COMP3331 Computer Networks and Applications

Assignment for Session 2, 2018

Brian Jordan

z5229651

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Assignment Report

Implementation of STP Protocol

For my STP Protocol implementation, I implemented a protocol similar to the TCP Go-Back-N protocol discussed in lecture. I worked in Java creating a Sender.java, Receiver.java, and Segment.java class. For the implementation of the sender and the receiver, I used my knowledge of UDP socket programming obtained from Lab 2 to initialize and transfer the packets between the sender and the receiver clients. In both of the client classes produced, I created a method for establishing the secure connection using a three-way handshake as well as a method for terminating the connection using the four-segment connection termination procedure.

My Sender class was made up of 3 different threads. Two of the threads were used for sending data, while the third was used for receiving ACKs back from the receiver client. I chose to use two sender threads so that one could handle the majority of the packets, while the other handled packets that were affected by the PLD in terms of reordering or delay.

The Receiver class worked sequentially without the use of multithreading. Packets that were received by the receiver client were processed and the corresponding ACK or duplicate ACK was sent back to the Sender client.

The Segment class constructs and maintains the details of each segment transferred and it also contains methods to check for data corruption, determine the type of segment being transferred , and creating the actual UDP packet.

For making the transfer of Data secure, I implemented a number of reliable transfer features including:

- Three-way handshake for connection establishment and a four-segment connection termination.
- A single-timer corresponding to the first packet of the window for timeout resending. This timer was adjusted by sample RTTs. from the successfully transmitted packets according to the given equations

- Fast Retransmission after receiving 3 duplicate ACKS
- Checksum used on the data of the Segments to check for bit errors
- Receiving buffer to account for out of order segments arriving at the receiver.
- Sliding Sender window that corresponds to the MWS input and only transmits segments with data lengths less than or equal to MSS.
- A segment header for identifying and containing information about the segment including Sequence Numbers, cumulative ACK Numbers and other elements mentioned next.

STP Header

Sequence Number (4 Bytes)	ACK Number (4 Bytes)	Flags (ACK,SYN,FYN) (4 Bytes)	Payload Length (4 Bytes)	Checksum (16 Bytes)

Sequence Number: Number used to keep track of the correct order of segments that the data is divided into to transfer from the sender to the receiver.

ACK Number: Number used to indicate which segments have arrived at the other client, and the value is the size of the payload data added to the last received sequence number.

Flags: An integer value corresponding to the type of packet that is being sent. This is produced by the bitwise or operation with the values of 1 for ACK, 2 for SYN, and 4 for FYN. Data segments are recognized by a Flag value of 0.

Payload Length: Integer that indicates the size of the data contained within the segment. This value is always less than or equal to the inputted MSS.

Checksum: 16 Byte hash value that is calculated from a particular segments payload data using Java's MessageDigest class and the MD5 algorithm. This helps determine whether or not the segments data was corrupted during packet transfer.

Trade-offs

Throughout the process of developing my program, I made a few tradeoffs in terms of designing my STP. The first was what to include in my segment header. For reliable transport, the header must include values such as Sequence Number and ACK Number but how flags are implemented and what other values to include are up to the designer of the protocol. After

taking different approaches such as originally not including payload length, I found the most effective version is the one I highlighted above. Another tradeoff was deciding to create another class for the segment object, which I found more helpful for organizing segment information. I didn't make any tradeoffs in terms of ways of making the transfer reliable, having implemented the concepts asked of us. Later on, I discuss runtime as an issue that I faced, but I could not come to a conclusion on how to improve it.

Sources of Code

I developed all of the code for my project on my own. I did look to internet resources for understanding topics I had not used before including multithreading, checksum creation, and converting between integer values and byte arrays. I used Oracle's Java Documentation as well as StackOverflow and a few other sites for understanding pre-existing libraries and seeing examples of their implementations. I also reached out to the tutors for some guidance especially regarding these topics I was less familiar with.

