1. **A brief discussion of how you have implemented the STP protocol. Provide a list of features that you have successfully implemented. In case you have not been able to get certain features of STP working, you should also mention that in your report.**

Sender features	**Receiver features**
Three-way-handshake	Three-way-handshake
Four-segment connection termination	Four-segment connection termination
SEQ and ACK numbers	SEQ and ACK numbers
MSS and MWS	Checksum
PLD module	Reorder segments
Timeout operation	Write log
Fast retransmission	
Write log	

I write some utility function first such as the encode and decode function to transform data, also do the checksum; the log function in both sender and receiver to write log and count different kinds of segments.

After preparation, I implement the three-way handshake to set up connection and then hold this state and wait for data transmitting. When the whole transmission is finished, sender and receiver terminate connection by finishing four-segment handwave.

Sender has a left-right organism to control retransmission. The left represents being ACK one, right represents send one. The left always catch up with the right until they are the same value. It also means the length of data is 0.

The sender sends several segments at one time and wait for ACKs. When the flag is not finished, the segment that sender send go through PLD module. If the random float is smaller than pDrop etc., then execute corresponding operation. For example, if corrupt occurred, the first bit of payload will be modified then receiver will check the checksum in header and discord it. If timeout happened, sender will resend that package in a new window, following other packs together.

There is a buffer in receiver that aimed to reorder the segments duplicated or out of order due to pOrder or retransmission. First reorder segments by their sequence number. If there are more than one segment and it is a duplicated segment, then pop it out of buffer. If the sequence number is next to other segments, then combine then and pop the original one.

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

DATA_LEN	4 byte	The length of data.
SEQ_NUM	4 byte	The sequence number.
ACK_NUM	4 byte	The acknowledge number.
FLAG	2 byte	Flag field, SYN, ACK or FIN
CHECK_SUM	2 byte	Check segment is corrupted or not.
DATA	n byte	Data, the payload of segment.

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

   In the PLD module, the original of retransmission I designed was: if the counter of ACK DUP is more than 3, then reset the counter to zero and retransmit the segment. It may lead to retransmit the same segment for several times constantly and consume tremendous running time. So, I finally set only retransmitting segment for one time, maybe it could not fit the specification perfectly but could save lot of running time.

4. **Indicate any segments of code that you have borrowed from the Web or other books.**

   All my code for this assignment is original, there is nothing from Web or other books.

5. Answer the following questions: (include any output as an appendix to the main report.pdf, appendix is not included in the 5-page limit)

a) It easily to indicate where dropping occurred. Focus on sequence numbers, if it suddenly jumps a gap with the size of MSS, there must be a drooping occurred.

```
rcv     0.01    D     101    100    1
snd     0.01    A       1      0  201
rcv     0.01    D     301    100    1
```

Like the figure 1 in appendix shows, the sequence number suddenly jump from 101 to 301 without 201, it means the segment with sequence number 201 has been dropped and will be retransmitted later (sequence number 201 between 601 and 701).

```
snd/DA  0.01    A       1      0  201
rcv     0.01    D     601    100    1
snd/DA  0.01    A       1      0  201
rcv     0.02    D     201    100    1
snd     0.02    A       1      0  701
rcv     0.03    D     701    100    1
```

According to figure 1 and figure 2, there are 4 drops and 24 drops separately in cases with pDrop = 0.1 and pDrop = 0.3

b) When gamma = 4, the segments transmitted and running time significantly decrease, because as the gamma increases, the timeout interval increases. Because random generated delay is more likely shorter than timeout interval, there will be less segments retransmitted due to timeout. However, when gamma = 6, segments transmitted and running time are similar with the case with gamma = 4. The reason is the increase of timeout interval is big enough and would not have too much influence. (Not sure)

	Segments transmitted	Running time
Gamma = 2	1201109	105.91
Gamma = 4	754141	69.02
Gamma = 6	759421	68.97

c) The file has been successfully transferred. The overall transfer took about 7 minutes. The pDrop may be contribute to running time most. First, segments dropped are more than the other three kind of segments. Second, the sender will retransmission constantly until receive ACK, while pDuplicate and pOrder only need to reorder at the receiver. Finally, pCorrupt is similar with pDrop, it also contributes to running time much.

