COMP3331: Computer Networks Assignment

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STP Protocol Report

1.

Implementation

The STP protocol was implemented in java similar to the pseudocode provided in 'Computer Networks Top Down Approach chapter 3.5.4'. List of features that were implemented:

- Three-way handshake (SYN, SYNACK, ACK)
- Four-segment Termination (FIN,ACK,FIN,ACK)

Sender:

- Multithreading
- RTO calculation using packet timestamps
- Timeout Retransmission
- Fast Retransmit
- PLD
- Cumulative acknowledgements

Receiver:

- Buffering out-of-order packets
- Duplicated acknowledgements

Multithreading implementation (for the Sender only):

One thread is created to receive acknowledgements and another to send data packets so that packets to-be-sent do not need to wait for $socket.receive(packet)$ to finish before sending.

A semaphore is used to ensure that when shared variables such as $send\_base$ and $nextSeqNum$ are modified or used in either thread, that section of code needs to acquire the lock and release it when it finishes to ensure the program is thread safe.

Three-way handshake implementation:

This follows the finite-state-machine in 3.5.6 of the textbook, where the actions of the sender is determined by the current state of the sender. Initially the state is set to $NONE$

In Sender loop:

1) If state is $NONE$: (in sending thread)
    a. Create a packet with SYN flag set to $true$
    b. Send packet and set $STATE = SYN\_SENT$
2) If state is SYN_SENT (in receiving thread):
    a. If received packet is a SYN ACK send an acknowledgment
    b. Set $STATE = ESTABLISHED$

In Receiver loop (initial $STATE = LISTENING$):

1) If $STATE = LISTENING$
    a. If packet is a SYN, extract sender IP and port from received packet and initialize buffer
    b. Send $SYNACK$ and set $STATE = SYN\_RCVD$
2) If $STATE = SYN\_RCVD$
    a. If packet is an ACK and not a SYN and has expected sequence and acknowledgement number set $STATE = ESTABLISHED$

Teardown is also implemented in similar manner according to the textbook

RTO calculation implementation:

At the Sender:

1) Set timestamp on every packet just before it is sent (but before PLD). Set the 'use timestamp' flag to 'true' in the packet header. If it is a retransmission set it to 'false'.
2) When a correct acknowledgment arrives (ack number > send base) that has its 'use timestamp' flag set to 'true', use the timestamp to calculate a Sample RTT
3) Update the Timeout interval using the formulas:

$$EstimatedRTT = (1 - \alpha) \times EstimatedRTT + \alpha \times SampleRTT$$

$$DevRTT = (1 - \beta) \times DevRTT + \beta \times \left| SampleRTT - EstimatedRTT \right|$$

$$TimeoutInterval = EstimatedRTT + gamma \times DevRTT$$

α is set to recommended value of 0.125, β is set to the recommended value of 0.25

At the Receiver:

1) When a packet carrying data arrives, create an ack packet and copy over the value of the 'use timestamp' flag and the timestamp value of the arriving packet to this ack and send it back to the sender.

Timeout timer implementation:

A single timer was used to implement timeout. Whenever the timer is set a new thread is started using java's $Timer.schedule(< timeout\ function >, TimeoutInterval)$

In Sender:

1) If $STATE = ESTABLISHED$ (in sending thread)
    a. If MWS is not violated after send:
        i. If timer is not started start it
        ii. Send next data packet (all data packets are stored in a $HashMap < SeqNum, Packet >$) called $packetMap$
2) If $STATE = ESTABLISHED$ (in receiving thread)
    a. If received ack has $ackNum > send\_base$:
        i. $send\_base = ackNum$ (cumulative acknowledgement)
        ii. If no un-acknowledged packets turn timer off
        iii. Else cancel and restart timer

        iv. Add ack to a duplicate ack map that maps the ack number to the number times the duplicate of the ack was received i.e., $ackMap < ackNum, 0 >$

3) If $TIMEOUT$ event (in timeout function):
    a. Cancel and restart timer
    b. Retransmit unacknowledged packet with lowest sequence number by doing $send(packetMap.get(send\_base))$

<u>Fast Retransmit Implementation</u>

In Sender:

1) If $STATE = ESTABLISHED$ (in receiving thread)
    a. if $ackNum \leq send\_base$ (this is a duplicate ack)
    b. Increment the number of times this ack was received in the $ackMap$
    c. If the number of times this ack was received is equal to three
        i. Fast retransmit by sending the packet mapped to $ackNum$ in $packetMap$
        ii. Reset the number of times this ack was received to zero

<u>Buffering out-of-order packet implementation</u>

Whenever packet arrive out of order, i.e., packets with sequence numbers greater than the sequence number of the next in-order packet, it is buffered so that when the gap is filled, the ack for the latest consecutive buffered packet is sent.

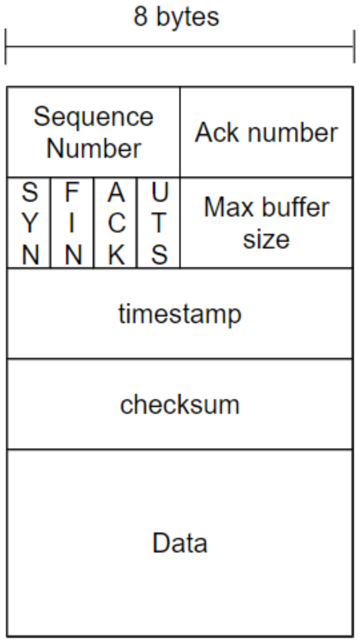
In Receiver:

1) If $STATE = ESTABLISHED$
    a. If the received packet does not have expected sequence number:
        i. Send duplicate ack
        ii. If packet is not already buffered:
            1. Add the sequence number to a priority queue (smallest to largest)
            2. Store packet in a $HashMap < seqNum, Packet >$ called $packetMap$
    b. If the received packet has expected sequence number:
        i. Add packet to $ArrayList < Packet >$ of in order packets
        ii. Increment next expected sequence number by packet data size
        iii. While next sequence number is at the head of priority queue and not empty
            1. add the packet mapped to this sequence number to in-order packet list
            2. increment expected sequence number by this packet data size
        iv. Send ack packet with ack number set to this new expected sequence number

<u>PLD Implementation</u>

Implemented packet drop, duplication, bit errors and out-of-order packets as specified in assignment specification. Every time a packet is randomly delayed with probability $pDelay$ a new thread is created using java's $Timer.schedule(< delay\ send\ function >, TimeoutInterval)$ so that other processes can continue.

2.



- 4 byte sequence number is the byte offset into the payload relative to the sequence number of the first byte of payload data
- 4 byte acknowledgment number indicates the next expected sequence number of the packet the ack-sender expects to receive
- SYN, FIN are flags used for connection establishment and teardown
- ACK flag indicates whether this packet is acknowledging a received packet or not
- UTS is 'Use Timestamp' flag which is set when the timestamp is to be used for RTT calculation
- 8 byte 'long' Timestamp is the time when this packet is sent
- 8 byte checksum is the calculated using java's CRC32 module which should be compared to the same checksum calculation at the receiver to see if there any bit errors
- The header ends here and the payload 'Data' is appended to the end of the file

3.