Questions

a. Experimenting with pDrop:

   Test 1 Sequence of Arriving Packets:

   1, 201, 301, 401, 501, 101, 601, 701, 801, 901, 1001, 1101, 1201, 1301, 1401, 1501, 1601, 1701, 1801, 2001, 2101, 2201, 2301, 1901, 2401, 2501, 2601, 2701, 2801, 2901, 3001, 3029

   Test 2 Sequence Numbers:

   1, 201, 101, 701, 301, 801, 401, 501, 1001, 601, 1201, 901, 1401, 1501, 1101, 1601, 1301, 1901, 2101, 1701, 1801, 2301, 2001, 2501, 2601, 2201, 2401, 2701, 2801, 2901, 3001, 3029

   The frequency of packet drop for Test 2 was greater than that of test 1 due to the larger pDrop value that was used as an input. This resulted in the packets of Test 2 arriving more out of order. It can be seen that in Test 1 packets 101 and 1901 were dropped given their time of arrival compared to the other packets. It can be seen that in Test 2 many were dropped given to the widely mixed order of packet arrival.

b. Experimenting with RTT:

   I had trouble with this part of the lab given the large percentage of packets dropped and the large size of test1.pdf. For me, the program would run and progress in the sending of the file, but it would take so long to just send part of the file that I wasn't able to reach the end. I worked for a long time trying to correct for this, but I was not able to speed up the runtime. This continues to confuse me, because I thought I implemented each part correctly including the RTO calculations that influence this part. Given the equation for calculating the new RTO, increasing gamma would increase the RTO more each time so the overall packet transfer would take longer.

c. Transferring test2.pdf:

   The file successfully transferred and took my program 55.68 seconds. pDrop contributed the most to the overall transfer time given that my receiver has a buffer that can process duplicated and out of order packets and of all of the actions of the PLD, more packets were dropped than any other function.

Appendix

```
<event>     <time> <type-of-packet> <seq-number> <number-of-bytes-data> <ack-number>
rcv         1539941022.37S              0              0                     0
snd         0.00   SA               0              0                     1
rcv         0.00   A                1              0                     1
rcv         0.01   D                1              100                   1
snd         0.01   A                1              0                     101
rcv         0.01   D                201            100                   1
snd/DA      0.01   A                1              0                     101
rcv         0.01   D                301            100                   1
snd/DA      0.01   A                1              0                     101
rcv         0.01   D                401            100                   1
snd/DA      0.02   A                1              0                     101
rcv         0.02   D                501            100                   1
snd/DA      0.02   A                1              0                     101
rcv         0.02   D                101            100                   1
snd         0.02   A                1              0                     601
rcv         0.02   D                601            100                   1
snd         0.03   A                1              0                     701
rcv         0.03   D                701            100                   1
snd         0.03   A                1              0                     801
rcv         0.03   D                801            100                   1
snd         0.03   A                1              0                     901
rcv         0.03   D                901            100                   1
snd         0.03   A                1              0                     1001
rcv         0.03   D                1001           100                   1
snd         0.03   A                1              0                     1101
rcv         0.03   D                1101           100                   1
snd         0.03   A                1              0                     1201
rcv         0.04   D                1201           100                   1
snd         0.04   A                1              0                     1301
rcv         0.04   D                1301           100                   1
snd         0.04   A                1              0                     1401
rcv         0.04   D                1401           100                   1
snd         0.04   A                1              0                     1501
rcv         0.04   D                1501           100                   1
snd         0.04   A                1              0                     1601
rcv         0.04   D                1601           100                   1
snd         0.04   A                1              0                     1701
rcv         0.04   D                1701           100                   1
snd         0.04   A                1              0                     1801
rcv         0.05   D                1801           100                   1
snd         0.05   A                1              0                     1901
rcv         0.05   D                2001           100                   1
snd/DA      0.05   A                1              0                     1901
rcv         0.05   D                2101           100                   1
snd/DA      0.05   A                1              0                     1901
rcv         0.05   D                2201           100                   1
snd/DA      0.05   A                1              0                     1901
rcv         0.05   D                2301           100                   1
snd/DA      0.05   A                1              0                     1901
rcv         0.06   D                1901           100                   1
snd         0.06   A                1              0                     2401
rcv         0.06   D                2401           100                   1
snd         0.06   A                1              0                     2501
rcv         0.06   D                2501           100                   1
snd         0.06   A                1              0                     2601
rcv         1.17   D                2601           100                   1
snd         1.17   A                1              0                     2701
rcv         2.28   D                2701           100                   1
snd         2.28   A                1              0                     2801
rcv         3.39   D                2801           100                   1
snd         3.39   A                1              0                     2901
rcv         4.50   D                2901           100                   1
snd         4.50   A                1              0                     3001
rcv         5.61   D                3001           28                    1
snd         5.61   A                1              0                     3029
rcv         5.61   F                3029           0                     1
snd         5.61   A                1              0                     3029
snd         5.61   F                1              0                     3029
rcv         5.61   A                3029           0                     2
================================================
Amount of Data Received:           3028 Bytes
Total segments received:           35
Data segments received:            31
Data Segments with bit errors:     0
Duplicate data segments received:  0
Duplicate Acks sent:               8
================================================
```

