Step 1(實現基本功能、一個 server、一個 client)

Server

```
==============================
Server's ip is 192.168.1.112
Server is listening on port 100
==============================
listening......

=====start the three-way handshake=====
Server's ip is 192.168.0.1
Server is listening on port 101
Send a packet(SYNACK) to 192.168.0.1:200
Received a packet(ACK) from 192.168.0.1:200
                Receive a packet (seq_num = 9233, ack_num = 6807)
=====complete the three-way handshake=====
Start to calculate the equation 1.1*60
[Ans] 66
```

client

```
AKIde-MacBook-Pro:c aki$ ./client -c 1.1*60

==============================
Client's ip is 192.168.0.1
Client is listening on port 200
==============================
Please Input Node [IP] [Port] you want to connect to:
192.168.1.112 100

=====start the three-way handshake=====
Send a packet(SYN) to 192.168.1.112:100
Received a packet(SYNACK) from 192.168.0.1:101
1:-c:1.1*60
Send a packet(ACK) to 192.168.0.1:101
=====complete the three-way handshake=====
Receive a answer from 192.168.0.1
                Receive a packet (seq_num = 6807, ack_num = 9244)
The answer is 66
```

Step2(server 可以同時接收兩個 client request、)

server

```
cwnd =  11, rwnd = 466944, threshold = 2560
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 801, ack_num = 73729)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 802, ack_num = 74753)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 803, ack_num = 75777)
                Send a packet at : 1024 byte

==============================
Server's ip is 192.168.1.112
Server is listening on port 100
==============================
listening......

=====start the three-way handshake=====
Server's ip is 192.168.0.1
Server is listening on port 102
Send a packet(SYNACK) to 192.168.0.1:400
                Receive a packet (seq_num = 804, ack_num = 76801)
                Send a packet at : 1024 byte
Received a packet(ACK) from 192.168.0.1:400
                Receive a packet (seq_num = 1960, ack_num = 6807)
=====complete the three-way handshake=====
Start to response DNS request www.google.com
                Receive a packet (seq_num = 805, ack_num = 77825)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 806, ack_num = 78849)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 807, ack_num = 79873)
                Send a packet at : 1024 byte
[IP] 216.58.200.228

==============================
Server's ip is 192.168.1.112
Server is listening on port 100
==============================
listening......
                Receive a packet (seq_num = 808, ack_num = 80897)
```

Client1

```
AKIde-MacBook-Pro:c aki$ ./client -f 1

==============================
Client's ip is 192.168.0.1
Client is listening on port 200
==============================
Please Input Node [IP] [Port] you want to connect to:
192.168.1.112 100

=====start the three-way handshake=====
Send a packet(SYN) to 192.168.1.112:100
Received a packet(SYNACK) from 192.168.0.1:101
1:-f:1
Send a packet(ACK) to 192.168.0.1:101
=====complete the three-way handshake=====
Receive a file from 192.168.0.1
                Receive a packet (seq_num = 1, ack_num = 735)
                Receive a packet (seq_num = 1025, ack_num = 736)
                Receive a packet (seq_num = 2049, ack_num = 737)
                Receive a packet (seq_num = 3073, ack_num = 738)
                Receive a packet (seq_num = 4097, ack_num = 739)
                Receive a packet (seq_num = 5121, ack_num = 740)
                Receive a packet (seq_num = 6145, ack_num = 741)
                Receive a packet (seq_num = 7169, ack_num = 742)
                Receive a packet (seq_num = 8193, ack_num = 743)
                Receive a packet (seq_num = 9217, ack_num = 744)
                Receive a packet (seq_num = 11265, ack_num = 746)
                Receive a packet (seq_num = 9217, ack_num = 743)
                Receive a packet (seq_num = 10241, ack_num = 744)
                Receive a packet (seq_num = 11265, ack_num = 745)
                Receive a packet (seq_num = 12289, ack_num = 746)
                Receive a packet (seq_num = 13313, ack_num = 747)
```

Client2

```
AKIde-MacBook-Pro:c aki$ ./client2 -d www.google.com

==============================
Client's ip is 192.168.0.1
Client is listening on port 400
==============================
Please Input Node [IP] [Port] you want to connect to:
192.168.1.112 100

=====start the three-way handshake=====
Send a packet(SYN) to 192.168.1.112:100
Received a packet(SYNACK) from 192.168.0.1:102
Send a packet(ACK) to 192.168.0.1:102
=====complete the three-way handshake=====
Receive a dns response from 192.168.0.1
                Receive a packet (seq_num = 6807, ack_num = 1979)
The IP of www.google.com is 216.58.200.228
```

Step3(client 可以要求多個 request)