Design tradeoffs considered and made:

- Multithreading was implemented and was a tradeoff between difficulty of implementation and the performance of the sender process, in the end it helped modularize the different tasks of sending and receiving and well as independent assertions of timeouts and delayed sending of packets.
- As an extension for slight improvement of performance, timestamps were implemented so that when the correct acknowledgments are rare due to high probability of network errors, updates to the timeout interval were more frequent to better reflect the state of the network.
- A possible improvement/extension would be to have a dynamic window size at both sender and receiver that changes based on the detected congestion of the network, i.e., congestion control. This would help promote fair use of shared bandwidth if multiple people are simultaneously

using this program to transfer data. This would be implemented by slowly increasing the congestion window to probe the state of the network. When a loss event occurs the congestion window size is cut down appropriately and the process restarts.

4.

The pseudocode from the ‘Computer Networks Top Down approach’ chapter 3.5.4 was used and is screenshot in the appendix

5.

a)

In the appendix for both pDrop 0.1, 0.3 in the sender log, the dropping occurred at the highlighted lines. For pDrop=0.3, duplicate acks are more rare than with pDrop=0.1 as the receiver can only send acks per packet it receives resulting in less fast retransmits and more timeouts.

b)

Gamma	No. packets sent	Total time (s)	No. of Retransmits	No. Fast Retransmit
2	12168	6627.71	5778	221
4	12167	10242.59	5780	218
6	12167	13884.70	5780	218

When the drop out is high, it makes it very rare for a correct ack to be received that does not come from a retransmission of a packet, so the timeout value is very rarely updated. The gamma value linearly affects the calculation of the timeout interval which can be seen in the formula:

$$TimeoutInterval = EstimatedRTT + gamma \times DevRTT$$

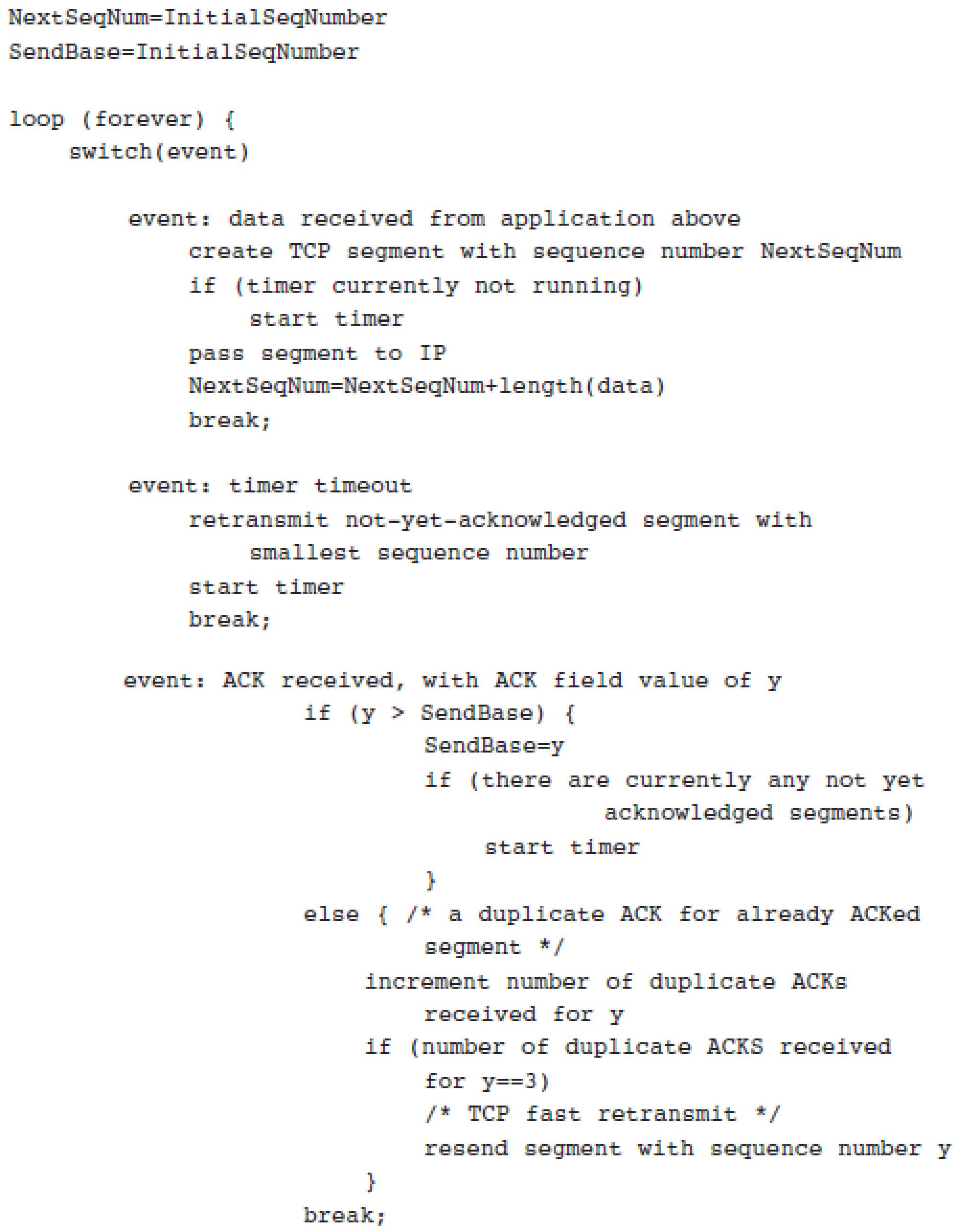
This is reflected in the results, where when the gamma value is increased by two, the total time to send the file takes approximately one hour more. Since high dropout probability lowers the number of duplicate acknowledgements that the receiver can send, the number of fast retransmissions is quite low for all cases. The number of retransmissions due to timeout are all approximately equal, meaning that increasing the value of gamma more than two i.e., effectively increasing the timeout interval, would be unnecessary as gamma=2 effectively accounts for all fluctuations in RTT i.e., there is enough time to allow all acknowledgements to arrive at the sender despite some outliers to prevent premature timeout.

c)

For test2.pdf, the file was successfully transferred with the specified parameters. The overall transfer took 848.19 seconds. If duplicate acks are not sent for corrupt packets, pCorrupt is the most critical factor that contributes the most overall transfer time with pDrop coming in on a close second. This was determined by setting all probabilities to zero except the target factor and checking the amount of time it takes to complete the file transfer. The log summaries and last entry is shown for all experiments in the appendix. The reason is because dropped and corrupt packets are not acknowledged by the receiver, so they cause more timeouts than the other factors and timeouts contribute the most time. Furthermore, corrupt packets must be received and processed at the receiver which is not the case for dropped packets. Hence it made sense that the corrupt experiment took the most time to complete.