a. Test 1 Receiving Packet Sequence

```
<event>     <time> <type-of-packet> <seq-number> <number-of-bytes-data> <ack-number>
rcv         1539941073.87S               0            0                      0
snd         0.00   SA                    0            0                      1
rcv         0.00   A                     1            0                      1
rcv         0.01   D                     1            100                    1
snd         0.01   A                     1            0                      101
rcv         0.01   D                     201          100                    1
snd/DA      0.01   A                     1            0                      101
rcv         1.63   D                     101          100                    1
snd         1.63   A                     1            0                      301
rcv         1.63   D                     701          100                    1
snd/DA      1.63   A                     1            0                      301
rcv         4.87   D                     301          100                    1
snd         4.87   A                     1            0                      401
rcv         4.88   D                     801          100                    1
snd/DA      4.88   A                     1            0                      401
rcv         8.11   D                     401          100                    1
snd         8.12   A                     1            0                      501
rcv         9.74   D                     501          100                    1
snd         9.74   A                     1            0                      601
rcv         9.74   D                     1001         100                    1
snd/DA      9.74   A                     1            0                      601
rcv         11.36  D                     601          100                    1
snd         11.36  A                     1            0                      901
rcv         11.36  D                     1201         100                    1
snd/DA      11.36  A                     1            0                      901
rcv         12.98  D                     901          100                    1
snd         12.98  A                     1            0                      1101
rcv         12.98  D                     1401         100                    1
snd/DA      12.98  A                     1            0                      1101
rcv         12.98  D                     1501         100                    1
snd/DA      12.98  A                     1            0                      1101
rcv         17.84  D                     1101         100                    1
snd         17.84  A                     1            0                      1301
rcv         17.85  D                     1601         100                    1
snd/DA      17.85  A                     1            0                      1301
rcv         21.09  D                     1301         100                    1
snd         21.09  A                     1            0                      1701
rcv         21.09  D                     1901         100                    1
snd/DA      21.09  A                     1            0                      1701
rcv         21.09  D                     2101         100                    1
snd/DA      21.09  A                     1            0                      1701
rcv         25.95  D                     1701         100                    1
snd         25.95  A                     1            0                      1801
rcv         27.57  D                     1801         100                    1
snd         27.58  A                     1            0                      2001
rcv         27.58  D                     2301         100                    1
snd/DA      27.58  A                     1            0                      2001
rcv         29.20  D                     2001         100                    1
snd         29.20  A                     1            0                      2201
rcv         29.20  D                     2501         100                    1
snd/DA      29.20  A                     1            0                      2201
rcv         29.20  D                     2601         100                    1
snd/DA      29.20  A                     1            0                      2201
rcv         30.82  D                     2201         100                    1
snd         30.82  A                     1            0                      2401
rcv         32.44  D                     2401         100                    1
snd         32.44  A                     1            0                      2701
rcv         34.06  D                     2701         100                    1
snd         34.06  A                     1            0                      2801
rcv         37.30  D                     2801         100                    1
snd         37.31  A                     1            0                      2901
rcv         38.93  D                     2901         100                    1
snd         38.93  A                     1            0                      3001
rcv         40.58  D                     3001         28                     1
snd         40.58  A                     1            0                      3029
rcv         40.58  F                     3029         0                      1
snd         40.58  A                     1            0                      3029
snd         40.58  F                     1            0                      3029
rcv         40.58  A                     3029         0                      2
================================================
Amount of Data Received:           3028 Bytes
Total segments received:           35
Data segments received:            31
Data Segments with bit errors:     0
Duplicate data segments received:  0
Duplicate Acks sent:               13
================================================
```

