<2016 Computer Network Homework>

Motivation

We divide the homework into two parts. First, you should understand the mechanism of TCP in detail including three-way handshake, data transmission, flow control, delayed ACKs, congestion control, and four-way handshake, etc. Second, you have to implement TCP in application layer and call UDP to transmit TCP packets.

Rules

1. Please use **C** or **C++** language in this homework and run your program on Ubuntu 14.04 platform.
2. Do not copy homework from your classmates or senior, etc. If TAs find the situation, any participants will get a grade of ZERO.
3. You have to deeply understand what your program do because TAs will ask you the concept of your code.
4. If you have any question, you can send email to *atmm1@hsn.cse.nsysu.edu.tw* or come to F-5008(High Speed Network Lab) to ask TAs but debugging.
5. You have to create Makefile to compile your program, and ensure your program can be compiled correctly.
6. You also need to submit a PDF that contains the picture of your program run's result in every step.
7. In each step, you can write a new program, respectively (but the program has to including the function of previous step).
8. The format of filename you upload should be "StudentID_Name.zip".
   Ex: B043040000_王小明.zip

Deadline

You should upload your homework to the Cyber University before 2016/06/20(Mon.) 23:59. If you do not submit your assignment on time, you will get a grade of ZERO.

Demo

The following figure shows the time you can come for demo.

Demo deadline: 2016/06/22(Wed.) 17:00

	Mon.	Tue.	Wed.	Thu.	Fri.
10:00 – 12:00	✓	✓	✓	✓	
14:00 – 17:00			✓		

Description

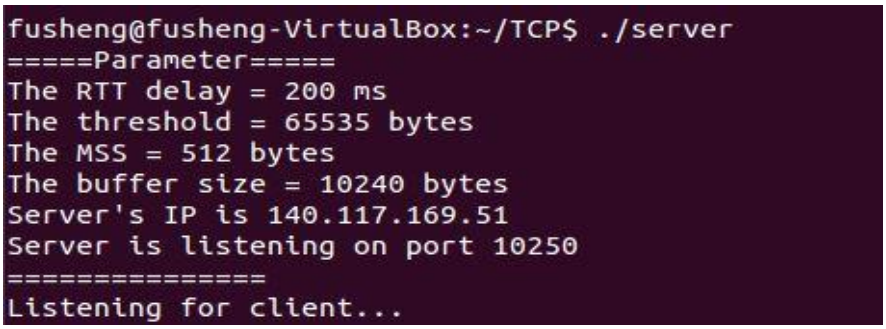
You have to obey the following schema:

- The TCP segment structure.
- The server port should be 10250, and the client port should be 10260.
- The initial sequence number should be set randomly (1~10000).
- Follow the format of all figures in every step.
- You have to create data randomly using (0~9, a~z, A~Z), and the data size is 10240 bytes.

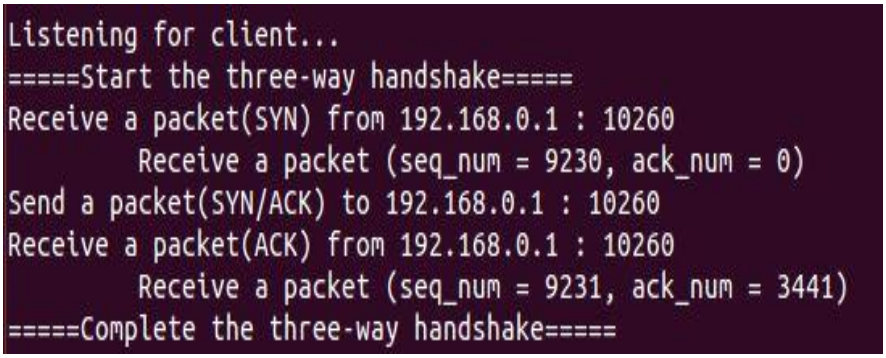
Step 1:

1. Set the parameters including RTT (200 ms), MSS (512 bytes), threshold (65535) and the receiver's buffer size (10KB=10240 bytes), etc.
2. First, you should implement the three/four way handshake.
3. Second, you also have to implement the data transmission (You need to ensure the data that can transmit from server to client, and ACK packet transmit from client to server).
4. Final, add the mechanism of flow control (sender's congestion window and receiver's buffer window).

