COMP3331 Assignment Report

Simple Transport Protocol

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1. Implementation of the STP protocol

Language

Python 2 is used for both the sender and receiver program.

Header

A header class is created with fields (sequence number, acknowledgement number, header length, checksum, syn flag, ack flag and fin flag), it also has class functions to help simplify the code when handling the headers. The header object is sent by packing its fields into an array then use pickle to serialize it and send as string, the opposite can be done to retrieve the header object from the string.

Program Flow

Both the sender and receiver consist of 3 main stages.

Establish Connection -> File Transfer -> Close Connection

The connection establishment is done exactly the same as the TCP three-way handshake, the connection closing is done exactly the same as the TCP connection termination except there is no TIME-WAIT in the client program after sending out the last ACK packet. The file transfer stage is very similar to how TCP transfer file except there is no doubling the timeout. Each of these stages is written in one function and the program ensure everything is done correctly before moving on to the next stage.

Sender Details

Timeout

For every packet sent, a tuple of the expecting ack number and the current time is appended to a timer list, when a packet is received, its ack number will be checked with the list and the time with the matching expecting ack number will be used to calculate the sample RTT with the current time, the timeout interval will the updated with the new sample RTT. Because there is a possibility for the packet to be dropped with the PLD module, the timer list is checked before the packet is being sent and if the expecting ack number exist already, it will update the time to prevent using the wrong time value.

The timeout interval is calculated by

$$TimeoutInterval = EstimatedRTT + gamma * DevRTT$$

$gamma$ is given as a user's argument.

Pipelining

Sender will send packets with incrementing seq number from a send base without waiting for acknowledgement as long as the total bytes of data (without headers) sent without acknowledgement is not greater than the *Maximum Window Size (MWS)* which is given as a user's input. Upon receiving acknowledgement, the sender will update the send base with the ack number received. After sending all the packets with pipelining, the sender will start a timer, if no acknowledgement is received within the timeout interval, it will send a packet from the send base again. The packets are also ensured to have data (without header) with size smaller than the *Maximum Segment Size (MSS)* which is given as a user argument.

Fast Retransmission

During a timeout interval, if a duplicate acknowledgement is received, it will be added to a list associated with a number indicating how many duplicated have been received, the number is incremented every time the same duplicate is received. If the number is 3, indicating 3 duplicate acknowledgements have been received, the sender will then immediately send packet with seq number equals to that ack number and the corresponding data without waiting for the timeout interval to end.

Packet Loss and Delay Module

The Packet Loss and Delay Module is implemented as a class and a wrapper for the send packet function, using the probabilities given as the user's arguments to decide whether or not it should either drop, duplicate, corrupt, reorder or delay the packet. For corrupting, a single bit of the packet is reversed and for delaying, a new thread will be started and sleep for the time to delay before sending the packet, this can ensure that other packets are sent normally in the correct time.

Log File

A log file with name *Sender_log.txt* will be created and record all the packets sent and received with a timestamp, it will also output an overall statistic at the end.

Receiver Details

Buffering Out-of-Order Packets

Upon receiving packet with seq number higher than the last ack number sent, the packet will be saved into a list in order of the corresponding seq num. When a new packet received with the right seq number, it will then check the buffer list and write all the subsequent buffered packets to the file and send acknowledgement with the last ack number, preventing the buffered packets from being sent again.

Log File

A log file with name *Receiver_log.txt* will be created and record all the packets sent and received with a timestamp, it will also output an overall statistic at the end.

List of Features Implemented

Sender

- Three-way handshake connection establishment
- Four-segment connection termination
- Round-trip-time estimation and RTO estimation
- Timeout retransmission
- Fast Retransmission
- Pipelining with MWS and MSS
- PLD module
- Generate checksum for data integrity
- Log file

Receiver

- Three-way handshake connection establishment
- Four-segment connection termination
- Buffering out-of-order segments
- Check for corrupted header or data
- Log file

There is a verbose option -v for both sender and receiver

2. Simple Transport Protocol Header

Header Diagram

<table>
<tr><td colspan="3">Sequence Number</td></tr>
<tr><td colspan="3">Acknowledgement Number</td></tr>
<tr><td colspan="3">Header Length</td></tr>
<tr><td colspan="3">Checksum</td></tr>
<tr><td>SYN</td><td>ACK</td><td>FIN</td></tr>
<tr><td colspan="3">Data</td></tr>
</table>