So, I conclude pDrop is the most critical contributing most in the overall transfer time.

6. Appendix

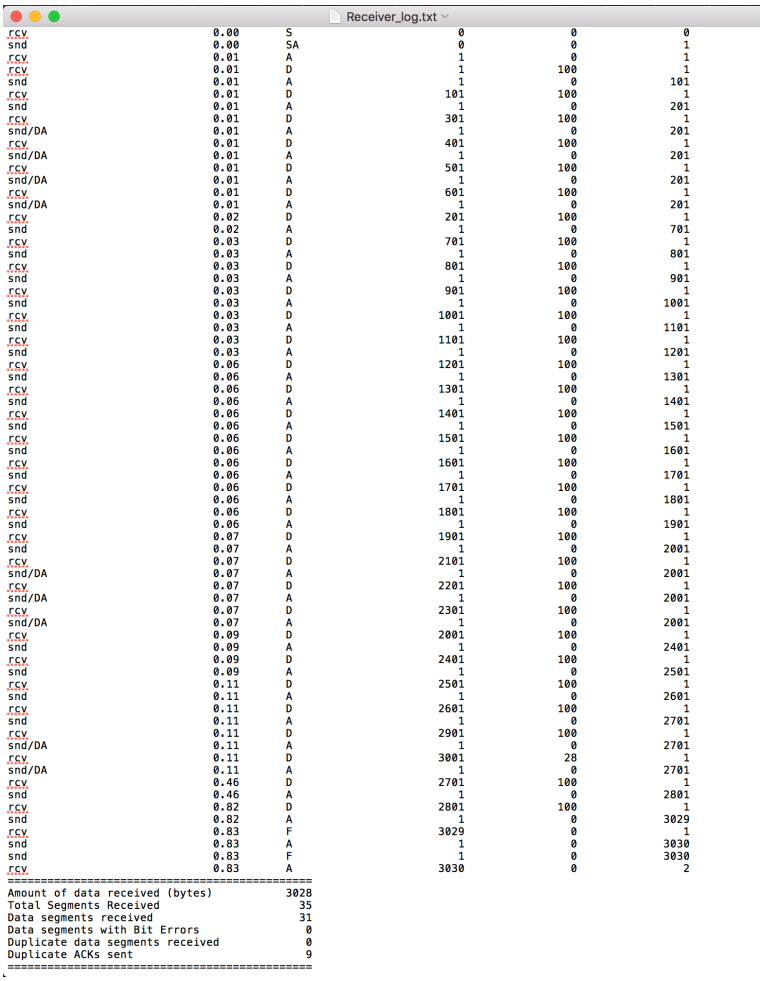


figure 1. receiver_log with pDrop = 0.1

Receiver_log.txt

rcv	0.00	S	0	0	0
snd	0.00	SA	0	0	1
rcv	0.01	A	1	0	1
rcv	0.01	D	101	100	1
snd/DA	0.01	A	1	0	1
rcv	0.01	D	201	100	1
snd/DA	0.01	A	1	0	1
rcv	0.02	D	301	100	1
snd/DA	0.02	A	1	0	1
rcv	3.03	D	1	100	1
snd	3.03	A	1	0	401
rcv	3.04	D	501	100	1
snd/DA	3.04	A	1	0	401
rcv	3.04	D	801	100	1
snd/DA	3.04	A	1	0	401
rcv	4.54	D	401	100	1
snd	4.54	A	1	0	601
rcv	4.55	D	1001	100	1
snd/DA	4.55	A	1	0	601
rcv	6.05	D	601	100	1
snd	6.05	A	1	0	701
rcv	6.06	D	1101	100	1
snd/DA	6.06	A	1	0	701
rcv	7.56	D	701	100	1
snd	7.56	A	1	0	901
rcv	7.58	D	1201	100	1
snd/DA	7.58	A	1	0	901
rcv	9.07	D	901	100	1
snd	9.07	A	1	0	1301
rcv	9.08	D	1601	100	1
snd/DA	9.08	A	1	0	1301
rcv	9.08	D	1701	100	1
snd/DA	9.08	A	1	0	1301
rcv	12.09	D	1301	100	1
snd	12.09	A	1	0	1401
rcv	12.09	D	1801	100	1
snd/DA	12.09	A	1	0	1401
rcv	13.60	D	1401	100	1
snd	13.60	A	1	0	1501
rcv	21.12	D	1501	100	1
snd	21.12	A	1	0	1901
rcv	21.13	D	2001	100	1
snd/DA	21.13	A	1	0	1901
rcv	21.13	D	2101	100	1
snd/DA	21.13	A	1	0	1901
rcv	21.13	D	2201	100	1
snd/DA	21.13	A	1	0	1901
rcv	21.13	D	2301	100	1
snd/DA	21.13	A	1	0	1901
rcv	22.64	D	1901	100	1
snd	22.64	A	1	0	2401
rcv	22.64	D	2701	100	1
snd/DA	22.64	A	1	0	2401
rcv	22.64	D	2801	100	1