Server side (parameter):



Server side (three-way handshake):



Client side (three-way handshake):

```
fusheng@fusheng-VirtualBox:~/TCP$ ./client 140.117.169.51 10250
```

```
=====Start the three-way handshake=====
Send a packet(SYN) to 140.117.169.51 : 10250
Receive a packet(SYN/ACK) from 140.117.169.51 : 10250
        Receive a packet (seq_num = 3440, ack_num = 9231)
Send a packet(ACK) to 140.117.169.51 : 10250
=====Complete the three-way handshake=====
```

Server side (data transmission):

```
=====Complete the three-way handshake=====
Start to send the file, the file size is 10240 bytes.
*****Slow start*****
cwnd = 1, rwnd = 10240, threshold = 65535
        Send a packet at : 1 byte
        Receive a packet (seq_num = 9232, ack_num = 2)
cwnd = 2, rwnd = 10239, threshold = 65535
        Send a packet at : 2 byte
        Receive a packet (seq_num = 9233, ack_num = 4)
cwnd = 4, rwnd = 10238, threshold = 65535
        Send a packet at : 4 byte
        Receive a packet (seq_num = 9234, ack_num = 8)
cwnd = 8, rwnd = 10236, threshold = 65535
        Send a packet at : 8 byte
        Receive a packet (seq_num = 9235, ack_num = 16)
cwnd = 16, rwnd = 10232, threshold = 65535
        Send a packet at : 16 byte
        Receive a packet (seq_num = 9236, ack_num = 32)
```

Client side (data transmission):

```
Receive a file from 140.117.169.51 : 10250
        Receive a packet (seq_num = 1, ack_num = 9232)
        Receive a packet (seq_num = 2, ack_num = 9233)
        Receive a packet (seq_num = 4, ack_num = 9234)
        Receive a packet (seq_num = 8, ack_num = 9235)
        Receive a packet (seq_num = 16, ack_num = 9236)
```

Server side (four-way handshake):

```
The file transmission is finish.
=====Start the four-way handshake=====
Send a packet(FIN) to 192.168.0.1 : 10260
Receive a packet(ACK) from 192.168.0.1 : 10260
        Receive a packet (seq_num = 9260, ack_num = 9729)
Receive a packet(FIN) from 192.168.0.1 : 10260
        Receive a packet (seq_num = 9260, ack_num = 9729)
Send a packet(ACK) to 192.168.0.1 : 10260
=====Complete the four-way handshake=====
Listening for client...
```

Client side (four-way handshake):

```
=====Start the four-way handshake=====
Receive a packet(FIN) from 140.117.169.51 : 10250
        Receive a packet (seq_num = 9728, ack_num = 9260)
Send a packet(ACK) to 140.117.169.51 : 10250
Send a packet(FIN) to 140.117.169.51 : 10250
Receive a packet(ACK) from 140.117.169.51 : 10250
        Receive a packet (seq_num = 9729, ack_num = 9261)
=====Complete the four-way handshake=====
```

Step 2:

1. Including the previous step's function.
2. Implements the NAT function in client side or you can build a router as NAT.
3. The client has to transform the IP from one to another by mapping table after server transmit the packet to client.
4. You need to design a mapping table and create two virtual IPs at least (Ex: You can type the command "**ifconfig eth0:0 192.168.0.1 up**" in terminal to create a virtual IP).
5. Additional, you have to print the mapping table in the client side (or NAT router) and show the virtual IPs using command "ifconfig" in terminal.

Print the virtual IP's information (if need).

```
fusheng@fusheng-VirtualBox:~$ ifconfig
eth0      Link encap:Ethernet  HWaddr 08:00:27:08:d8:fd
          inet addr:192.168.1.135  Bcast:192.168.1.255  Mask:255.255.255.0
          inet6 addr: fe80::a00:27ff:fe08:d8fd/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:533246 errors:0 dropped:44 overruns:0 frame:0
          TX packets:1889 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:38426613 (38.4 MB)  TX bytes:299376 (299.3 KB)

eth0:0    Link encap:Ethernet  HWaddr 08:00:27:08:d8:fd
          inet addr:192.168.0.1  Bcast:192.168.0.255  Mask:255.255.255.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1

eth0:1    Link encap:Ethernet  HWaddr 08:00:27:08:d8:fd
          inet addr:192.168.0.2  Bcast:192.168.0.255  Mask:255.255.255.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1

eth0:2    Link encap:Ethernet  HWaddr 08:00:27:08:d8:fd
          inet addr:192.168.0.3  Bcast:192.168.0.255  Mask:255.255.255.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
```

In the following figure, the server's IP is 192.168.1.135, the client's IP is 192.168.0.2, and the WAN IP is 192.168.0.1

(Attention: In reality, all of them are virtual IPs.)