Header Field Details

- *Sequence Number and Acknowledgement Number* are used to implement a reliable protocol where they can ensure all the data are sent, they are the same as TCP
- *Header Length* is used as the offset to data
- *Checksum* is the MD5 hash of the seq number, ack number, header length and data. It is used as a verification to ensure data integrity
- *SYN, ACK* and *FIN* flags are used to indicate the type of the packet
- *Data* is the actual payload being sent, its size is smaller or equals to the MSS

3. Design Trade-offs/Possible Improvements & Extensions

Design Trade-offs

- Because of using pickle to send the header object, it creates a variable header length rather than a fixed length like c, which made it a bit harder to implement the header length and checksum calculations
- TIME-WAIT in the connection termination stage is not implemented since I don't think it is necessary with its usage

Possible Improvements & Extensions

- Extend checksum to also include the SYN, ACK and FIN flags to further improve data integrity
- Send the header as raw bytes rather than string so that it can have a fixed header length
- Dynamically adjust the MWS and MSS base on the internet performance such as RTTs and number of timeouts occurring

4. Code

All codes are written by me.

5. Questions

A.

See 5.A.1 for pdrop=0.1 and 5.A.2 for pdrop=0.3 in Appendix

We can see with pdrop=0.3, the receiver received more packets, this is probably because with more packets dropped, the sender sent back packets when timeout and due to the MWS, more packets are being sent other than just the dropped packets.
To find out where packets are dropped, we simply have to look for out-of-order seq number. For example, in 5.A.1 we can see the seq number received from

147170 -> 147270 -> 147470

Seq number 147370 is not present, meaning that packet with this seq number is dropped.
Another example in 5.A.2, we can see the seq number received from

147170 -> 147570

Seq number 147270, 147370 and 147470 are not present, meaning that these packets are dropped.

B.

Gamma	Packet Transmitted	Time (sec)
2	18950	159.13
4	18134	1042.59
6	17475	2260.09

The time required to transfer the file increase dramatically as gamma increases, this is because base on the equation used to calculate the seconds for timeout interval, gamma is a multiplier and thus have great effect increasing the timeout interval. Since about half of the packets are dropped, the sender will always have to wait for the whole timeout interval and thus in the end, the time required to transfer the file increased by a huge amount as gamma increases. However, the packets transmitted decrease as gamma increases, this is because with increasing timeout interval, it allows the delayed packets to reach the receiver and received acknowledgement before the timeout interval finishes, thus preventing duplicating packets being sent again as the sender thought the delayed packets are lost.

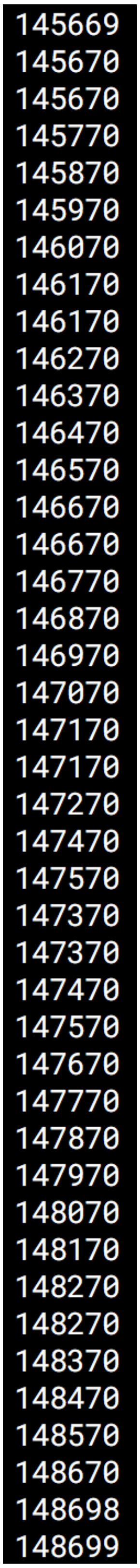
C.

See 5.C.1 for sender's log and 5.C.2 for receiver's log in Appendix

The file has been successfully transferred, the overall transfer time is 140.33 seconds.
I think dropped packets are the most critical contributing in overall transfer time, this is because for corrupted, duplicate and reordered packets, the receiver will always send an acknowledgment back to the sender which can trigger the fast retransmission to speed up the transfer process, however for dropped packets no acknowledgment will be sent back to the sender and thus the sender will always have to wait for the whole timeout interval before proceeding and is thus critical in increasing the overall transfer time.