snd/DA	22.64	A	1	0	2401
rcv	25.65	D	2401	100	1
snd	25.65	A	1	0	2501
rcv	27.16	D	2501	100	1
snd	27.16	A	1	0	2601
rcv	27.16	D	3001	28	1
snd/DA	27.16	A	1	0	2601
rcv	30.18	D	2601	100	1
snd	30.18	A	1	0	2901
rcv	33.20	D	2901	100	1
snd	33.20	A	1	0	3029
rcv	33.20	F	3029	0	1
snd	33.20	A	1	0	3030
snd	33.20	F	1	0	3030
rcv	33.20	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                         18
============================================
```

figure 2. receiver_log with pDrop = 0.3

```
============================================================
Size of the file (in Bytes)                          308203
Segments transmitted (including drop & RXT)         1201109
Number of Segments handled by PLD                     26246
Number of Segments dropped                                0
Number of Segments Corrupted                              0
Number of Segments Re-ordered                             0
Number of Segments Duplicated                             0
Number of Segments Delayed                          1180065
Number of Retransmissions due to TIMEOUT               7301
Number of FAST RETRANSMISSION                         12780
Number of DUP ACKS received                         1194957
============================================================
```

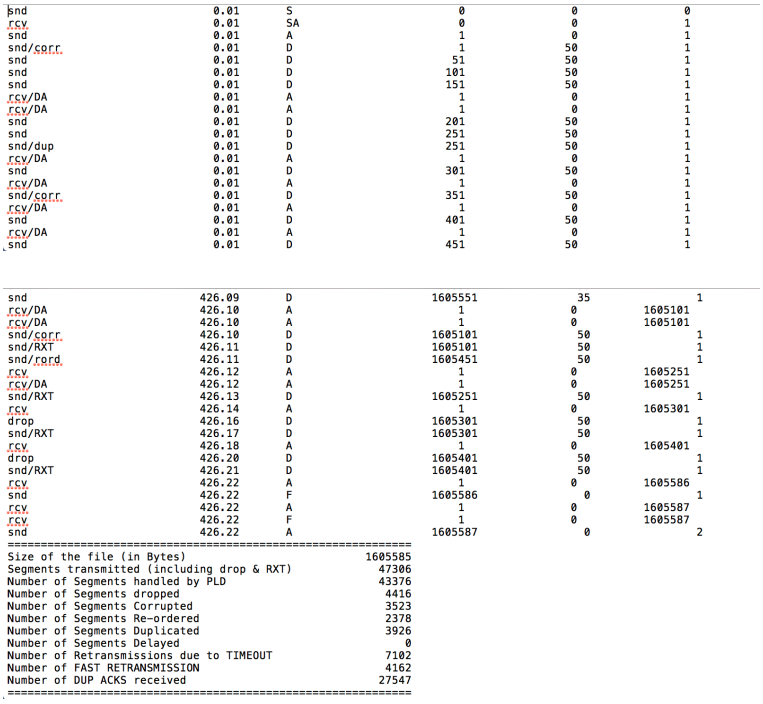
figure 3. sender_log with gamma = 2