Appendix

4. Pseudo code used from ‘Computer Network Top Down Approach’ chapter 3.5.4



```
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
                             }
                     else { /* a duplicate ACK for already ACKed
                             segment */
                         increment number of duplicate ACKs
                             received for y
                         if (number of duplicate ACKS received
                             for y==3)
                             /* TCP fast retransmit */
                             resend segment with sequence number y
                         }
                     break;
```

5a. test0.pdf

pDrop = 0.1
Sender_log.txt:

```
snd              0.00     S        0        0          0
rcv              0.14    SA        0        0          1
snd              0.14     A        1        0          1
snd              0.14     D        1      100          1
drop             0.14     D      101      100          1
snd              0.14     D      201      100          1
snd              0.15     D      301      100          1
rcv              0.15     A        1        0        101
snd              0.16     D      401      100          1
snd              0.16     D      501      100          1
rcv/DA           0.16     A        1        0        101
rcv/DA           0.16     A        1        0        101
rcv/DA           0.16     A        1        0        101
snd/RXT          0.16     D      101      100          1
rcv/DA           0.16     A        1        0        101
rcv              0.16     A        1        0        601
snd              0.16     D      601      100          1
snd              0.16     D      701      100          1
snd              0.16     D      801      100          1
snd              0.16     D      901      100          1
snd              0.16     D     1001      100          1
rcv              0.16     A        1        0        701
snd              0.17     D     1101      100          1
rcv              0.17     A        1        0        801
snd              0.17     D     1201      100          1
rcv              0.17     A        1        0        901
snd              0.17     D     1301      100          1
rcv              0.17     A        1        0       1001
snd              0.17     D     1401      100          1
rcv              0.17     A        1        0       1101
snd              0.17     D     1501      100          1
rcv              0.17     A        1        0       1201
snd              0.17     D     1601      100          1
rcv              0.17     A        1        0       1301
snd              0.17     D     1701      100          1
rcv              0.17     A        1        0       1401
snd              0.17     D     1801      100          1
rcv              0.17     A        1        0       1501
drop             0.17     D     1901      100          1
rcv              0.17     A        1        0       1601
snd              0.17     D     2001      100          1
rcv              0.17     A        1        0       1701
snd              0.17     D     2101      100          1
rcv              0.17     A        1        0       1801
snd              0.17     D     2201      100          1
rcv              0.18     A        1        0       1901
snd              0.18     D     2301      100          1
```

```
rcv/DA            0.18    A        1        0       1901
rcv/DA            0.18    A        1        0       1901
rcv/DA            0.18    A        1        0       1901
snd/RXT           0.18    D     1901      100          1
rcv/DA            0.18    A        1        0       1901
rcv               0.18    A        1        0       2401
snd               0.18    D     2401      100          1
snd               0.18    D     2501      100          1
snd               0.18    D     2601      100          1
snd               0.18    D     2701      100          1
snd               0.18    D     2801      100          1
rcv               0.18    A        1        0       2501
snd               0.18    D     2901      100          1
rcv               0.18    A        1        0       2601
snd               0.18    D     3001       28          1
rcv               0.18    A        1        0       2701
rcv               0.18    A        1        0       2801
rcv               0.18    A        1        0       2901
rcv               0.18    A        1        0       3001
rcv               0.19    A        1        0       3029
snd               0.19    F     3029        0          1
rcv               0.19    A        1        0       3030
rcv               0.19    F        1        0       3030
snd               0.19    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 RETRANSMISSON                          2
Number of DUP ACKS received                           8
========================================================
```

Receiver_log.txt

```
rcv               0.00    S        0        0          0
snd               0.02   SA        0        0          1
rcv               0.07    A        1        0          1
rcv               0.08    D        1      100          1
snd               0.08    A        1        0        101
rcv               0.08    D      201      100          1
snd/DA            0.08    A        1        0        101
rcv               0.08    D      301      100          1
snd/DA            0.08    A        1        0        101
rcv               0.08    D      401      100          1
snd/DA            0.08    A        1        0        101
```

```
rcv             0.08    D    501     100        1
snd/DA          0.08    A      1       0      101
rcv             0.09    D    101     100        1
snd             0.09    A      1       0      601
rcv             0.09    D    601     100        1
snd             0.09    A      1       0      701
rcv             0.09    D    701     100        1
snd             0.09    A      1       0      801
rcv             0.09    D    801     100        1
snd             0.09    A      1       0      901
rcv             0.09    D    901     100        1
snd             0.09    A      1       0     1001
rcv             0.09    D   1001     100        1
snd             0.09    A      1       0     1101
rcv             0.09    D   1101     100        1
snd             0.09    A      1       0     1201
rcv             0.09    D   1201     100        1
snd             0.09    A      1       0     1301
rcv             0.09    D   1301     100        1
snd             0.09    A      1       0     1401
rcv             0.09    D   1401     100        1
snd             0.09    A      1       0     1501
rcv             0.10    D   1501     100        1
snd             0.10    A      1       0     1601
rcv             0.10    D   1601     100        1
snd             0.10    A      1       0     1701
rcv             0.10    D   1701     100        1
snd             0.10    A      1       0     1801
rcv             0.10    D   1801     100        1
snd             0.10    A      1       0     1901
rcv             0.10    D   2001     100        1
snd/DA          0.10    A      1       0     1901
rcv             0.10    D   2101     100        1
snd/DA          0.10    A      1       0     1901
rcv             0.10    D   2201     100        1
snd/DA          0.10    A      1       0     1901
rcv             0.10    D   2301     100        1
snd/DA          0.10    A      1       0     1901
rcv             0.10    D   1901     100        1
snd             0.10    A      1       0     2401
rcv             0.11    D   2401     100        1
snd             0.11    A      1       0     2501
rcv             0.11    D   2501     100        1
snd             0.11    A      1       0     2601
rcv             0.11    D   2601     100        1
snd             0.11    A      1       0     2701
rcv             0.11    D   2701     100        1
snd             0.11    A      1       0     2801
rcv             0.11    D   2801     100        1
snd             0.11    A      1       0     2901
rcv             0.11    D   2901     100        1
snd             0.11    A      1       0     3001
```

```
rcv                 0.11     D     3001        28           1
snd                 0.11     A        1         0        3029
rcv                 0.11     F     3029         0           1
snd                 0.11     A        1         0        3030
snd                 0.11     F        1         0        3030
rcv                 0.11     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
=========================================================
```

pDrop = 0.3

Sender_log.txt:

```
snd                 0.00     S        0         0           0
rcv                 0.17    SA        0         0           1
snd                 0.17     A        1         0           1
snd                 0.17     D        1       100           1
drop                0.17     D      101       100           1
snd                 0.17     D      201       100           1
drop                0.18     D      301       100           1
rcv                 0.18     A        1         0         101
drop                0.18     D      401       100           1
drop                0.18     D      501       100           1
rcv/DA              0.18     A        1         0         101
snd/RXT             1.80     D      101       100           1
rcv                 1.80     A        1         0         301
drop                1.81     D      601       100           1
snd                 1.81     D      701       100           1
rcv/DA              1.81     A        1         0         301
drop                3.45     D      301       100           1
snd/RXT             5.07     D      301       100           1
rcv                 5.07     A        1         0         401
snd                 5.07     D      801       100           1
rcv/DA              5.07     A        1         0         401
drop                6.70     D      401       100           1
snd/RXT             8.34     D      401       100           1
rcv                 8.34     A        1         0         501
drop                8.34     D      901       100           1
snd/RXT             9.96     D      501       100           1
rcv                 9.96     A        1         0         601
snd                 9.96     D     1001       100           1
rcv/DA              9.97     A        1         0         601
snd/RXT            11.59     D      601       100           1
rcv                11.59     A        1         0         901
drop               11.59     D     1101       100           1
```