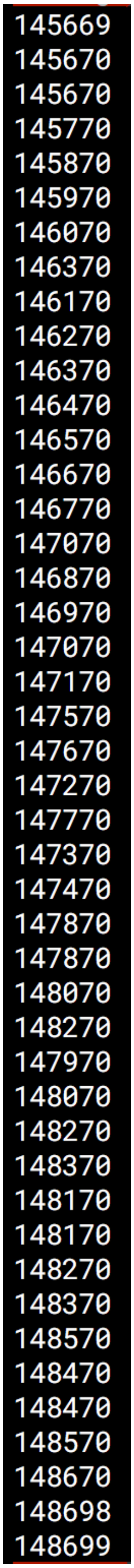
Appendix

5.A.1 Received seq number with pdrop=0.1



```
145669
145670
145670
145770
145870
145970
146070
146170
146170
146270
146370
146470
146570
146670
146670
146770
146870
146970
147070
147170
147170
147270
147470
147570
147370
147370
147470
147570
147670
147770
147870
147970
148070
148170
148270
148270
148370
148470
148570
148670
148698
148699
```

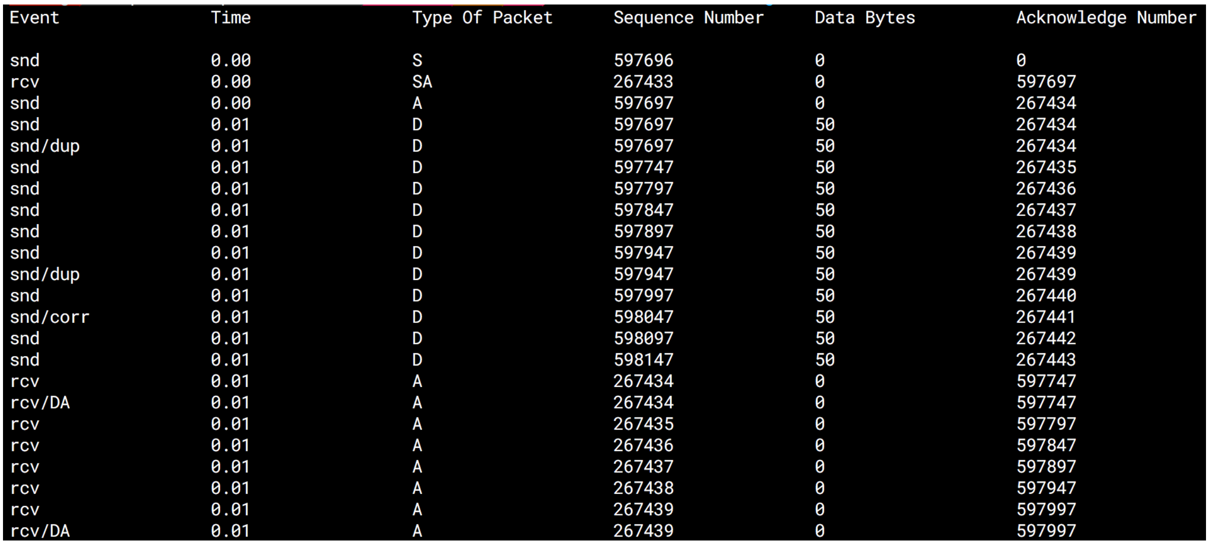
5.A.2 Received seq number with pdrop=0.3



```
145669
145670
145670
145770
145870
145970
146070
146370
146170
146270
146370
146470
146570
146670
146770
147070
146870
146970
147070
147170
147570
147670
147270
147770
147370
147470
147870
147870
148070
148270
147970
148070
148270
148370
148170
148170
148270
148370
148570
148470
148470
148570
148670
148698
148699
```