Server side:

```
Listening for client...
=====Start the three-way handshake=====
Receive a packet(SYN) from 192.168.0.1 : 10260
        Receive a packet (seq_num = 146, ack_num = 0)
Send a packet(SYN/ACK) to 192.168.0.1 : 10260
Receive a packet(ACK) from 192.168.0.1 : 10260
        Receive a packet (seq_num = 147, ack_num = 3947)
=====Complete the three-way handshake=====
```

The client's IP has to transform from LAN to WAN address.

Client side:

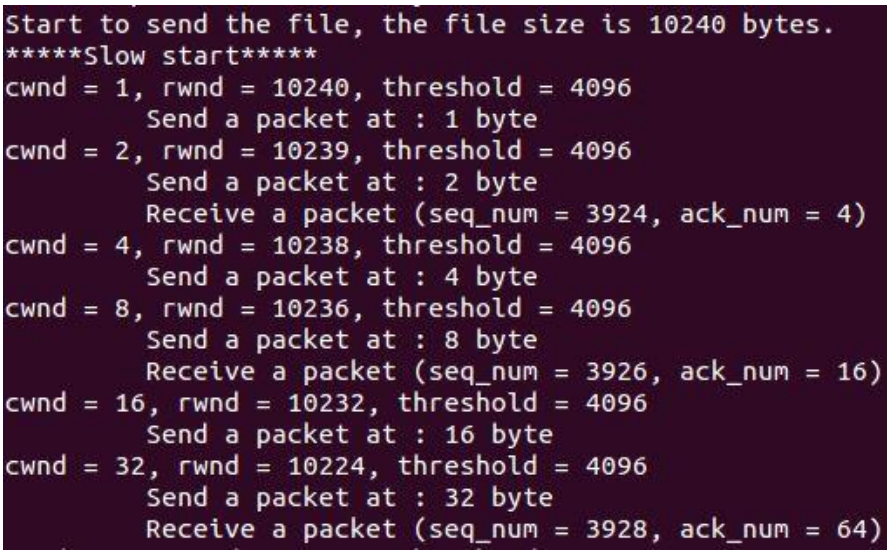
```
fusheng@fusheng-VirtualBox:~/TCP$ ./client 192.168.1.135 10250
------------NAT translation table-----------
  WAN side addr     |     LAN side addr
192.168.0.1 : 10260        192.168.0.2 : 10260
192.168.0.1 : 10265        192.168.0.3 : 10265
Client's IP is 192.168.0.2
=====Start the three-way handshake=====
Send a packet(SYN) to 192.168.1.135 : 10250
Receive a packet(SYN/ACK) from 192.168.1.135 : 10250
        Receive a packet (seq_num = 3946, ack_num = 147)
Send a packet(ACK) to 192.168.1.135 : 10250
=====Complete the three-way handshake=====
```

You have to show the mapping table and client's IP.

Step 3:

1. Including the previous step's function.
2. Implement the delayed ACKs, you can wait up to 500ms for next packet, or delay for two packets, then send an ACK packet to server.

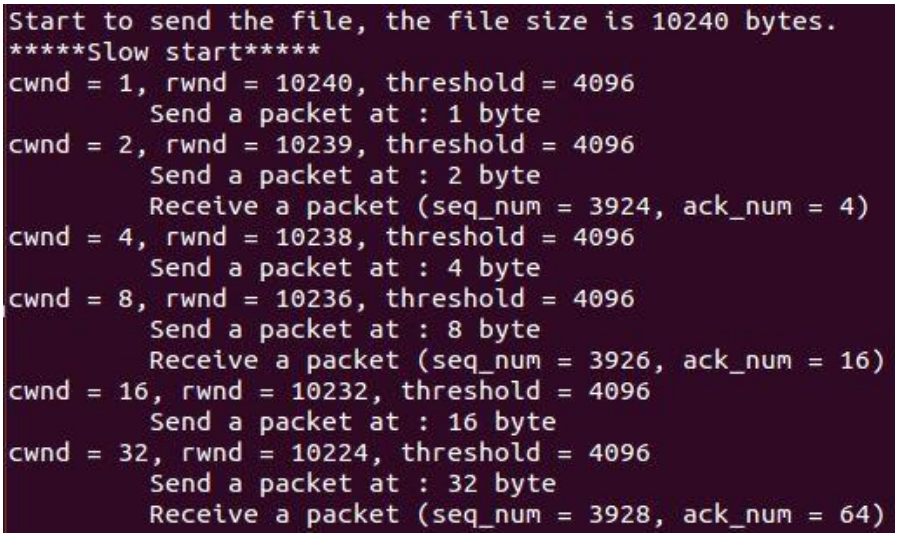
   Server side:



Step 4:

1. Including the previous step's function.
2. Implement the congestion control including slow start and congestion avoidance.
3. You need to reset the threshold as 4096 in order to enter the status of congestion avoidance.

   Server side (slow start):



Client side (slow start):

```
Receive a packet (seq_num = 1, ack_num = 2416)
Receive a packet (seq_num = 2, ack_num = 2417)
Receive a packet (seq_num = 4, ack_num = 2418)
Receive a packet (seq_num = 8, ack_num = 2419)
Receive a packet (seq_num = 16, ack_num = 2420)
Receive a packet (seq_num = 32, ack_num = 2421)
```

Server side (congestion avoidance):

```
cwnd = 2048, rwnd = 9216, threshold = 4096
        Send a packet at : 2048 byte
        Send a packet at : 2560 byte
        Send a packet at : 3072 byte
        Send a packet at : 3584 byte
        Receive a packet (seq_num = 3936, ack_num = 3072)
        Receive a packet (seq_num = 3938, ack_num = 4096)
*****Congestion avoidance*****
cwnd = 4096, rwnd = 8192, threshold = 4096
        Send a packet at : 4096 byte
        Send a packet at : 4608 byte
        Send a packet at : 5120 byte
        Send a packet at : 5632 byte
        Send a packet at : 6144 byte
        Send a packet at : 6656 byte
        Send a packet at : 7168 byte
        Send a packet at : 7680 byte
        Receive a packet (seq_num = 3940, ack_num = 5120)
        Receive a packet (seq_num = 3942, ack_num = 6144)
        Receive a packet (seq_num = 3944, ack_num = 7168)
        Receive a packet (seq_num = 3946, ack_num = 8192)
cwnd = 4608, rwnd = 6144, threshold = 4096
        Send a packet at : 8192 byte
        Send a packet at : 8704 byte
        Send a packet at : 9216 byte
        Send a packet at : 9728 byte
        Receive a packet (seq_num = 3948, ack_num = 9216)
        Receive a packet (seq_num = 3950, ack_num = 10240)
The file transmission is finish.
```

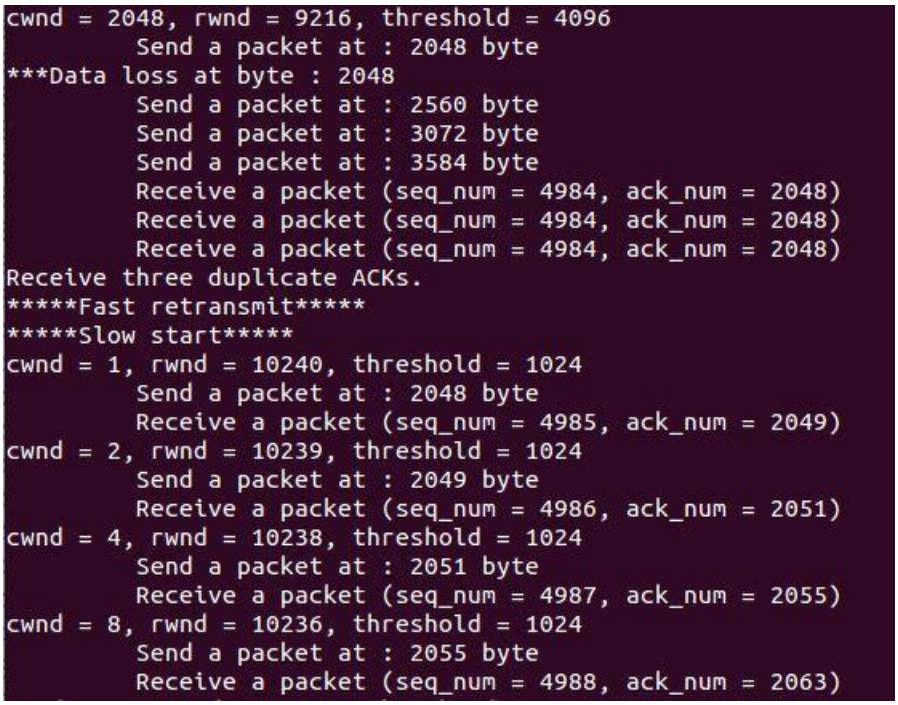
Client side (congestion avoidance):

```
Receive a packet (seq_num = 4096, ack_num = 2432)
Receive a packet (seq_num = 4608, ack_num = 2433)
Receive a packet (seq_num = 5120, ack_num = 2434)
Receive a packet (seq_num = 5632, ack_num = 2435)
Receive a packet (seq_num = 6144, ack_num = 2436)
Receive a packet (seq_num = 6656, ack_num = 2437)
Receive a packet (seq_num = 7168, ack_num = 2438)
Receive a packet (seq_num = 7680, ack_num = 2439)
Receive a packet (seq_num = 8192, ack_num = 2440)
Receive a packet (seq_num = 8704, ack_num = 2441)
Receive a packet (seq_num = 9216, ack_num = 2442)
Receive a packet (seq_num = 9728, ack_num = 2443)
Receive a packet (seq_num = 9728, ack_num = 2444)
```