```
============================================================
Size of the file (in Bytes)                          308203
Segments transmitted (including drop & RXT)          754141
Number of Segments handled by PLD                     16729
Number of Segments dropped                                0
Number of Segments Corrupted                              0
Number of Segments Re-ordered                             0
Number of Segments Duplicated                             0
Number of Segments Delayed                           740719
Number of Retransmissions due to TIMEOUT               2542
Number of FAST RETRANSMISSION                          8022
Number of DUP ACKS received                          747990
============================================================
```

figure 4. sender_log with gamma = 4

```
============================================================
Size of the file (in Bytes)                          308203
Segments transmitted (including drop & RXT)          759421
Number of Segments handled by PLD                     15536
Number of Segments dropped                                0
Number of Segments Corrupted                              0
Number of Segments Re-ordered                             0
Number of Segments Duplicated                             0
Number of Segments Delayed                           746976
Number of Retransmissions due to TIMEOUT               1910
Number of FAST RETRANSMISSION                          7464
Number of DUP ACKS received                          753259
============================================================
```

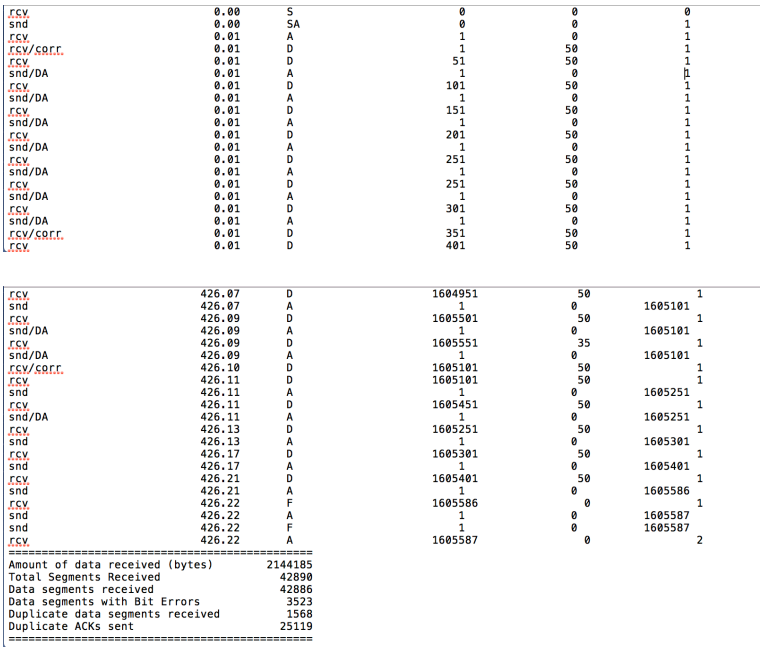
figure 5. sender_log with gamma = 6