5.C.1 Sender's log

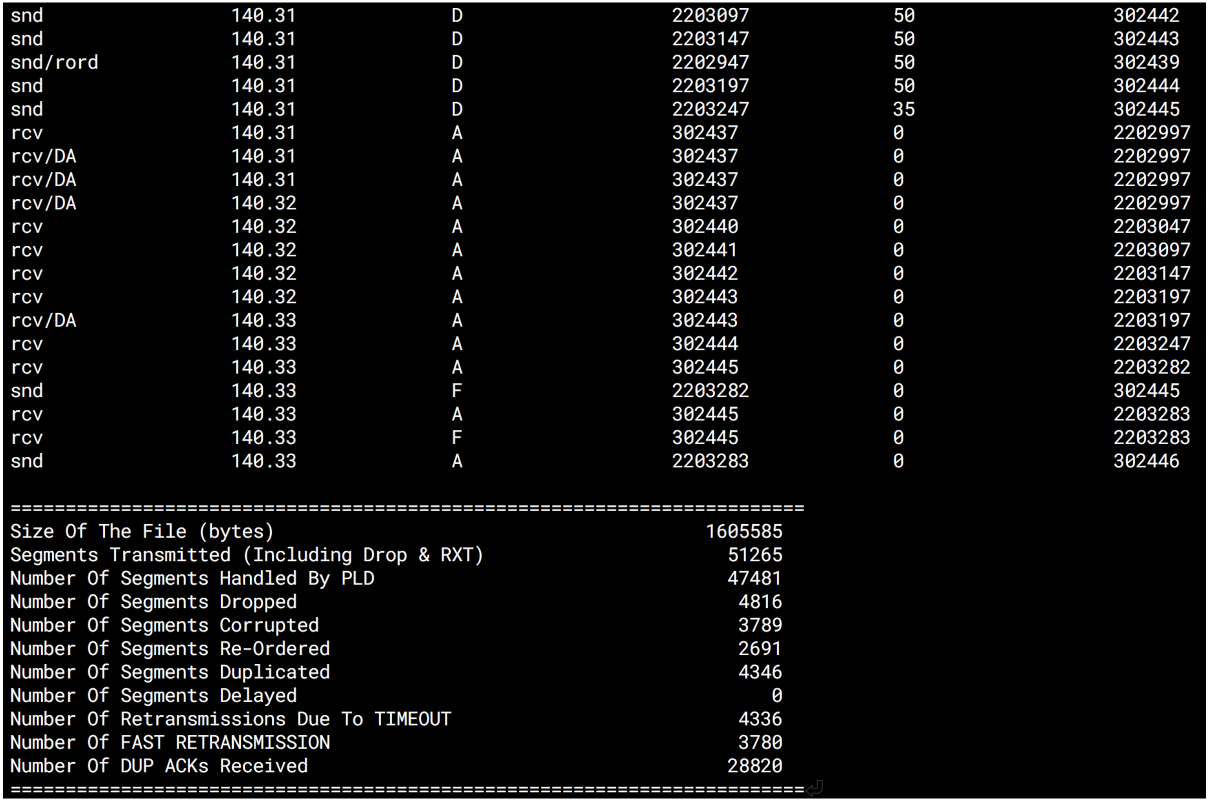
Connection establishment and first 20 entries



```
Event               Time                Type Of Packet      Sequence Number     Data Bytes          Acknowledge Number

snd                 0.00                S                   597696              0                   0
rcv                 0.00                SA                  267433              0                   597697
snd                 0.00                A                   597697              0                   267434
snd                 0.01                D                   597697              50                  267434
snd/dup             0.01                D                   597697              50                  267434
snd                 0.01                D                   597747              50                  267435
snd                 0.01                D                   597797              50                  267436
snd                 0.01                D                   597847              50                  267437
snd                 0.01                D                   597897              50                  267438
snd                 0.01                D                   597947              50                  267439
snd/dup             0.01                D                   597947              50                  267439
snd                 0.01                D                   597997              50                  267440
snd/corr            0.01                D                   598047              50                  267441
snd                 0.01                D                   598097              50                  267442
snd                 0.01                D                   598147              50                  267443
rcv                 0.01                A                   267434              0                   597747
rcv/DA              0.01                A                   267434              0                   597747
rcv                 0.01                A                   267435              0                   597797
rcv                 0.01                A                   267436              0                   597847
rcv                 0.01                A                   267437              0                   597897
rcv                 0.01                A                   267438              0                   597947
rcv                 0.01                A                   267439              0                   597997
rcv/DA              0.01                A                   267439              0                   597997
```