Server

```
==============================
Server's ip is 192.168.1.112
Server is listening on port 100
==============================
listening......

==============================
Server's ip is 192.168.1.112
Server is listening on port 100
==============================
listening......

=====start the three-way handshake=====
Server's ip is 192.168.0.1
Server is listening on port 101
Send a packet(SYNACK) to 192.168.0.1:400
Received a packet(ACK) from 192.168.0.1:400
                Receive a packet (seq_num = 3822, ack_num = 6807)
=====complete the three-way handshake=====
Start to response DNS request www.google.com
[IP] 216.58.200.228
Start to calculate the equation 1+1
[Ans] 2
```

client

```
AKIde-MacBook-Pro:c aki$ ./client2 -d www.google.com -c 1+1

==============================
Client's ip is 192.168.0.1
Client is listening on port 400
==============================
Please Input Node [IP] [Port] you want to connect to:
192.168.1.112 100

=====start the three-way handshake=====
Send a packet(SYN) to 192.168.1.112:100
Received a packet(SYNACK) from 192.168.0.1:101
Send a packet(ACK) to 192.168.0.1:101
=====complete the three-way handshake=====
Receive a dns response from 192.168.0.1
                Receive a packet (seq_num = 6807, ack_num = 3848)
The IP of www.google.com is 216.58.200.228
Receive a answer from 192.168.0.1
                Receive a packet (seq_num = 6807, ack_num = 3848)
The answer is 2
```

Step4(增加丟失的封包)

server

```
cwnd =  5, rwnd = 518144, threshold = 4096
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1172, ack_num = 16385)
***Data loss at byte : 14336
                Receive a packet (seq_num = 1172, ack_num = 16385)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1172, ack_num = 16385)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1172, ack_num = 16385)
Receive 3 duplicate ack!!
```

Client

```
Receive a packet (seq_num = 254977, ack_num = 1409)
Receive a packet (seq_num = 256001, ack_num = 1410)
Receive a packet (seq_num = 257025, ack_num = 1411)
Receive a packet (seq_num = 258049, ack_num = 1412)
Receive a packet (seq_num = 259073, ack_num = 1413)
Receive a packet (seq_num = 260097, ack_num = 1414)
Receive a packet (seq_num = 261121, ack_num = 1415)
Receive a packet (seq_num = 262145, ack_num = 1416)
Receive a packet (seq_num = 263169, ack_num = 1417)
Receive a packet (seq_num = 264193, ack_num = 1418)
Receive a packet (seq_num = 265217, ack_num = 1419)
```

Step5(延遲封包)

Step6(雍塞避免)

Step7(重傳)

Step8(快速重傳)

server

```
======fast retransmit=====
======fast recovery=====
Sack list:
left = 16385 ,right = 17408
cwnd =  5, rwnd = 524288, threshold = 2560
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1172, ack_num = 16385)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1173, ack_num = 17409)
=====congestion avoidance======
Sack list:
left = 19457 ,right = 15360
cwnd =  2, rwnd = 522240, threshold = 2560
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1174, ack_num = 18433)
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1175, ack_num = 19457)
Sack list:
left = 19457 ,right = 15360
cwnd =  3, rwnd = 520192, threshold = 2560
                Send a packet at : 1024 byte
                Receive a packet (seq_num = 1176, ack_num = 20481)
                Send a packet at : 1024 byte
```

```
    Receive a packet (seq_num = 258049, ack_num = 1412)
    Receive a packet (seq_num = 259073, ack_num = 1413)
    Receive a packet (seq_num = 260097, ack_num = 1414)
    Receive a packet (seq_num = 261121, ack_num = 1415)
    Receive a packet (seq_num = 262145, ack_num = 1416)
    Receive a packet (seq_num = 263169, ack_num = 1417)
    Receive a packet (seq_num = 264193, ack_num = 1418)
    Receive a packet (seq_num = 265217, ack_num = 1419)
    Receive a packet (seq_num = 266241, ack_num = 1420)
    Receive a packet (seq_num = 267265, ack_num = 1421)
    Receive a packet (seq_num = 268289, ack_num = 1422)
    Receive a packet (seq_num = 269313, ack_num = 1423)
    Receive a packet (seq_num = 270337, ack_num = 1424)
    Receive a packet (seq_num = 271361, ack_num = 1425)
    Receive a packet (seq_num = 272385, ack_num = 1426)
    Receive a packet (seq_num = 273409, ack_num = 1427)
    Receive a packet (seq_num = 274433, ack_num = 1428)
    Receive a packet (seq_num = 275457, ack_num = 1429)
```

Client

```
Receive a packet (seq_num = 254977, ack_num = 1409)
Receive a packet (seq_num = 256001, ack_num = 1410)
Receive a packet (seq_num = 257025, ack_num = 1411)
Receive a packet (seq_num = 258049, ack_num = 1412)
Receive a packet (seq_num = 259073, ack_num = 1413)
Receive a packet (seq_num = 260097, ack_num = 1414)
Receive a packet (seq_num = 261121, ack_num = 1415)
Receive a packet (seq_num = 262145, ack_num = 1416)
Receive a packet (seq_num = 263169, ack_num = 1417)
Receive a packet (seq_num = 264193, ack_num = 1418)
Receive a packet (seq_num = 265217, ack_num = 1419)
```