snd	11.59	D	1201	100	1
drop	11.59	D	1301	100	1
rcv/DA	11.59	A	1	0	901
snd/RXT	13.23	D	901	100	1
rcv	13.23	A	1	0	1101
snd	13.23	D	1401	100	1
snd	13.23	D	1501	100	1
rcv/DA	13.23	A	1	0	1101
rcv/DA	13.23	A	1	0	1101
drop	14.85	D	1101	100	1
drop	16.49	D	1101	100	1
snd/RXT	18.12	D	1101	100	1
rcv	18.12	A	1	0	1301
snd	18.12	D	1601	100	1
drop	18.12	D	1701	100	1
rcv/DA	18.12	A	1	0	1301
drop	19.75	D	1301	100	1
snd/RXT	21.38	D	1301	100	1
rcv	21.38	A	1	0	1701
drop	21.38	D	1801	100	1
snd	21.38	D	1901	100	1
drop	21.38	D	2001	100	1
snd	21.38	D	2101	100	1
rcv/DA	21.38	A	1	0	1701
rcv/DA	21.39	A	1	0	1701
drop	23.02	D	1701	100	1
drop	24.64	D	1701	100	1
snd/RXT	26.27	D	1701	100	1
rcv	26.27	A	1	0	1801
drop	26.27	D	2201	100	1
snd/RXT	27.90	D	1801	100	1
rcv	27.90	A	1	0	2001
snd	27.90	D	2301	100	1
drop	27.90	D	2401	100	1
rcv/DA	27.90	A	1	0	2001
snd/RXT	29.52	D	2001	100	1
rcv	29.52	A	1	0	2201
snd	29.52	D	2501	100	1
snd	29.52	D	2601	100	1
rcv/DA	29.52	A	1	0	2201
rcv/DA	29.52	A	1	0	2201
snd/RXT	31.15	D	2201	100	1
rcv	31.15	A	1	0	2401
drop	31.15	D	2701	100	1
drop	31.15	D	2801	100	1
snd/RXT	32.77	D	2401	100	1
rcv	32.77	A	1	0	2701
snd	32.77	D	2901	100	1
drop	32.77	D	3001	28	1
rcv/DA	32.77	A	1	0	2701
snd/RXT	34.38	D	2701	100	1
rcv	34.39	A	1	0	2801

```
snd/RXT         36.01     D    2801      100          1
rcv             36.01     A       1        0       3001
snd/RXT         37.64     D    3001       28          1
rcv             37.64     A       1        0       3029
snd             37.64     F    3029        0          1
rcv             37.64     A       1        0       3030
rcv             37.64     F       1        0       3030
snd             37.64     A    3030        0          2
========================================================
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 RETRANSMISSON                         0
Number of DUP ACKS received                         14
========================================================
```

Receiver_log.txt

```
rcv              0.00     S       0        0          0
snd              0.02    SA       0        0          1
rcv              0.10     A       1        0          1
rcv              0.11     D       1      100          1
snd              0.11     A       1        0        101
rcv              0.11     D     201      100          1
snd/DA           0.11     A       1        0        101
rcv              1.74     D     101      100          1
snd              1.74     A       1        0        301
rcv              1.74     D     701      100          1
snd/DA           1.74     A       1        0        301
rcv              5.00     D     301      100          1
snd              5.00     A       1        0        401
rcv              5.00     D     801      100          1
snd/DA           5.00     A       1        0        401
rcv              8.27     D     401      100          1
snd              8.27     A       1        0        501
rcv              9.90     D     501      100          1
snd              9.90     A       1        0        601
rcv              9.90     D    1001      100          1
snd/DA           9.90     A       1        0        601
rcv             11.52     D     601      100          1
snd             11.52     A       1        0        901
rcv             11.52     D    1201      100          1
snd/DA          11.52     A       1        0        901
rcv             13.16     D     901      100          1
snd             13.16     A       1        0       1101
```