Last 20 entries and summary statistics

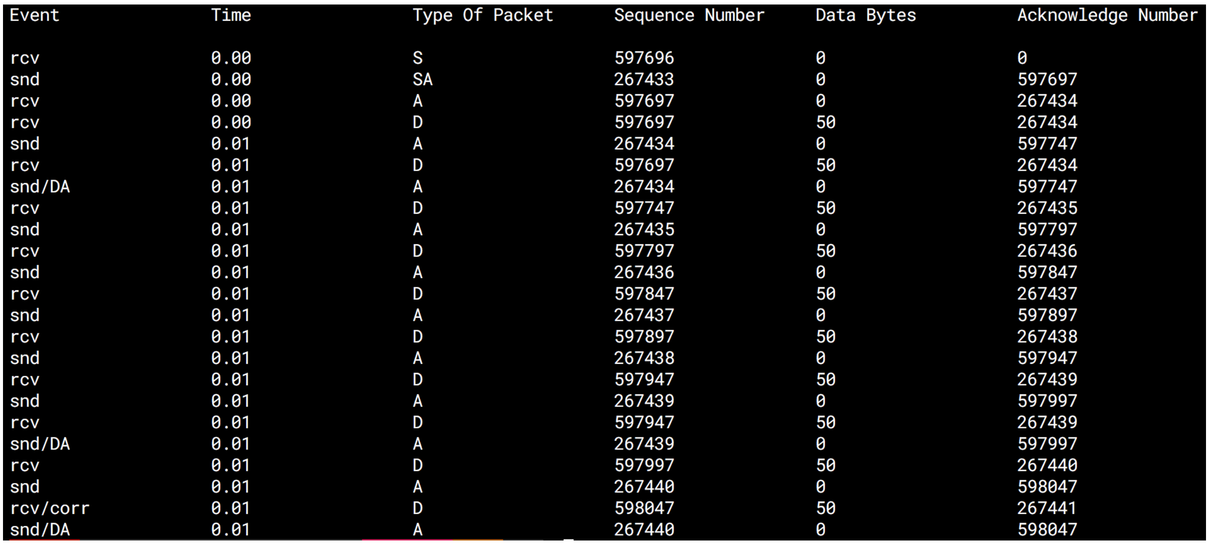


```
snd                 140.31              D                   2203097             50                  302442
snd                 140.31              D                   2203147             50                  302443
snd/rord            140.31              D                   2202947             50                  302439
snd                 140.31              D                   2203197             50                  302444
snd                 140.31              D                   2203247             35                  302445
rcv                 140.31              A                   302437              0                   2202997
rcv/DA              140.31              A                   302437              0                   2202997
rcv/DA              140.31              A                   302437              0                   2202997
rcv/DA              140.32              A                   302437              0                   2202997
rcv                 140.32              A                   302440              0                   2203047
rcv                 140.32              A                   302441              0                   2203097
rcv                 140.32              A                   302442              0                   2203147
rcv                 140.32              A                   302443              0                   2203197
rcv/DA              140.33              A                   302443              0                   2203197
rcv                 140.33              A                   302444              0                   2203247
rcv                 140.33              A                   302445              0                   2203282
snd                 140.33              F                   2203282             0                   302445
rcv                 140.33              A                   302445              0                   2203283
rcv                 140.33              F                   302445              0                   2203283
snd                 140.33              A                   2203283             0                   302446

========================================================================
Size Of The File (bytes)                                        1605585
Segments Transmitted (Including Drop & RXT)                       51265
Number Of Segments Handled By PLD                                 47481
Number Of Segments Dropped                                         4816
Number Of Segments Corrupted                                       3789
Number Of Segments Re-Ordered                                      2691
Number Of Segments Duplicated                                      4346
Number Of Segments Delayed                                            0
Number Of Retransmissions Due To TIMEOUT                           4336
Number Of FAST RETRANSMISSION                                      3780
Number Of DUP ACKs Received                                       28820
========================================================================
```

