 40.27 D 551 50 1 snd 41.12 D 101 50 1 rcv 42.50 A 1 0 101 rcv 43.44 A 1 0 101 rcv 44.60 A 1 0 101 snd 45.64 D 101 50 1 rcv 47.88 A 1 0 101 rcv 48.09 A 1 0 101 rcv 52.54 A 1 0 101 snd 52.94 D 101 50 1 rcv 53.53 A 1 0 101 rcv 54.15 A 1 0 101 rcv 58.73 A 1 0 551 snd 58.97 D 601 50 1 snd 60.39 D 651 50 1 snd 61.96 D 701 50 1 snd 62.64 D 751 50 1 snd 63.95 D 801 50 1 snd 65.14 D 851 50 1 snd 66.18 D 901 50 1 snd 67.25 D 951 50 1 drop 68.36 D 1001 50 1 snd 69.56 D 551 50 1 rcv 70.73 A 1 0 551 rcv 71.65 A 1 0 551 rcv 72.84 A 1 0 551 snd 74.20 D 551 50 1 rcv 75.46 A 1 0 551 rcv 76.53 A 1 0 551 rcv 77.56 A 1 0 551 snd 78.79 D 551 50 1 rcv 79.97 A 1 0 551 rcv 81.58 A 1 0 551 rcv 87.23 A 1 0 1001 snd 87.44 D 1051 50 1 snd 88.99 D 1101 50 1 snd 90.09 D 1151 50 1 snd 91.17 D 1201 50 1 drop 92.37 D 1251 50 1 snd 93.30 D 1301 50 1 snd 94.49 D 1351 50 1 snd 95.67 D 1401 50 1 snd 97.03 D 1451 50 1 snd 98.13 D 1001 50 1 rcv 99.23 A 1 0 1001 rcv 100.30 A 1 0 1001 rcv 101.50 A 1 0 1001 snd 102.43 D 1001 50 1 rcv 103.60 A 1 0 1001 rcv 104.60 A 1 0 1001 rcv 106.08 A 1 0 1001 snd 107.13 D 1001 50 1 rcv 108.38 A 1 0 1001 rcv 109.86 A 1 0 1001 rcv 113.68 A 1 0 1251 snd 114.00 D 1501 50 1 snd 115.12 D 1551 50 1 snd 116.46 D 1601 50 1 snd 117.59 D 1651 50 1 snd 118.65 D 1701 50 1 snd 119.74 D 1251 50 1 rcv 121.11 A 1 0 1251 rcv 122.19 A 1 0 1251 rcv 123.41 A 1 0 1251 snd 124.33 D 1251 50 1 rcv 125.46 A 1 0 1251 rcv 126.72 A 1 0 1251 rcv 136.58 A 1 0 1751 snd 136.80 D 1751 50 1 snd 138.44 D 1801 50 1 snd 140.43 D 1851 50 1 snd 141.62 D 1901 50 1 snd 142.84 D 1951 2 1 rcv 144.55 A 1 0 1801 rcv 145.34 A 1 0 1851 rcv 146.33 A 1 0 1901 rcv 148.76 A 1 0 1951 rcv 151.49 A 1 0 1953 snd 151.75 F 1953 0 1 rcv 153.99 A 1 0 1954 rcv 154.95 F 1 0 1954 snd 155.13 A 1954 0 2 </pre> <p>Amount of Data Transferred: 1952 Number of Data Segments Sent: 48 Number of Packets Dropped: 4 Number of Retransmitted Segments: 12 Number of Duplicate Acknowledgements received: 29</p>	<pre> rcv 0.02 S 0 0 0 snd 19.34 SA 0 0 1 rcv 20.71 A 1 0 1 rcv 22.67 D 1 50 1 snd 23.24 A 1 0 51 rcv 24.50 D 51 50 1 snd 26.80 A 1 0 101 rcv 27.35 D 151 50 1 snd 28.94 A 1 0 101 rcv 29.84 D 201 50 1 snd 32.44 A 1 0 101 rcv 32.67 D 251 50 1 snd 33.56 A 1 0 101 rcv 34.88 D 301 50 1 snd 36.85 A 1 0 101 rcv 38.30 D 351 50 1 snd 39.93 A 1 0 101 rcv 40.34 D 401 50 1 snd 41.69 A 1 0 101 rcv 42.66 D 451 50 1 snd 44.60 A 1 0 101 rcv 44.89 D 501 50 1 snd 47.17 A 1 0 101 rcv 47.47 D 51 50 1 rcv 50.87 D 101 50 1 snd 58.42 A 1 0 551 rcv 58.59 D 101 50 1 rcv 59.62 D 101 50 1 rcv 60.94 D 601 50 1 snd 61.79 A 1 0 551 rcv 63.02 D 651 50 1 snd 64.34 A 1 0 551 rcv 65.43 D 701 50 1 snd 66.49 A 1 0 551 rcv 67.61 D 751 50 1 snd 68.81 A 1 0 551 rcv 69.92 D 801 50 1 snd 71.24 A 1 0 551 rcv 72.04 D 851 50 1 snd 73.33 A 1 0 551 rcv 74.57 D 901 50 1 snd 75.64 A 1 0 551 rcv 76.86 D 951 50 1 snd 78.04 A 1 0 551 rcv 79.16 D 551 50 1 snd 86.91 A 1 0 1001 rcv 87.10 D 551 50 1 rcv 88.18 D 551 50 1 rcv 89.34 D 1051 50 1 snd 90.38 A 1 0 1001 rcv 91.56 D 1101 50 1 snd 92.90 A 1 0 1001 rcv 93.66 D 1151 50 1 snd 95.00 A 1 0 1001 rcv 96.16 D 1201 50 1 snd 97.37 A 1 0 1001 rcv 98.45 D 1301 50 1 snd 99.53 A 1 0 1001 rcv 100.70 D 1351 50 1 snd 102.08 A 1 0 1001 rcv 102.81 D 1401 50 1 snd 103.94 A 1 0 1001 rcv 105.28 D 1451 50 1 snd 106.43 A 1 0 1001 rcv 107.48 D 1001 50 1 snd 113.36 A 1 0 1251 rcv 113.89 D 1001 50 1 rcv 114.34 D 1001 50 1 rcv 115.48 D 1501 50 1 snd 116.81 A 1 0 1251 rcv 117.89 D 1551 50 1 snd 118.98 A 1 0 1251 rcv 120.14 D 1601 50 1 snd 121.46 A 1 0 1251 rcv 122.47 D 1651 50 1 snd 123.72 A 1 0 1251 rcv 124.64 D 1701 50 1 snd 125.78 A 1 0 1251 rcv 127.04 D 1251 50 1 snd 136.29 A 1 0 1751 rcv 136.47 D 1251 50 1 rcv 138.28 D 1751 50 1 snd 138.62 A 1 0 1801 rcv 140.47 D 1801 50 1 snd 142.13 A 1 0 1851 rcv 143.18 D 1851 50 1 snd 145.56 A 1 0 1901 rcv 146.64 D 1901 50 1 snd 148.44 A 1 0 1951 rcv 149.57 D 1951 2 1 snd 151.16 A 1 0 1953 rcv 151.59 F 1953 0 1 snd 153.68 A 1 0 1954 snd 154.69 F 1 0 1954 rcv 155.49 A 1954 0 2 </pre> <p>Amount of Data received: 1952 Number of Data segments Received: 48 Number of duplicate segments received: 8</p>