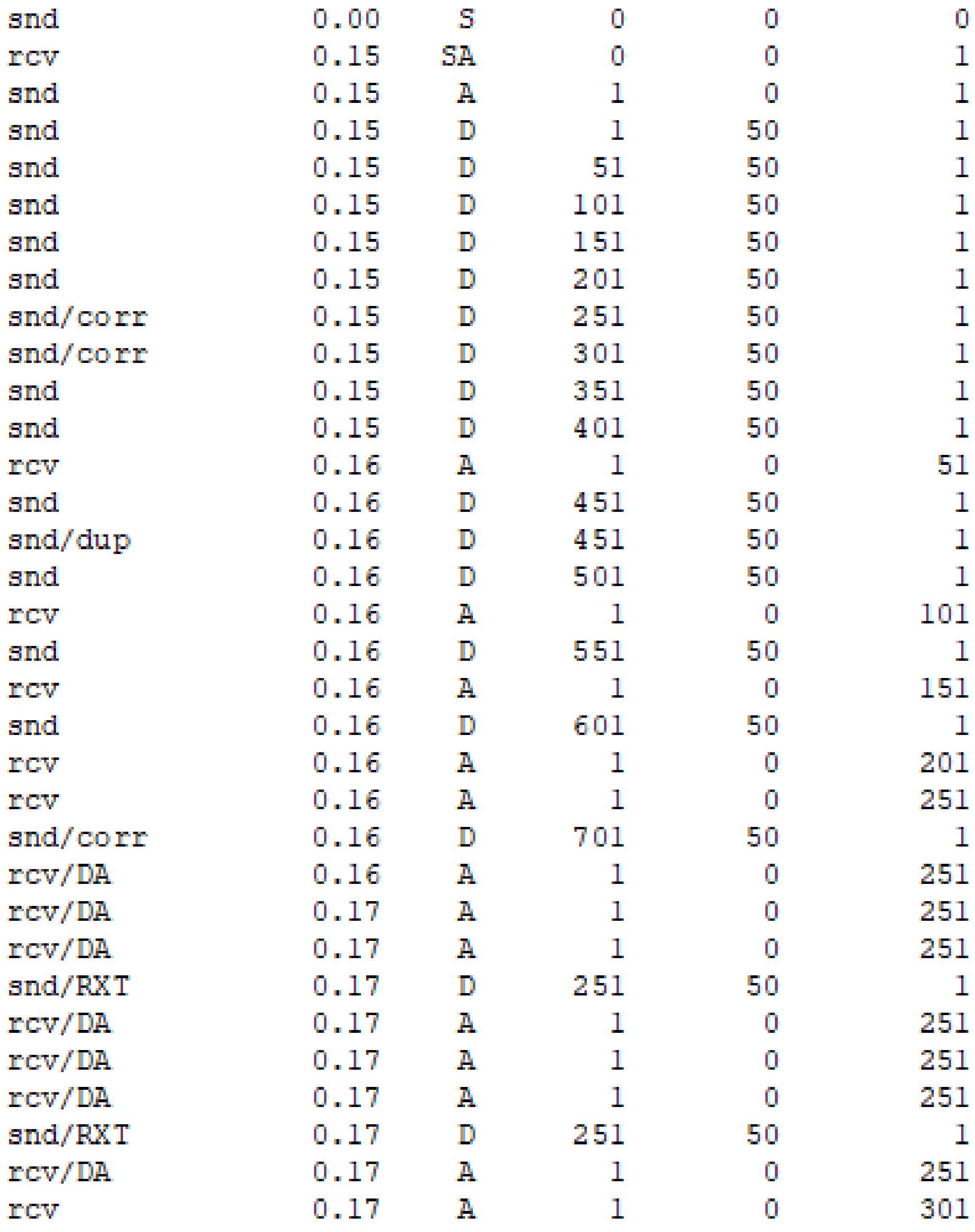
```
rcv             13.16     D    1401      100          1
snd/DA          13.16     A       1        0       1101
rcv             13.16     D    1501      100          1
snd/DA          13.16     A       1        0       1101
rcv             18.05     D    1101      100          1
snd             18.05     A       1        0       1301
rcv             18.05     D    1601      100          1
snd/DA          18.05     A       1        0       1301
rcv             21.32     D    1301      100          1
snd             21.32     A       1        0       1701
rcv             21.32     D    1901      100          1
snd/DA          21.32     A       1        0       1701
rcv             21.32     D    2101      100          1
snd/DA          21.32     A       1        0       1701
rcv             26.20     D    1701      100          1
snd             26.20     A       1        0       1801
rcv             27.83     D    1801      100          1
snd             27.83     A       1        0       2001
rcv             27.83     D    2301      100          1
snd/DA          27.83     A       1        0       2001
rcv             29.45     D    2001      100          1
snd             29.45     A       1        0       2201
rcv             29.45     D    2501      100          1
snd/DA          29.45     A       1        0       2201
rcv             29.45     D    2601      100          1
snd/DA          29.45     A       1        0       2201
rcv             31.08     D    2201      100          1
snd             31.08     A       1        0       2401
rcv             32.70     D    2401      100          1
snd             32.70     A       1        0       2701
rcv             32.70     D    2901      100          1
snd/DA          32.70     A       1        0       2701
rcv             34.32     D    2701      100          1
snd             34.32     A       1        0       2801
rcv             35.94     D    2801      100          1
snd             35.94     A       1        0       3001
rcv             37.57     D    3001       28          1
snd             37.57     A       1        0       3029
rcv             37.57     F    3029        0          1
snd             37.57     A       1        0       3030
snd             37.57     F       1        0       3030
rcv             37.57     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
```

Appendix

5c.