5.C.2 Receiver’s log

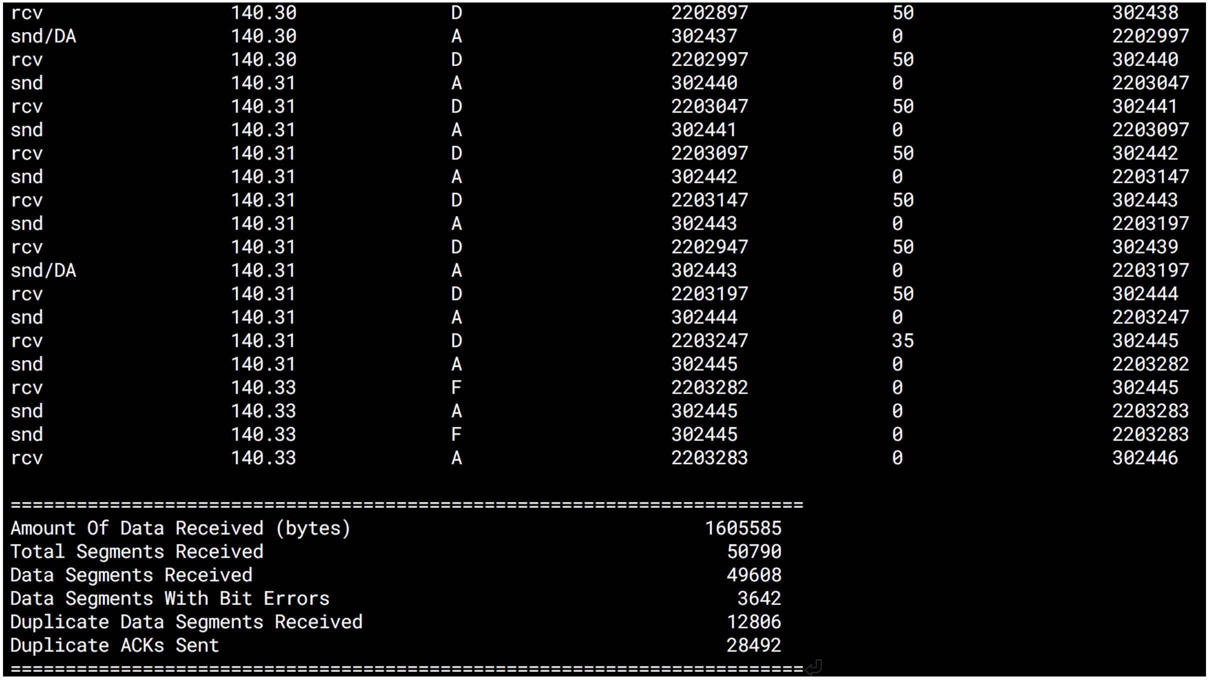
Connection establishment and first 20 entries



```
Event               Time                Type Of Packet      Sequence Number     Data Bytes          Acknowledge Number

rcv                 0.00                S                   597696              0                   0
snd                 0.00                SA                  267433              0                   597697
rcv                 0.00                A                   597697              0                   267434
rcv                 0.00                D                   597697              50                  267434
snd                 0.01                A                   267434              0                   597747
rcv                 0.01                D                   597697              50                  267434
snd/DA              0.01                A                   267434              0                   597747
rcv                 0.01                D                   597747              50                  267435
snd                 0.01                A                   267435              0                   597797
rcv                 0.01                D                   597797              50                  267436
snd                 0.01                A                   267436              0                   597847
rcv                 0.01                D                   597847              50                  267437
snd                 0.01                A                   267437              0                   597897
rcv                 0.01                D                   597897              50                  267438
snd                 0.01                A                   267438              0                   597947
rcv                 0.01                D                   597947              50                  267439
snd                 0.01                A                   267439              0                   597997
rcv                 0.01                D                   597947              50                  267439
snd/DA              0.01                A                   267439              0                   597997
rcv                 0.01                D                   597997              50                  267440
snd                 0.01                A                   267440              0                   598047
rcv/corr            0.01                D                   598047              50                  267441
snd/DA              0.01                A                   267440              0                   598047
```

Last 20 entries and summary statistics



```
rcv                 140.30              D                   2202897             50                  302438
snd/DA              140.30              A                   302437              0                   2202997
rcv                 140.30              D                   2202997             50                  302440
snd                 140.31              A                   302440              0                   2203047
rcv                 140.31              D                   2203047             50                  302441
snd                 140.31              A                   302441              0                   2203097
rcv                 140.31              D                   2203097             50                  302442
snd                 140.31              A                   302442              0                   2203147
rcv                 140.31              D                   2203147             50                  302443
snd                 140.31              A                   302443              0                   2203197
rcv                 140.31              D                   2202947             50                  302439
snd/DA              140.31              A                   302443              0                   2203197
rcv                 140.31              D                   2203197             50                  302444
snd                 140.31              A                   302444              0                   2203247
rcv                 140.31              D                   2203247             35                  302445
snd                 140.31              A                   302445              0                   2203282
rcv                 140.33              F                   2203282             0                   302445
snd                 140.33              A                   302445              0                   2203283
snd                 140.33              F                   302445              0                   2203283
rcv                 140.33              A                   2203283             0                   302446

========================================================================
Amount Of Data Received (bytes)                                 1605585
Total Segments Received                                           50790
Data Segments Received                                            49608
Data Segments With Bit Errors                                      3642
Duplicate Data Segments Received                                  12806
Duplicate ACKs Sent                                               28492
========================================================================
```