```
snd                     0.01        S                   0               0               0
rcv                     0.01        SA                  0               0               1
snd                     0.01        A                   1               0               1
snd/corr                0.01        D                   1              50               1
snd                     0.01        D                  51              50               1
snd                     0.01        D                 101              50               1
snd                     0.01        D                 151              50               1
rcv/DA                  0.01        A                   1               0               1
rcv/DA                  0.01        A                   1               0               1
snd                     0.01        D                 201              50               1
snd                     0.01        D                 251              50               1
snd/dup                 0.01        D                 251              50               1
rcv/DA                  0.01        A                   1               0               1
snd                     0.01        D                 301              50               1
rcv/DA                  0.01        A                   1               0               1
snd/corr                0.01        D                 351              50               1
rcv/DA                  0.01        A                   1               0               1
snd                     0.01        D                 401              50               1
rcv/DA                  0.01        A                   1               0               1
snd                     0.01        D                 451              50               1

snd                    426.09       D             1605551              35               1
rcv/DA                 426.10       A                   1               0         1605101
rcv/DA                 426.10       A                   1               0         1605101
snd/corr               426.10       D             1605101              50               1
snd/RXT                426.11       D             1605101              50               1
snd/rord               426.11       D             1605451              50               1
rcv                    426.12       A                   1               0         1605251
rcv/DA                 426.12       A                   1               0         1605251
snd/RXT                426.13       D             1605251              50               1
rcv                    426.14       A                   1               0         1605301
drop                   426.16       D             1605301              50               1
snd/RXT                426.17       D             1605301              50               1
rcv                    426.18       A                   1               0         1605401
drop                   426.20       D             1605401              50               1
snd/RXT                426.21       D             1605401              50               1
rcv                    426.22       A                   1               0         1605586
snd                    426.22       F             1605586               0               1
rcv                    426.22       A                   1               0         1605587
rcv                    426.22       F                   1               0         1605587
snd                    426.22       A             1605587               0               2
============================================================
Size of the file (in Bytes)                         1605585
Segments transmitted (including drop & RXT)           47306
Number of Segments handled by PLD                     43376
Number of Segments dropped                             4416
Number of Segments Corrupted                           3523
Number of Segments Re-ordered                          2378
Number of Segments Duplicated                          3926
Number of Segments Delayed                                0
Number of Retransmissions due to TIMEOUT               7102
Number of FAST RETRANSMISSION                          4162
Number of DUP ACKS received                           27547
============================================================
```

figure 6. first and last 20 entries of sender_log



```
rcv                     0.00        S                   0               0               0
snd                     0.00        SA                  0               0               1
rcv                     0.01        A                   1               0               1
rcv/corr                0.01        D                   1              50               1
rcv                     0.01        D                  51              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 101              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 151              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 201              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 251              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 251              50               1
snd/DA                  0.01        A                   1               0               1
rcv                     0.01        D                 301              50               1
snd/DA                  0.01        A                   1               0               1
rcv/corr                0.01        D                 351              50               1
rcv                     0.01        D                 401              50               1

rcv                    426.07       D             1604951              50               1
snd                    426.07       A                   1               0         1605101
rcv                    426.09       D             1605501              50               1
snd/DA                 426.09       A                   1               0         1605101
rcv                    426.09       D             1605551              35               1
snd/DA                 426.09       A                   1               0         1605101
rcv/corr               426.10       D             1605101              50               1
rcv                    426.11       D             1605101              50               1
snd                    426.11       A                   1               0         1605251
rcv                    426.11       D             1605451              50               1
snd/DA                 426.11       A                   1               0         1605251
rcv                    426.13       D             1605251              50               1
snd                    426.13       A                   1               0         1605301
rcv                    426.17       D             1605301              50               1
snd                    426.17       A                   1               0         1605401
rcv                    426.21       D             1605401              50               1
snd                    426.21       A                   1               0         1605586
rcv                    426.22       F             1605586               0               1
snd                    426.22       A                   1               0         1605587
snd                    426.22       F                   1               0         1605587
rcv                    426.22       A             1605587               0               2
================================================
Amount of data received (bytes)         2144185
Total Segments Received                   42890
Data segments received                    42886
Data segments with Bit Errors              3523
Duplicate data segments received           1568
Duplicate ACKs sent                       25119
================================================
```

figure 7. first and last 20 entries of receiver_log