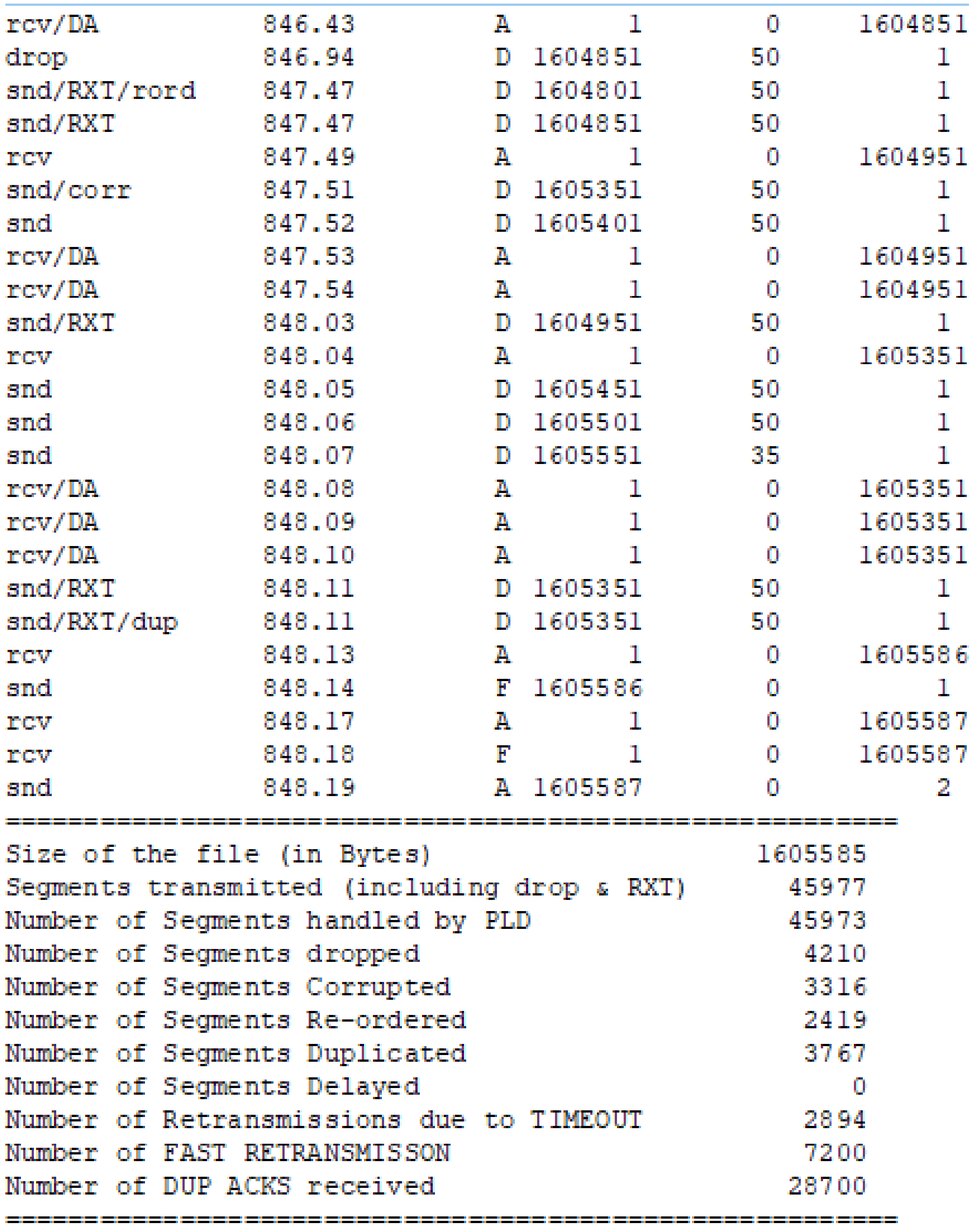
Sender_log.txt

Connection establishment + first 30 of entries



```
snd          0.00   S     0    0    0
rcv          0.15   SA    0    0    1
snd          0.15   A     1    0    1
snd          0.15   D     1   50    1
snd          0.15   D    51   50    1
snd          0.15   D   101   50    1
snd          0.15   D   151   50    1
snd          0.15   D   201   50    1
snd/corr     0.15   D   251   50    1
snd/corr     0.15   D   301   50    1
snd          0.15   D   351   50    1
snd          0.15   D   401   50    1
rcv          0.16   A     1    0   51
snd          0.16   D   451   50    1
snd/dup      0.16   D   451   50    1
snd          0.16   D   501   50    1
rcv          0.16   A     1    0  101
snd          0.16   D   551   50    1
rcv          0.16   A     1    0  151
snd          0.16   D   601   50    1
rcv          0.16   A     1    0  201
rcv          0.16   A     1    0  251
snd/corr     0.16   D   701   50    1
rcv/DA       0.16   A     1    0  251
rcv/DA       0.17   A     1    0  251
rcv/DA       0.17   A     1    0  251
snd/RXT      0.17   D   251   50    1
rcv/DA       0.17   A     1    0  251
rcv/DA       0.17   A     1    0  251
rcv/DA       0.17   A     1    0  251
snd/RXT      0.17   D   251   50    1
rcv/DA       0.17   A     1    0  251
rcv          0.17   A     1    0  301
```

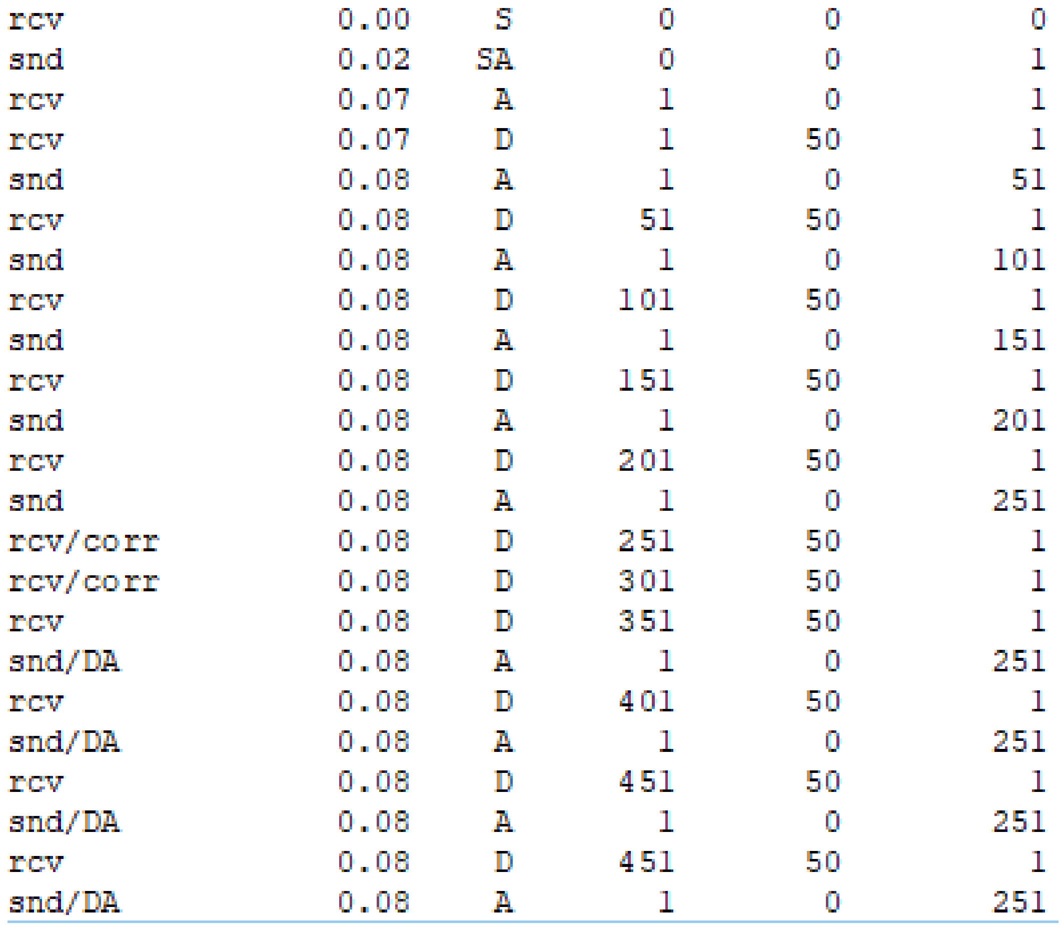
Last 20 entries + tear down + summary statistics



```
rcv/DA          846.43       A       1        0    1604851
drop            846.94       D 1604851       50          1
snd/RXT/rord    847.47       D 1604801       50          1
snd/RXT         847.47       D 1604851       50          1
rcv             847.49       A       1        0    1604951
snd/corr        847.51       D 1605351       50          1
snd             847.52       D 1605401       50          1
rcv/DA          847.53       A       1        0    1604951
rcv/DA          847.54       A       1        0    1604951
snd/RXT         848.03       D 1604951       50          1
rcv             848.04       A       1        0    1605351
snd             848.05       D 1605451       50          1
snd             848.06       D 1605501       50          1
snd             848.07       D 1605551       35          1
rcv/DA          848.08       A       1        0    1605351
rcv/DA          848.09       A       1        0    1605351
rcv/DA          848.10       A       1        0    1605351
snd/RXT         848.11       D 1605351       50          1
snd/RXT/dup     848.11       D 1605351       50          1
rcv             848.13       A       1        0    1605586
snd             848.14       F 1605586        0          1
rcv             848.17       A       1        0    1605587
rcv             848.18       F       1        0    1605587
snd             848.19       A 1605587        0          2
=========================================================
Size of the file (in Bytes)                      1605585
Segments transmitted (including drop & RXT)        45977
Number of Segments handled by PLD                  45973
Number of Segments dropped                          4210
Number of Segments Corrupted                        3316
Number of Segments Re-ordered                       2419
Number of Segments Duplicated                       3767
Number of Segments Delayed                             0
Number of Retransmissions due to TIMEOUT            2894
Number of FAST RETRANSMISSON                        7200
Number of DUP ACKS received                        28700
=========================================================
```