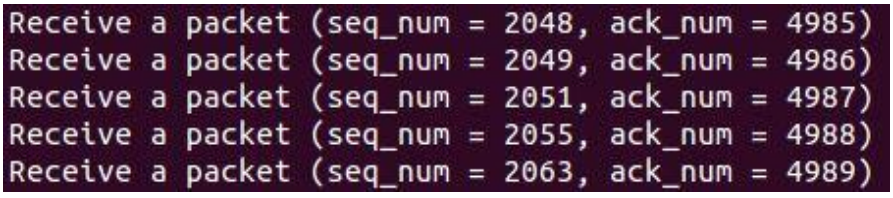
Step 5:

1. Including the previous step's function.
2. Implement the mechanism of fast retransmit.
3. You need to design a packet loss at byte 2048 to get duplicated ACKs, then the fast retransmit will execute.
4. You can ignore the mechanism of delayed ACK to implement this step in order to check the receive packets.

Server side:



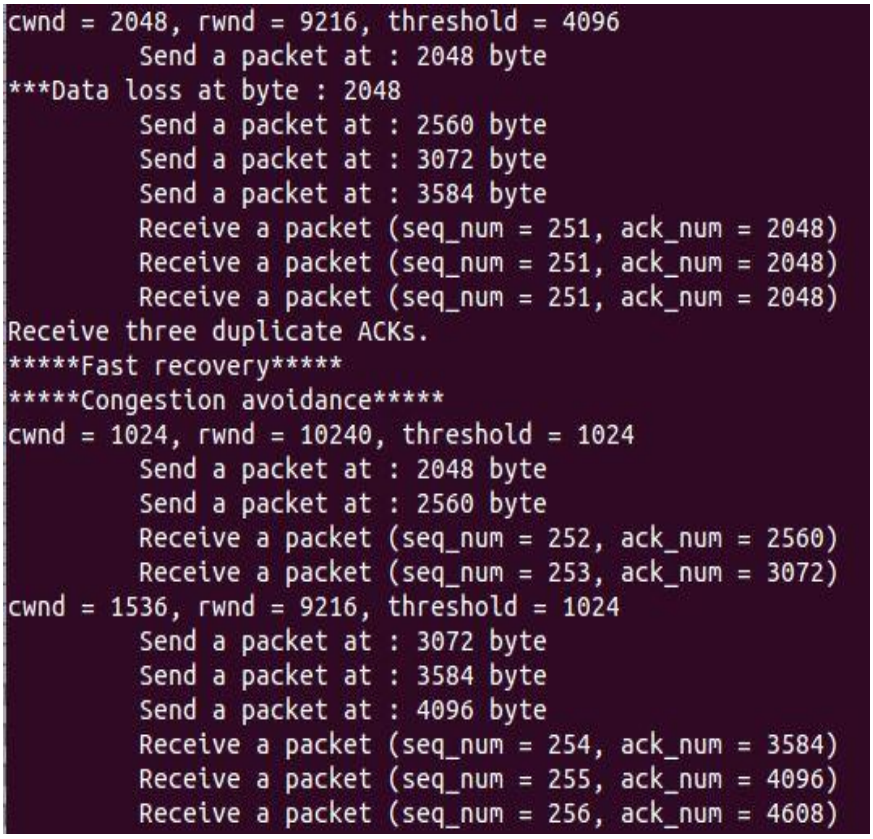
Client side:



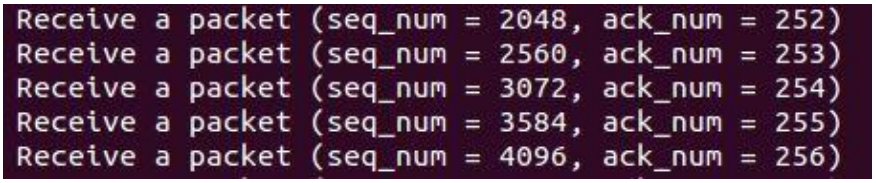
Step 6:

1. Including the previous step's function.
2. Implement the mechanism of fast recovery.
3. You need to design a packet loss at byte 2048 to get duplicated ACKs, then the fast retransmit will execute, and enter the state of fast recovery.
4. You can ignore the mechanism of delayed ACK to implement this step in order to check the receive packets.

Server side:



Client side:



Step 7:

1. Including the previous step's function.
2. Implement the mechanism of TCP SACK, and using three blocks in this step.
3. You need to design a packet loss at byte 5120, 6144 and 7168 to create three SACK blocks.
4. You can ignore the mechanism of delayed ACK to implement this step in order to check the receive packets.

Server side:

```
cwnd = 2048, rwnd = 8704, threshold = 4096
         Send a packet at : 2048 byte
         Send a packet at : 2560 byte
         Send a packet at : 3072 byte
         Send a packet at : 3584 byte
         Receive a packet (seq_num = 5202, ack_num = 2560)
         Receive a packet (seq_num = 5203, ack_num = 3072)
         Receive a packet (seq_num = 5204, ack_num = 3584)
         Receive a packet (seq_num = 5205, ack_num = 4096)
*****Congestion avoidance*****
cwnd = 4096, rwnd = 6656, threshold = 4096
         Send a packet at : 4096 byte
         Send a packet at : 4608 byte
         Send a packet at : 5120 byte
***Data loss at byte : 5120
         Send a packet at : 5632 byte
         Send a packet at : 6144 byte
***Data loss at byte : 6144
         Send a packet at : 6656 byte
         Send a packet at : 7168 byte
***Data loss at byte : 7168
         Send a packet at : 7680 byte
         Receive a packet (seq_num = 5206, ack_num = 4608)
         Receive a packet (seq_num = 5207, ack_num = 5120)
         Receive a packet (seq_num = 5207, ack_num = 5120)
         Receive a packet (seq_num = 5207, ack_num = 5120)
         Receive a packet (seq_num = 5207, ack_num = 5120)
Receive three duplicate ACKs.
*****Fast recovery*****
*****Congestion avoidance*****
cwnd = 2560, rwnd = 5632, threshold = 2048
         Send a packet at : 5120 byte
         Send a packet at : 6144 byte
         Send a packet at : 7168 byte
         Send a packet at : 8192 byte
         Send a packet at : 8704 byte
         Receive a packet (seq_num = 5208, ack_num = 6144)
         Receive a packet (seq_num = 5209, ack_num = 7168)
         Receive a packet (seq_num = 5210, ack_num = 8192)
         Receive a packet (seq_num = 5211, ack_num = 8704)
         Receive a packet (seq_num = 5212, ack_num = 9216)
```

Client side (the output format of client is different, print each ACK packet):

```
=====Complete the three-way handshake=====
Receive a file from 140.117.169.51 : 10250
ACK     1 Left  1 Right 2 Left  2 Right 3 Left  3 Right
2
4
8
16
32
64
128
256
512
1024
1536
2048
2560
3072
3584
4096
4608
5120
5120    5632    6144
5120    5632    6144    6656    7168
5120    5632    6144    6656    7168    7680    8192
6144    6656    7168    7680    8192
7168    7680    8192
8192
8704
9216
9728
```

Step 8:

1. Including the previous step’s function.
2. Implement the TCP Reno, if the channel speed is lower than 95% of original speed, you need to discard the packet and retransmit the packet.
3. There is no strict output format, you just show your result in demo.