a. Test 2 Receiving Packet Sequence

```
<event>     <time> <type-of-packet> <seq-number> <number-of-bytes-data> <ack-number>
snd         0.01   S               0            0                     0
rcv         0.03   SA              0            0                     1
snd         0.03   A               1            0                     1
snd         0.03   D               1            50                    1
snd         0.04   D               51           50                    1
rcv         0.04   A               1            0                     51
snd         0.04   D               101          50                    1
rcv         0.04   A               1            0                     101
snd         0.04   D               151          50                    1
rcv         0.04   A               1            0                     151
snd         0.04   D               201          50                    1
rcv         0.04   A               1            0                     201
snd/corr    0.04   D               251          50                    1
snd/corr    0.05   D               301          50                    1
rcv         0.05   A               1            0                     251
snd         0.05   D               351          50                    1
rcv/DA      0.05   A               1            0                     251
snd         0.05   D               401          50                    1
rcv/DA      0.05   A               1            0                     251
snd         0.05   D               451          50                    1
```

```
snd         55.69  D               1605351      50                    1
rcv/DA      55.69  A               1            0                     1604951
snd         55.70  D               1605401      50                    1
snd/dup     55.70  D               1605401      50                    1
rcv/DA      55.70  A               1            0                     1604951
rcv/DA      55.70  A               1            0                     1604951
snd/RXT     55.70  D               1604951      50                    1
rcv         55.70  A               1            0                     1605301
snd/RXT     55.70  D               1605301      50                    1
rcv         55.70  A               1            0                     1605451
snd/RXT     55.70  D               1605451      50                    1
rcv         55.70  A               1            0                     1605501
snd/RXT     55.70  D               1605501      50                    1
rcv         55.70  A               1            0                     1605551
snd/RXT     55.70  D               1605551      35                    1
rcv         55.70  A               1            0                     1605586
snd         55.70  F               1605586      0                     1
rcv         55.70  A               1            0                     1605586
rcv         55.70  F               1            0                     1605586
snd         55.70  A               1605586      0                     2
=================================================
Size of the file:                                 1605585 Bytes
Segments transmitted:                             43387
Number of Segments handled by PLD:                43383
Number of Segments Dropped:                       4356
Number of Segments Corrupted:                     3449
Number of Segments Re-ordered:                    1
Number of Segments Duplicated:                    3816
Number of Segments Delayed:                       0
Number of Retransmissions due to timeout:         1854
Number of Fast Retransmissions:                   5605
Number of Duplicate Acknowledgements received:    20113
=================================================
```

c. Test2.pdf file transfer Sender Log

```
<event>     <time> <type-of-packet> <seq-number> <number-of-bytes-data> <ack-number>
rcv         1539945935.69S              0              0                     0
snd         0.00   SA               0              0                     1
rcv         0.00   A                1              0                     1
rcv         0.01   D                1              50                    1
snd         0.01   A                1              0                     51
rcv         0.01   D                51             50                    1
snd         0.01   A                1              0                     101
rcv         0.01   D                101            50                    1
snd         0.01   A                1              0                     151
rcv         0.01   D                151            50                    1
snd         0.01   A                1              0                     201
rcv         0.02   D                201            50                    1
snd         0.02   A                1              0                     251
rcv/corr    0.02   D                251            50                    1
rcv/corr    0.02   D                301            50                    1
rcv         0.02   D                351            50                    1
snd/DA      0.02   A                1              0                     251
rcv         0.02   D                401            50                    1
snd/DA      0.02   A                1              0                     251
rcv         0.03   D                451            50                    1

rcv         55.66  D                1604901        50                    1
snd         55.66  A                1              0                     1604951
rcv         55.67  D                1605351        50                    1
snd/DA      55.67  A                1              0                     1604951
rcv         55.67  D                1605401        50                    1
snd/DA      55.67  A                1              0                     1604951
rcv         55.67  D                1605401        50                    1
snd/DA      55.67  A                1              0                     1604951
rcv         55.67  D                1604951        50                    1
snd         55.67  A                1              0                     1605301
rcv         55.67  D                1605301        50                    1
snd         55.67  A                1              0                     1605451
rcv         55.67  D                1605451        50                    1
snd         55.67  A                1              0                     1605501
rcv         55.67  D                1605501        50                    1
snd         55.67  A                1              0                     1605551
rcv         55.67  D                1605551        35                    1
snd         55.67  A                1              0                     1605586
rcv         55.67  F                1605586        0                     1
snd         55.67  A                1              0                     1605586
snd         55.68  F                1              0                     1605586
rcv         55.68  A                1605586        0                     2
================================================
Amount of Data Received:           1951335 Bytes
Total segments received:           39031
Data segments received:            39027
Data Segments with bit errors:     3766
Duplicate data segments received:  3149
Duplicate Acks sent:               20113
================================================
```

C. Test2.pdf file transfer Receiver Log