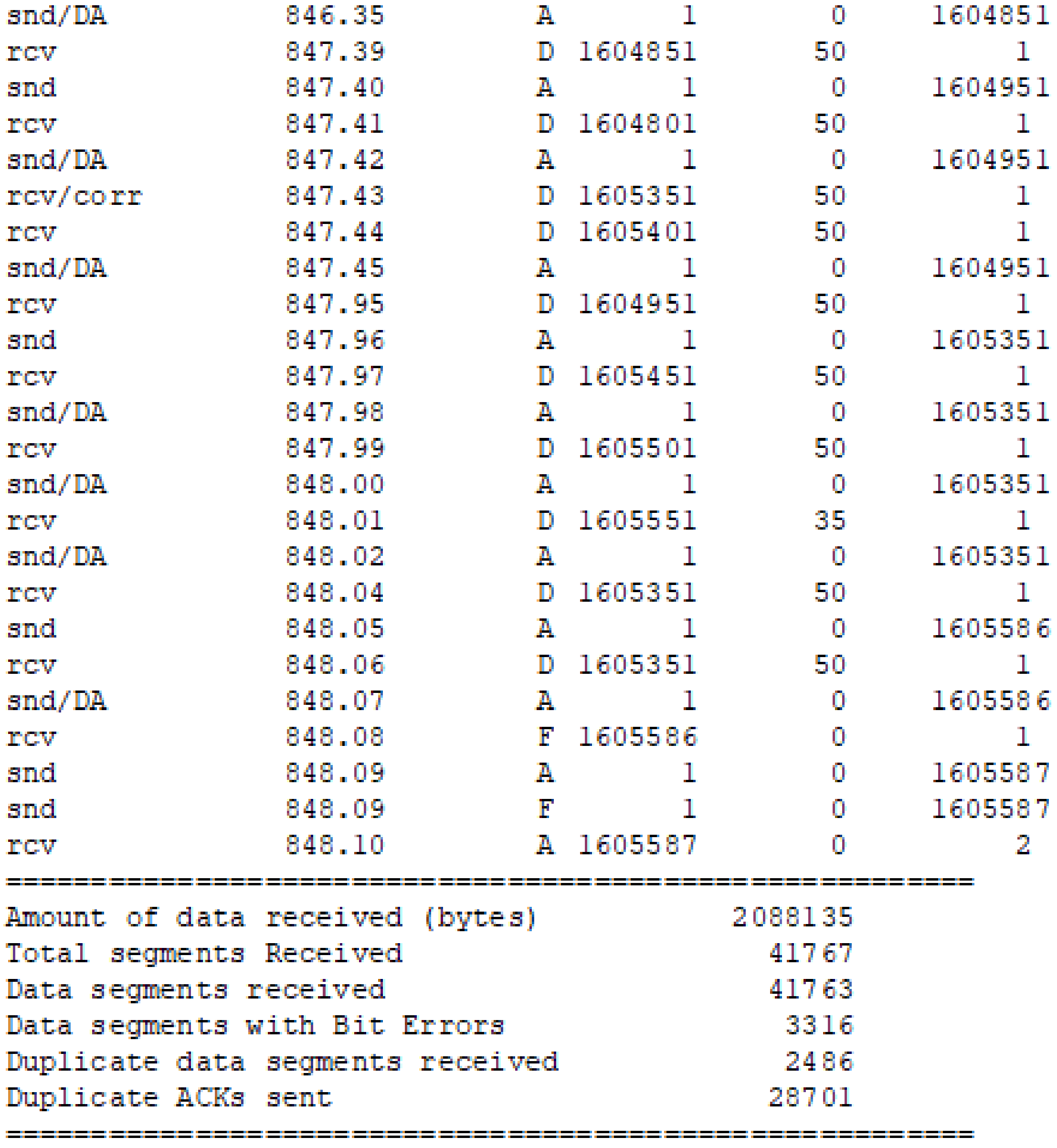
Receiver_log.txt

Connection establishment + first 30 entries



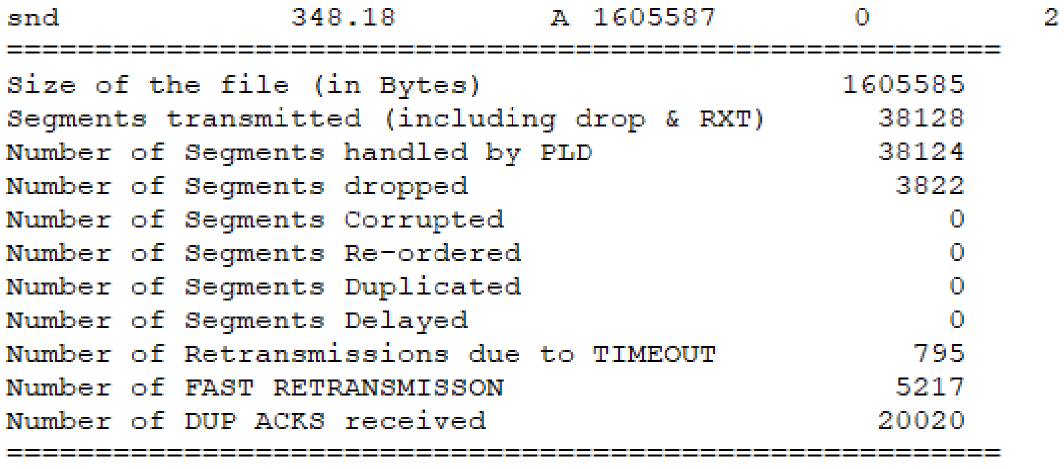
```
rcv          0.00   S     0    0     0
snd          0.02  SA     0    0     1
rcv          0.07   A     1    0     1
rcv          0.07   D     1   50     1
snd          0.08   A     1    0    51
rcv          0.08   D    51   50     1
snd          0.08   A     1    0   101
rcv          0.08   D   101   50     1
snd          0.08   A     1    0   151
rcv          0.08   D   151   50     1
snd          0.08   A     1    0   201
rcv          0.08   D   201   50     1
snd          0.08   A     1    0   251
rcv/corr     0.08   D   251   50     1
rcv/corr     0.08   D   301   50     1
rcv          0.08   D   351   50     1
snd/DA       0.08   A     1    0   251
rcv          0.08   D   401   50     1
snd/DA       0.08   A     1    0   251
rcv          0.08   D   451   50     1
snd/DA       0.08   A     1    0   251
rcv          0.08   D   451   50     1
snd/DA       0.08   A     1    0   251
```

Last 20 entries + teardown + summary statistics



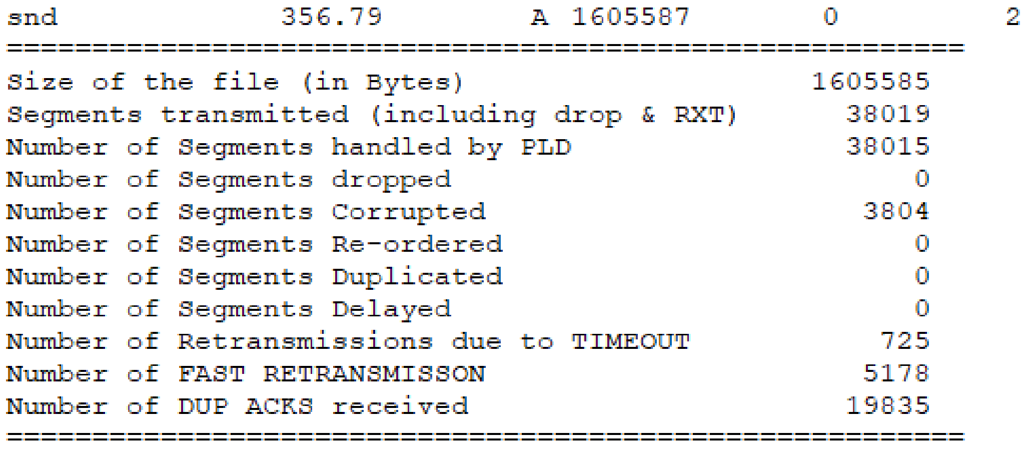
```
snd/DA          846.35        A       1        0     1604851
rcv             847.39        D 1604851       50           1
snd             847.40        A       1        0     1604951
rcv             847.41        D 1604801       50           1
snd/DA          847.42        A       1        0     1604951
rcv/corr        847.43        D 1605351       50           1
rcv             847.44        D 1605401       50           1
snd/DA          847.45        A       1        0     1604951
rcv             847.95        D 1604951       50           1
snd             847.96        A       1        0     1605351
rcv             847.97        D 1605451       50           1
snd/DA          847.98        A       1        0     1605351
rcv             847.99        D 1605501       50           1
snd/DA          848.00        A       1        0     1605351
rcv             848.01        D 1605551       35           1
snd/DA          848.02        A       1        0     1605351
rcv             848.04        D 1605351       50           1
snd             848.05        A       1        0     1605586
rcv             848.06        D 1605351       50           1
snd/DA          848.07        A       1        0     1605586
rcv             848.08        F 1605586        0           1
snd             848.09        A       1        0     1605587
snd             848.09        F       1        0     1605587
rcv             848.10        A 1605587        0           2
==========================================================
Amount of data received (bytes)           2088135
Total segments Received                     41767
Data segments received                      41763
Data segments with Bit Errors                3316
Duplicate data segments received             2486
Duplicate ACKs sent                         28701
==========================================================
```

Dropout only



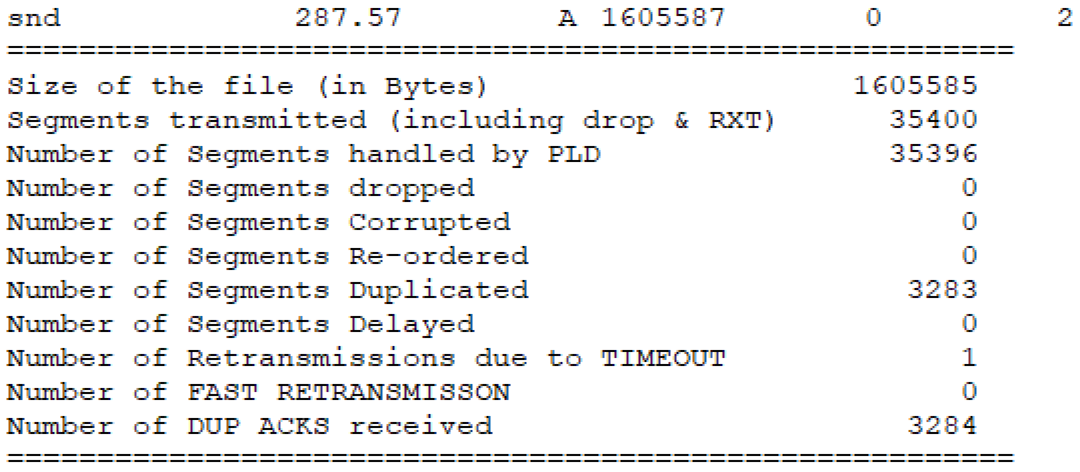
```
snd              348.18          A  1605587       0          2
=========================================================
Size of the file (in Bytes)                        1605585
Segments transmitted (including drop & RXT)          38128
Number of Segments handled by PLD                    38124
Number of Segments dropped                            3822
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               795
Number of FAST RETRANSMISSON                          5217
Number of DUP ACKS received                          20020
=========================================================
```

Corrupt only



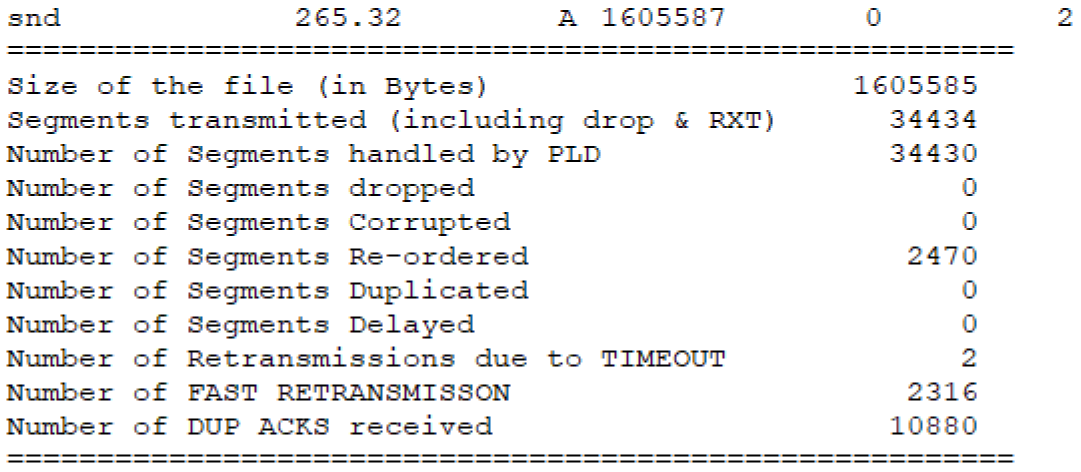
```
snd              356.79          A  1605587       0          2
=========================================================
Size of the file (in Bytes)                        1605585
Segments transmitted (including drop & RXT)          38019
Number of Segments handled by PLD                    38015
Number of Segments dropped                               0
Number of Segments Corrupted                          3804
Number of Segments Re-ordered                            0
Number of Segments Duplicated                            0
Number of Segments Delayed                               0
Number of Retransmissions due to TIMEOUT               725
Number of FAST RETRANSMISSON                          5178
Number of DUP ACKS received                          19835
=========================================================
```

Duplicate only



```
snd              287.57          A  1605587       0          2
=========================================================
Size of the file (in Bytes)                        1605585
Segments transmitted (including drop & RXT)          35400
Number of Segments handled by PLD                    35396
Number of Segments dropped                               0
Number of Segments Corrupted                             0
Number of Segments Re-ordered                            0
Number of Segments Duplicated                         3283
Number of Segments Delayed                               0
Number of Retransmissions due to TIMEOUT                 1
Number of FAST RETRANSMISSON                             0
Number of DUP ACKS received                           3284
=========================================================
```

Reordering only



```
snd             265.32        A  1605587      0          2
========================================================
Size of the file (in Bytes)                    1605585
Segments transmitted (including drop & RXT)      34434
Number of Segments handled by PLD                34430
Number of Segments dropped                           0
Number of Segments Corrupted                         0
Number of Segments Re-ordered                     2470
Number of Segments Duplicated                        0
Number of Segments Delayed                           0
Number of Retransmissions due to TIMEOUT             2
Number of FAST RETRANSMISSON                      2316
Number of DUP ACKS received                      10880
========================================================
```